Bapuji Educational Association ®
Bapuji Institute of Engineering and Technology, Davangere – 577 004
Department of Civil Engineering

Course File Check List

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2020-21 odd Sem

Tentative Academic Calendar of VTU, Belagavi for ODD Semester of 2020-2021

	I Sem B. E. / B. Tech. / B. Arch./B.Plan	I sem M.Tech./MBA /MCA/M.Arch.	III, V & VII Sem B. E. /B. Tech./B.Plan/ B.Arch & IX Sem B. Arch.	III & V Sem MCA	III Sem MBA	III Sem M. Tech.	III Sem M. Arch.
Commencement of ODD Semester	Will be announced later	Will be announced later	01.09.2020	01.09.2020	01.09.2020	01.09.2020	01.09.2020
Last Working day of ODD Semester			17.12.2020	17.12.2020	17.12.2020	17.12.2020	17.12.2020
Practical Examinations			21.12.2020 To 31.12.2020	21.12.2020 To 31.12.2020	21.12.2020 To 31.12.2020	21.12.2020 To 31.12.2020	21.12.2020 To 31.12.2020
Theory Examinations			04.01.2021 To 23.01.2021	04.01.2021 To 23.01.2021	04.01.2021 To 23.01.2021	04.01.2021 To 23.01.2021	04.01.2021 To 23.01.2021
Internship Viva-Voce			-	-	-	25.01.2021 To 08.02.2021	-
Professional training / Organization study			-	-	-		-
Commencement of EVEN Semester			08.02.2021	08.02.2021	08.02.2021	22.02.2021	08.02.2021

NOTE

- VII Semester B. E / B. Tech students shall have to undergo INTERNSHIP as per circular of University **VTU/Aca/2019-20/85, dated 12.05.2020.**
- I Semester B. E/ B. Tech / B. Arch Students shall compulsorily undergo Induction Program for a period of 3 Weeks as per the schedule given by VTU Belagavi
- The classroom sessions for all the higher semesters would be commencing from 01.09.2020(Tentative) in ONLINE mode until further orders.
- The Institute needs to function for six days a week with additional hours.
- The faculty/staff shall be available to undertake any work assigned by the university.
- If any of the above date is declared to be a holiday then the corresponding event will come into effect on the next working day.
- Notification regarding Calendar of Events relating to the conduct of University Examinations will be issued by the Registrar (Evaluation) from time to time.
- **Academic Calendar may be modified based on guidelines/directions issued in future by MHRD/UGC/AICTE/State Government.**

12.7.2020

REGISTRAR

Bapuji Institute of Engineering and Technology, Davangere-577004

CALENDER OF EVENTS - ODD SEMESTER: SEPTEMBER-JANUARY- 2020-21 (Tentative)

PARTICULARS	I sem BE/B Tech	III, V BE/B.Tech	VII sem BE/B.Tech	III & V sem MCA	III sem MBA	III sem M.Tech
Commencement of ODD Sem	14-12-2020	01-09-2020	01-09-2020	01-09-2020	01-09-2020	01-09-2020
Last Working Day	25-03-2021	16-01-2021	16-01-2021	16-01-2021	16-01-2021	16-01-2021
1st CIE Series	------	19-10-2020 To 24-10-2020	19-10-2020 To 24-10-2020	19-10-2020 To 24-10-2020	15-10-2020 To 17-10-2020	19-10-2020 To 24-10-2020
2nd CIE Series	------	07-12-2020 To 09-12-2020	07-12-2020 To 09-12-2020	07-12-2020 To 09-12-2020	26-11-2020 To 28-11-2020	07-12-2020 To 09-12-2020
3rd CIE Series	------	11-01-2021 To 13-01-2021	11-01-2021 To 13-01-2021	11-01-2021 To 13-01-2021	7-01-2021 To 9-01-2021	11-01-2021 To 13-01-2021
Practical Examination	29-03-2021 Onwards #	21-01-2021 Onwards #	21-01-2021 Onwards #	08-02-2021 Onwards #	------	21-01-2021 Onwards #
Theory Examination	12-04-2021 To 30-04-2021	08-02-2021 To 27-03-2021	08-02-2021 To 27-03-2021	21-01-2021 To 06-02-2021	21-01-2021 To 19-02-2021	28-01-2021 To 13-02-2021
Internship	------	------	29-03-2021 To 10-04-2021	------	------	------
Internship Viva-Voce	------	------	------	------	------	15-02-2021 To 22-02-2021
Professional Training/Organization Study	------	------	------	------	22-02-2021 To 03-04-2021	------
Commencement of Even Semester	03-05-2021	29-03-2021	12-04-2021	15-02-2021	05-04-2021	23-02-2021

Notification regarding the calendar of events relating to the conduct of University Examination will be issued by the Registrar (Evaluation) from time to time.

Dean Academic

Principal

Vision of BIET

To be a center of excellence recognized nationally and internationally, in distinctive areas of engineering education and research, based on a culture of innovation and invention.

Mission of BIET

BIET contributes to the growth and development of its students by imparting a broad based engineering education and empowering them to be successful in their chosen field by inculcating in them positive approach, leadership qualities and ethical values

VISION OF THE DEPARTMENT

To train the students to become Civil Engineers with leadership qualities, having ability to take up professional assignments and research with a focus on innovative approaches to cater to the needs of the society.

MISSION OF THE DEPARTMENT

1. To provide quality education through updated curriculum and conducive teaching learning environment for the students to excel in higher studies, competitive examinations and professional career.
2. To impart soft skills, leadership qualities and professional ethics among the graduates to handle the projects independently with confidence.
3. To deal with the contemporary issues and to cater to the socio-economic needs.
4. To build industry-institute interaction and to establish good rapport with alumni.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO 1: Core Competence: Graduates will be able to plan, analyse, design and construct sustainable Civil Engineering Infrastructure.

PEO 2: Professional Skills: Graduates will be professional engineers with a sense of ethics, creativity, leadership, self-confidence and independent thinking to cater to the needs of the society.

PEO 3: Societal Needs: Graduates will be able to contribute effectively for the development of industry and professional bodies.

PEO 4: Cognitive Intelligence: Graduates will be able to take up competitive examinations, higher studies and involve in research and entrepreneurship activities.

PROGRAM SPECIFIC OUTCOMES (PSOs)

Students after the completion of the Program will be able to

1. Apply the fundamental concepts, software and codal provisions in the analysis, design and construction of sustainable civil engineering infrastructure.
2. Inculcate professional and leadership qualities, sense of ethics and confidence related to civil engineering.

Faculty will be able to

3. Contribute to the overall development of civil engineering community through the professional bodies and offer services to the society.

3D - CV301
3B - CV305

Name of the Faculty : MER							
Time / Day	8 – 9	9 – 10	10.30 – 11.30	11.30 – 12.30	2 – 3	3 – 4	4 – 5
Mon	18CV32 – A				18CV35 – B		18CVL57 – T (B)
Tue		18CV32 – A					
Wed	18CV35 – B			18CV32 – A	18CVL57 – A3 (MER + SH)		
Thu		18CV35 – B	18CV32 – A		18CVL57 – B1 (MER + GNS)		
Fri		18CVL38 – A1 (MER + CPA)					
Sat		18CV32 – A					

Time Table Coordinator

HOD

Principal

Period : From September 2020 To February - 2021 Semester : Odd/Even

Name of the Teacher : Raghu. M.E

Designation : Assistant Professor

Department : civil Department

Sl. No.	Sem. / Sec. / Branch	Subject Name	Subject Code
1	III rd / A / civil	Strength of materials	18CV32
2	III / B / civil	Basic surveying	18CV35
3	III / A / A1 / civil	Basic material testing lab	18CVL38
4			
5			
6			
7			

	Reviews at the end of the				End of Semester
	1st Month	2nd Month	3rd Month	4th Month	
Signature of Staff	[signature] 30.9.2021	[signature] 30.10.2021	[signature] 30.12.2021	[signature] 28.2.2021	[signature] 21/3/2021
Signature of the Head of Department	[signature] 30/9/21	[signature] 3/10/21	[signature]	[signature] 2/2/2021	[signature] 26/3/2021
Signature of the Principal	[signature] PRINCIPAL Japuji Institute of Engineering & Technology DAVANGERE.		[signature] PRINCIPAL Japuji Institute of Engineering & Technology DAVANGERE.		[signature] PRINCIPAL Japuji Institute of Engineering & Technology DAVANGERE.

Class : III rd Sem. A section | Subject Code : 18CV32 | Subject : Strength of Materials | Total No. of Classes : 28

Sl No.	USN	NAME	9/9/20	10/9/20	12/9/20	14/9/20	15/9/20	16/9/20	19/9/20	21/9/20	22/9/20	23/9/20	25/9/20	28/9/20	29/9/20	30/9/20	01/10/20	03/10/20	05/10/20	06/10/20	07/10/20	08/10/20	10/10/20	12/10/20	13/10/20	14/10/20	15/10/20	20/10/20	21/10/20	27/10/20	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
1	4BD19CV001	Aban Sharief X	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
2	4BD19CV003	Afzal Noorsabnavar X	1	2	A	3	4	5	6	7	8	9	10	A	A	A	A	11	12	13	14	15	16	17	18	19	20	21	22	23							
3	4BD19CV005	Akashdeep R Andanur X	1	2	3	4	5	6	7	8	9	A	10	11	12	13	14	15	16	17	18	19	20	A	21	22	23	24	25	26							
4	4BD19CV006	Akhila C Akula X	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	A	A							
5	4BD19CV007	Akshatha Ashoka Putalekara X	1	2	3	4	5	6	7	8	9	10	11	12	13	14	A	15	16	17	A	18	19	20	21	22	23	24	25	A							
6	4BD19CV009	Akshaya Kumara. L.M X	1	2	A	3	4	5	7	A	8	9	A	A	A	10	11	A	A	12	13	A	14	A	15	A	A	A	A	A							
7	4BD19CV011	Amith K.M	1	2	3	A	4	5	6	7	8	9	A	10	11	A	A	A	12	13	A	A	14	15	16	A	A	A	A	17							
8	4BD19CV013	Arpitha Basanagoudapatil	1	2	3	A	4	5	6	A	7	8	A	9	A	10	11	A	12	13	14	15	16	A	17	18	19	20	21	A							
9	4BD19CV015	Basavaraj S Patil	1	A	2	3	4	A	5	6	A	A	A	A	A	A	A	7	A	8	A	A	9	10	11	12	13	14	15	16							
10	4BD19CV017	Bhumika P. X	1	A	2	3	4	5	6	7	8	9	A	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26							
11	4BD19CV019	Chinmayee K. X	1	2	3	4	5	6	7	8	9	10	11	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27							
12	4BD19CV021	Darshan V.K. X	1	A	A	A	A	A	2	3	4	A	5	A	A	A	A	A	A	A	A	6	7	A	A	A	A	8	A	A							
13	4BD19CV023	Ganesh U Shirigeri X	1	2	3	4	5	6	7	8	9	10	11	12	13	A	A	14	15	A	16	17	18	19	A	20	21	22	23	24							
14	4BD19CV025	Hemanth Kumar DV X	A	1	2	A	A	A	A	A	3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
15	4BD19CV027	Jhanavi R	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							
16	4BD19CV029	Kruthik. S.P. X	1	2	3	4	A	5	A	A	A	A	A	6	A	A	A	7	8	9	10	11	12	A	A	13	14	15	16	17							
17	4BD19CV031	M Syed Anwar	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
18	4BD19CV033	Manjunatha. M X	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							
19	4BD19CV035	Mithun. Y X	1	A	A	A	2	3	4	A	5	A	6	7	A	A	A	A	A	A	A	8	9	A	10	A	A	11	A	A							
20	4BD19CV037	Mohammed Faizan makandar	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							
21	4BD19CV039	Nadeem sha A. Z. X	1	A	A	2	3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
22	4BD19CV041	Nanda K.B X	1	2	3	4	5	A	6	A	7	8	9	A	A	10	11	12	13	14	15	16	17	28	19	20	21	22	A	23							
23	4BD19CV043	Niranjan. G.M X	1	A	2	3	4	A	5	6	A	7	8	9	A	A	10	A	11	12	A	13	14	A	A	A	A	A	15	A							
24	4BD19CV047	Pooja. P. X	1	A	A	A	A	A	2	A	A	A	3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	4							
25	4BD19CV049	Pradeep. P.N. X	1	2	3	4	5	A	6	7	A	A	A	A	A	A	A	A	A	A	A	8	A	A	9	10	11	A	A	A							
26	4BD19CV051	Prashanth. N.R X	1	2	3	4	5	6	7	8	9	10	11	12	A	A	13	A	14	15	16	17	18	19	20	21	22	23	A	24							
27	4BD19CV053	Raghavendra Vaditre	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
28	4BD19CV055	Rakesh. H.N. X	1	2	3	4	5	6	7	A	8	A	9	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
29	4BD19CV057	Sambhram S Patil	1	2	3	4	5	A	6	7	A	A	A	A	A	A	A	8	9	10	11	12	13	14	15	A	A	16	17	18							
30	4BD19CV059	Sevanth B.M	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							

Initials of Teacher

Initials of H.O.D.

Initial of Principal

PRINCIPAL
Bapuji Institute of Engineering & Technology
DAVANGERE.

Class : III A   Subject Code : 18CV32   Subject : Strength of materials   Total No. of Classes : 56

SI No.	USN	NAME	28/10/20	29/10/20	02/11/20	03/11/20	04/11/20	05/11/20	07/11/20	09/11/20	10/11/20	11/11/20	12/11/20	17/11/20	18/11/20	19/11/20	21/11/20	23/11/20	24/11/20	25/11/20	26/11/20	28/11/20	30/11/20	01/12/20	02/12/20	12/12/20	14/12/20	15/12/20	16/12/20	21/12/20	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
1		Aban Shariff	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	1	10	24	23	08	19	29
2		Afzal Noorsabnavar	A	A	A	24	25	26	27	A	28	29	30	A	31	32	33	34	A	35	36	37	A	A	38	39	A	40	41	A	2	10	30	30	12	24	34
3		Akashdeep R Andanur	27	28	29	30	30	31	31	33	34	35	36	37	38	39	40	41	42	A	A	43	A	A	A	44	45	46	47	48	3	10	30	30	21	27	37
4		Akhila C Akula	27	28	27	30	31	32	33	34	35	36	37	38	39	40	41	42	43	43	44	45	46	47	A	48	49	50	51	52	4	10	30	30	19	27	37
5		Akshatha Ashoka P	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	A	48	49	50	52	53	5	10	30	30	15	25	35
6		Akshaya Kumara L M	26	A	A	A	A	A	A	A	A	28	28	A	29	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	6	10	29	30	18	26	36
7		Amith K M	A	A	18	19	20	21	22	23	24	A	A	25	26	27	A	28	A	A	29	A	30	A	A	A	A	A	A	A	7	10	24	30	14	23	33
8		Arpitha Basanagouda Patil	22	23	24	25	26	27	28	29	30	31	32	A	33	A	A	34	35	36	37	38	39	40	41	A	A	42	A	43	08	10	30	30	10	23	33
9		Basavaraj S Patil	17	A	18	19	20	21	A	22	A	A	A	23	24	25	26	27	28	A	A	A	A	29	A	A	30	A	A	A	09	10	26	30	AB	19	29
10		Bhumika P	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	10	10	30	30	07	23	33
11		Chinmayee K	27	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	A	50	51	52	53	54	11	10	30	30	27	27	37
12		Darshan V N	A	9	A	A	A	A	A	A	10	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	12	10	24	24	9	15	25
13		Ganesh U S	25	26	A	A	A	A	27	28	29	30	31	32	33	34	A	35	36	37	38	39	40	41	42	43	44	45	46	A	13	10	30	30	23	28	38
14		Hemanth Kumar D V	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	14	10	24	27	03	18	28
15		Jhanavi R (change of branch)	29	30	A	A	31	32	33	34	35	36	37	A	A	38	A	39	A	A	A	A	A	A	A	A	A	A	A	A	15	AB	AB	AB	AB	AB	AB
16		Kruthik S P	18	A	19	20	21	22	A	A	A	A	A	A	23	24	A	25	A	A	26	A	A	27	A	A	A	A	A	A	16	10	30	30	17	26	36
17		M Syed Anwar	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	17	Left the course					
18		Manjunatha M	29	A	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	18	10	30	30	24	28	38
19		Mithun Y	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	12	A	A	A	A	A	13	14	15	16	16	17	18	19	10	21	19	02	14	24
20		Mohammed Faizan Mantalader	29	A	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	46	47	48	49	50	51	52	53	54	20	10	26	30	21	26	36
21		Nadeemsha A Z	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	4	A	A	A	21	10	25	23	13	21	31
22		Nanda K B	24	25	26	27	28	29	A	30	31	32	A	33	31	35	36	37	38	39	A	40	A	41	42	43	44	A	A	45	22	10	30	30	21	27	37
23		Niranjan G M	A	A	A	18	A	A	A	A	17	18	A	A	19	20	A	21	22	23	24	A	A	25	A	A	A	26	27	28	23	10	25	30	05	22	32
24		Pooja P	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	4	A	A	A	A	5	A	A	A	A	A	A	24	10	25	30	00	19	29
25		Pradeep P N	A	A	A	A	A	A	A	A	A	A	11	A	12	13	A	14	15	A	A	15	16	17	18	20	21	22	A	A	25	10	23	21	04	16	26
26		Prashanth N R	A	A	A	26	27	A	A	28	A	29	A	A	30	31	32	33	34	A	35	36	37	38	A	39	40	41	A	A	26	10	24	28	12	22	32
27		Raghavendra V	A	A	A	A	A	A	2	A	3	A	4	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	27	10	30	30	04	22	32
28		Rakesh H N	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	28	10	25	21	12	20	30
29		Sambhram Snati	19	A	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	A	35	A	A	36	A	37	38	39	40	41	29	10	26	30	AB	15	29
30		Sevanth	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	30	10	30	23	08	21	31

Initials of Teacher

Initials of H.O.D.

Initial of Principal

PRINCIPAL
Bapuji Institute of Engineering & Technology
DAVANGERE

Class: III rd sem A | Subject Code: 18CV32 | Subject: Strength of materials | Total No. of Classes: 28.

Sl No.	USN	NAME	9/9/20	10/9/20	12/9/20	14/9/20	15/9/20	16/9/20	19/9/20	21/9/20	22/9/20	23/9/20	25/9	28/9/20	29/9/20	30/9/20	01/10/20	03/10/20	05/10/20	06/10/20	07/10/20	08/10/20	10/10/20	12/10/20	13/10/20	14/10/20	15/10/20	16/10/15	21/10/13	27/10/13	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
31	4BD19CV061	Shreya D.K. ✗	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	1	2	A	A	A	A	A	A	A	A							
32	4BD19CV063	Soundarya N.M ✗	1	2	3	4	5	6	7	8	9	10	A	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	A	A							
33	4BD19CV065	Swathi V Kote ✗	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							
34	4BD19CV067	U Madhushree	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A	A	A	18	19	20	21	22	23	24	25							
35	4BD19CV069	Vaishnavi V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A	A	A	18	19	20	21	22	23	24	25							
36	4BD19CV070	Veeresh K.K. ✗	1	2	A	3	A	A	4	5	6	7	8	9	A	A	A	10	11	12	A	13	14	15	16	17	18	19	A	20							
37	4BD19CV073	Vijayalakshmi R. Telkar ✗	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							
38	4BD19CV075	Vikas S.M.	1	A	A	2	3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	4	5	6	A	7	A							
39	4BD19CV077	Vivekananda H.M ✗	1	2	A	A	A	A	A	A	A	A	A	A	A	A	A	3	4	5	A	A	A	A	6	7	8	9	10	11							
40	4BD19CV079	Yugh B. Jain ✗	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	1	2	3	4	A	A							
41	4BD18CV099	Vinay Kumar M	A	1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	2	3							
42	4BD17CV052	Mohammed Azhar Basith ✗	← Admission on 21/09/2020 →									A	A	1	A	2	A	3	4	5	A	6	7	A	A	8	9	A	A	A							
43		Trupthi S.R. ✗	← Admission on [illegible] →										A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
44	4BD18CV027	Harshith N.	← Admission on 07/10/2020 →																			A	1	2	3	4	5	6	7	8							
45		Channesh H. Patil ✗	← Admission on 10/10/2020 →																				1	2	3	A	A	A	4	5							
46	4BD18CV076	A Shivaraj K.H ✗	← Admission on 15/10/2020 →																									A	1	A							
47		Bharath Reddy N ✗	← Admission on 14/10/2020 →																									A	1	2							
48		A Mohammed Shadir ✗	← Admission on 16/10/2020 →																									A	A	A							
49		Abhilash S.V	← Admission on 03/11/2020 →																																		
50		Dhanush R. ✗	← Admission on 04/11/2020 →																																		
51		Surabhi S. Bharadwaj	← Admission on 07/11/2020 →																																		
52		Chethan Kotraiah ✗	← Admission on 09/11/2020 →																																		
53		Vinod Kumar Budihal ✗	← Admission on 13/11/2020 →																																		
54		Nandesh M Mathod	← Admission on 13/11/2020 →																																		
55	change of Branch	Santhosh S Bagoor ✗	← Admitted on 18/11/2020 →																																		
56	4BD17CV100	A Sujith R	← Admitted on 18/11/202 →																																		
57		Rohith A ✗	← " 20/11/2020 →																																		
58	change of Branch	Kiran M.M. ✗	← Admitted on 2. 21/11/2020 →																																		
59		Sumai N. Raikar ✗	← Admitted on 22/11/2020 →																																		
60		Murugharajendra H.V	← Admitted on 25/11/2020 →																																		
61		Shree Harsha T.R ✗																																			
		Initials of Teacher																																			
		Initials of H.O.D.																																			
		Initial of Principal																																			

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Bapuji Institute of Engineering & Technology
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Class: III rd A-section Subject Code: 18CV32 Subject: Strength of Materials Total No. of Classes: 56

Sl No.	USN	NAME	28/10/20	29/10/20	2/11/20	03/11/20	04/11/20	05/11/20	07/11/20	9/11/20	10/11/20	11/11/20	12/11/20	17/11/20	18/11/20	19/11/20	21/11/20	23/11/20	24/11/20	25/11/20	26/11/20	28/11/20	30/11/20	1/12/20	2/12/20	12/12/20	14/12/20	15/12/20	16/12/20	21/12/20	No. of Days Present	% 10	Test Marks I 30	II 30	III 30	Average	Remarks
31		Shreya. D.K	A	3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	31	10	24	23	02	17	27
32		Soundarya. N-M	26	A	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	A	51	32	10	30	30	19	27	37
33		Swathi V Koti.	A	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	33	10	30	30	11	24	34
34		U Madhushree	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	34	10	30	38	28	26	36
35		Vaishnavi. V.	25	27	28	29	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	A	46	47	48	49	50	51	52	53	35	10	30	30	20	27	37
36		Veeresh. K. K.	A	21	22	23	24	A	25	26	27	A	A	A	A	A	A	A	A	A	A	A	A	A	A	28	A	A	A	29	36	10	30	25	01	20	30
37		Vijayalakshmi. R. Telkar	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	37	10	30	30	20	27	37
38		Vikas. S.M.	8	A	A	9	A	10	A	11	12	A	13	A	A	A	A	A	A	14	A	A	A	15	A	A	16	A	A	A	38	10	17	30	00	16	26
39		Vivekananda. H-M	12	A	13	14	15	16	17	18	19	A	20	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	39	10	30	22	01	18	28
40		Yugh B. Jain	A	5	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	40	10	26	30	12	23	33
41		Vinay Kumar. M.	A	A	A	4	5	6	A	A	7	A	A	8	9	A	A	10	A	A	A	A	A	11	A	A	A	A	A	12	41	10	24	23	05	19	29
42		Mohammed Azhar Baists	10	A	A	A	11	A	12	[illegible]	13	A	A	A	A	A	A	A	14	A	15	A	A	16	17	A	A	A	18	19	42	10	21	25	06	18	28
43		Trupthi. S-R.	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	43	10	30	30	02	21	31
44		Harshith - N.	9	10	11	A	12	13	14	15	16	17	18	A	19	A	20	21	22	A	23	24	25	A	26	27	28	29	30	31	44	10	30	30	07	23	33
45		Channesh. H. Patel	6	7	A	A	8	9	10	11	12	13	14	15	16	A	17	18	19	20	A	21	22	23	A	24	25	26	27	28	45	10	28	30	01	20	30
46		Shivaraj. K. H.	A	2	3	A	4	A	5	6	7	8	9	10	11	A	12	A	13	14	A	15	16	17	A	18	A	A	19	A	46	10	18	27	05	15	25
47		Bharath Reddy	3	A	A	4	5	A	6	A	7	A	8	A	A	A	9	9	A	10	A	A	A	A	A	A	A	11	A	A	47	10	27	29	03	20	30
48		Mohammed Khadir	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	48	10	30	30	06	22	32
49		Abhilash S.V	A			A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	49	10	30	30	04	22	32
50		Dhanush. R.	A						A	A	A	1	A	A	A	A	A	A	A	A	2	3	4	5	A	A	A	A	A	A	50	10	28	24	01	18	28
51		Surabhi. S. Bharadwaj	A							A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	51	10	30	30	00	20	30
52		Chethan Kotrech.	A								A	1	2	3	A	A	A	A	4	A	5	A	6	A	7	A	8	9	10	11	52	10	24	27	06	19	29
53		Vinod Kumar M Mathad	A											A	A	A	1	2	3	A	A	4	5	6	7	A	8	A	A	9	53	10	30	20	00	17	27
54		Nandish. M Mathad.	A											A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	54	10	30	30	07	23	33
55	Change of Branch	Santhosh B Bagar	A													A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	55	10	30	28	07	22	32
56	Change of Branch 4UB20CV100	Sujith R	A														A	A	1	A	A	A	A	A	A	A	A	A	A	A	56	Left the course					
57	4UB20CV...	Rohith R	A														1	2	3	4	5	A	6	7	A	A	A	A	A	A	57	10	30	30	04	22	32
58	Change of Branch	Kiran. N. M	A														A	A	A	A	A	A	A	A	A	A	A	A	A	A	58	10	23	30	10	21	31
59	Change of Branch	Sujay. N. Paibar															1	A	A	A	1	2	A	3	4	5	6	A	A	A	59	10	30	26	05	22	32
60		Murughrajendra. H.V	A																			A	A	A	A	A	A	1	A	A	60	10	30	30	01	21	31
61	Shree harsha. T.R	Shree harsha T.R.																							1	1	2	3	4		61	10	30	30	03	21	31
		Initials of Teacher																																			
		Initials of H.O.D.																																			
		Initial of Principal																																			

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Class: III A Section Subject Code: 18CV32 Subject: Strength of Materials Total No. of Classes: 21/56

Sl No.	USN	NAME	DATE	No. of Days Present	% (10)	Test Marks I (30)	Test Marks II (30)	Test Marks III (30)	Average (30)	Remarks
62	~~Sandeep B.N.~~	~~Sandeep B.N.~~ 2/11/2020	Admission on 2/11/2020.	62	10	29	30	05	22	32
63	Shankar Rao K	Shankar Rao K 2/11/2020	Admission on 2/12/2020	63	10	30	28	0	20	30
64	~~Amrit~~	Ambika H.G.	Admission 23/12/2020	64	10	30	25	21	26	36
65		Triveni G.	Admission 23/12/2020	65	10	30	27	13	24	34
66		Pallavi O.	Admission on 23/12/2020	66	10	30	30	20	27	37
67		Harish S D	Admission on 24/12/2020	67	10	17	16	6	13	23
68		Veena B Bharamgoudra	24/12/2020	68	10	30	30	62	21	31
69		Harsha K N	26/12/2020	69	10	30	30	17	26	36
70		Harish K G	28-12-2020	70	10	30	27	01	20	30
71		Trupthi S. Ballkai	29/12/2020	71	10	30	30	04	22	32
72		Deepak L	31/12/2020	72	10	30	28	11	23	33
73		Firdosh Anjum H	21/12/2020	73	10	30	28	05	21	31

Initials of Teacher

Initials of H.O.D.

Initial of Principal

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Bapuji Institute of Engineering & Technology
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Class: III B Section | Subject Code: 18CV35 | Subject: Basic Surveying | Total No. of Classes: 28

Sl No.	USN	NAME	10/9/20	14/9/20	15/9/20	16/9/20	21/9/20	23/9/20	28/9/20	30/9/20	01/10/20	05/10/20	07/10/20
1	4BD19CV002	Abhishek K Chitragar	A	A	A	A	A	A	A	A	A	A	A
2	4BD19CV004	Ajay A Jajuri	1	2	3	4	5	6	7	8	A	A	9
3	4BD19CV008	Akshay B M.	A	A	A	A	A	A	A	A	A	A	A
4	4BD19CV010	Ali Akbar	A	A	A	A	A	A	A	A	A	A	A
5	4BD19CV012	Anusha S.	1	A	A	A	2	A	3	A	A	A	A
6	4BD19CV014	B Sayyed Ismail Zabiulla	A	A	A	A	A	A	A	A	A	A	A
7	4BD19CV016	Bharathgouda K.N.	A	A	A	A	A	A	1	A	2	3	4
8	4BD19CV018	Chandan. B.V	A	A	1	2	3	A	4	5	A	A	A
9	4BD19CV022	Deepa P	1	2	3	4	5	6	7	8	9	10	11
10	4BD19CV024	Harish K.T.	A	A	A	A	A	1	2	A	3	A	4
11	4BD19CV028	Karthik D Vernekar	1	2	3	4	5	6	7	A	A	A	A
12	4BD19CV030	Lakshmi. B.S	1	A	2	3	A	A	4	A	A	A	5
13	4BD19CV032	Mallikarjun. T.M.	1	2	3	4	5	6	7	8	9	10	A
14	4BD19CV034	Manoj Swamy K.M	1	2	3	4	5	6	7	8	9	10	11
15	4BD19CV036	Mohammed Ameerkhan	1	2	3	4	A	A	A	A	A	A	A
16	4BD19CV038	Mohit B V	1	2	A	A	A	3	4	5	A	A	A
17	4BD19CV040	Namratha P Ram	A	A	1	2	A	3	4	5	6	A	7
18	4BD19CV042	Nandini. K.	1	2	3	4	5	6	7	8	9	10	11
19	4BD19CV044	P. N. Mohammed Salauddin	A	A	A	A	A	A	A	A	A	A	A
20	4BD19CV046	Pooja. M.P.	A	1	2	3	4	5	6	7	8	9	10
21	4BD19CV048	Pradeep. K.B	A	A	1	2	A	3	4	5	A	A	6
22	4BD19CV050	Prajwal G.T Matad	1	2	3	4	5	6	7	A	A	8	9
23	4BD19CV052	Prerana. V.	1	2	3	4	5	6	7	8	9	10	11
24	4BD19CV054	Raghu. Doddamani	A	A	A	A	A	A	A	A	A	A	A
25	4BD19CV056	Rukhsar Banu. A.K	1	2	3	4	5	6	7	8	9	10	11
26	4BD19CV058	Sanjay. G.A.	1	2	3	4	5	6	7	8	A	A	A
27	4BD19CV060	Shashi Kiran. C.R	1	A	A	A	A	A	A	A	A	A	A
28	4BD19CV062	Siraj Ahamed Y.B	1	A	3	4	5	6	7	8	9	10	11
29	4BD19CV064	Sunil N Rathod	A	1	A	A	A	A	2	A	A	3	4
30	4BD19CV066	Tejaswini. M.	1	2	3	4	5	6	7	8	9	10	11
		Initials of Teacher											
		Initials of H.O.D.											
		Initial of Principal											

Sl No.	07/10/20	12/10/20	14/10/20	15/10/20	21/10/20	22/10/20	28/10/20	29/10/20	04/11/20	05/11/20	09/11/20	11/11/20	18/11/20	19/11/20	23/11/20	25/11/20	26/11/20	No. of Days Present	%	Test Marks I	II	III	Average	Remarks
1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
2	10	A	11	12	13	A	14	15	A	16	A	A	A	17	A	A	A							
3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
4	1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
5	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
6	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
7	A	A	A	5	6	A	A	A	A	A	A	A	A	7	A	A	A							
8	A	A	A	A	6	A	A	A	A	7	A	A	A	A	A	8	A							
9	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							
10	A	5	6	7	8	9	A	A	A	A	A	A	10	A	A	11	A							
11	A	A	A	8	A	A	A	A	A	A	A	A	A	A	A	A	A							
12	A	A	6	7	8	A	A	A	A	9	A	10	A	A	11	12	13							
13	11	A	A	12	13	A	A	A	14	A	15	A	A	A	A	16	A							
14	12	13	14	15	A	16	17	18	19	20	21	22	23	24	25	26	A							
15	A	A	5	6	A	A	A	A	A	7	A	A	A	A	A	A	A							
16	A	6	7	8	A	9	10	11	A	12	13	14	15	16	A	A	17							
17	8	A	A	A	9	A	A	A	A	A	A	A	A	A	A	A	A							
18	12	13	14	15	16	17	18	19	20	21	22	23	A	A	A	A	24							
19	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
20	11	A	12	13	14	A	15	16	A	17	18	A	19	20	A	21	22							
21	A	A	7	8	9	A	10	A	11	12	A	13	14	15	16	17	18							
22	A	10	11	12	13	14	15	A	A	A	A	A	16	A	A	17	A							
23	12	A	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27							
24	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
25	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							
26	A	A	A	A	9	10	A	11	12	13	A	14	15	A	A	A	A							
27	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
28	12	13	14	15	16	17	18	19	20	21	22	23	24	A	25	26	27							
29	A	5	A	6	7	A	A	8	A	9	A	10	11	A	12	13	A							
30	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							

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Class: III B Section

Subject Code: 18CV35

Subject: Basic Surveying

Total No. of Classes: 36

Sl No.	USN	NAME	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
1	4BD19CV002	Abhishek K C	1	AB	AB	AB	AB	AB	AB
2	4BD19CV004	Ajay A Jaju	2	10	24	21	10	17	27
3	4BD19CV008	Akshay B M.	3	10	21	23	9	18	28
4	4BD19CV010	Ali Akbor	4	10	25	16	3	15	25
5	4BD19CV012	Anusha. S.	5	AB	AB	AB	AB	AB	AB
6	4BD19CV014	B. Sayyed Isr	6	10	24	21	00	15	25
7	4BD19CV016	Bharathgouda	7	10	25	21	00	16	26
8	4BD19CV018	Chandan. B.V	8	10	26	30	12	23	33
9	4BD19CV022	Deepa P.	9	10	30	30	25	29	39
10	4BD19CV024	Harish. K.T.	10	10	22	20	3	15	25
11	4BD19CV028	Karthik D ver	11	AB	AB	AB	AB	AB	AB
12	4BD19CV030	Lakshmi. B.S	12	10	27	30	08	22	32
13	4BD19CV032	mallikarjun.	13	10	26	23	11	20	30
14	4BD19CV034	Manoj Swamy	14	10	26	25	13	22	32
15	4BD19CV036	Mohammed Ame	15	10	22	14	01	13	23
16	4BD19CV038	Mohit B V	16	10	25	26	07	20	30
17	4BD19CV040	Namratha P E	17	10	22	30	07	20	30
18	4BD19CV042	Nandini. K.	18	10	3	30	21	27	37
19	4BD19CV044	P. N. Mohammed	19	10	20	18	00	13	23
20	4BD19CV046	Pooja. M. P	20	10	26	18	15	20	30
21	4BD19CV048	Pradeep. K. B	21	10	27	26	05	19	29
22	4BD19CV050	Prajwal G.T.	22	10	28	26	14	23	33
23	4BD19CV052	Prerana. V.	23	10	20	30	17	25	35
24	4BD19CV054	Raghu. Dodda	24	10	16	23	00	13	23
25	4BD19CV056	Rukhsar Banu	25	10	30	30	26	29	39
26	4BD19CV058	Sanjay. G. F	26	10	25	23	17	22	32
27	4BD19CV060	Shashi Ki	27	10	27	23	10	20	30
28	4BD19CV062	Siraj Ahamed	28	10	30	26	10	22	39 32
29	4BD19CV064	Sunil N Rath	29	10	28	23	05	19	29
30	4BD19CV066	Tejaswini M.	30	10	30	30	23	28	35

Sl No.	02/12/20	14/12/20	16/12	21/12	23/12	28/12/20	30/12/20	31/12/20	4/01/21	5/01/21	7/1/21
1	A	A	A	A	A	A	A	A	K	A	A
2	18 A	A	A	A	18	A	A	A	A	A	A
3	A	A	A	A	A	A	A	A	A	A	A
4	A	A	A	A	A	A	A	A	A	A	A
5	4	A	A	A	A	A	A	A	A	A	A
6	A	A	A	A	A	A	A	A	A	A	A
7	8 A	A	A	A	A	A	A	A	A	A	A
8	9	A	A	A	10	A	A	A	A	A	A
9	29	30	31	32	33	34	35	36	37	38	39
10	12 A	A	12	A	A	A	A	A	A	A	A
11	9 A	A	A	A	A	A	A	A	A	A	A
12	14 A	A	A	A	A	14	A	A	A	A	A
13	A	A	17	A	18	19	20	21	A	A	A
14	27	28	A	A	29	30	31	32	A	33	A
15	7 A	A	A	A	A	A	A	A	A	A	A
16	18	A	19	A	20	21	22	23	A	24	25
17	10 A	A	A	A	A	A	A	A	A	A	A
18	25 A	25	26	27	A	28	29	29	30	31	32
19	A	A	A	A	A	A	A	A	A	A	A
20	23 A	23	24	25	26	27	28	29	30	31	32
21	19	A	A	20	21	22	23	24	25	26	27
22	28 A	A	A	A	A	A	A	A	A	A	A
23	28	29	30	31	32	33	34	35	36	37	38
24	A	A	A	A	A	A	A	A	A	A	A
25	29	30	31	32	33	34	35	36	37	38	39
26	16	A	A	A	A	A	A	A	A	A	A
27	2 A	A	A	A	A	A	A	A	A	A	A
28	28	A	A	29	A	30	31	A	A	32	33
29	14	A	15	16	17	A	A	A	A	18	19
30	29	A	30	31	32	33	34	35	36	37	38

Sl No.	19/1/21	17/1/21	21/1/21	01/2/21	3/2/21	4/2/21	10/2/21	11/2/21	15/2/21	17/2/21	17/2/21	18/2/21	18/2/21	19/2/21	23/2/21	25/2/21	26/2/21
1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
2	A	A	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
4	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
5	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
6	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
7	A	A	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
8	A	A	11	12	13	14	15	A	A	A	A	A	A	16	17	18	19
9	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
10	A	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
11	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
12	14	A	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
13	A	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
14	34	35	A	36	37	38	39	40	41	42	43	44	45	46	47	48	49
15	A	A	A	10	11	12	13	14	15	16	17	18	19	20	21	22	23
16	26	A	A	27	28	29	30	31	32	33	34	35	36	37	38	39	40
17	A	A	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
18	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
19	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
20	33	34	A	35	36	37	38	39	40	41	42	43	44	45	46	47	48
21	28	29	A	30	31	32	33	34	35	36	37	38	39	40	41	42	43
22	A	A	A	18	19	20	21	22	23	24	25	26	27	28	29	30	31
23	39	A	A	40	41	42	43	44	45	46	47	48	49	50	51	52	53
24	A	2	A	3	4	5	6	A	8	9	10	11	12	13	14	15	16
25	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
26	A	A	A	17	18	19	20	21	22	23	24	25	26	27	28	29	30
27	A	2	A	3	4	5	6	7	8	9	10	11	12	13	14	15	16
28	34	35	A	36	37	38	39	40	41	42	43	44	45	46	47	48	49
29	A	A	A	20	21	22	23	24	25	26	27	28	29	30	31	32	33
30	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55

Initials of Teacher

Initials of H.O.D.

Initial of Principal

PRINCIPAL
Bapuji Institute of Engineering & Technology
DAVANGERE.

Class: III 'B' Section | Subject Code: 18CV35 | Subject: Basic Surveying | Total No. of Classes: 28

DATE: 10/9/20, 14/9/20, 15/9/20, 16/9/20, 21/9/20, 23/9/20, 28/9/20, 30/9/20, 1/10/20, 5/10/20, 7/10/20, 8/10/20, 12/10/20, 14/10/20, 15/10/20, 21/10/20, 22/10/20, 28/10/20, 29/10/20, 04/11/20, 05/11/20, 07/11/20, 11/11/20, 18/11/20, 13/11/20, 23/11/20, 25/11/20, 26/11/20

Sl No.	USN	NAME	Attendance (in date order)	No. of Days Present	%	Test Marks I	II	III	Average	Remarks
31	4BD19CV068	Vaishnavi. V.	1 A 2 3 4 5 6 7 8 9 A A 10 11 12 13 14 15 16 17 18 19 20 21 21 22 23 24							
32	4BD19CV070	Veeresh B. R. S. V	A A A A A 1 2 3 4 5 6 7 8 9 10 A 11 12 13 A 14 15 A A A A A 16							
33	4BD19CV072	Veman M Giraddi	A A 1 2 A 3 4 5 6 A A 7 8 A A A A A A A A A A A A A A 9							
34	4BD19CV074	Vikas D. Yadav	1 A 2 3 A A 4 5 6 A 7 8 A 9 A A A A 10 11 A A A A A A 12 13							
35	4BD19CV076	Vivek A P N	A A A A A A A A A A A A 1 A A A A A A A A A A A A A A A							
36	4BD19CV078	Yashaswini. M.U.	A A A A A A A A A A A A A A A A A A A A A A A A A A A A							
37	4BD19CV080	Zaiba Anjum	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28							
38	4BD18CV090	Tejesh. B R	—— 1 2 A A A A A A A A A A A A A A A A A A A A A A							
39	4BD17CV065	Pavan K. G. D.	[illegible] A A A A A A A A A A A A A A A A 1 A 2 3 4 5 A A A A							
40	4BD18CV024	Ganesh. B. G.	11/10/20 A A A A A A A A A A A A A A A A A 2 A A A B A A A							
41	4BD18CV047	Mohan. A. D.	24/9/2020 → A A A A A A A A 1 2 3 4 A A 5 A A A A A C A							
42	4BD18CV078	Siddesh Gowda. M. S	24/9/2020 → A A A A A A A A A A A A A A A A A A A A A A							
43	4BD18CV092	Uday. K. H.	1/10/2020 → A A A A A A A A A A A A A A A A A A A A A							
44	4BD17CV025	Dishanth	04/10/2020 → A A A A A A A A A A A A A A A A A A A A A							
45	4BD17CV002	Adarsh. N. G.	5/10/2020 → A A A A A A A A A A A A A A A A A A A A							
46	[Lsky]	Shreyas. R.	06/11/2020 → A A A A 1 2 A 3 A 4 A 5 A C A A A 7							
47	4BD18CV075	Shashanka. N. B	23/10/20 → A A A A A A 1 A A A A A							
48		Mohan Kumar S. B.	29/10/2020 → A A A A A A 1 A A A A							
49		Sharath. K. R.	03/11/2020 → A 1 2 3 4 5 6 7							
50		Chetan. G	06/11/2020 → A A A A A A A A							
51		Chirudeep. J.	7/11/2020 → A A A A A A A							
52		Vinay. K.	9/11/2020 → A A A A A A							
53		Hila Swamy	12/11/2020 → A A A A A							
54	Changed Branch	Rathan R Rathod	18/11/2020 → 1 2 3 A							
55		Hemanth. H. Y.	18/11/2020 → A A A A							
56		Prajwal Kumar S. K.	20/11/2020 → A A A							
57		Sohaan	Admission 20/11/2020 → A A A							
58		Rohith Kumar N. L	Admission on 23/11/2020 → A 1 2							
59		Vinay D K	Admission on 24/11/2020 → A A							
60		Darshan D Anugh H. G	Admission on 2/12/2020 →							
61		Dakshay. D.	Admission on 9/12/2020 →							

Initials of Teacher

Initials of H.O.D.

Initial of Principal

PRINCIPAL
Jain Institute of Engineering & Technology
DAVANGERE.

Class : III 'B' Section | Subject Code : 18CV35 | Subject : Basic Surveying | Total No. of Classes : 56

Sl No.	USN	NAME	DATE	10/12/20	14/12/20	16/12/20	21/12/20	23/12/20	28/12/20	30/12/20	31/12/20	4/1/21	5/1/21	11/1/21	18/1/21	12/1/21	21/1/21	01/2/21	3/2/21	4/2/21	10/2/21	11/2/21	15/2/21	17/2/21	18/2/21	18/2/21	18/2/21	19/2/21	20/2/21	23/2/21	26/2/21	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
31	4BD19CV068	Vaishnavi	31	25	26	27	28	29	30	31	32	33	34	35	36	A	A	37	38	39	A	40	41	42	43	44	45	46	47	48	49	31	10	27	26	13	22	32
32	4BD19CV070	Veeresh B.	32	A	A	A	A	A	A	A	A	A	A	A	A	A	A	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	10	27	23	03	18	28
33	4BD15CV072	Veman M C	33	A	A	10	A	A	A	A	A	A	A	A	A	A	A	11	12	13	14	15	16	17	18	19	20	21	22	23	24	33	10	22	22	11	19	29
34	4BD15CV074	Vikas D	34	A	A	15	A	A	16	A	A	A	A	A	A	A	A	17	18	19	20	21	22	23	24	25	26	27	28	29	30	34	10	26	23	13	21	31
35	4BD15CV076	Vivek A P	35	A	A	A	A	A	A	A	A	A	A	A	A	A	A	3	4	5	6	7	8	9	10	11	12	13	14	15	16	35	10	18	26	13	19	29
36	4BD19CV078	Yashaswini	36	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	36	AB	AB	AB	AB	AB	AB
37	4BD15CV080	Zaiba Anjum	37	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	37	10	20	30	20	27	37
38	4BD18CV090	Tejesh B R	38	A	A	A	A	A	A	A	A	A	A	A	A	A	A	4	5	6	7	8	9	10	11	12	13	14	15	16	17	38	10	26	25	04	19	29
39	4BD17CV065	Pavan K C	39	A	A	A	A	A	A	A	A	A	A	A	A	A	A	7	8	9	10	11	12	13	14	15	16	17	18	19	20	39	10	26	20	06	18	28
40	4BD18CV024	Ganesh B C	40	A	A	5	5	6	7	A	A	A	A	A	A	8	A	9	10	11	12	13	14	15	16	17	18	19	20	21	22	40	10	19	15	15	17	27
41	4BD18CV047	Mohan A D	41	A	A	A	A	8	A	A	A	A	A	A	A	A	A	10	11	12	13	14	15	16	17	18	19	20	21	22	23	41	10	27	22	03	18	28
42	4BD18CV078	Siddesh Gowda	42	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	42	10	17	19	09	15	21
43	4BD18CV092	Uday K H	43	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	43	10	12	21	8	14	24
44	4BD17CV025	Dishanth	44	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	Left				44	AB	AB	AB	AB	AB	AB
45	4BD17CV002	Adarsh N C	45	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	Left				45	AB	AB	AB	AB	AB	AB
46	(Lst)	Shreyas R	46	8	A	9	A	10	A	11	12	A	A	13	A	A	A	14	15	16	17	18	19	20	21	22	23	24	25	26	27	46	10	30	25	19	25	35
47	4BD18CV075	Shashank N	47	A	A	A	A	A	A	A	A	A	A	A	A	A	A	3	4	5	6	7	8	9	10	11	12	13	14	15	16	47	10	23	23	02	18	28
48		Mohan Kumar	48	A	A	2	A	A	A	3	A	4	A	A	A	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	48	10	28	26	13	23	33
49		Sharath K R	49	8	A	9	A	10	A	A	A	A	A	A	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	49	10	30	27	14	24	34
50		Chetan C	50	A	A	A	A	A	A	A	A	A	A	A	A	A	2	3	4	5	A	6	7	8	9	10	11	12	13	14	15	50	10	27	25	10	21	31
51		Chirudeep J	51	A	A	A	A	A	A	A	A	A	A	A	1	2	3	4	5	A	6	7	8	9	10	11	12	13	14	15		51	10	24	20	05	17	27
52		Vinay K	52	A	A	A	A	A	A	A	A	A	A	A	A	2	3	4	5	A	6	7	8	9	10	11	12	13	14	15		52	10	26	17	13	19	29
53		Hala Swamy J	53	A	A	A	A	A	A	A	A	A	A	A	1	A	2	3	4	A	5	6	7	8	9	10	11	12	13	14		53	10	25	22	13	20	30
54	(Change Branch)	Rathan R	54	A	4	A	A	5	6	7	A	A	8	A	9	A	10	11	12	A	13	14	15	16	17	18	19	20	21	22		54	10	30	25	14	23	33
55		Hemanth H	55	1	A	A	2	A	A	A	A	A	A	A	3	A	4	5	6	A	7	8	9	10	11	12	13	14	15	16		55	10	26	30	23	27	37
56		Prajwal Kar	56	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	2	3	4			56	09	19	94	09	08	21
57		Sohaan	57	A	A	1	A	A	A	A	A	A	A	A	A	A	2	3	4	A	5	6	7	8	9	10	11	12	13	14		57	10	30	20	06	19	29
58		Rohith Kumar	58	3	4	5	6	7	8	A	9	A	A	A	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	58	10	30	26	16	24	34
59		Vinay D V	59	A	A	A	A	A	A	A	A	A	A	A	A	A	1	2	3	4	A	5	6	7	8	9	10	11	12	13	14	59	10	27	26	06	20	30
60		Darshan D A	60	A	A	A	A	A	A	1	2	A	A	A	3	4	5	6	7	8	A	9	10	11	12	13	14	15	16	17	18	60	10	26	25	17	23	33
61		Dakshay D		A	1	A	A	A	A	A	A	A	A	A	A	A	A	2	3	4	A	5	6	7	8	9	10	11	12	13	14	61	10	27	29	05	21	31

Initials of Teacher

Initials of H.O.D.

Initial of Principal

PRINCIPAL
Jain Institute of Engineering & Technology
DAVANGERE.

Class: III B | Subject Code: 18CV35 | Subject: Basic Surveying | Total No. of Classes: 56

Sl No.	USN	NAME	02/12/20	14/12/20	16/12/20	21/12/20	23/12/20	28/12/20	30/12/20	31/12/20	4/1/21	5/1/21	7/1/21
62	1	Harshith. B. P 22.12.2020	Admission on 22.12.2020					1	2	3	A	A	[illegible]
63		Sandeep. K 23.12.2020	Admission on 23.12.2020					A	A	A	A	A	A
64		Abhishek. H 23.12.2020						A	1	A	A	A	A
65		Vinay H. R 23.12.2020						A	1	A	A	A	A
66		Chidananda. H 23.12						A	1	A	A	A	2
67		Kallesh. M. N 24.12						A	A	A	A	A	A
68		Bhavana. M 30.12								A	A	A	1
69		Ganesh. L 31.12	Admission on 31.12.2020						1	2	3	A	4
70		Muralidhar. B. 31.12									A	A	1
71		Mithun Chavan 31.12									A	A	A
72		Mohammed Shadab Azeez 31.12								1	1	A	A
73		Mohammed Thoufiq.											
		Initials of Teacher	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Initials of H.O.D.								✓			
		Initial of Principal											

Sl No.	13/1/21	19/1/21	21/1/21	1/2/21	4/2/21	8/2/21	10/2/21	13/2/21	15/2/21	17/2/21	12/2/21	18/2/21	18/2/21	19/2/21	22/2/21	23/2/21	26/2/21	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
62	A	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20							
63	A	1	2	3	4	5	A	6	7	8	9	10	11	12	13	14	15							
64	A	1	2	3	4	5	A	6	7	8	9	10	11	12	13	14	15							
65	A	1	2	3	4	5	A	6	7	8	9	10	11	12	13	14	15							
66	A	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18							
67	A	1	2	3	4	5	A	6	7	8	9	10	11	12	13	14	15							
68	A	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17							
69	A	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20							
70	A	2	A	3	4	5	A	6	7	8	9	10	11	12	13	14	15							
71	A	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16							
72	A	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17							
73				1	2	3	4	5	6	7	8	9	10	11	12	13	14							
Initials of Teacher	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							

PRINCIPAL
[illegible] Institute of Engineering & Technology
DAVANGERE.

Class : III B Subject Code : 18CV35

Sl No.	USN	NAME	DATE											
62		Harshith B P 22.12.20							1	2	3	A	A	C
63		Sandeep. K 23.12.20							A	1	A	A	A	A
64		Abhishek. H 23.12.20							A	1	A	A	A	A
65		Vinay H. R 23.12.20							A	1	A	A	A	A
66		Chidananda. H 23.12							A	1	A	A	A	2
67		Kallesh. M N 24.12							A	A	A	A	A	A
68		Bhavana. M 30.12									A	A	A	1
69		Ganesh. L 31.12								1	2	3	A	4
70		Muralidhar. B 31.12										A	A	1
71		Mithun chavan										A	A	A
72		Mohammed chadar									1	1	A	A
73		Mohammed												

Initials of Teacher

Initials of H.O.D.

Initial of Principal

Class : III B

Total No. of Classes : 56

Sl No.	USN	NAME	No. of Days Present	%	Test Marks I	II	III	Average	Remarks
			62	10	30	23	12	22	32
			63	10	22	30	16	23	33
			64	10	24	30	30	28	35
			65	10	28	26	8	21	31
			66	10	30	23	18	24	34
			67	10	25	17	14	15	29
			68	10	30	26	12	23	33
			69	10	26	30	10	22	32
			70	10	28	29	26	25	35
			71	10	30	20	16	22	32
			72	10	26	26	20	24	34
			73	10	26	28	14	23	33

Initials

Initials

Initial

PRINCIPAL
Jain Institute of Engineering & Technology
DAVANGERE.

Class: III A Subject Code: 18CVL38

Subject: Basic Materials Testing lab Total No. of Classes: 10

Sl No.	USN	NAME	8/1/21	8/01/21	15/01/21	26/01/21	5/02/21	12/02/21	19/02/21	26/02/21	1/3/21	5/3/21	No. of Days Present	%	Test Marks I	II	III	Average	Remarks
1.	4BD19CV001	Aban Sharif	1	2	A	4	5	6	7	8	A	9		1	20+10		3+	1	30
2.	4BD19CV003	Afzal Noorsabnavar	A	A	2	3	4	A	5	6	7	8		2	22+14			=	36
3	4BD19CV005	Akashdeep R Andanur	1	2	3	4	5	6	7	8	9	10		3	23+15			=	38
4	4BD19CV006	Akhila C Akula.	1	2	3	4	5	6	7	8	9	10		4	24+15			=	39
5	4BD19CV007	Akshatha Ashoka Duttalkar	1	2	3	4	5	6	7	8	9	10		5	24+16			=	40
6	009	Akshaya Kumara. L.M.	1	2	3	4	5	6	7	8	A	9		6	22+13			=	35
7	011	Amith K.M.	A	1	A	2	3	4	A	5	A	6		7	22+13			=	35
8	013	Arpitha Balanagouda Patil	1	2	3	4	A	A	5	6	7	8		8	24+15			=	39
9	015	Basavaraj S Patil		A	A	A	A	A	A	A	A	A		9	19+10			=	29
10	017	Bhumika P.	1	2	3	4	5	6	7	8	9	10		10	23+15			=	38
11	019	Chinmayee.K.	1	2	3	4	5	6	7	8	9	11		11	24+15			=	39
12	021	Darshan V.N.	1	2	3	4	5	A	A	6	7	8		12	20+14			=	34
13	023	Ganesh U Shirigeri	1	2	A	3	4	5	A	6	7	8		13	24+14			=	38
14	025	Hemanth Kumar. D.V.	1	2	3	4	5	A	A	6	7	8		14	23+14			=	34
15	4BD18CV099	Vinay Kumar M.	1	2	A		A	A	A	A	A	A		15	20+13			=	23
16	4BD18CV027	Harshith N	1	2	3	4	5	6	A	7	A	8		16	21+13			=	34
17		Bharath Reddy N	1	2	3	4	5	A	6	7	8	9		17	22+14			=	36
18		Dhanush.R	A	1	2	3	4	5	6	7	8	10		18	23+14			=	37
19		Vinod Kumar Budhihal	1	A	2	3	4	5	6	7	8	9		19	22+11			=	33
~~20~~	~~4BD17CV100~~	~~Sujith R.~~ left	A	A	A	A	A	A	A	A	A			20	left				
21		Suraj N. Raikar	1	2	3	4	5	6	7	8	9	10		21	22+15			=	37
22		Sandeep B.N	1	2	A	3	A	4	5	6	7	8		22	24+15			=	39
23.		Triveni G.	1	2	3	4	5	6	7	8	9	10		23	23+14			=	37
24		Veena B Bharamagoudar	1	2	A	3	4	5	6	7	8	9		24	23+14			=	37
25.		Trupthi Balikai	A	A	A	2	3	4	5	6	7	8		25	23+14			=	37
		Initials of Teacher	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							
		Initials of H.O.D.										✓							
		Initial of Principal																	

PRINCIPAL
Bapuji Institute of Engineering & Technology
DAVANGERE.

Class : 3 A

Subject Code : 18CV32

Subject : Strength of Materials

Total No. of Classes : 94

SI No.	USN	NAME	23/12/20	26/12/20	28/12/20	29/12/20	30/12/20	02/01/21	05/01/21	06/01/21	07/01/21	[illegible]	[illegible]	9/1/21	13/1/21	18/1/21	19/1/21	25/1/21	27/1/21	28/1/21	29/1/21	1/2/21	2/2/21	3/2/21	4/2/21	6/2/21	8/2/21	10/2/21	11/2/21	[illegible] 78	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
1	4BD19CV001		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	40							
2	003		42	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68							
3	005		49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	85							
4	006		53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	89							
5	007		54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	90							
6	009		29 A	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	66							
7	011		44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	80							
8	013		44 A	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	80							
9	015		31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58							
10	017		55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	91							
11	019		55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	91							
12	021		47	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	47							
13	023		47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	83							
14	025		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	42							
15	027		26 A	Change of Branch																																	
16	029		28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	65							
17	031			Left the college																																	
18	033		56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	93							
19	035		19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	55							
20	037		55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	91							
21	039		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	41							
22	041		46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	82							
23	043		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	A	52	53	54	64							
24	047		6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	42							
25	049		23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	59							
26	051		42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69							
27	053		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32							
28	055		11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	48							
29	057		42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	78							
30	057		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	37							
31																																					
		Initials of Teacher																																			
		Initials of H.O.D.																																			
		Initial of Principal																																			

PRINCIPAL
Bapuji Institute of Engineering & Technology
DAVANGERE.

Class : 3rd

Subject Code : 18CV32

Subject : Strength of Materials

Total No. of Classes : 94

Sl No.	USN	NAME	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
31	4BD18CV061		40						
32	63		88						
33	65		92						
34	67		90						
35	69		90						
36	71		66						
37	73		83						
38	75		53						
39	77		57						
40	79		42						
41	4BD18CV099	Vinay kumar. M.	45						
42	4BD17CV052	Mohammed Azhar Baiths	56						
43		Trupthi. C. R.	32						
44	4BD18CV027	Harshith. N.	68						
45		Channesh. H. Patil	65						
46	4BD18CV076	Shivaraj. K. H.	56						
47		Bharath Reddy N	39						
48		Mohammed Ishaqdir	29						
49		Abhilash. B. V	35						
50		Dhanush. R	42						
51		Surabhi S. Bharadwaj	37						
52		Chethan Kotraish.	45						
53		Vinod kumar Budhihal	53						
54		Nandish M Mathad.	37						
55	Change of Branch	Santhosh S Bayoor	37						
56	4BD17CV160	Sujith. R	Left the college						
57		Rohith. A	35						
58	Change of branch	Kiran. M. M	33						
59		Suraj. N. Raikar.	49						
60		Murugharajendra. H. V	38						
61		Shree Harsha. J. R.	41						

Initials of Teacher

Initials of H.O.D.

Initial of Principal

PRINCIPAL
Jain Institute of Engineering & Technology
DAVANGERE.

Class : 2nd B | Subject Code : 18CV32 | Subject : Strength of Materials | Total No. of Classes : 94

Sl No.	USN	NAME	23/12/20	26/12/20	28/12/20	29/12/20	30/12/20	04/1/21	05/1/21	06/1/21	8/1/21	7/1/21	11/1/21	12/1/21	13/1/21	18/1/21	19/1/21	25/1/21	27/1/21	28/1/21	29/1/21	1/2/21	2/2/21	3/2/21	4/2/21	5/2/21	8/2/21	10/2/21	11/2/21	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
62		Sandeep. B.N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	37						
63		Shankar Rao Kulkarni. C.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	37						
64		Ambika. H. J.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	24	37						
65		Triveni. G.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	37						
66		Pallavi. O.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	37						
67		Harika. C.B	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22	23	24	25	26	36						
68		Veena B Bharamgoudar	24/12/2020 →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	36						
69		Harsha. C. N.	24/12/2020 →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25		35						
70		Harish. C.G.	26/12/2020 →		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		25						
71		Truthi S Balikai	28/12/2020 →			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22			32						
72		Deepak. L	29/12/2020 →				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		23						
73		Firdous Anjum. H.	31/12/2020 →				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		32						

Initials of Teacher

Initials of H.O.D.

Initial of Principal

PRINCIPAL
Bapuji Institute of Engineering & Technology
DAVANGERE.

LESSON PLAN

Subject : Subject Code : Class :

Period	Date	Topics Planned	Date	Topics Covered	Remarks
35	07.11.2020	Rankine Gordon's formula equation Problems.	07.11.2020	Rankine Gordon's formula equation Problems	covered
36	09.11.2020	Problems of Euler's Gordon's eqn.	09.11.2020	Problems of Euler's Gordon's eqn.	covered
37	11.11.2020	Module: 2. Compound Stress. Introduction	11.11.2020	Module: 2 Compound Stress Introduction	covered.
38	12.11.2020	General two dimensional Stress System Principal Stress & Planes	12.11.2020	General two Dimensional Stress System Principal Stress & Planes	covered
39	17.11.2020	Problems on Principal Stress & Planes	17.11.2020.	Problems on Principal Stress & Planes	covered.
40	18.11.2020	Problems on Principal Stress & Planes	18.11.2020	Problems on Principal Stress & Planes	covered
41	19.11.2020	Module: 3 Shear Force & Bending Moment Introduction	19.11.2020	Module: 3 Shear Force & Bending moment : Introduction	covered.
42	21.11.2020	Types of Beams, Loading Supports,	21.11.2020	Types of Beams, Loading Supports	covered
43	23.11.2020	Simply supported Beam with Point load & eccentric loading with Problems	23.11.2020	Simply supported Beam with Point load & eccentric loading with problems	covered.
44	24.11.2020	Simply supported Beam with udl with Problems	24.11.2020.	Simple supported Beam with udl with Problems	covered
45	25.11.2020	Simply supported Beam with Problems	25.11.2020.	Simply supported Beam	covered
46	26.11.2020	Problems on simply supported Beam with Different loading condition	26.11.2020	Problems on simply supported Beam	covered
47	28.11.2020	Problems.	28.11.2020	Problems	covered
48	30.11.2020	Overhanging beam Derivation for with Different loading	30.11.2020	Overhanging beam with different loading conditions	covered
49	1/12/2020	Problems	1/12/2020	Problems	covered
50	2/12/20	Problems	2/12/20.	Problems	covered
51	12/12/20	Cantilever beam with different loading conditions	12/12/20	Cantilever beam with different loading conditions	covered.

LESSON PLAN

Period	Date	Topics Planned	Date	Topics Covered	Remarks
52	14/12/20	problems	14/12/20	problems.	covered
53	15/12/20	module: 4 Bending stress Introduction	15/12/20	module 4 Bending shear stress Introduction.	covered.
54	16/12/20	Derivation on equation for Bending stress $\frac{M}{I}=\frac{E}{R}=\frac{f}{y}$	16/12/20	Derivation on equation Bending stress $\frac{M}{I}=\frac{E}{R}=\frac{f}{y}$	covered
55	21/12/20	problem on Bending stress	21/12/20	problem on Bending stress	covered.
56	22/12/20.	problem on Bending stress	22/12/20	problem on Bending stresses	covered.
57	23/12/20	problem on Bending stress.	23/12/20	problem on Bending stress	covered.
58	26/12/20	Deflection of Beams module 5	26/12/20	Deflection of Beams	covered
59	28/12/20	Derivation of Beams. simply supported Beam with point.	28/12/20	Derivation of Beams simply supported Beam with point	covered
60	28/12/20.	UDL UDV problems	28/12/20.	UDL, UVL problems	covered

Text Books :

1. B. S. Basavarajaiah, P. Mahadevappa. Strength of materials in SI units University of Press (India).
2. R Subramanian. Strength of materials latest edition.

Reference Books :

1. R.K. Bansal, A Text book of Strength of materials. 4th edition Laxmi publication, 2010.
2. D. H. Young. S.P. Timoshenko. "elements of strength of materials.
3. S. Ramamrutham. Strength of materials.
4. S.S. Bhavikatti. by Strength of materials
5. ....

Signature of Faculty

HOD

TUTORIAL CLASSES

Date	Topics Discussed	Remarks
61	Problems on Deflection	covered
62	Problem on deflection	covered.
63	Problem on deflection	covered
64	Problem on deflection	covered.
65	Problem on Deflection	covered.
66	Problem on Deflection	covered
67	Module: 2 [For Diploma] Thick & Thin cylinders Derivation of hoopstress & longitudinal stress.	covered
68	Problem on same	covered
69	Problem on Thick cylinders	covered
70	Thick cylinders Derivations	covered
71	Problems on Thick cylinders	covered
72	Problems on thick cylinders	

Test	Date	Class Strength	No. of Students Appeared	No. of Students Scored < 15	Signature of the HOD
T1	24/10/20	70	70	0	[signature]
T2	07.12.2020	70	70	0	[signature]
T3	22.02.2021	70	67	50	[signature]

LESSON PLAN

Subject : Basic surveying Subject Code : 18CV35 Class : III rd B

Period	Date	Topics Planned	Date	Topics Covered	Remarks
1	10/9/20	Module! I. Definition of surveying objectives & Importance	10/9/20	Module! I. Defination of surveying objectives & importance	covered
2	14/9/20	Classification of surveying.	14/9/20	Classification of surveying	covered
3	15/9/20	Principles of surveying	15/9/20	principles of surveying	covered
4	16/9/20	Applications of surveying unit of measurement	16/9/20	Applications of surveying unit of measurements	covered
5	21/9/20	Surveying measurement errors, types of errors precision &	21/9/20	surveying measurement errors, types of errors, precision	covered
6.	23/9/20	Accuracy, classification of maps, map & Numbering	23/9/20	Accuracy, classification of maps. maps & Numbering	covered.
7	28/9/20	Measurement of Horizontal Distances: Measuring tape & types, measurement using tapes, Taping on	28/9/20	Measurement of Horizontal distances Measuring tape measurement using tapes,	covered
8	30/9/20	Level ground. + Direct Ranging + In Direct Ranging	30/9/20	level ground. + Direct ranging + Indirect ranging.	covered
9	1/10/20	Sloping ground Direct & Indirect Ranging	1/10/20	sloping ground by Direct & Indirect ranging	covered
10	05/10/20	EDM, basic principles Booking of tape survey work	05/10/20	EDM, basic principles of Booking of tape survey work	covered
11	07/10/20	conventional symbols, obstacles in tape surveying	07/10/20	conventional symbols, obstacles in tape surveying	covered
12	08/10/20	Problems	08/10/20	Problems	covered.
13	12/10/20	Module! 4 plane table surveying accessories	12/10/20	module-4 plane table surveying accessories	covered
14	14/10/20	Setting up the plane table surveying	14/10/20	setting up the plane table surveying	covered
15	15/10/20	methods of plane table surveying Radiation	15/10/20	methods of plane table surveying Radiation	covered
16	21/10/20	Intersection method. Traversing Advantages & Disadvantages Plane table surveying	21/10/20	Intersection method Traversing Advantages & Disadvantages Plane table surveying	covered
17	22/10/20	Resection Two point Problems, Three Point Problem	22/10/20.	Resection - Two Point Problem & Three Point Problem	covered.

LESSON PLAN

Subject: Basic surveying Subject Code: 18CV35 Class: 3rd B

Period	Date	Topics Planned	Date	Topics Covered	Remarks
18	28.10.20	Three Point Problem & 7	28.10.20	Three Point Problem	covered
19	29.10.20	Module 5: Area & volume Different Area - method of area calculation	29.10.20	Module 5: Area & volume. Introduction	Covered.
20	04.11.20	offsets at Regular intervals.	04.11.20	offsets at Regular Intervals.	covered.
21	05.11.20	Area from co-ordinates, with problems.	05.11.2020	Area from co-ordinates with Problems	covered.
22	9.11.20	Problems on Areas by Different methods	9.11.2020	Problems on Areas by Different methods	covered
23	11.11.20.	volume: Different methods Problems on volume	11.11.2020	volume: Different methods & problems on volume	covered
24	18.11.2020	Problems on volume.	18.11.2020	Problems on volume	covered
25	15.11.2020	Module: 2 compass surveying Introduction	15.11.2020	Module: 2 compass surveying Introduction	covered
26	23.11.2020	Definitions of Fore Bearing Back Bearing, WCB, QB problems	23.11.2020.	Definitions of Fore Bearing Back Bearing, WCB, QB Problems	covered.
27	25.11.2020	Magnetic Dip & Declination with problems, surveyor Prismatic compass, surveyor compass with construction	25.11.2020	Magnetic Dip & Declination with problems. Prismatic compass, surveyor compass with construction.	covered.
28	26.11.2020	Problems on Interior angles	26.11.2020	Problems on Interior angles (Included angles)	covered
29	02/12/2020	Local attraction, Introduction Problems	02/11/2020	Local attraction Problems	covered
30	14/12/2020	Problems on local attraction	14/11/2020	Problems on local attraction	covered
31	16/12/2020.	Traverse: computation Introduction	16/12/2020	Traverse computation	covered
32	21/12/2020	1. Dependent co-ordinates 2. Independent co-ordinates 3. closing error. with problems	16/12/2020	1. Dependent co-ordinates 2. Independent co-ordinates 3. closing error with problems.	covered
33	23/12/2020.	1. Bowditch Rule, 2. Transit Rule with problems	23/12/2020	Problems	covered
34	28/12/2020.	omitted measurements problems	28/12/2020.	omitted measurements with problems	covered

LESSON PLAN

Subject: Basic surveying Subject Code: 18CV35 Class: 2nd B

Period	Date	Topics Planned	Date	Topics Covered	Remarks
35	30.12.20	Module 3 levelling: Basic definitions methods of levelling.	30.12.20	Module 3 levelling: Basic definitions methods of levelling	covered
36	31.12.20	Dumpy level, Auto level, digital levelling & laser levelling	31.12.20	Dumpy level, Auto level, digital levelling & laser levelling	covered
37	4.1.21	Curvature and refraction corrections,	4.1.21	Curvature & refraction corrections	covered
38	5.1.21	Booking & reduction of levels. Problems	5.1.21	Booking & reduction of levels & problems	covered
39	7.1.21	Problems on levelling	7.1.21	Problems on levelling	covered
40	13.1.21	Problems on levelling Differential levelling	13.1.21	problems on Differential levelling	covered.
41	17.1.21	problems on Differential levelling	17.1.21	problems on Differential levelling	covered
42	21.1.21	Profile levelling with problems	21.1.21	Profile levelling with problems	covered
43	01.2.21	fly levelling with problems	01.2.21	fly levelling with problems.	covered
44	3.2.2021	Reciprocal levelling	3.2.2021	Reciprocal levelling	covered
45	4.2.2021	problems on Reciprocal levelling	4.2.2021	Problems on Reciprocal levelling.	covered
46	10.2.2021	module 4 Plane table surveying accessories, setting up plane table surveying	10.2.2021	module: 4 Plane table surveying accessories setting up plane table surveying	covered
47	11.2.2021	method of plane table surveying	11.2.2021	methods of plane table surveying	covered.
48	15.2.2021	Advantages & Disadvantages of plane table surveying Resection of two-point Problems, three-point Problems	15.2.2021	Advantages & Disadvantages of plane table surveying Resection of two-point three point problems	covered
49	17.2.2021	Three point problems	17.2.2021	Three point problems	covered.
50.	17.2.2021	module: 5 Area & Volume Area - methods of Area calculation, offsets at regular intervals.	17.2.2021	module: 5 Area & Volume Area - methods of area calculation, offsets at regular intervals	covered
51	18.2.2021	Area from co-ordinates with problems, by different method, volumes: Different methods	18.2.2021	Area from co-ordinates with problems, by different method, volume Different methods.	covered

LESSON PLAN

Period	Date	Topics Planned	Date	Topics Covered	Remarks

Text Books :

1. B.C. Punmia, "Surveying Vol. I. Laxmi Publications Pvt. Limited New Delhi - 2005.

2. Kanetkar T.P. & S.V. Kulkarni. Surveying & Leveling.

Reference Books :

1. S.K. Duggal 'Surveying Volume 1.

2. K.R. Arora. Surveying Volume 1

3. R. Subramanian. Surveying & Leveling.

4.

5.

Signature of Faculty

HOD

TUTORIAL CLASSES

Date	Topics Discussed	Remarks

Test	Date	Class Strength	No. of Students Appeared	No. of Students Scored < 15	Signature of the HOD
T1	23.10.2020	67	67	00	[signature]
T2	09.12.2020	67	67	00	[signature]
T3	23.02.2021	67	67	[illegible]	[signature]

TIME TABLE Raghu M.E

Day / Time	1 8.00 - 9.00	2 9.00 - 10.00	10.00 - 10.30	3 10.30 - 11.30	4 11.30 - 12.30	12.30 - 2.00	5 2.00 - 3.00	6 3.00 - 4.00	7 4.00 - 5.00
MONDAY	18CV32-A		SHORT BREAK			LUNCH BREAK	18CV35 - B		18CVL57 - T (B)
TUESDAY		18CV32-A							
WEDNESDAY	18CV35-B				18CV32-B		← 18CVL57 - A3 (MEET SH)		
THURSDAY		18CV35-B		18CV32-A			← 18CVL57 - B1 (MEER+ANS)		
FRIDAY		← 18CVL 38 A1 (MER+CPA)							
SATURDAY		18CV32-A							

3rd A - Section
= Strength of Materials
3rd B - Section
= Basic Surveying
18CVL57-T (B)
= Surveying Practice
18CVL57- B1 & A3
- Surveying Practice.
18CVL38 - A1
Building Materials Lab

Sign. of the Staff

Sign. of the HOD

PRINCIPAL
Sign. of the Principal
Bapuji Institute of Engineering & Technology
DAVANGERE.

Course File Check List

1. Contents
2. Academic calendar of VTU, Institute and Department
3. Vision, Mission statements of Institute
4. Vision, Mission, PEOs, POs, PSOs statements of Department
5. Individual time table
6. Syllabus
7. Course Articulation Matrix [CO-PO, CO-PSO mapping]
8. Lesson plan
9. Text books / Reference books referred
10. Attendance register
11. Course material
    a) Notes
    b) PPT
    c) NPTEL / Youtube Videos
12. Additional topics taken to meet the POs.
    a) Site visits
    b) Technical talks
    c) Quiz
    d) Group discussion
    e) Blended learning
    f) Model making competition
    g) Modern tool (Computing tool) usage
13. Exam question papers
14. Test and Assignment question papers (with scheme of evaluation)
15. Result analysis
    a) Percentage CO covered / Percentage of CO addressed.
    b) CO-PO and CO-PSO Attainment
    c) Percentage of students passed
16. Counselling report (Actions taken to improve Weak students / Slow learners)

2020-21 odd Sem

Tentative Academic Calendar of VTU, Belagavi for ODD Semester of 2020-2021

	I Sem B. E. / B. Tech. / B. Arch./B.Plan	I sem M.Tech./MBA /MCA/M.Arch.	III, V & VII Sem B. E. /B. Tech./B.Plan/ B.Arch & IX Sem B. Arch.	III & V Sem MCA	III Sem MBA	III Sem M. Tech.	III Sem M. Arch.
Commencement of ODD Semester	Will be announced later	Will be announced later	01.09.2020	01.09.2020	01.09.2020	01.09.2020	01.09.2020
Last Working day of ODD Semester			17.12.2020	17.12.2020	17.12.2020	17.12.2020	17.12.2020
Practical Examinations			21.12.2020 To 31.12.2020	21.12.2020 To 31.12.2020	21.12.2020 To 31.12.2020	21.12.2020 To 31.12.2020	21.12.2020 To 31.12.2020
Theory Examinations			04.01.2021 To 23.01.2021	04.01.2021 To 23.01.2021	04.01.2021 To 23.01.2021	04.01.2021 To 23.01.2021	04.01.2021 To 23.01.2021
Internship Viva-Voce			-	-	-	25.01.2021 To 08.02.2021	-
Professional training / Organization study			-	-	-	-	-
Commencement of EVEN Semester			08.02.2021	08.02.2021	08.02.2021	22.02.2021	08.02.2021

NOTE

- VII Semester B. E / B. Tech students shall have to undergo INTERNSHIP as per circular of University **VTU/Aca/2019-20/85, dated 12.05.2020.**
- I Semester B. E/ B. Tech / B. Arch Students shall compulsorily undergo Induction Program for a period of 3 Weeks as per the schedule given by VTU Belagavi
- The classroom sessions for all the higher semesters would be commencing from 01.09.2020(Tentative) in ONLINE mode until further orders.
- The Institute needs to function for six days a week with additional hours.
- The faculty/staff shall be available to undertake any work assigned by the university.
- If any of the above date is declared to be a holiday then the corresponding event will come into effect on the next working day.
- Notification regarding Calendar of Events relating to the conduct of University Examinations will be issued by the Registrar (Evaluation) from time to time.
- **Academic Calendar may be modified based on guidelines/directions issued in future by MHRD/UGC/AICTE/State Government.**

12.7.2020

REGISTRAR

Bapuji Institute of Engineering and Technology, Davangere-577004

CALENDER OF EVENTS - ODD SEMESTER: SEPTEMBER-JANUARY- 2020-21 (Tentative)

PARTICULARS	I sem BE/B Tech	III, V BE/B.Tech	VII sem BE/B.Tech	III & V sem MCA	III sem MBA	III sem M.Tech
Commencement of ODD Sem	14-12-2020	01-09-2020	01-09-2020	01-09-2020	01-09-2020	01-09-2020
Last Working Day	25-03-2021	16-01-2021	16-01-2021	16-01-2021	16-01-2021	16-01-2021
1st CIE Series	------	19-10-2020 To 24-10-2020	19-10-2020 To 24-10-2020	19-10-2020 To 24-10-2020	15-10-2020 To 17-10-2020	19-10-2020 To 24-10-2020
2nd CIE Series	------	07-12-2020 To 09-12-2020	07-12-2020 To 09-12-2020	07-12-2020 To 09-12-2020	26-11-2020 To 28-11-2020	07-12-2020 To 09-12-2020
3rd CIE Series	------	11-01-2021 To 13-01-2021	11-01-2021 To 13-01-2021	11-01-2021 To 13-01-2021	7-01-2021 To 9-01-2021	11-01-2021 To 13-01-2021
Practical Examination	29-03-2021 Onwards #	21-01-2021 Onwards #	21-01-2021 Onwards #	08-02-2021 Onwards #	------	21-01-2021 Onwards #
Theory Examination	12-04-2021 To 30-04-2021	08-02-2021 To 27-03-2021	08-02-2021 To 27-03-2021	21-01-2021 To 06-02-2021	21-01-2021 To 19-02-2021	28-01-2021 To 13-02-2021
Internship	------	------	29-03-2021 To 10-04-2021	------	------	------
Internship Viva-Voce	------	------	------	------	------	15-02-2021 To 22-02-2021
Professional Training/Organization Study	------	------	------	------	22-02-2021 To 03-04-2021	------
Commencement of Even Semester	03-05-2021	29-03-2021	12-04-2021	15-02-2021	05-04-2021	23-02-2021

Notification regarding the calendar of events relating to the conduct of University Examination will be issued by the Registrar (Evaluation) from time to time.

Dean Academic

Principal

Vision of BIET

To be a center of excellence recognized nationally and internationally, in distinctive areas of engineering education and research, based on a culture of innovation and invention.

Mission of BIET

BIET contributes to the growth and development of its students by imparting a broad based engineering education and empowering them to be successful in their chosen field by inculcating in them positive approach, leadership qualities and ethical values

VISION OF THE DEPARTMENT

To train the students to become Civil Engineers with leadership qualities, having ability to take up professional assignments and research with a focus on innovative approaches to cater to the needs of the society.

MISSION OF THE DEPARTMENT

1. To provide quality education through updated curriculum and conducive teaching learning environment for the students to excel in higher studies, competitive examinations and professional career.
2. To impart soft skills, leadership qualities and professional ethics among the graduates to handle the projects independently with confidence.
3. To deal with the contemporary issues and to cater to the socio-economic needs.
4. To build industry-institute interaction and to establish good rapport with alumni.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO 1: Core Competence: Graduates will be able to plan, analyse, design and construct sustainable Civil Engineering Infrastructure.

PEO 2: Professional Skills: Graduates will be professional engineers with a sense of ethics, creativity, leadership, self-confidence and independent thinking to cater to the needs of the society.

PEO 3: Societal Needs: Graduates will be able to contribute effectively for the development of industry and professional bodies.

PEO 4: Cognitive Intelligence: Graduates will be able to take up competitive examinations, higher studies and involve in research and entrepreneurship activities.

PROGRAM SPECIFIC OUTCOMES (PSOs)

Students after the completion of the Program will be able to

1. Apply the fundamental concepts, software and codal provisions in the analysis, design and construction of sustainable civil engineering infrastructure.
2. Inculcate professional and leadership qualities, sense of ethics and confidence related to civil engineering.

Faculty will be able to

3. Contribute to the overall development of civil engineering community through the professional bodies and offer services to the society.

3A - CV301
3B - CV305

Name of the Faculty : MER							
Time / Day	8 – 9	9 – 10	10.30 – 11.30	11.30 – 12.30	2 – 3	3 – 4	4 – 5
Mon	18CV32 – A				18CV35 – B		18CVL57 – T (B)
Tue		18CV32 – A					
Wed	18CV35 – B			18CV32 – A	18CVL57 – A3 (MER + SH)		
Thu		18CV35 – B	18CV32 – A		18CVL57 – B1 (MER + GNS)		
Fri		18CVL38 – A1 (MER + CPA)					
Sat		18CV32 – A					

Time Table Coordinator HOD Principal

B. E. CIVIL ENGINEERING
Choice Based Credit System (CBCS) and Outcome Based Education (OBE)
SEMESTER - III

STRENGTH OF MATERIALS

Course Code	**18CV32**	CIE Marks	40
Teaching Hours/Week (L:T:P)	(3:2:0)	SEE Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives: This course will enable students

1. To understand the basic concepts of the stresses and strains for different materials and strength of structural elements.
2. To know the development of internal forces and resistance mechanism for one dimensional and two-dimensional structural elements.
3. To analyse and understand different internal forces and stresses induced due to representative loads on structural elements.
4. To determine slope and deflections of beams.
5. To evaluate the behaviour of torsion members, columns and struts.

Module-1

Simple Stresses and Strain: Introduction, Definition and concept and of stress and strain. Hooke's law, Stress-Strain diagrams for ferrous and non-ferrous materials, factor of safety, Elongation of tapering bars of circular and rectangular cross sections, Elongation due to self-weight. Saint Venant's principle, Compound bars, Temperature stresses, Compound section subjected to temperature stresses, state of simple shear, Elastic constants and their relationship.

Module-2

Compound Stresses: Introduction, state of stress at a point, General two dimensional stress system, Principal stresses and principal planes. Mohr's circle of stresses. Theory of failures: Max. Shear stress theory and Max. principal stress theory.

Thin and Thick Cylinders: Introduction, Thin cylinders subjected to internal pressure; Hoop stresses, Longitudinal stress and change in volume. Thick cylinders subjected to both internal and external pressure; Lame's equation, radial and hoop stress distribution.

Module-3

Shear Force and Bending Moment in Beams: Introduction to types of beams, supports and loadings. Definition of bending moment and shear force, Sign conventions, relationship between load intensity, bending moment and shear force. Shear force and bending moment diagrams for statically determinate beams subjected to points load, uniformly distributed loads, uniformly varying loads, couple and their combinations.

Module-4

Bending and Shear Stresses in Beams: Introduction, pure bending theory, Assumptions, derivation of bending equation, modulus of rupture, section modulus, flexural rigidity. Expression for transverse shear stress in beams, Bending and shear stress distribution diagrams for circular, rectangular, 'I', and 'T' sections. Shear centre (only concept).

Torsion in Circular Shaft: Introduction, pure torsion, Assumptions, derivation of torsion equation for circular shafts, torsional rigidity and polar modulus Power transmitted by a shaft.

Module-5

Deflection of Beams: Definition of slope, Deflection and curvature, Sign conventions, Derivation of moment-curvature equation. Double integration method and Macaulay's method: Slope and deflection for standard loading cases and for determinate prismatic beams subjected to point loads, UDL, UVL and couple.

Columns and Struts: Introduction, short and long columns. Euler's theory; Assumptions, Derivation for Euler's Buckling load for different end conditions, Limitations of Euler's theory. Rankine-Gordon's formula for columns.

Course outcomes: After studying this course, students will be able;

1. To evaluate the basic concepts of the stresses and strains for different materials and strength of structural elements.
2. To evaluate the development of internal forces and resistance mechanism for one dimensional and two dimensional structural elements.
3. To analyse different internal forces and stresses induced due to representative loads on structural elements.
4. To evaluate slope and deflections of beams.
5. To evaluate the behaviour of torsion members, columns and struts.

Question paper pattern:

- The question paper will have ten full questions carrying equal marks.
- Each full question will be for 20 marks.
- There will be two full questions (with a maximum of four sub- questions) from each module.
- Each full question will have sub- question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbooks:

1. B.S. Basavarajaiah, P. Mahadevappa "Strength of Materials" in SI Units, University Press (India) Pvt. Ltd., 3rd Edition,2010
2. Ferdinand P. Beer, E. Russell Johnston and Jr. John T. De Wolf "Mechanics of Materials", Tata McGraw-Hill, Third Edition, SI Units

Reference Books:

1. D.H. Young, S.P. Timoshenko "Elements of Strength of Materials" East West Press Pvt. Ltd., 5th Edition (Reprint2014).
2. R K Bansal, "A Textbook of Strength of Materials", 4th Edition, Laxmi Publications, 2010.
3. S.S. Rattan "Strength of Materials" McGraw Hill Education (India) Pvt. Ltd., 2nd Edition (Sixth reprint2013).
4. Vazirani, V N, Ratwani M M. and S K Duggal "Analysis of Structures Vol. I", 17th Edition, Khanna Publishers, New Delhi.
5. S Ramamrutham
6. R Subramanian
7. S.S Bhavikatti

Title & Code	Strength of Materials (18CV32)
CO	**Statement**
18CV32.1	**Evaluate** the stresses and strains for ferrous and non-ferrous materials
18CV32.2	**Evaluate** the internal stresses developed in one dimensional, two dimensional structural elements and cylinders
18CV32.3	**Evaluate** the bending moment, shear force in prismatic beams and corresponding stresses
18CV32.4	**Analyse** and **design** the circular shafts subjected to torsion
18CV32.5	**Evaluate** the slope and deflection of prismatic beams
18CV32.6	**Evaluate** the failure loads for the columns and struts

Course Title		Strength of Materials										
CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
18CV32.1	2	2	-	1	-	-	-	-	-	-	-	2
18CV32.2	2	2	-	1	-	-	-	-	-	-	-	2
18CV32.3	2	2	-	1	-	-	-	-	-	-	-	2
18CV32.4	2	2	-	1	-	-	-	-	-	-	-	2
18CV32.5	2	2	-	1	-	-	-	-	-	-	-	2
18CV32.6	2	2	-	1	-	-	-	-	-	-	-	2
Average	2	2		1								2

CO	PSO1	PSO2
18CV32.1	2	2
18CV32.2	2	2
18CV32.3	2	2
18CV32.4	2	2
18CV32.5	2	2
18CV32.6	2	2
Average	2	2

CBCS SCHEME

18CV32

USN | | | | | | | | | | |

Third Semester B.E. Degree Examination, Jan./Feb. 2021
Strength of Materials

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Explain longitudinal strain and lateral strain. **(04 Marks)**

b. State and illustrate Saint Venant's principle. **(06 Marks)**

c. A tension test was conducted on mild steel bar and the following data was obtained from the test:
Diameter of the bar = 18mm
Gauge length of the bar = 82mm
Load at proportional limit = 75KN
Extension at a load of 62KN = 0.113mm
Load at failure = 82KN
Final gauge length of the bar = 106mm
Diameter of the bar at failure = 14mm
Determine the Young's modulus, proportional limit, true breaking stress, %elongation and percentage reduction in cross sectional area. **(10 Marks)**

OR

2 a. What are the elastic constants and explain them briefly. **(06 Marks)**

b. Obtain expression for temperature stress in a bar of uniform cross section when expansion or contraction is prevented partially. **(04 Marks)**

c. A weight of 390KN is supported by a short column of 250mm square in section. The column is reinforced with 8 steel bars of cross sectional area $2500mm^2$. Find the stresses in steel and concrete if $E_s=15E_c$.
If stress in concrete must not exceed $4.5MN/m^2$, what area of steel is required in order that column may support a load of 480KN. **(10 Marks)**

Module-2

3 a. Derive Lame's equation for the radial and hoop stress for thick cylinder subjected to internal and external fluid pressure. **(08 Marks)**

b. A 2-dimensional element has the tensile stresses of $600MN/m^2$ and compressive stress of $400MN/m^2$ acting on two mutually perpendicular planes and two equal shear stresses of $200MN/m^2$ on their planes. Determine
i) Resultant stress on a plane inclined at 30° wrt x-axis.
ii) The magnitude and direction of principal stresses.
iii) Magnitude and direction of maximum shear stress. **(12 Marks)**

OR

4 a. Obtain expression for volumetric strain in thin cylinder subjected to internal pressure in the form of $e_v = \frac{pd}{2tE}\left[\frac{5}{2} - \frac{2}{m}\right]$. **(08 Marks)**

b. A cast iron pipe has 200mm internal diameter and 50mm metal thickness and carries water under a pressure of $5N/mm^2$ Calculate the maximum and minimum intensities of circumferential stresses and sketch the distribution of circumferential stress intensity and the intensity of radial pressure across the section. **(12 Marks)**

Module-3

5 a. Define shear force, bending moment and point of contraflexure. Explain how to calculate them? **(06 Marks)**

b. Develop shear force diagram and bending moment diagrams for the beam loaded shown in Fig. Q5(b) marking the values at salient points. Determine the position and magnitude of maximum bending moment.

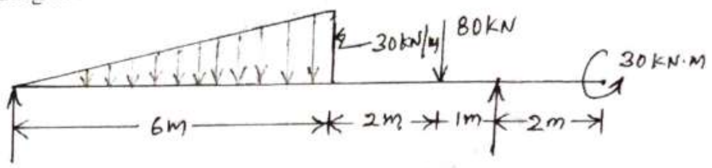

Fig. Q5(b) **(14 Marks)**

OR

6 a. Obtain the relationship between udl, shear force and bending moment. **(06 Marks)**

b. Construct SFD and BMD for the beam loaded shown in Fig. Q6(b). Also locate the point of contraflexure.

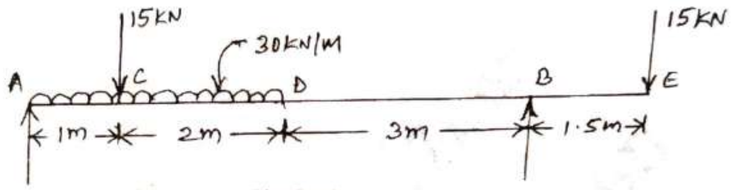

Fig.Q6(b) **(14 Marks)**

Module-4

7 a. Derive torsional equation with usual notations. **(06 Marks)**

b. A T-section of flange 120mm×12mm and overall depth 200mm with 12mm web thickness is loaded such that at a section it has a bending moment of 20KN.m and shear force of 120KN. Sketch the bending and shear stress distribution diagram marking the salient values. **(14 Marks)**

OR

8 a. Derive Bernoulli-Euler bending equation with usual notations. **(08 Marks)**

b. A solid circular shaft has to transmit power of 1000KW at 120rpm. Find the diameter of the shaft if the shear stress of the material is not to exceed $80N/mm^2$ The maximum torque is 1.25 times the mean torque. What percentage saving in material could be obtained if the shaft is replaced by a hollow one whose internal diameter is 0.6 times the external diameter? The length of the shaft, material and maximum shear stress being same. **(12 Marks)**

Module-5

9 a. Define slope, deflection and elastic curve. Explain Macaulay's method of determining slope and deflection. **(10 Marks)**

b. Compare the crippling loads given by Euler's and Rankine's formula for a tubular steel column 2.5m long having outer and inner diameter as 40mm and 30mm respectively. The column is loaded through pin joints at the ends. Take permissible compressive stress as $320N/mm^2$, Rankine constant as $\frac{1}{7500}$ and E=210GPa. For what length of the column of their cross section, does the Euler's formula cease to apply? **(10 Marks)**

OR

10 a. Differentiate between short and long column and what are the limitations of Euler's theory. **(06 Marks)**

b. Calculate slope at A and deflection at D for the overhanging beam shown in Fig. Q10(b). Take E = 200GPa and I = 50×10^6mm^4. **(14 Marks)**

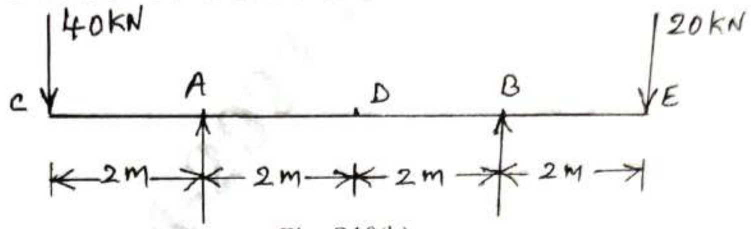

Fig. Q10(b).

* * * * *

CBCS SCHEME

USN | | | | | | | | | |

17CV/CT32

Third Semester B.E. Degree Examination, Jan./Feb. 2021
Strength of Materials

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. Define: (i) Young's modulus (ii) Bulk modulus (iii) Poisson's ratio. Derive a relationship between them. **(10 Marks)**

b. Two solid cylindrical rods are connected and loaded as shown in Fig.Q1(b). Determine: (i) Total deformation (ii) Deformation at point B. E_S = 200 GPa, E_b = 100 GPa.

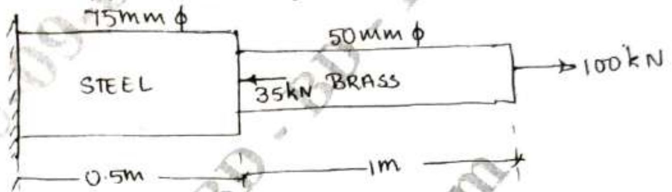

Fig.Q1(b) **(10 Marks)**

OR

2 a. A compound bar made of steel plate 60 mm wide and 10 mm thick to which a copper plate 60 mm wide and 5 mm thick are rigidly connected to each other. The length of the bar is 0.7 m. If the temperature is raised by 80°C. Determine the stress in each metal and the change in length.
E_S = 200 GPa, $\alpha_S = 12 \times 10^{-6}/°C$; E_{cu} = 100 GPa, $\alpha_{cu} = 17 \times 10^{-6}/°C$ **(12 Marks)**

b. Derive an expression for extension of the bar due to its self weight only having area 'A' and length L suspended from its top. **(04 Marks)**

c. Write a note on thermal stresses. **(04 Marks)**

Module-2

3 a. At a certain point in a strained material the stress condition shown in Fig.Q3(a) exists. Find:
(i) The normal and shear stress on the inclined plane AB
(ii) Principal stresses and principal planes
(iii) Maximum shear stresses and their planes

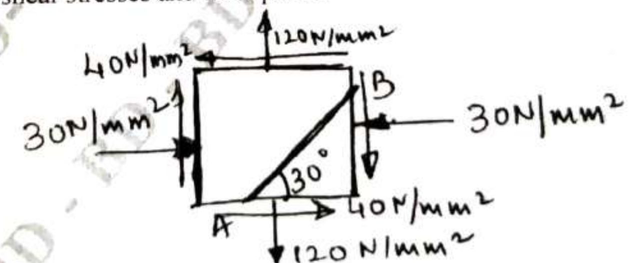

Fig.Q3(a) **(12 Marks)**

b. Derive an expressions for volumetric strain in case of a thin cylindrical shell of diameter 'd' subjected to internal pressure 'p'. **(05 Marks)**

c. Define: (i) Principal stresses (ii) Principal planes **(03 Marks)**

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

OR

4 a. A cylindrical shell is 3m long 1m internal diameter and is subjected to an internal pressure of 1 N/mm^2. If thickness of the shell is 12mm, find the circumferential stress and longitudinal stress. Also find maximum shear stress and the changes in the dimensions of the shell. Take E = 200 kN/mm^2 and $\mu = 0.3$. **(10 Marks)**

b. A thick metallic cylindrical shell of 150 mm, internal diameter is required to withstand an internal pressure of 8 MPa. Find the necessary thickness of cylinder, if permissible stress of the section is 20 MPa. **(10 Marks)**

Module-3

5 a. Derive relation between shear force, bending moment and load. **(06 Marks)**

b. Calculate SF and BM at salient points and draw SFD and BMD for the beam shown in Fig.Q5(b).

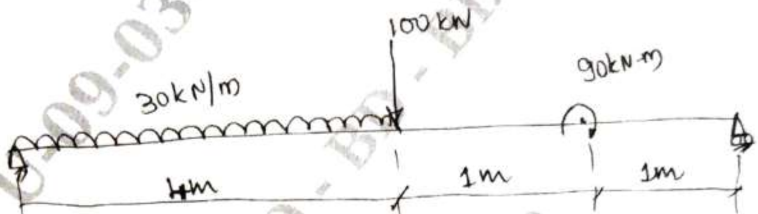

Fig.Q5(b) **(14 Marks)**

OR

6 a. Define: (i) Bending moment (ii) Shear force **(04 Marks)**

b. Draw SFD and BMD for beam shown in Fig.Q6(b).

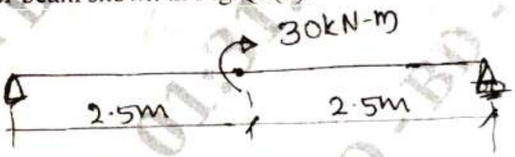

Fig.Q6(b) **(06 Marks)**

c. Draw SFD and BMD for simply supported beam of length L with point load 'P' placed at a distance 'a' from right support and 'b' from left support. **(10 Marks)**

Module-4

7 a. Define: (i) Torsional strength (ii) Torsional stiffness (iii) Torsional rigidity **(06 Marks)**

b. A shaft transmits 300 KW power at 120 rpm. Determine:

(i) The necessary diameter of solid circular shaft.

(ii) The necessary outer diameter of hollow circular section such that the inner diameter being 2/3 of the outer diameter. Take allowable shear stress as 70 N/mm^2. **(14 Marks)**

OR

8 Write short notes on any four:

a. Maximum principal stress theory

b. Maximum shear stress theory

c. Maximum principal strain theory

d. Maximum strain energy theory

e. Maximum shear strain energy theory **(20 Marks)**

Module-5

9 a. Show that for a rectangular cross section maximum shear stress is 1.5 times average shear stress. **(06 Marks)**

b. A simply supported beam of span 6 m has a cross section as shown in Fig.Q9(b). It carries 2 point loads each of 30 kN at a distance of 2m from each support. Calculate the bending stress and shear stress for maximum values of bending moment and shear force respectively. Draw neat diagram of bending stress and shear stress distribution across the cross section.

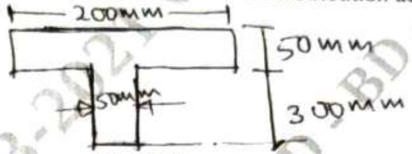

Fig.Q9(b) **(14 Marks)**

OR

10 a. Derive an expression for Euler's buckling load for long column with one end fixed and other end free. **(08 Marks)**

b. The cross section of a column is a hollow rectangular section with its external dimensions 200 mm × 150 mm. The internal dimension are 150 × 100 mm. The column is 5m long and fixed at both ends. If E = 120 GPa, calculate the critical load using Euler's formula. Compare the above load with the value obtained from Rankine's formula. The permissible compressive stress is 500 N/mm^2. The Rankine's constant is 1/6000. **(12 Marks)**

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CBCS SCHEME

USN | | | | | | | | | | |

18CV32

Third Semester B.E. Degree Examination, Aug./Sept.2020
Strength of Materials

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. Sketch a typical stress-strain curve for a ductile material and explain briefly the salient features of the curve. **(05 Marks)**

b. Derive an expression for the deformation of a rectangular tapering bar of uniform thickness. **(05 Marks)**

c. Determine the value of P that will not except a maximum deformation of 2mm or a stress of 120 MPa in steel, 80 MPa in Aluminium and 115 MPa in bronze (Fig.Q1(c)). Given the following data:
$A_b = 600\ mm^2$, $E_b = 0.84\times10^5\ N/mm^2$
$A_a = 800\ mm^2$, $E_a = 0.7\times10^5\ N/mm^2$
$A_s = 400\ mm^2$, $E_s = 2.1\times10^5\ N/mm^2$

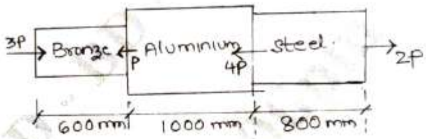

Fig.Q1(c) **(10 Marks)**

OR

2 a. Derive the relationship between Young's modulus and bulk modulus. **(05 Marks)**

b. A load of 270 kN is acting on a RCC column of size 200mm × 200mm. The column is reinforced with 10 bars of 12mm diameter each. Determine the stress in steel and concrete. $E_s = 16.5\ E_c$. **(05 Marks)**

c. A bar of brass 25mm diameter is enclosed in a steel tube of 50mm external diameter and 25mm internal diameter. The bar and tube are both initially 1m long and rigidly fastened at both the ends. Find the stresses in the two materials when the temperature rises from 10°C to 90°C.
If the composite bar is then subjected to an axial tensile load of 60 kN, find the resulting stresses given that : $E_s = 200\times10^3$ MPa, $E_b = 100\times10^3$ MPa, $\alpha_s = 11.6\times10^{-6}/°C$, $\alpha_b = 18.7\times10^{-6}/°C$. **(10 Marks)**

Module-2

3 a. Explain the maximum shear stress theory. **(05 Marks)**

b. Explain the procedure for determining stresses in a general two dimensional stress system using Mohr's circle. **(05 Marks)**

c. At a point in a strained material, the state of stresses is as shown in Fig.Q3(c). Determine the principal stresses, maximum shear stress and sketch the orientation of the principal planes.

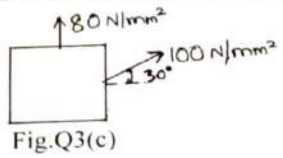

Fig.Q3(c) **(10 Marks)**

OR

4 a. In a thin cylinder, show that he hoop stress is twice the longitudinal stress. **(08 Marks)**

b. The maximum stress permitted in a thick cylinder of internal diameter 100mm and external diameter 150mm is 16 N/mm^2. If the internal pressure is 12 N/mm^2, what external pressure can be applied? Plot curves showing the variation of Hoop stress and radial stress through the material. **(12 Marks)**

Module-3

5 a. Define the terms: **(04 Marks)**
(i) Bending Moment (ii) Point of Inflexion.

b. Draw SFD and BMD for the cantilever beam shown in Fig.Q5(b).

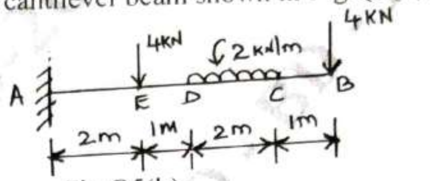

Fig.Q5(b) **(06 Marks)**

c. Draw SFD and BMD for a simply supported beam carrying two point loads of 12 kN at 1/3rd span from either supports in addition to a UDL of 10 kN/m throughout span of beam is 6m. **(10 Marks)**

OR

6 a. Establish the relationship between shear force, bending moment and load intensity. **(06 Marks)**

b. Draw SFD and BMD for the beam shown in Fig.Q6(b). Locate maximum shear force maximum bending moment and point of contraflexure.

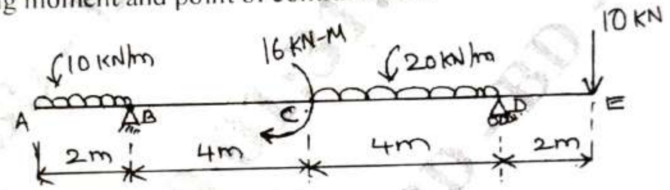

Fig.Q6(b) **(14 Marks)**

Module-4

7 a. Derive the simple bending equation in the form $\frac{M}{I} = \frac{f}{y} = \frac{E}{R}$ with usual notations. **(08 Marks)**

b. A beam of I section consists of 180mm × 15mm flanges and a web of 280mm × 15mm. It is subjected to a bending moment of 120 kN-m and a shear force of 60 kN. Sketch the bending stress distribution and shear stress distribution along the depth of the section. **(12 Marks)**

OR

8 a. Derive the torsion equation for a circular shaft subjected to pure torsion. **(10 Marks)**

b. A solid shaft of 60mm diameter is to be replaced by a hollow shaft of same length. The outer diameter of hollow shaft is same as that of solid shaft. If the angle of twist per unit torsional moment is the same in both cases, determine the inner diameter of hollow shaft. Take the modulus of rigidity of hollow shaft to be three times that of solid shaft. **(10 Marks)**

Module-5

9 a. Derive an expression for the slope and deflection of a simply supported beam carrying a central concentrated load. **(08 Marks)**

b. A simply supported beam of constant cross section is 10m long. It is loaded with two point loads of 100 kN and 80 kN at points 2m and 6m from the left end respectively. Calculate the deflection under each load the maximum deflection. Take E = 200 GPa and $I = 18\times10^{8}\ mm^{4}$. **(12 Marks)**

OR

10 a. Distinguish between long and short columns. **(04 Marks)**

b. What are the limitations of Euler's column theory? **(04 Marks)**

c. A hollow cast iron column whose outside diameter is 200mm has a thickness of 20mm. It is 4.5m long and fixed at both ends. Calculate (i) Slenderness ratio (ii) Ratio of Euler's and Rankine's critical loads. Take E = 100 GPa, $\alpha = \frac{1}{1600}$ and $\sigma_c = 550\ N/mm^2$. **(12 Marks)**

* * * * *

CBCS SCHEME

USN | | | | | | | | | | |

17CV/CT32

Third Semester B.E. Degree Examination, Aug./Sept. 2020
Strength of Materials

Time: 3 hrs. Max. Marks: 100

Note: 1. ***Answer any FIVE full questions, choosing ONE full question from each module.***
2. ***Missing data, if any can be assumed.***

Module-1

1 a. Define the four elastic constants. **(08 Marks)**

b. A steel rod of 30 mm in diameter is enclosed in an aluminium tube of 32 mm internal diameter and 60 mm external diameter. Both the bars are of length 750 mm and are rigidly connected to each other. The composite bar is subjected to an increase in temperature of 40°C. Compute the stresses in each material due to the temperature increase.
If the bar is also subjected to a compression of 200 kN, compute the resultant stresses. Also, find the final deformation of the compound bar.
Material properties are : $E_S = 200$ GPa, $\alpha_S = 12\times10^{-6}/°C$
$E_A = 80$ GPa, $\alpha_A = 22\times10^{-6}/°C$ **(12 Marks)**

OR

2 a. Sketch a typical stress strain curve for mild steel and briefly discuss the salient points on the curve. **(06 Marks)**

b. Derive an expression for elongation of a tapering rectangular plate of uniform thickness subjected to an axial load. **(08 Marks)**

c. A steel flat of thickness 25 mm tapers uniformly from 300 mm to 150 mm over a length of 750 mm. If the flat is subjected to an axial tension of 300 kN, compute the elongation of the flat. What is the % error if average area is used in calculating the extension? $E_s = 200$ KN/mm^2. Also, compute the maximum stress. **(06 Marks)**

Module-2

3 a. Show that the sum of the normal stresses on any two perpendicular planes in a general two dimensional system is $(\sigma_x + \sigma_y)$. **(06 Marks)**

b. A closed cylindrical steel vessel 8 m long and 3.2 m internal diameter is subjected to an internal pressure of 5 MPa with thickness of vessel being 50 mm. Assuming E = 200 GPa and $\mu = 0.3$, compute hoop and longitudinal stresses, maximum shear stress and changes in length, diameter and volume. **(08 Marks)**

c. Compute the maximum and minimum hoop stress and plot their variation across the pipe thickness having an internal diameter of 500 mm and thickness 80 mm if the pipe is subjected to an internal fluid pressure of 10 MPa. **(06 Marks)**

OR

4 a. Derive expressions for circumferential and longitudinal stresses in a thin cylinder subjected to internal pressure, p. **(06 Marks)**

b. Direct stresses of magnitude 120 MPa tensile and 80 MPa compressive are acting at a point along with a shear stress of 50 N/mm^2. Compute the normal and tangential stresses on a plane inclined at 40° anticlockwise with the plane on which 120 MPa tensile stress is acting. Also, compute the magnitudes of principal stresses and planes. Sketch the stresses and their planes. **(14 Marks)**

Module-3

5 a. A Cantilever beam is subjected to a UDL of 20 kN/m throughout its length. Sketch SFD and BMD indicating salient values. Cantilever length = 3 m. **(05 Marks)**

b. Sketch SFD and BMD for the beam shown in Fig. Q5 (b) indicating salient values (including point of contraflexure, maximum –ve and maximum +ve BMS and maximum SF). **(15 Marks)**

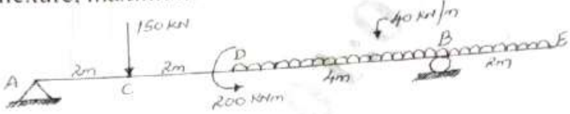

Fig. Q5 (b)

OR

6 a. A simply supported beam of span 8 m is carrying a concentrated load of 100 kN at a distance of 3 m from the left support. Sketch SFD and BMD indicating salient values. **(05 Marks)**

b. Sketch SFD and BMD for the beam shown in Fig. Q6 (b) indicating salient values (including point of contraflexure, maximum –ve and maximum +ve BMS and maximum SF). **(15 Marks)**

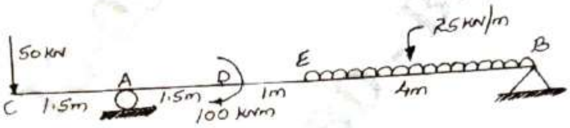

Fig. Q6 (b)

Module-4

7 a. Show that the strength of hollow shafts is greater than solid shaft having same material, length and weight. **(08 Marks)**

b. Explain maximum shear stress theory of failure. **(06 Marks)**

c. A steel shaft of diameter 150 mm transmits 250 kW at 200 rpm with $T_{max} = 1.35T_{mean}$. Compute the maximum shear stress and sketch the stress variation. **(06 Marks)**

OR

8 a. Explain maximum strain energy theory of failure. **(06 Marks)**

b. A hollow circular shaft rotates at 200 rpm transmitting a power of 600 KW. Compute the diameters of the shaft if the external diameter is 1.5 times the internal diameter permissible shear stress in the material is 80 MPa and the angle of twist is 1.1° over a length of 3 m. $T_{max} = 1.35\ T_{mean}$ and G = 80 GPa. Also, calculate the torque carried by a solid shaft of same length, cross sectional area and material as that of hollow shaft with the permissible shear stress and angle of twist being same. What is the percentage difference in torque carrying capacities? **(14 Marks)**

Module-5

9 a. Derive an expression for Euler's crippling load in a column with one end fixed and other end free. **(10 Marks)**

b. An unsymmetrical I section with top flange 300×20, bottom flange 150×15 and web thickness of 12 mm is used as a simply supported beam of span 6 m with a uniformly distributed load of 40 kN/m over its entire length. Overall depth of beam is 400 mm. Compute the maximum tensile and compressive stresses and sketch the bending stress distribution. Also, compute the shear stresses at salient points and sketch the shear stress distribution at support. **(10 Marks)**

OR

10 a. Derive an expression for shear stress in a beam with usual notations. **(10 Marks)**

b. A hollow rectangular column having external dimensions of 250×375 with thickness = 10 mm is used as a column of length 3.5 m with both ends of the column being fixed. Compute the buckling load using both the formulae. E = 200 GPa, Rankine's constant are $\alpha = \frac{1}{7500}$ and $\sigma_c = 320\ N/mm^2$. Comment on the formula giving larger load. **(10 Marks)** semester

C

CBCS SCHEME

USN

17CV/CT32

Third Semester B.E. Degree Examination, Aug./Sept. 2020
Strength of Materials

Time: 3 hrs. Max. Marks: 100

Note: 1. ***Answer any FIVE full questions, choosing ONE full question from each module.***
2. ***Missing data, if any can be assumed.***

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Define the four elastic constants. **(08 Marks)**

b. A steel rod of 30 mm in diameter is enclosed in an aluminium tube of 32 mm internal diameter and 60 mm external diameter. Both the bars are of length 750 mm and are rigidly connected to each other. The composite bar is subjected to an increase in temperature of 40°C. Compute the stresses in each material due to the temperature increase.
If the bar is also subjected to a compression of 200 kN, compute the resultant stresses. Also, find the final deformation of the compound bar.
Material properties are : $E_S = 200$ GPa, $\alpha_S = 12\times10^{-6}/^\circ C$
$E_A = 80$ GPa, $\alpha_A = 22\times10^{-6}/^\circ C$ **(12 Marks)**

OR

2 a. Sketch a typical stress strain curve for mild steel and briefly discuss the salient points on the curve. **(06 Marks)**

b. Derive an expression for elongation of a tapering rectangular plate of uniform thickness subjected to an axial load. **(08 Marks)**

c. A steel flat of thickness 25 mm tapers uniformly from 300 mm to 150 mm over a length of 750 mm. If the flat is subjected to an axial tension of 300 kN, compute the elongation of the flat. What is the % error if average area is used in calculating the extension? $E_S = 200$ KN/mm^2. Also, compute the maximum stress. **(06 Marks)**

Module-2

3 a. Show that the sum of the normal stresses on any two perpendicular planes in a general two dimensional system is $(\sigma_x + \sigma_y)$. **(06 Marks)**

b. A closed cylindrical steel vessel 8 m long and 3.2 m internal diameter is subjected to an internal pressure of 5 MPa with thickness of vessel being 50 mm. Assuming E = 200 GPa and $\mu = 0.3$, compute hoop and longitudinal stresses, maximum shear stress and changes in length, diameter and volume. **(08 Marks)**

c. Compute the maximum and minimum hoop stress and plot their variation across the pipe thickness having an internal diameter of 500 mm and thickness 80 mm if the pipe is subjected to an internal fluid pressure of 10 MPa. **(06 Marks)**

OR

4 a. Derive expressions for circumferential and longitudinal stresses in a thin cylinder subjected to internal pressure, p. **(06 Marks)**

b. Direct stresses of magnitude 120 MPa tensile and 80 MPa compressive are acting at a point along with a shear stress of 50 N/mm^2. Compute the normal and tangential stresses on a plane inclined at 40° anticlockwise with the plane on which 120 MPa tensile stress is acting. Also, compute the magnitudes of principal stresses and planes. Sketch the stresses and their planes. **(14 Marks)**

Module-3

5 a. A Cantilever beam is subjected to a UDL of 20 kN/m throughout its length. Sketch SFD and BMD indicating salient values. Cantilever length = 3 m. **(05 Marks)**

b. Sketch SFD and BMD for the beam shown in Fig. Q5 (b) indicating salient values (including point of contraflexure, maximum –ve and maximum +ve BMS and maximum SF). **(15 Marks)**

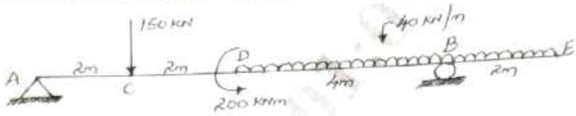

Fig. Q5 (b)

OR

6 a. A simply supported beam of span 8 m is carrying a concentrated load of 100 kN at a distance of 3 m from the left support. Sketch SFD and BMD indicating salient values. **(05 Marks)**

b. Sketch SFD and BMD for the beam shown in Fig. Q6 (b) indicating salient values (including point of contraflexure, maximum –ve and maximum +ve BMS and maximum SF). **(15 Marks)**

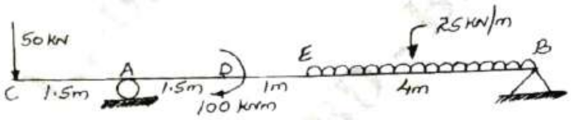

Fig. Q6 (b)

Module-4

7 a. Show that the strength of hollow shafts is greater than solid shaft having same material, length and weight. **(08 Marks)**

b. Explain maximum shear stress theory of failure. **(06 Marks)**

c. A steel shaft of diameter 150 mm transmits 250 kW at 200 rpm with $T_{max} = 1.35T_{mean}$. Compute the maximum shear stress and sketch the stress variation. **(06 Marks)**

OR

8 a. Explain maximum strain energy theory of failure. **(06 Marks)**

b. A hollow circular shaft rotates at 200 rpm transmitting a power of 600 KW. Compute the diameters of the shaft if the external diameter is 1.5 times the internal diameter permissible shear stress in the material is 80 MPa and the angle of twist is 1.1° over a length of 3 m. $T_{max} = 1.35\ T_{mean}$ and G = 80 GPa. Also, calculate the torque carried by a solid shaft of same length, cross sectional area and material as that of hollow shaft with the permissible shear stress and angle of twist being same. What is the percentage difference in torque carrying capacities? **(14 Marks)**

Module-5

9 a. Derive an expression for Euler's crippling load in a column with one end fixed and other end free. **(10 Marks)**

b. An unsymmetrical I section with top flange 300×20, bottom flange 150×15 and web thickness of 12 mm is used as a simply supported beam of span 6 m with a uniformly distributed load of 40 kN/m over its entire length. Overall depth of beam is 400 mm. Compute the maximum tensile and compressive stresses and sketch the bending stress distribution. Also, compute the shear stresses at salient points and sketch the shear stress distribution at support. **(10 Marks)**

OR

10 a. Derive an expression for shear stress in a beam with usual notations. **(10 Marks)**

b. A hollow rectangular column having external dimensions of 250×375 with thickness = 10 mm is used as a column of length 3.5 m with both ends of the column being fixed. Compute the buckling load using both the formulae. E = 200 GPa, Rankine's constant are $\alpha = \frac{1}{7500}$ and $\sigma_c = 320\ N/mm^2$. Comment on the formula giving larger load. **(10 Marks)**

CBCS SCHEME

15CV/CT32

USN

Third Semester B.E. Degree Examination, June/July 2019

Strength of Materials

Time: 3 hrs. Max. Marks: 80

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. Define : (i) Modulus of Rigidity (ii) Poisson's ratio **(04 Marks)**

b. Prove that the total extension of a uniformly tapering rod of diameter D_1 and D_2, when the rod is subjected to an axial load 'P' is given by $dl = \frac{4PL}{\pi E D_1 D_2}$. **(06 Marks)**

c. An axial pull of 40,000 N is acting on a bar consisting of three sections of length 300mm, 250mm and 200mm and of diameters 20mm, 40mm and 50mm respectively. If the Young's modulus = 2×10^5 N/mm², determine (i) Stress in each section (ii) total extension of the bar. **(06 Marks)**

OR

2 a. Explain elasticity and elastic limit. **(04 Marks)**

b. A steel bar 300mm long, 50mm wide and 40mm thick is subjected to a pull of 300 kN in the direction of its length. Determine the change in volume. Take E = 2×10^5 N/mm² and Poisson's ratio = 0.25. **(06 Marks)**

c. A reinforced short concrete column 250mm × 250mm in section is reinforced with 8 steel bars. The total area of steel bars is 2500 mm². The column carries a load of 390 kN. If the modulus of elasticity for steel is 15 times that of concrete. Find the stresses in concrete and steel. **(06 Marks)**

Module-2

3 a. Differentiate between thin cylinder and a thick cylinder. Find an expression for the radial pressure and hoop stress at any point in case of a thick cylinder. **(10 Marks)**

b. A rectangular bar of cross section area of 11,000 mm² is subjected to a tensile load 'P' as shown in Fig.Q3(b). The permissible normal and shear stresses on the oblique plane BC are given as 7 N/mm² and 3.5 N/mm² respectively. Determine the safe value of 'P'. **(06 Marks)**

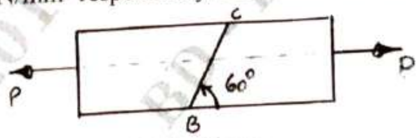

Fig.Q3(b)

OR

4 a. Determine the maximum and minimum hoop stress across the section of a pipe 400mm internal diameter and 100mm thick, when the pipe contains a fluid at a pressure of 8 N/mm². Also sketch the radial pressure distribution and hoop stress distribution across the section. **(08 Marks)**

b. At a point in a strained material the principal tensile stresses across two perpendicular planes are 80 N/mm² and 40 N/mm². Determine normal stress, shear stress and the resultant stress on a plane inclined at 20° with the major principal plane. Determine also the obliquity. **(08 Marks)**

Module-3

5 a. Define (i) Shear force (ii) Bending moment. **(02 Marks)**

b. Draw the SF and BM diagrams for a cantilever of length 'L' carrying a point load 'W' at the free end. **(04 Marks)**

c. Draw the SF and BM diagrams of a simply supported beam of length 7 mt carrying uniformly distributed loads as shown in Fig.Q5(c). **(10 Marks)**

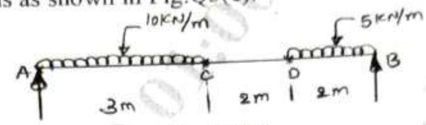

Fig.Q5(c)

OR

6 A horizontal beam 10mt long is carrying a uniformly distributed load of 1 kN/m. The beam is supported on two supports 6 mt apart. Find the position of the supports, so that bending moment on the beam is as small as possible. Also draw the SF and BM diagram. **(16 Marks)**

Module-4

7 a. Define the terms : (i) Neutral axis (ii) Section modulus. **(04 Marks)**

b. A hollow mild steel tube 6m long 40mm internal diameter and 5mm thick is used as a strut with both ends hinged. Find the crippling load and safe load taking factor of safety as 3. Take $E = 2\times10^5$ N/mm^2. **(06 Marks)**

c. The external and internal diameter of a hollow cast iron column are 50mm and 40mm respectively. If the length of this column is 3m and both of its ends are fixed, determine the crippling load using Rankine's formula. Take the values of $\sigma_c = 550$ N/mm^2 and $\alpha = \frac{1}{1600}$ in Rankine's formula. **(06 Marks)**

OR

8 a. Define (i) Buckling load (ii) Slenderness ratio. **(04 Marks)**

b. A timber beam of rectangular section of length 8m is simply supported. The beam carries a U.D.L. of 12 kN/m ran over the entire length and a point load of 10 kN at 3m from the left support. If the depth is two times the width and the stress in the timber is not to exceed 8 N/mm^2, find the suitable dimensions of the section. **(12 Marks)**

Module-5

9 a. List the theories of failures. **(04 Marks)**

b. A hollow shaft of external diameter 120mm transmits 300 kW power at 200 r.p.m. Determine the maximum internal diameter if the maximum stress in the shaft is not to exceed 60 N/mm^2. **(06 Marks)**

c. Determine the diameter of a solid steel shaft which will transmit 90 kW at 160 r.p.m. Also determine the length of the shaft if the twist must not exceed 1° over the entire length. The maximum shear stress is limited to 60 N/mm^2. Take the value of modulus of rigidity = 8×10^4 N/mm^2. **(06 Marks)**

OR

10 a. Derive the relation for a circular shaft when subjected to a torsion as given below:

$$\frac{T}{J} = \frac{\tau}{R} = \frac{C\theta}{L}$$ **(08 Marks)**

b. State and explain theory of maximum principal strain theory. **(08 Marks)**

* * * * *

CBCS SCHEME

USN

15CV/CT32

Third Semester B.E. Degree Examination, Jan./Feb. 2021
Strength of Materials

Time: 3 hrs. Max. Marks: 80

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. State and explain Elastic constants. **(04 Marks)**

b. A bar of 20mm is tested in tension. It is observed that when a load of 40kN is applied, the extension measured over a gauge length of 200mm is 0.12mm and contraction in diameter is 0.0036min. Find Poisson's ratio and elastic constants E, C, K. **(12 Marks)**

OR

2 a. Define temperature stresses and state its importance. **(06 Marks)**

b. A composite bar is rigidly fitted at the supports A and B as shown in the Fig.Q.2(b). Determine the reactions at the supports when temperature rises by 20°C. Take $E_a = 70\ GN/m^2$, $E_s = 200\ GN/m^2$, $\alpha_a = 11 \times 10^{-6}/°C$ and $\alpha_s = 12 \times 10^{-6}/°C$. **(10 Marks)**

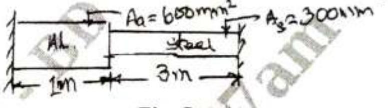

Fig.Q.2(b)

Module-2

3 a. Define principal planes and principal stresses. **(04 Marks)**

b. Stresses acting at a point in a two dimensional stress system shown in the Fig.Q.3(b), find:
   i) Normal and shear stresses on the inclined plane
   ii) Principal stresses and their planes
   iii) Maximum shear stresses and their planes.

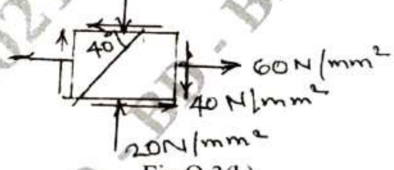

Fig.Q.3(b)

(12 Marks)

OR

4 a. Derive expressions for hoop stress and longitudinal stress in a thin cylinder. **(06 Marks)**

b. A cylindrical thin shell 800mm diameter and 3m long is having 10mm metal thickness. The shell is subjected to an internal pressure of $2.5 N/mm^2$. Determine:
   i) Change in diameter
   ii) Change in length
   iii) Change in volume

Take $E = 2 \times 10^5 N/mm^2$ $\mu = 0.3$ **(10 Marks)**

Module-3

5 a. Derive the relationship between intensity of load, shear force and bending moment. **(06 Marks)**

b. Draw shear force and bending moment diagrams for the beam shown in the Fig.Q.5(b).

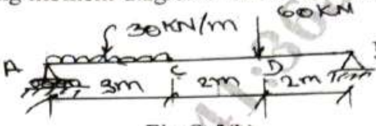

Fig.Q.5(b)

(10 Marks)

OR

6 a. Explain:
i) Sagging bending moment
ii) Hogging bending moment
iii) Point of contra flexure. **(06 Marks)**

b. Draw shear force and bending moment diagrams for the beam shown in the Fig.Q.6(b). Locate the points of contra flexure. **(10 Marks)**

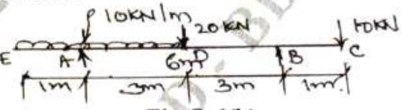

Fig.Q.6(b)

Module-4

7 a. What are assumptions made in bending theory? **(04 Marks)**

b. Derive the bending equation $\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$ with usual notations. **(06 Marks)**

c. Prove that maximum shear stress is 1.5 times the average shear stress in rectangular section. **(06 Marks)**

OR

8 a. What is effective length of column? How it is related with end conditions of column and explain with neat sketches. **(08 Marks)**

b. A hollow cast iron column whose outside diameter is 200mm and has a thickness of 20mm, 4.5m long and is fixed at both ends. Evaluate Rankine's crippling load using $f_c = 550N/mm^2$. Take Rankines constant $\frac{1}{1600}$. **(08 Marks)**

Module-5

9 a. Derive the Torsion equation $\frac{T}{J} = \frac{\tau}{R} = \frac{C\theta}{L}$ with usual notation. **(06 Marks)**

b. A solid circular shaft is to be designed to transmit 440kW power at 280rpm. If the maximum shear stress is not to exceed $40N/mm^2$ and the angle of twist is not to exceed 1° per meter length, determine the diameter of the shaft. Take modulus of rigidity $84kN/mm^2$. **(10 Marks)**

OR

10 a. Explain: i) Maximum principal stress theory ii) Maximum shear stress theory. **(06 Marks)**

b. A bolt is required to resist an axial tension of 25kN and a transverse shear of 20kN. Find the size of the bolt by using i) Maximum principal stress theory ii) Maximum shear stress theory $\sigma_e = 300N/mm^2$, F.S = 3 **(10 Marks)**

* * * * *

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Bapuji Institute of Engineering and Technology, Davangere–577 004
Department of Civil Engineering

Assignment

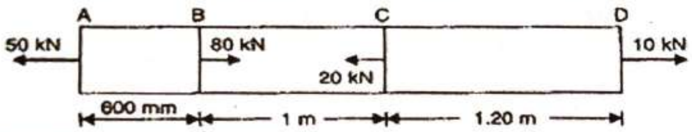
Date	25	10	20

Assignment No.	01	Maximum Marks	10
Course/Subject Title	Strength of Materials	Course/Subject Code	18CV32
Semester	III	Scheme	CBCS – 18

Course Outcome Statements : After the successful completion of the course, the students will be able to Outcome Statements	
18CV32.1	Evaluate the stresses and strains for ferrous and non-ferrous materials
18CV32.2	Evaluate the internal stresses developed in one dimensional, two dimensional structural elements and cylinders
18CV32.3	Evaluate the bending moment, shear force in prismatic beams and corresponding stresses
18CV32.4	Analyse and design the circular shafts subjected to torsion
18CV32.5	Evaluate the slope and deflection of prismatic beams
18CV32.6	Evaluate the failure loads for the columns and struts

Note :

Q. No.	Question	Marks	RBT Level	CO
	Module -1			
1	Draw stress versus strain curve for mild steel specimen subjected to axial tension indicating the salient points. Define the elastic constants.		L1	CO1
2	Derive the expression for elongation of tapering circular bar due to axial load P. Use standard notations.		L2	CO1
3	A bras bar having cross- sectional area of $1000mm^2$, is subjected to axial forces as shown in fig. Find the total elongation of the bar. Take $E= 1.05\times10^5 N/mm^2$.		L3	CO1



Q. No.	Question	Marks	RBT Level	CO
4	A compound tube consists of a steel tube 140mm internal diameter and 160mm external diameter and an outer brass tube 160mm internal diameter and 180mm external diameter. The two tubes are of the same length. The compound tube carries an axial load of 900KN. find the stress and the load carried by each tube and the amount it shortens. Length of each tube is 140mm. take young's modulus for the steel as $2 \times 10^5 N/^{mm2}$ and for brass as $1\times10^5 N/mm^2$.		L3	CO1
5	A Steel rail is 12.6m long and is laid at a temperature of 24°c the maximum temperature expected is 44°c a) Estimate the minimum gap between two rails to be left so that temperature stress does not develop. b) Calculate the thermal stress developed in the rails, if 1) No expansion joint is prevented. 2) If a 2mm gap is provided for expansion. c) If the stress developed is $20MN/m^2$, what is the gap b/w the rails? Take $E = 2\times10^5 N/mm^2$ and $\alpha = 12\times10^{-6}$ / °c		L3	CO1
6	Derive the relationship b/w Modulus of elasticity (E) and Bulk modulus (K).		L3	CO1
7	A Steel flat of thickness25mm tapers uniformly from 300mm to 150mm over a length of 750mm. if the flat is subjected to an axial tension of 300knN, compute the elongation of the flat. What is the % error if average area is used in calculating the extension?		L3	CO1
	Module -2			
8	Define Thick and thin cylinders. Derive an expression for hoop stress.		L4	CO2
9	A thin cylindrical shell 1m in diameter &3m long has a metal thickness of 10mm. if it is subjected to an internal pressure of 3Mpa. Determine hoop stress, longitudinal stress, change in length, change in diameter and change in volume. If E= 210GPa & μ =0.3.		L4	CO2
10	Derive the lame's equations for radial and hoop stresses for thick cylinder to internal		L2	CO2

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Department of Civil Engineering

Assignment

Date	25	10	20

	& external fluid pressure.			
11	A Thick cylinder of internal diameter 200mm is subjected to an internal fluid pressure of 40mpa. If the allowable stress in tension for the material is 120Mpa. Find the thickness required.		L2	CO2
	Module -4			
12	Derive the pure torsion equation with usual notations.		L2	CO4
13	Prove that a hallow circular shaft is stronger than a solid circular shaft in torsion. Which have same materials, length and weight?		L2	CO4
14.	Determine the diameter of solid shaft which will transmit 90Kn at 160rpm, if the shear stress in the shaft is limited to 60Mpa. Find also length of the shaft. If the twist is limited to1°. Given $C = 8\times10^4$Mpa.		L4	CO4
15	A 150mm diameter solid steel shaft is transmitting 450kw power at 90rpm. Compute the maximum shear stress. Find the change that would occur in the shearing stress. If the speed increased to 360rpm.		L4	CO4

Last date for submission	30	11	2020

RBT (Revised Bloom's Taxonomy) Levels : Cognitive Domain		
L1 : Remembering	L2 : Understanding	L3 : Applying
L4 : Analysing	L5 : Evaluating	L6 : Creating

Raghu M E
Course Coordinator
(Faculty in charge)

ASSISTANT PROFESSOR
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Coordinator
DQAC
11/12/2020

Program Coordinator
(HOD, Civil)
11/12/2020

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...Institute of Engineering and Technology, Davangere-577 004
Department of Civil Engineering

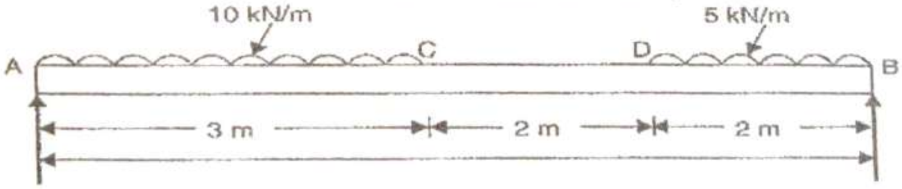
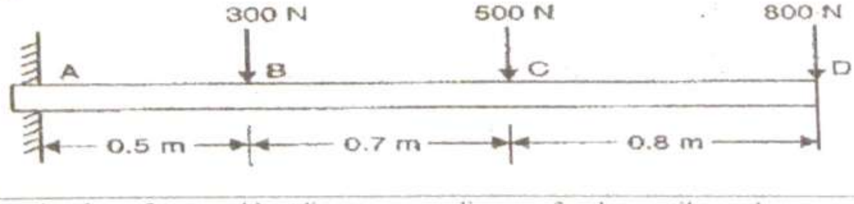
Assignment

Assignment No.	02	Date	10	12	2020
Course/Subject Title	Strength of Materials	Maximum Marks	10		
Semester	III	Course/Subject Code	18CV32		
		Scheme	CBCS – 18		

Course Outcome Statements : After the successful completion of the course, the students will be able to Outcome Statements

18CV32.1	Evaluate the stresses and strains for ferrous and non-ferrous materials
18CV32.2	Evaluate the internal stresses developed in one dimensional, two dimensional structural elements and cylinders
18CV32.3	Evaluate the bending moment, shear force in prismatic beams and corresponding stresses
18CV32.4	Analyse and design the circular shafts subjected to torsion
18CV32.5	Evaluate the slope and deflection of prismatic beams
18CV32.6	Evaluate the failure loads for the columns and struts

Note :

Q. No.	Question	Marks	RBT Level	CO
	Module -2			
1	Derive an Expression for two dimensional stress system.		L2	CO2
2	A rectangular block of material is subjected to a tensile stress of 110 N/mm^2 on one plane and a tensile stress of 47 N/mm^2 on the right angles to the former. Each of the above stress is accomplished by a shear stress of 63 N/mm^2 and that associated with the former tensile stress tends to rotate the block in anticlockwise. Find 1) the direction and magnitude of principal stress. 2) Magnitude of the greatest Shear Stress.		L3	CO2
3	Explain the procedure for determining stresses in a general two dimensional stress system using Mohr's circle		L2	CO2
4	Explain the a) Maximum Shear stress theory. b) Maximum shear strain theory		L2	CO2
	Module -3			
5	Define Shear force, bending moment and point of Inflexion.		L1	CO3
6	Establish the relationship between shear force, bending moment and load intensity.		L2	CO3
7	Draw the shear force and bending moment for cantilever beam subjected to uniformly varying load.		L2	CO3
8	Draw the shear force and bending moment diagram for the simply supported beam of length 7m carrying a uniformly distributed load as shown in fig 		L4	CO3
9	Draw the shear force and bending moment diagram for the cantilever beam as shown in fig 		L4	CO2
10	Draw the shear force and bending moment diagram for the cantilever beam as shown in fig		L3	CO3

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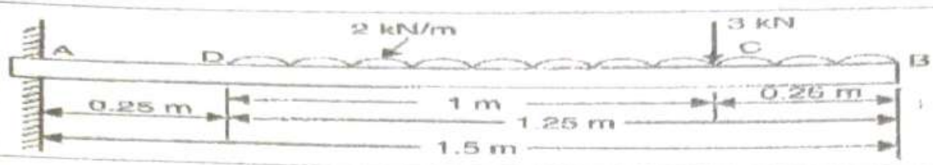
Department of Civil Engineering

Assignment

Date	10	12	2020

				
	Module – 5			
11	Distinguish between long and short columns.		L2	CO6
12	Derive an expression for Euler's crippling load when both ends of the column are hinged.		L2	CO6
13	What are the limitations of Euler's column theory?		L2	CO6
14	A steel bar of rectangular section 30mm×40mm pinned at both ends is subjected to axial compression. The bar is 1.75m long. Determine the buckling load and corresponding axial stress using Euler's formula. Determine the minimum length for which Euler's equation, if proportionality limit of material is 200Mpa.		L3	CO6
15.	A hallow CI column whose outside diameter is 200mm as a thickness of 20mm. it is 4.5m long and fixed at both ends.1) Calculate safe load by Rankine's formula using FOS=4 2) Calculate the ratio of Euler's and Rankine's critical load and slenderness ratio. Take fc= 550N/mm^2 a= 1/1600 in Rankine's formulae and E= 9.4×10^4N/mm^2.		L3	CO6

Last date for submission	30	12	2020

RBT (Revised Bloom's Taxonomy) Levels : Cognitive Domain		
L1 : Remembering	L2 : Understanding	L3 : Applying
L4 : Analysing	L5 : Evaluating	L6 : Creating

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11/12/2020
Program Coordinator
(HOD, Civil)

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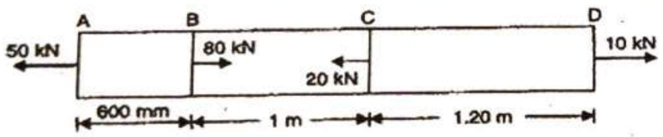
Department of Civil Engineering

USN										

Subject Title	Strength of Materials		
Semester	III A	Subject Code	18CV32
Date	24/10/2020	Scheme	CBCS
Time	9:30 -10:30	IA No.	01
		Max. Marks	30

Course Outcome Statements	
18CV32.1	Evaluate the stresses and strains for ferrous and non-ferrous materials
18CV32.2	Evaluate the internal stresses developed in one dimensional, two dimensional structural elements and cylinders
18CV32.3	Evaluate the bending moment, shear force in prismatic beams and corresponding stresses
18CV32.4	Analyse and design the circular shafts subjected to torsion
18CV32.5	Evaluate the slope and deflection of prismatic beams
18CV32.6	Evaluate the failure loads for the columns and struts

NOTE: Answer any five questions. Each questions carries equal marks

Q. No.	Questions	Marks	RBT Level	CO
1	**Draw stress versus strain curve for mild steel specimen subjected to axial tension indicating the salient points. Define the elastic constants.**	6	L1	CO1
2	**Derive the expression for elongation of tapering circular bar due to axial load P. Use standard notations.**	6	L2	CO1
3	**A bras bar having cross- sectional area of 1000mm^2, is subjected to axial forces as shown in fig. Find the total elongation of the bar. Take E= 1.05×10^{5}N/mm^2.** 	6	L3	CO1
4	**A compound tube consists of a steel tube 140mm internal diameter and 160mm external diameter and an outer brass tube 160mm internal diameter and 180mm external diameter. The two tubes are of the same length. The compound tube carries an axial load of 900KN. find the stress and the load carried by each tube and the amount it shortens. Length of each tube is 140mm. take young's modulus for the steel as 2 × 10^5 N/^{mm2} and for brass as 1×10^5 N/mm^2.**	6	L3	CO1
5	**A Steel rail is 12.6m long and is laid at a temperature of 24°c the maximum temperature expected is 44°c** **a) Estimate the minimum gap between two rails to be left so that temperature stress does not develop.** **b) Calculate the thermal stress developed in the rails, if 1) No expansion joint is prevented. 2) If a 2mm gap is provided for expansion.** **c) If the stress developed is 20MN/m^2, what is the gap b/w the rails? Take E = 2×10^{5}N/mm^2 and α = 12×10^{-6} / °c**	6	L3	CO1
6	**Derive the relationship b/w Modulus of elasticity (E) and Bulk modulus (K).**	6	L3	CO1

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Department of Civil Engineering

RBT (Revised Bloom's Taxonomy) Levels		
L1 : Remembering	L2 : Understanding	L3 : Applying
L4 : Analysing	L5 : Evaluating	L6 : Creating

23/10/2020
Course Coordinator
(Faculty in charge)
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Program Coordinator
(HOD, Civil)

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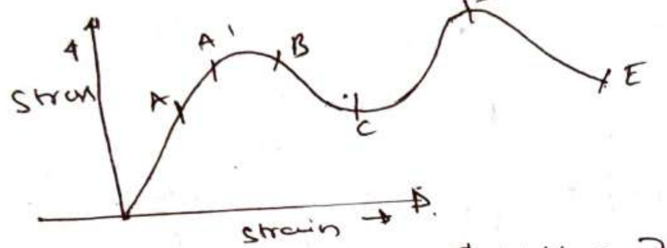
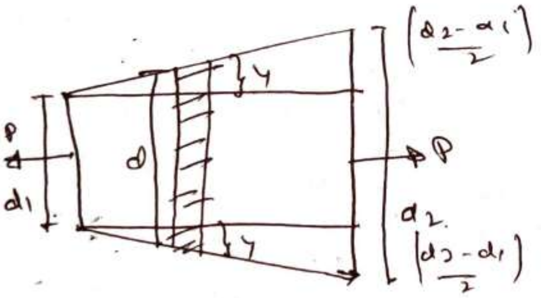
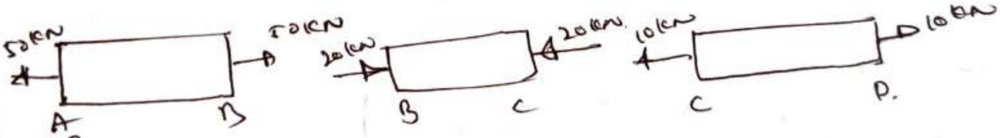
Department of Civil Engineering

Scheme of Valuation

Course/Subject Title	Strength of Materials	Course/Subject Code	18CV32
Semester	III A	CIE No.	01
Date	24/10/2020	Max. Marks	30

Q.	Solution	Marks
	Answer any five full questions.	
1.	 A = proportionality limit; B = upper yield point; C = lower yield point; D = ultimate strength; E = Breaking point.	Fig with explanation – 4m
	Elastic constants $4 \times 1/2 = 2m$	2m
		6m
Q2	Tapering circular bar due to axial load P.  $\delta = \frac{4PL}{\pi E d_1 d_2}$ Explanation	6m
Q3	 **AB** Increased length of AB $= \frac{P_1}{AE_1} \times L_1 = \frac{50\times1000}{1000\times1.05\times10^5} \times 600 = 0.2857$	
	Part **BC** Decreased length BC $= \frac{P_2}{AE} \times L_2 = \frac{20\times10^3 \times 1000}{1000\times1.05\times10^5} = 0.1904$	
	Part **BD** $BD = \frac{P_3 \times L_3}{AE} = \frac{10000}{1000\times1.5\times10^5} \times 2200 = 0.2857$	

Course Coordinator (Faculty in charge) | Coordinator DQAC | Program Coordinator (HOD, Civil)

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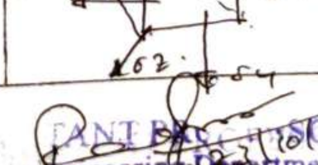
Bapuji Institute of Engineering and Technology, Davangere–577 004
Department of Civil Engineering

Scheme of Valuation

Q.	Solution	Marks
	Total elongation of bar = 0.2851 − 0.1904 + 0.2095	6m
04	Area of steel tube = $\pi/4 (160^2 - 140^2) = 4712.38\ mm^2$	
	Area of Brass tube = $\pi/4 (180^2 - 160^2) = 5340.70\ mm^2$	
	$\frac{\sigma s}{Es} = \frac{\sigma b}{Eb}$ — 1m ; $\sigma s \times As + \sigma b \times Ab = 900 \times 10^3$	
	$\sigma s = 2\sigma b$ — 1m ; $\sigma b = 60.95\ N/mm^2$ — 1m	
	$\sigma s = 121.9\ N/mm^2$ — 1m	
	$Pb = \sigma b \times Ab = 60.95 \times 5340.7$; $Ps = \sigma s \times As$; $Ps = 121.9 \times 4712.4$	
	$Pb = 325.515\ kN$ — 1m ; $Ps = 574.44\ kN$ — 1m	
	Decrease in length of compound tube: $\frac{\sigma b}{Eb} \times L = \frac{60.95 \times 140}{1 \times 10^5} = 0.0853\ mm$	1m
05	$E = 2 \times 10^5\ N/mm^2$	6m
	(1) Free Expansion of rail − $\Delta = \alpha t l$; $\delta = 3.024\ mm$ — 1m	
	(2) (a) If no Expansion Joint is provided, free Expansion prevented is equal to 3.024	
	$\frac{PL}{AE} = 3.024$ (or) $\sigma = \alpha t E$; $\sigma = 48\ N/mm^2$	2m
	(b) If a gap of 2mm is provided, free Expansion $\Delta = \alpha t l - \delta$; $\sigma = 16.253\ N/mm^2$	1m
	(3) $\sigma t = 20\ N/mm^2$; $\Delta = \frac{PL}{AE} = \Delta = 1.26\ mm$; $\Delta = \alpha t l - \delta$; $\sigma = 1.76\ mm$	2m
		6m
06	Modulus of elasticity (E) & Bulk modulus (K)	Fig - 1m
		
	$ev = ex + ey + ez$ — 1m	
	$\frac{\delta V}{V} = \frac{3\sigma}{E}(1-2\mu)$ 2m	06m
	Bulk modulus = $\frac{\sigma}{\delta V / V}$; $3K(1-2\mu) = E$ — 2m	

23/12/2020 — Course Coordinator (Faculty In charge) — Civil Engineering Department, B.I.E.T., Davangere.

23/12/2020 — Coordinator DQAC

23/12/2020 — Program Coordinator (HOD, Civil)

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Bapuji Institute of Engineering and Technology, Davangere–577 004
Department of Civil Engineering

USN										

Subject Title	Strength of Materials		
Semester	III A	Subject Code	18CV32
Date	07/12/2020	Scheme	CBCS
Time	3:00 -04:00 PM	IA No.	02
		Max. Marks	30

Course Outcome Statements	
18CV32.1	Evaluate the stresses and strains for ferrous and non-ferrous materials
18CV32.2	Evaluate the internal stresses developed in one dimensional, two dimensional structural elements and cylinders
18CV32.3	Evaluate the bending moment, shear force in prismatic beams and corresponding stresses
18CV32.4	Analyse and design the circular shafts subjected to torsion
18CV32.5	Evaluate the slope and deflection of prismatic beams
18CV32.6	Evaluate the failure loads for the columns and struts

NOTE: Answer any one full question from each part.

Q. No.	Questions	Marks	RBT Level	CO
	Part -A			
1a)	Derive an Expression for two dimensional stress system.	8	L2	CO2
1b)	A rectangular block of material is subjected to a tensile stress of110N/mm^2 on one plane and a tensile stress of 47 N/mm^{2}on the right angles to the former. Each of the above stress is accomplished by a shear stress of 63 N/mm^{2}and that associated with the former tensile stress tends to rotate the block in anticlockwise. Find 1) the direction and magnitude of principal stress. 2) Magnitude of the greatest Shear Stress.	7	L3	CO2
	OR			
2a)	Define Thick and thin cylinders. Derive an expression for hoop stress.	8	L2	CO2
2b)	Find the thickness of metal necessary for a cylindrical shell of internal diameter 160mm to withstand a pressure of8N/mm^2. The maximum hoop stress in the section is not to exceed 35mpa.	7	L3	CO2
	Part - B			
3a)	Derive the pure torsion equation with usual notations.	8	L2	CO4
3b)	A steel bar of rectangular section 30mm×40mm pinned at both ends is subjected to axial compression. The bar is 1.75m long. Determine the buckling load and corresponding axial stress using Euler's formula. Determine the minimum length for which Euler's equation, if proportionality limit of material is 200Mpa.	7	L3	CO6
	OR			
4a)	Derive an expression for Euler's crippling load when both ends of the column are hinged.	8	L2	CO6
4b)	Determine the diameter of solid shaft which will transmit 90kN at 160rpm, if the shear stress in the shaft is limited to 60Mpa. Find also length of the shaft. If the twist is limited to 1°. Given C = 8×10^{4}Mpa.	7	L3	CO4

RBT (Revised Bloom's Taxonomy) Levels		
L1 : Remembering	L2 : Understanding	L3 : Applying
L4 : Analysing	L5 : Evaluating	L6 : Creating

07/12/2020
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11/12/2020.
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(HOD, Civil)

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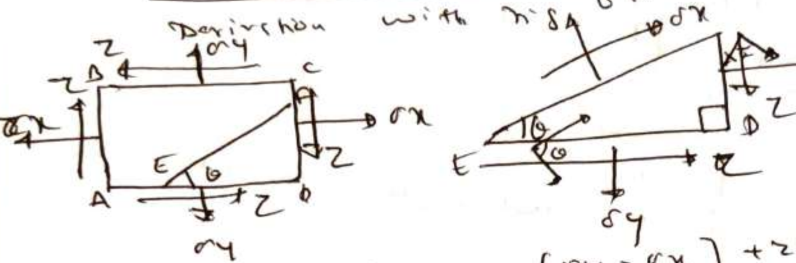
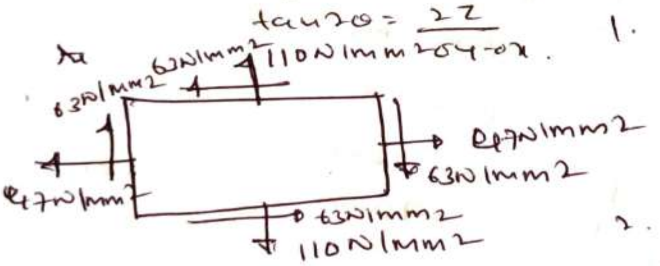
Department of Civil Engineering

Scheme of Valuation

Course/Subject Title	Strength of Materials	**Course/Subject Code**	18CV32
Semester	III rd A	**CIE No.**	01
Date	7/12/2020	**Max. Marks**	30

Q.	Solution	Marks
1.	Answer any one full question from each part. Part – A.	
1a	Two Dimensional system.	8m
	Derivation with fig. σn 	fig with explanation — 8m
	$\sigma n = \left(\frac{\sigma x + \sigma y}{2}\right) + \cos 2\theta \left[\frac{\sigma y - \sigma x}{2}\right] + \tau \sin 2\theta$	
	$\sigma t = \left[\frac{\sigma y - \sigma x}{2}\right] \sin 2\theta - \tau \cos 2\theta$	
	$\tan 2\theta = \frac{2\tau}{\sigma y - \sigma x}$	
1b		
	1. Major principal stress $\sigma n_1 = \left[\frac{\sigma x + \sigma y}{2}\right] + \sqrt{\left(\frac{\sigma y - \sigma x}{2}\right)^2 + \tau^2}$	
	$\sigma n = 148.93\ N/mm^2$	2½
	2. Minor principal stress $\sigma n_2 = \left(\frac{\sigma x + \sigma y}{2}\right) - \sqrt{\left[\frac{\sigma y - \sigma x}{2}\right]^2 + \tau^2}$	
	$\sigma n_2 = 8.07\ N/mm^2$	2½
	3. Direction. $\tan 2\theta = \frac{2\tau}{\sigma y - \sigma x}$, $\theta = 31°43'$ ~ 1M	
	(4) magnitude $\sigma t\rvert_{max} = \frac{1}{2}\sqrt{(\sigma x - \sigma y)^2 + 4\tau^2}$, $\sigma t\rvert_{max} = 70.43\ N/mm^2$	1m
2(b)	Thin cylinder: If the thickness of the wall of the cylindrical vessel is less than $\frac{1}{15}$ to $\frac{1}{20}$ of its internal diameter.	2m
	Thick cylinder: If the thickness of the wall of the cylindrical vessel is more than $\frac{1}{20}$ of the its internal diameter.	2m

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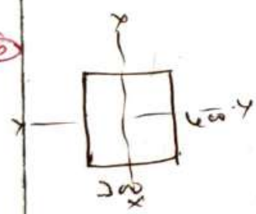
Department of Civil Engineering

Scheme of Valuation

Q.	Solution	Marks
	Expression of hoop stress $\sigma_1 = \frac{pd}{2t}$. Fig with h's. –	3m
	Longitudinal stress $\sigma_2 = \frac{pd}{4t}$ with h's. –	3m
		8m
2(b)	$p_x = \frac{b}{x^2} - a \rightarrow \quad \sigma_x = \frac{b}{x^2} + a \rightarrow (2)$ – 2m	
	$6400a + b = 51200 \rightarrow (iii)$	7m
	$6400a + b = 224000 \rightarrow (iv)$	
	$a = 13.5 \quad b = 137600.$ – 4m	
	$t = 20.96mm$ – 1m	
	Part B	
3(a)	Derive the Torsion equation with usual notations	
	fig – 1m	8m
	Explanation – 7m	
	$\frac{T}{J} = \frac{C\theta}{L} = \frac{\sigma_s}{R}$	
3(b)		
	$I_{xx} = \frac{bd^3}{12} = 160\times10^3 mm^4$	
	$I_{yy} = \frac{b^3d}{12} = 90\times10^3 mm^4$ } 1m	
	$k_{min} = \sqrt{\frac{I_{min}}{A}} = 8.66mm$	
	$l = 1.75m \quad l_e = l = 1750mm \quad E = 2\times10^5 MPa.$	
	case (1) axial stress	
	$P_{cr} = \frac{\pi^2 E I_{min}}{l_e^2}$ $P_{cr} = 58.00\times10^3 N$ – 2m	
	Axial stress $\sigma = \frac{Load}{Area} = \frac{P_{cr}}{A} = \frac{58\times10^3}{30\times40}$ $\sigma = 48.33MPa$ – 2m	7m
	case: 2	
	$P_{cr} = \frac{\pi^2 E I}{l_e^2} = \frac{\pi^2 E (Ak^2)}{l_e^2}$	
	$\sigma_{cr} = \frac{\pi^2 E k^2}{l_e^2}$ } 2m	
	$l_e = 99.34 \times k_{min}$	
	$l_e = 860.33mm$	

Course Coordinator (Faculty in charge) Coordinator DQAC Program Coordinator (HOD, Civil)

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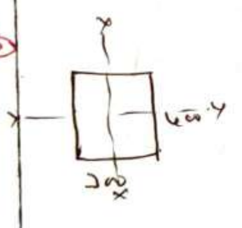
Department of Civil Engineering

Scheme of Valuation

Q.	Solution	Marks
	Expression of hoop stress $\sigma_1 = \frac{pd}{2t}$. Eq with fig. —	3m
	Longitudinal stress $\sigma_2 = \frac{pd}{4t}$ with fig. —	3m
2(b)		8m
	$p_x = \frac{b}{x^2} - a \rightarrow \quad \sigma_x = \frac{b}{x^2} + a \rightarrow (2)$ — 2m	
	$-6400a + b = 51200$ — (iii)	
	$6400a + b = 224000 \rightarrow$ (iv)	7m
	$a = 13.5$ $\quad$ $b = 137600$. — 4m	
	$t = 20.56$ mm — 1m	
	Part B	
3(a)	Derive the Torsion equation with usual notations	
	fig — 1m	
	Explanation — 7m	8m
	$\frac{T}{J} = \frac{C\theta}{L} = \frac{fs}{R}$	
3(b)		
	$I_{xx} = \frac{bd^3}{12} = 160\times10^3\ mm^4$	
	$I_{yy} = \frac{b^3d}{12} = 90\times10^3\ mm^4$ — 1m	
	$k_{min} = \sqrt{\frac{I_{min}}{A}} = 8.66$ mm	
	$l = 1.75$ m $\quad l_e = l = 1750$ mm $\quad E = 2\times10^5$ MPa.	
	case (i) axial stress	
	$P_{cr} = \frac{\pi^2 E I_{min}}{l_e^2}$ $\quad P_{cr} = 58.00\times10^3$ N — 2m	
	Axial stress $f = \frac{Load}{Area} = \frac{P_{cr}}{A} = \frac{58\times10^3}{30\times40}$ $\quad f = 48.33$ MPa — 2m	7m
	case: 2	
	$P_{cr} = \frac{\pi^2 E I}{l_e^2} = \frac{\pi^2 E (Ak^2)}{l_e^2}$	
	$f_{cr} = \frac{\pi^2 E k^2}{l_e^2}$ — 2m	
	$l_e = 99.34\times k_{min}$	
	$l_e = 860.33$ mm	

Course Coordinator (Faculty in charge) | Coordinator DQAC | Program Coordinator (HOD, Civil)

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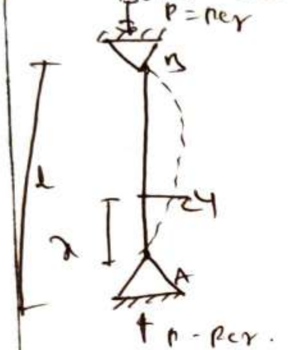
Scheme of Valuation

Course/Subject Title			
Semester		Course/Subject Code	
Date		CIE No.	
		Max. Marks	

Q.	Solution	Marks
4(a)	Both ends of the column are hinged  $P = \frac{\pi^2 EI}{l^2}$ $l = l_e$ Derivation with fig. 5 marks	5m.
4(b)	$P = \frac{2\pi NT}{60}$ $T = 5.371\times10^6$ N-mm $\frac{T}{J} = \frac{\tau}{R}$ $d = 76.96$ mm — 3.5m $\frac{T}{J} = \frac{C\theta}{L}$ $L = 892.57$ mm — 3.5m	7m

Course Coordinator (Faculty in charge)
ASSISTANT PROFESSOR, Civil Engineering Department, B.I.E.T.

Coordinator DQAC 11/12/2020

Program Coordinator (HOD, Civil) 11/12/20

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Department of Civil Engineering

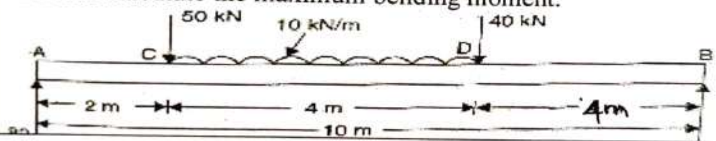
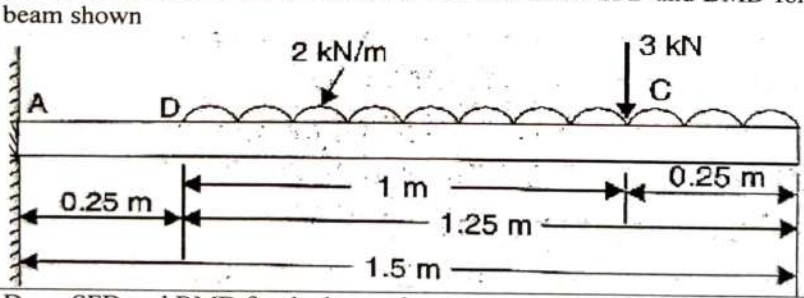
USN										

Course/Subject Title	Strength of Materials		
Semester	III A	**Course/Subject Code**	18CV32
Date	23/02/2021	**Scheme**	CBCS – 18
Time	3:00to 4:00 PM	**CIE No.**	3
		Max. Marks	30

Course Outcome Statements : After the successful completion of the course, the students will be able to

CO1	**Evaluate** the stresses and strains for ferrous and non-ferrous materials
CO2	**Evaluate** the internal stresses developed in one dimensional, two dimensional structural elements and cylinders
CO3	**Evaluate** the bending moment, shear force in prismatic beams and corresponding stresses
CO4	**Analyse** and **design** the circular shafts subjected to torsion
CO5	**Evaluate** the slope and deflection of prismatic beams
CO6	**Evaluate** the failure loads for the columns and struts

Note : Answer ~~all~~ one full Questions

Q. No.	Question	Marks	RBT Level	CO
	Part A			
1 a)	Establish the relationship between shear force, bending moment and load intensity.	5	L2	CO3
1 b)	A Simply Supported beam of length 10m, carries the uniformly distributes load and two point load as shown in fig. Draw SFD and BMD for the beam and also calculate the maximum bending moment. 	10	L3	CO3
	OR			
2 a)	A Cantilever 1.5m long is loaded with a uniformly distributed load of 2kN/m run over a length of 1.25m from the free end. It also carries a point load of 3kN at a distance of 0.25m from the free end. Draw SFD and BMD for the beam shown 	5	L3	CO3
2 b)	Draw SFD and BMD for the beam shown	10	L3	CO3

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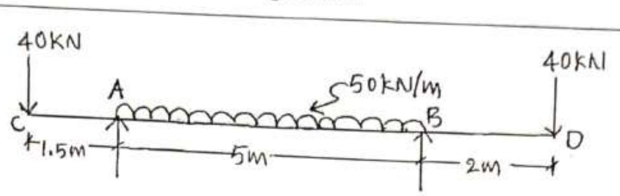
Q. No.	Question	Marks	RBT Level	CO
	Note : Answer all Questions			
				
	Part B			
3 a)	List the assumptions made in theory of bending and Derive the equation of pure bending with usual notations.	5	L2	CO3
3 b)	Determine the defection at the mid-span and slope at the supports for a simply supported beam of span L,m subjected to concentrated load W at mid-span.	10	L3	CO5
	OR			
4 a)	Derive the Euler's-Bernoulli differential differential equation for flexure.	5	L2	CO5
4 b)	A timber beam 200mm×300mm is simply supported over a span of 10m. What UDL can it carry if the maximum permissible stress is 7.5Mpa. Find the maximum bending stress and radius of curvature at a section 1m from left support. Take E=12.6×10^3 N/mm^2.	10	L3	CO3

RBT (Revised Bloom's Taxonomy) Levels : Cognitive Domain		
L1 : Remembering	L2 : Understanding	L3 : Applying
L4 : Analysing	L5 : Evaluating	L6 : Creating

20.2.21
Course Coordinator
(Raghu M.E)
ASSISTANT PROFESSOR
Civil Engineering Department
B.I.E.T., Davangere.

Coordinator
DQAC

Program Coordinator
(HOD, Civil)

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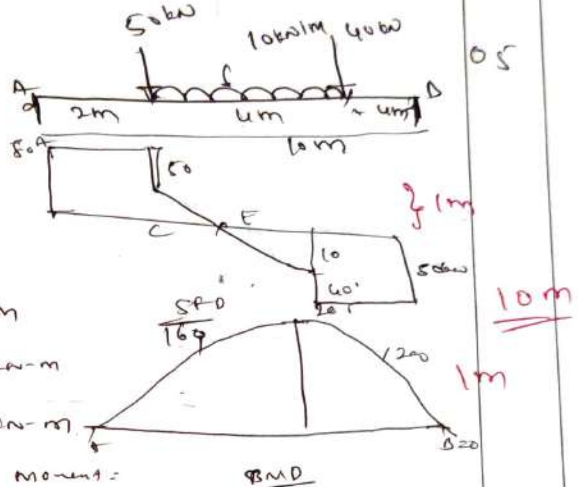
Scheme of Valuation

Course/Subject Title	Strength of Materials		
Semester	IIIrd sem	Course/Subject Code	18CV32
Date	23-02-2021	CIE No.	03
		Max. Marks	30

1a) Derivation carries - 5m.
Fig - 1m.
Explanation - 4m

1b)

$R_{AV} + R_{BV} = 130kN$.
$R_{BV} = 50kN$
$R_{AV} = 80kN$ } 2m

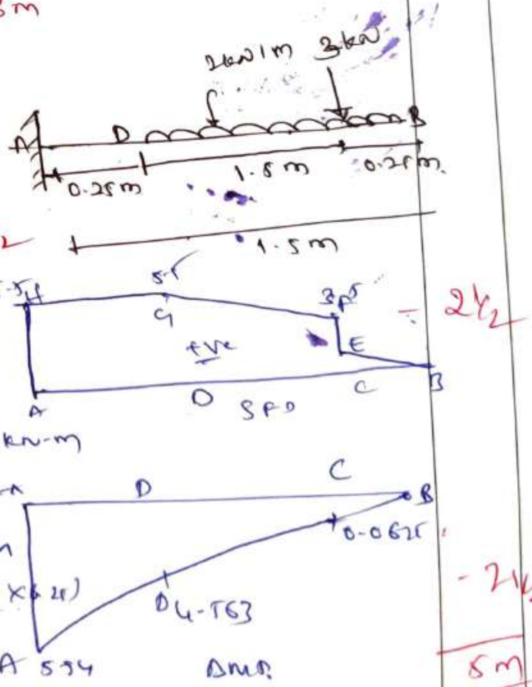


$SF)_A = +80kN$
$SF)_{C\ left} = 80kN$
$SF)_{C\ Right} = 30kN$
$SF)_{D\ Left} = -10kN$
$SF)_{D\ Right} = -50kN$.
$SF)_B = -50kN$.

BM
$BM)_A = 0$
$BM)_B = 0$
$BM)_C = 160kN\text{-}m$
$BM)_D = 200kN\text{-}m$
$BM)_E = 205kN\text{-}m$
Max Bending Moment = 205kN·m 3m

$x = 5m$
3m

2(a)



$SF]_B = 0$.
$SF]_{C\ Left} = 2 \times 0.25 = 0.5kN$.
$SF)_{C\ Right} = 0.5 + 3 = 3.5kN$ +ve.
$SF)_D = 3.5 + 2 \times 1 = 5.5kN$.
$SF)_A = 5.5kN$.
} 2½

$BM)_B = 0$
BM at $C = -2 \times 0.25 \times \frac{0.25}{2} = -0.0625kN\text{-}m$
BM at $D = -2 \times 1.25 \times \frac{1.25}{2} + (3 \times 1) = -4.563kN\text{-}m$
BM at $A = -2 \times (1.25 \times \frac{1.25}{2} + 0.25) - 3 \times (1 \times 0.25)$
$= -5.94kN\cdot m$

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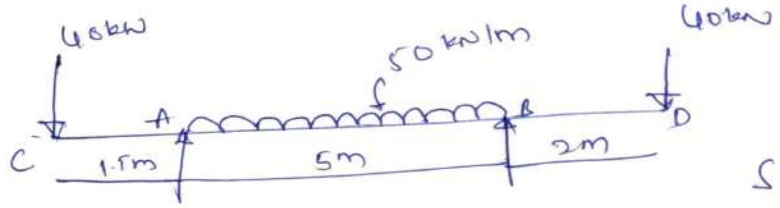
2 (b)



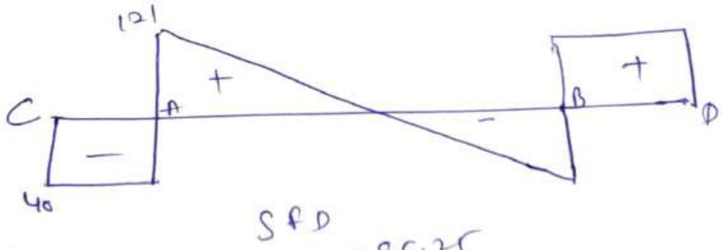
$SF]_C = -40k$

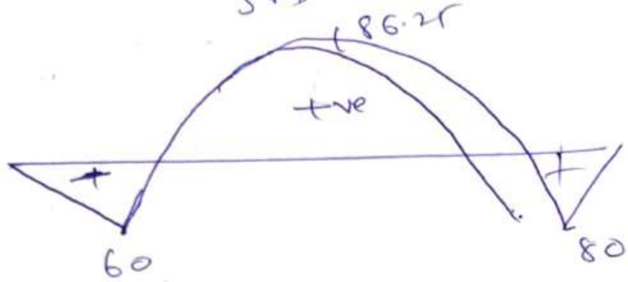
$SF)_A = 121kN$

$SF)_B = -129+169$
$= 40 kN$

$SF)_D = +40 kN$

- 5m





$BM)_C = 0$

$BM)_A = -60 kN$

$BM)_E = 86.25 kN\cdot m$

$BM)_B = -80kN.$

$BM)_D = 0$

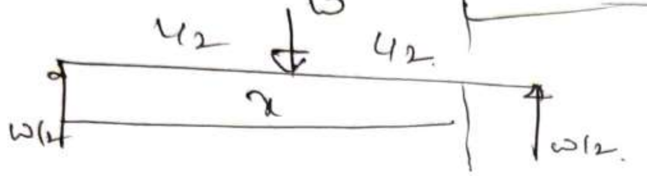
- 5m

- 10m

Scheme of Valuation

3a Assumption – 1m
Derivation – 4m } $\frac{M}{I} = \frac{f}{y} = \frac{E}{R}$ – 5m

3b



3b
~~Assumption = 1m~~
~~Derivation – 4m~~ } ~~$\frac{M}{I} = \frac{f}{y} = \frac{E}{R}$~~ – 5m

$BM)_{x-x} = \frac{Wx}{2} - W(x - \frac{L}{2})$ } (2)

$EI\frac{d^2y}{dx^2} = -\frac{Wx}{2} + W(x - L/2)$

$EI\frac{dy}{dx} = -\frac{Wx^2}{4} + \frac{W}{2}(x - \frac{L}{2})^2 + C_1 \rightarrow (1)$ – (1)

$EI\,y = \frac{-Wx^3}{12} + \frac{W}{6}(x - \frac{L}{2})^3 + C_1x + C_2 \rightarrow (2)$ – (1)

Boundary condition (2m)

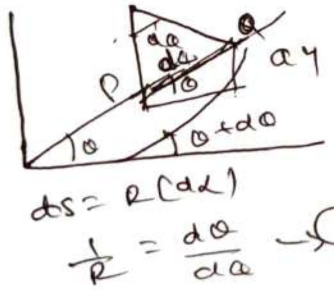
$C_2 = 0, \quad C_1 = \frac{WL^2}{16}$

Slope $\frac{dy}{dx})_A = \frac{WL^2}{16EI}, \quad \frac{dy}{dx})_B = \frac{-WL^2}{16EI}$ } (2) (10m)

Deflection

$y_{max} = \frac{WL^2}{48EI}$ } (2)

4a



} 1m

$ds = R(d\alpha)$

$\frac{1}{R} = \frac{d\theta}{d\alpha} \rightarrow (1)$ } (2)

$\tan\theta = \frac{dy}{dx} \quad \sec\theta = \frac{d\alpha}{dx}$

$\frac{dy}{dx} = \tan\theta$

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$$\frac{d^2y}{dx^2} = \sec^2\theta \cdot \frac{d\theta}{dx}$$

$$\frac{d\theta}{dx} = \frac{d\theta}{d\theta} \times \frac{d\theta}{dq} = \frac{1}{R}\sec\theta$$

$$\frac{d^2y}{dx^2} = \sec^2\theta \left(\frac{1}{R}\right)\sec\theta$$

$$= \sec^3\theta \left(\frac{1}{R}\right)$$

$$\frac{1}{R} = \frac{(d^2y/dx^2)}{(\sec^2\theta)^{3/2}}$$

$$\frac{1}{R} = \frac{d^2y(dx^2)}{\left(1+\frac{dy}{dx}^2\right)^{3/2}}$$

$$\frac{1}{R} = \frac{d^2y}{dx^2}$$

} 2m

$$\boxed{M = EI \cdot \frac{d^2y}{dx^2}}$$ 0.5m

4(b) $I = 450\times10^6\ mm^4 \rightarrow (1)$ 1m

$$\frac{M}{I} = \frac{f}{a} = \frac{E}{R}$$

$$M = \frac{fI}{y} = \frac{7.5\times450\times10^6}{(300/2)} = 22.5\times10^6\ N\text{-}mm$$ } 2m

$$M = \frac{wl^2}{8} = 22.5\times10^6$$ — 1m

$w = 1.8\ kN/m$ BM at $1m = 9\times1 - \frac{1.8\times1^2}{2} = 8.1\ kN\text{-}m$ } 2m

Bending stress at 1m $= \frac{M}{I} = \frac{f}{y}$

$$f_{1m} = \frac{M\times y}{I} = 2.7\ MPa$$ } 2m

R at m $= \frac{M}{I} = \frac{E}{R}$

$R = 700\times10^3\ mm^3$ } 2m

10 M.

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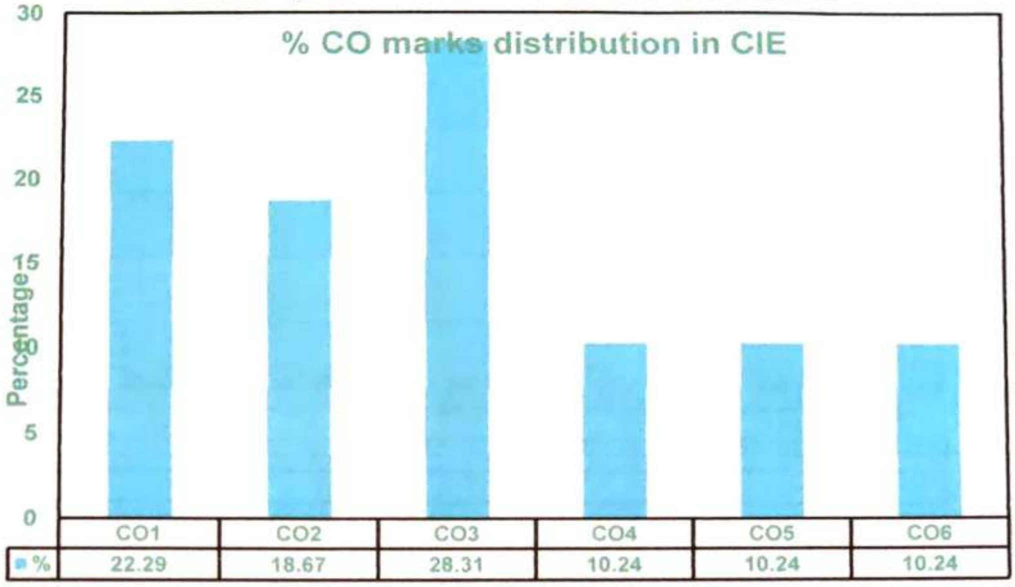
Department of Civil Engineering

Attainment

Strength of materials 18CV32 ODD SEM 2020-21



20-2021

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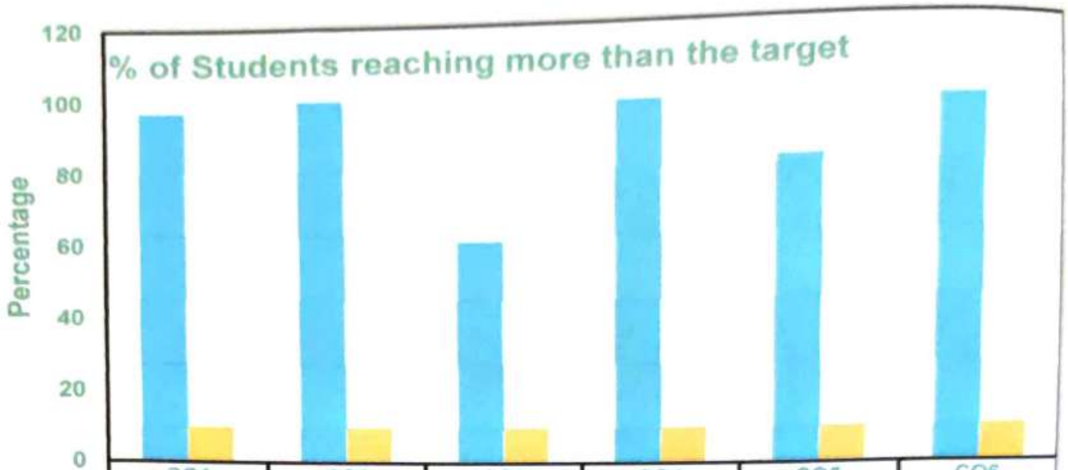

	CO1	CO2	CO3	CO4	CO5	CO6
CIE	97	100	61	99	83	98
SEE	10	10	10	10	10	10

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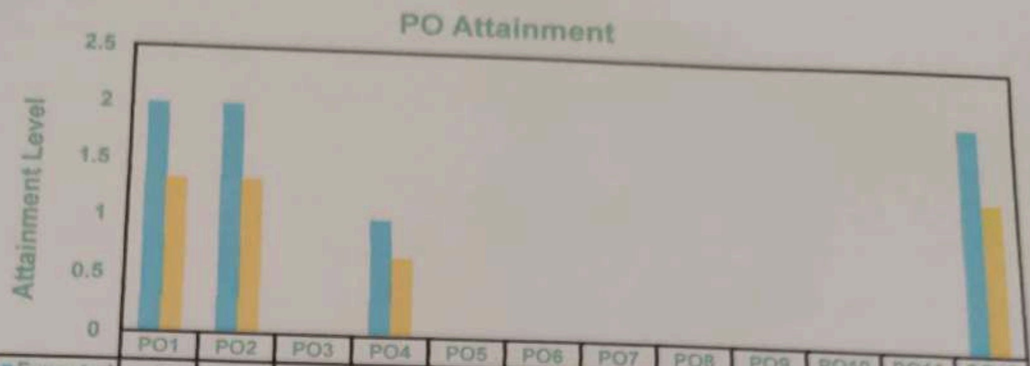
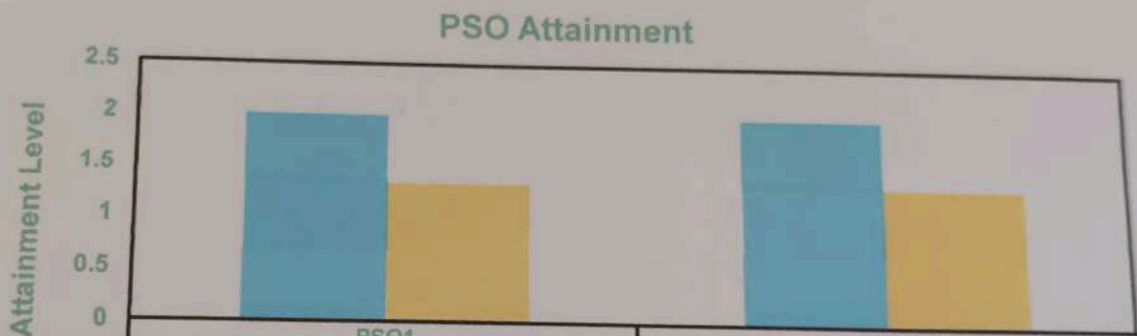
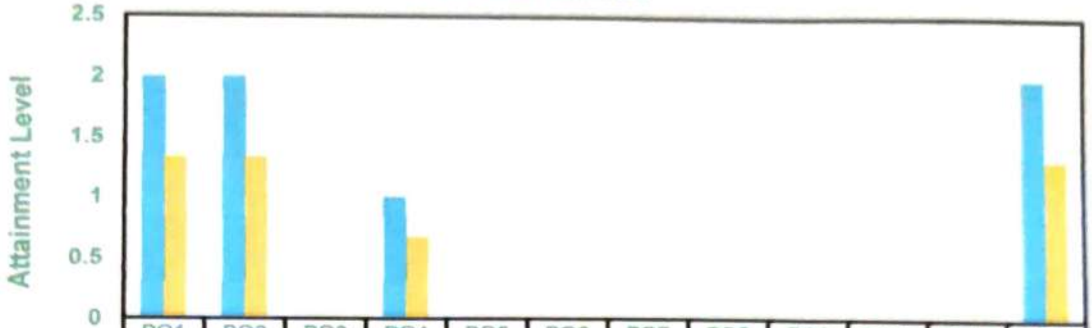


	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
Expected	2	2	0	1	0	0	0	0	0	0	0	2
Actual	1.33	1.33	0	0.67	0	0	0	0	0	0	0	1.33



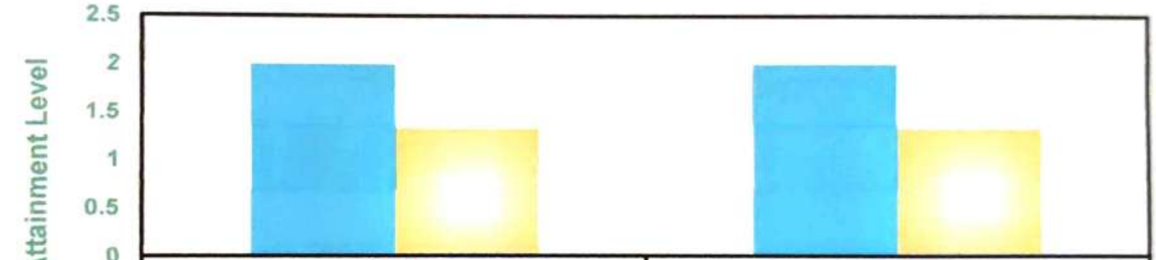
	PSO1	PSO2
Expected	2	2
Actual	1.33	1.33

PO Attainment



	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
Expected	2	2	0	1	0	0	0	0	0	0	0	2
Actual	1.33	1.33	0	0.67	0	0	0	0	0	0	0	1.33

PSO Attainment



	PSO1	PSO2
Expected	2	2
Actual	1.33	1.33

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Department of Civil Engineering

Result Analysis **Academic Year : 2020 -2021 ODD SEM**

Name of the Faculty		Raghu M E		Academic Year : 2020 - 2021 ODD SEM	
Sl. No.	Subject Title	Subject Code	Total No. of students appeared for the exam	No. of Students passed	Pass Percentage
1	Strength of materials	18CV32	70	41	59

Staff in Charge

HOD Civil

Period : From September 2020 To February - 2021 Semester : Odd/Even

Name of the Teacher : Raghu. M.E

Designation : Assistant Professor

Department : civil Department

Sl. No.	Sem. / Sec. / Branch	Subject Name	Subject Code
1	III rd | A | civil	Strength of materials	18CV32
2	III | B | civil	Basic surveying	18CV35
3	III | A | A1 | civil	Basic material testing lab	18CVL38
4			
5			
6			
7			

	Reviews at the end of the				End of Semester
	1st Month	2nd Month	3rd Month	4th Month	
Signature of Staff	30.9.2021	30.10.2021	30.12.2021	28.2.2021	21/3/2021
Signature of the Head of Department	30/9/21	3/10/21		27/2/2021	26/3/2021
Signature of the Principal	PRINCIPAL Japuji Institute of Engineering & Technology DAVANGERE.		PRINCIPAL Japuji Institute of Engineering & Technology DAVANGERE.		PRINCIPAL Japuji Institute of Engineering & Technology DAVANGERE.

Class : III rd Sem. A section Subject Code : 18CV32 Subject : Strength of Materials Total No. of Classes : 28

Sl No.	USN	NAME	9/9/20	10/9/20	12/9/20	14/9/20	15/9/20	16/9/20	19/9/20	21/9/20	22/9/20	23/9/20	25/9/20	28/9/20	29/9/20	30/9/20	01/10/20	03/10/20	05/10/20	06/10/20	07/10/20	08/10/20	10/10/20	12/10/20	13/10/20	14/10/20	15/10/20	20/10/20	21/10/20	27/10/20	No. of Days Present	%	Test Marks I	II	III	Average	Remarks
1	4BD19CV001	Aban Sharief	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
2	4BD19CV003	Afzal Noorsabnavar	1	2	A	3	4	5	6	7	8	9	10	A	A	A	A	11	12	13	14	15	16	17	18	19	20	21	22	23							
3	4BD19CV005	Akashdeep R Andanur	1	2	3	4	5	6	7	8	9	A	10	11	12	13	14	15	16	17	18	19	20	A	21	22	23	24	25	26							
4	4BD19CV006	Akhila C Akula	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	A	A							
5	4BD19CV007	Akshatha Ashoka Putalekarar	1	2	3	4	5	6	7	8	9	10	11	12	13	14	A	15	16	17	A	18	19	20	21	22	23	24	25	A							
6	4BD19CV009	Akshaya Kumara. L.M	1	2	A	3	4	5	7	A	8	9	A	A	A	10	11	A	A	12	13	A	14	A	15	A	A	A	A	A							
7	4BD19CV011	Amith K.M	1	2	3	A	4	5	6	7	8	9	A	10	11	A	A	A	12	13	A	A	14	15	16	A	A	A	A	12							
8	4BD19CV013	Arpitha Basanagoudapatil	1	2	3	A	4	5	6	A	7	8	A	9	A	10	11	A	12	13	14	15	16	A	17	18	19	20	21	A							
9	4BD19CV015	Basavaraj S Patil	1	A	2	3	4	A	5	6	A	A	A	A	A	A	A	7	A	8	A	A	9	10	11	12	13	14	15	16							
10	4BD19CV017	Bhumika P.	1	A	2	3	4	5	6	7	8	9	A	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26							
11	4BD19CV019	Chinmayee K.	1	2	3	4	5	6	7	8	9	10	11	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27							
12	4BD19CV021	Darshan V.N.	1	A	A	A	A	A	2	3	4	A	5	A	A	A	A	A	A	A	A	6	7	A	A	A	A	8	A	A							
13	4BD19CV023	Ganesh U Shirigeri	1	2	3	4	5	6	7	8	9	10	11	12	13	A	A	14	15	A	16	17	18	19	A	20	21	22	23	24							
14	4BD19CV025	Hemanth Kumar DV	A	1	2	A	A	A	A	A	3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
15	4BD19CV027	Jhanavi R	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							
16	4BD19CV029	Kruthik. S.P.	1	2	3	4	A	5	A	A	A	A	A	6	A	A	A	7	8	9	10	11	12	A	A	13	14	15	16	17							
17	4BD19CV031	M Syed Anwar	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
18	4BD19CV033	Manjunatha. M	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							
19	4BD19CV035	Mithun. Y	1	A	A	A	2	3	4	A	5	A	6	7	A	A	A	A	A	A	A	8	9	A	10	A	A	11	A	A							
20	4BD19CV037	Mohammed Faizan makandar	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							
21	4BD19CV039	Nadeem sha A.Z.	1	A	A	2	3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
22	4BD19CV041	Nanda K.B	1	2	3	4	5	A	6	A	7	8	9	A	A	10	11	12	13	14	15	16	17	18	19	20	21	22	A	23							
23	4BD19CV043	Niranjan. G.M	1	A	2	3	4	A	5	6	A	7	8	9	A	A	10	A	11	12	A	13	14	A	A	A	A	A	15	A							
24	4BD19CV047	Pooja. P.	1	A	A	A	A	A	2	A	A	A	3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	4							
25	4BD19CV049	Pradeep. P.N.	1	2	3	4	5	A	6	7	A	A	A	A	A	A	A	A	A	A	A	8	A	A	9	10	11	A	A	A							
26	4BD19CV051	Prashanth. N.R	1	2	3	4	5	6	7	8	9	10	11	12	A	A	13	A	14	15	16	17	18	19	20	21	22	23	A	24							
27	4BD19CV053	Raghavendra Vaditke	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
28	4BD19CV055	Rakesh. H.N.	1	2	3	4	5	6	7	A	8	A	9	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
29	4BD19CV057	Sambhram S Patil	1	2	3	4	5	A	6	7	A	A	A	A	A	A	A	8	9	10	11	12	13	14	15	A	A	16	17	18							
30	4BD19CV059	Sevanth B.M	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							

Initials of Teacher

Initials of H.O.D.

Initial of Principal

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Jain Institute of Engineering & Technology
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Class : III A Subject Code : 18CV32 Subject : Strength of materials Total No. of Classes : 56

Sl No.	USN	NAME	28/10/20	29/10/20	02/11/20	03/11/20	04/11/20	05/11/20	07/11/20	09/11/20	10/11/20	11/11/20	12/11/20
1		Aban Sharief	A	A	A	A	A	A	A	A	A	A	A
2		Afzal Noorsabnavar	A	24 A	A	24	25	26	27	A	28	29	30
3		Akashdeep R Andanur	27	28	29	30	30	31	32	33	34	35	36
4		Akhila C Akula	27	28	29	30	31	32	33	34	35	36	37
5		Akshatha Ashoka P	26	27	28	29	30	31	32	33	34	35	36
6		Akshaya kumara. L.M	26	A	A	A	A	A	A	A	A	28	28
7		Amith. K.M	A	18 A	18	19	20	21	22	23	24	A	A
8		Arpitha Basanagouda Patil	22	23	24	25	26	27	28	29	30	31	32
9		Basavaraj S Patil	17	A	18	19	20	21	A	22	A	A	A
10		Bhumika. P.	27	28	29	30	31	32	33	34	35	36	37
11		Chinmayee. K.	28	29	30	31	32	33	34	35	36	37	38
12		Darshan. V.n	A	9	A	A	A	A	A	A	10	A	A
13		Ganesh. U.S.	25	26	A	A	A	A	27	28	29	30	31
14		Hemanth Kumar. D.V.	A	4 A	A	A	A	A	A	A	A	A	A
15		Jhanavi. R. (change of stream)	29	30	A	A	31	32	33	34	35	36	37
16		Kruthik. S. P.	18	A	19	21	21	22	A	A	A	A	A
17		M-Syed Anwar	A	A	A	A	A	A	A	A	A	A	A
18		Manjunatha. M	29	A	30	31	32	33	34	35	36	37	38
19		Mithun. Y.	A	12 A	A	A	A	A	A	A	A	A	A
20		Mohammed Faizan Mantaludar	29	A	30	31	32	33	34	35	36	37	38
21		Nadeem sha. A.Z.	A	3 A	A	A	A	A	A	A	A	A	A
22		Nanda. K. B	24	25	26	27	28	29	A	30	31	32	A
23		Niranjan. G.M.	A	16 A	A	16	A	A	A	A	17	18	A
24		Pooja. P.	A	5 A	A	A	A	A	A	A	A	A	A
25		Pradeep. P.N.	A	11 A	A	A	A	A	A	A	A	A	11
26		Prashanth. N.R.	A	25 A	A	26	27	A	A	28	A	29	A
27		Raghavendra V.	A	2 A	A	A	A	A	2	A	3	A	4
28		Rakesh. H.N.	A	10 A	A	A	A	A	A	A	A	A	A
29		Sambhram Snati	19	A	20	21	22	23	24	25	26	27	28
30		Sevanth	A	A	A	A	A	A	A	A	A	A	A

Sl No.	NAME	17/11/20	18/11/20	19/11/20	21/11/20	23/11/20	24/11/20	25/11/20	26/11/20	28/11/20	30/11/20	01/12/20	02/12/20	12/12/20	14/12/20	15/12/20	16/12/20	21/12/20
1	Aban Sharief	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
2	Afzal Noorsabnavar	A	31	32	33	34	A	35	36	37	A	A	38	39	A	40	41	A
3	Akashdeep R Andanur	37	38	39	40	41	42	A	A	43	A	A	A	44	45	46	47	48
4	Akhila C Akula	38	39	40	41	42	43	43	44	45	46	47	A	48	49	50	51	52
5	Akshatha Ashoka P	37	38	39	40	41	42	43	44	45	46	47	A	48	49	50	52	53
6	Akshaya kumara. L.M	A	29	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
7	Amith. K.M	25	26	27	A	28	A	A	29	A	30	A	A	A	A	A	A	A
8	Arpitha Basanagouda Patil	A	33	A	A	34	35	36	37	38	39	40	41	A	A	42	A	43
9	Basavaraj S Patil	23	24	25	26	27	28	A	A	A	A	29	A	A	30	A	A	A
10	Bhumika. P.	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
11	Chinmayee. K.	39	40	41	42	43	44	45	46	47	48	49	A	50	51	52	53	54
12	Darshan. V.n	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
13	Ganesh. U.S.	32	33	34	A	35	36	37	38	39	40	41	42	43	44	45	46	A
14	Hemanth Kumar. D.V.	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
15	Jhanavi. R.	A	A	38	A	39	A	A	A	A	A	A	A	A	A	A	A	A
16	Kruthik. S. P.	A	23	24	A	25	A	A	A	26	A	A	27	A	A	A	A	A
17	M-Syed Anwar	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
18	Manjunatha. M	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
19	Mithun. Y.	A	A	A	A	12	A	A	A	A	A	13	14	15	16	16	17	18
20	Mohammed Faizan Mantaludar	39	40	41	42	43	44	45	A	46	47	48	49	50	51	52	53	54
21	Nadeem sha. A.Z.	A	A	A	A	A	A	A	A	A	A	A	A	A	A	4	A	A
22	Nanda. K. B	33	34	35	36	37	38	39	A	40	A	41	42	43	44	A	A	45
23	Niranjan. G.M.	A	19	20	A	21	22	23	24	A	A	25	A	A	A	26	27	28
24	Pooja. P.	A	A	A	A	A	A	A	A	A	A	5	A	A	A	A	A	A
25	Pradeep. P.N.	A	12	13	A	13	14	A	A	15	16	17	18	20	21	22	A	A
26	Prashanth. N.R.	A	30	31	32	33	34	A	35	36	37	38	A	39	40	41	A	A
27	Raghavendra V.	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
28	Rakesh. H.N.	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
29	Sambhram Snati	29	30	31	32	33	34	A	35	A	A	36	A	37	38	39	40	41
30	Sevanth	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

Sl No.	NAME	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
1	Aban Sharief	1	10	24	23	08	19	29
2	Afzal Noorsabnavar	2	10	30	30	12	24	34
3	Akashdeep R Andanur	3	10	30	30	21	27	37
4	Akhila C Akula	4	10	30	30	19	27	37
5	Akshatha Ashoka P	5	10	30	30	15	25	35
6	Akshaya kumara. L.M	6	10	29	30	18	26	36
7	Amith. K.M	7	10	24	30	14	23	33
8	Arpitha Basanagouda Patil	8	10	30	30	10	23	33
9	Basavaraj S Patil	09	10	26	30	AB	19	29
10	Bhumika. P.	10	10	30	30	07	23	33
11	Chinmayee. K.	11	10	30	30	27	27	37
12	Darshan. V.n	12	10	24	24	9	15	25
13	Ganesh. U.S.	13	10	30	30	23	28	38
14	Hemanth Kumar. D.V.	14	10	24	27	03	18	28
15	Jhanavi. R.	15	AB	AB (change of branch)	AB	AB	AB	AB
16	Kruthik. S. P.	16	10	30	30	17	26	36
17	M-Syed Anwar	17		Left the course				
18	Manjunatha. M	18	10	30	30	24	28	38
19	Mithun. Y.	19	10	21	19	02	14	24
20	Mohammed Faizan Mantaludar	20	10	26	30	21	26	36
21	Nadeem sha. A.Z.	21	10	25	23	13	21	31
22	Nanda. K. B	22	10	30	30	21	27	37
23	Niranjan. G.M.	23	10	25	30	05	22	32
24	Pooja. P.	24	10	25	30	00	19	29
25	Pradeep. P.N.	25	10	23	21	04	16	26
26	Prashanth. N.R.	26	10	24	28	12	22	32
27	Raghavendra V.	27	10	30	30	04	22	32
28	Rakesh. H.N.	28	10	25	21	12	20	30
29	Sambhram Snati	29	10	26	30	AB	15	29
30	Sevanth	30	10	30	23	08	21	31

Initials of Teacher
Initials of H.O.D.
Initial of Principal

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Class: III[rd] sem A   Subject Code: 18CV32   Subject: Strength of materials   Total No. of Classes: 28.

Sl No.	USN	NAME	9/9/20	10/9/20	12/9/20	14/9/20	15/9/20	16/9/20	19/9/20	21/9/20	22/9/20	23/9/20	25/9	28/9/20	29/9/20	30/9/20	01/10/20	03/10/20	05/10/20	06/10/20	07/10/20	08/10/20	10/10/20	12/10/20	13/10/20	14/10/20	15/10/20	16/10/15	21/10/13	27/10/13	No. of Days Present	%	Test Marks I	II	III	Average	Remarks
31	4BD19CV061	Shreya D.K. ×	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	1	2	A	A	A	A	A	A	A	A							
32	4BD19CV063	Soundarya N.M ×	1	2	3	4	5	6	7	8	9	10	A	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	A	A							
33	4BD19CV065	Swathi V Kote ×	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							
34	4BD19CV067	U Madhushree	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A	A	A	18	19	20	21	22	23	24	25							
35	4BD19CV069	Vaishnavi V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A	A	A	18	19	20	21	22	23	24	25							
36	4BD19CV070	Veeresh K.K. ×	1	2	A	3	A	A	4	5	6	7	8	9	A	A	A	10	11	12	A	13	14	15	16	17	18	19	A	20							
37	4BD19CV073	Vijayalakshmi R. Telkar	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							
38	4BD19CV075	Vikas S.M.	1	A	A	2	3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	4	5	6	A	7	A							
39	4BD19CV077	Vivekananda H.M ×	1	2	A	A	A	A	A	A	A	A	A	A	A	A	A	3	4	5	A	A	A	A	6	7	8	9	10	11							
40	4BD19CV079	Yugh B. Jain ×	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	2	3	4	A	A							
41	4BD18CV099	Vinay Kumar M	A	1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	2	3							
42	4BD17CV052	Mohammed Azhar Basith	Admission on 21/09/2020										A	1	A	2	A	3	4	5	A	1	2	A	A	8	9	A	A	A							
43		Trupthi S.R. ×	Admission on [illegible]/2020										A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
44	4BD18CV027	Harshith N.	Admission on 07/10/2020																			A	1	2	3	4	5	6	7	8							
45		Channesh H. Patil ×	Admission on 10/10/2020																				1	2	3	A	A	A	4	5							
46	4BD18CV076	A Shivaraj K.H ×	Admission on 15/10/2020																									A	1	A							
47		Bharath Reddy N ×	Admission on 14/10/2020																									A	1	2							
48		A Mohammed Bhadin ×	Admission on 16/10/2020																									A	A	A							
49		Abhilash S.V	Admission on 3/11/2020																																		
50		Dhanush R. ×	Admission on 4/11/2020																																		
51		Surabhi S. Bharadwaj	Admission on 07/11/2020																																		
52		Chethan Kotraiah ×	Admission on 09/11/2020																																		
53		Vinod Kumar Budihal	Admission on 13/11/2020																																		
54		Nandesh M Mathod	Admission on 13/11/2020																																		
55	change of Branch	Santhosh S Bagoor ×	Admitted on 18/11/2020																																		
56	4BD17CV160	A Sujith R	Admitted on 18/11/2020																																		
57		Rohith A ×	— " — 20/11/2020																																		
58	change of Branch	Kiran M.M. ×	Admitted on 21/11/2020																																		
59		Suhas N. Raikar ×	Admitted on 22/11/2020																																		
60		Murugharajendra H.V	Admitted on 25/11/2020																																		
61		Shree Hallas T.R ×																																			
		Initials of Teacher	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							
		Initials of H.O.D.										✓																✓									
		Initial of Principal																																			

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Class: III rd A-section Subject Code: 18CV32 Subject: Strength of Materials Total No. of Classes: 56

Sl No.	USN	NAME	28/10/20	29/10/20	2/11/20	03/11/20	04/11/20	05/11/20	07/11/20	9/11/20	10/11/20	11/11/20	12/11/20	17/11/20	18/11/20	19/11/20	21/11/20	23/11/20	24/11/20	25/11/20	26/11/20	28/11/20	30/11/20	1/12/20	2/12/20	12/12/20	14/12/20	15/12/20	16/12/20	21/12/20	No. of Days Present	% 10	Test Marks I (30)	II	III	Average	Remarks
31		Shreya. D.K	A	3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	31	10	24	23	02	17	27
32		Soundarya. N.M	26	A	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	A	51	32	10	30	30	19	27	37
33		Swathi V Koti.	A	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	33	10	30	30	11	24	34
34		U Madhushree	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	34	10	30	38	28	26	36
35		Vaishnavi. V.	26	27	28	29	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	A	46	47	48	49	50	51	52	53	35	10	30	30	20	27	37
36		Veeresh. K. K.	A	21	22	23	24	A	25	26	27	A	A	A	A	A	A	A	A	A	A	A	A	A	A	28	A	A	A	29	36	10	30	25	01	20	30
37		Vijayalakshmi. R. Telkar	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	37	10	30	30	20	27	37
38		Vikas. S.M	8	A	A	9	A	10	A	11	12	A	13	A	A	A	A	A	A	14	A	A	A	15	A	16	A	A	A	A	38	10	17	30	00	16	26
39		Vivekananda. H.M	12	A	13	14	15	16	17	18	19	A	20	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	39	10	30	22	01	18	28
40		Yugh B. Jain	A	5	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	40	10	26	30	12	23	33
41		Vinay Kumar. M.	A	A	A	4	5	6	A	A	7	A	A	8	9	A	A	10	A	A	A	A	A	11	A	A	A	A	A	12	41	10	24	23	05	19	29
42		Mohammed Azhar Baigs	10	A	A	A	11	A	12	A	13	A	A	A	A	A	A	A	14	A	15	A	A	16	17	A	A	A	18	19	42	10	21	25	06	18	28
43		Trupthi. S.R.	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	43	10	30	30	02	21	31
44		Harshith. N.	9	10	11	A	12	13	14	15	16	17	18	A	19	A	20	21	22	A	23	24	25	A	26	27	28	29	30	31	44	10	30	30	07	23	33
45		Channesh. H. Patel	6	7	A	A	8	9	10	11	12	13	14	15	16	A	17	18	19	20	A	21	22	23	A	24	25	26	27	28	45	10	28	30	01	20	30
46		Shivaraj. K.H.	A	2	3	A	4	A	5	6	7	8	9	10	11	A	12	A	13	14	A	15	16	17	A	18	A	A	19	A	46	10	18	27	05	15	25
47		Bharath Reddy	3	A	A	4	5	A	6	A	7	A	8	A	A	A	9	A	10	A	A	A	A	A	A	A	11	A	A	A	47	10	27	29	03	20	30
48		Mohammed Khadir	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	48	10	30	30	06	22	32
49		Abhilash S.V				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	49	10	30	30	04	22	32
50		Dhanush. R.							A	A	A	1	A	A	A	A	A	A	A	A	2	3	4	5	A	A	A	A	A	A	50	10	28	24	01	18	28
51		Surabhi. S. Bharadwaj								A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	51	10	30	30	00	20	30
52		Chethan Kotrudh.									A	1	2	3	A	A	A	A	4	A	5	A	6	A	7	A	8	9	10	11	52	10	24	27	06	19	29
53		Vinod Kumar M Mathad												A	A	A	1	2	3	A	A	4	5	6	7	A	8	A	A	9	53	10	30	20	00	17	27
54		Nandish. M Mathad.												A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	54	10	30	30	07	23	33
55	Change of Branch	~~Nandish M Mathad~~ Santhosh B Bagur														A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	55	10	30	28	07	22	32
56	Change of Branch 4BD19CV...	~~Santhosh S Bagodi~~ Sujith R															A	A	1	A	A	A	A	A	A	A	A	A	A	A	56	Left the course					
57	~~4BD...~~	~~Sujith R.~~ Rohith N																1	2	3	4	5	A	6	7	A	A	A	A	A	57	10	30	30	04	22	32
58	Change of Branch	~~Rohith A.~~ Kiran N.M																A	A	A	A	A	A	A	A	A	A	A	A	A	58	10	23	30	10	21	31
59	Change of Branch	Suhas N Paikar ~~Kiran N.M~~																1	A	A	A	1	2	A	3	4	5	6	A	A	59	10	30	26	05	22	32
60		Murugharajendra. H.V																			A	A	A	A	A	A	1	A	A	A	60	10	30	30	01	21	31
61	Shree harsha T.R	Shree harsha T.R.																							1	1	2	3	4		61	10	30	30	03	21	31

Initials of Teacher

Initials of H.O.D.

Initial of Principal

PRINCIPAL
Bapuji Institute of Engineering & Technology
DAVANGERE.

Class : III A Section   Subject Code : 18CV32   Subject : Strength of Materials   Total No. of Classes : 21/56

Sl No.	USN	NAME	DATE (attendance notes)	No. of Days Present	% (10)	Test Marks I (30)	Test Marks II (30)	Test Marks III (30)	Average (30)	Remarks
62	~~Sandeep B.N.~~	~~Sandeep B.N.~~ 2/11/2020	Admission on 2/11/2020	62	10	29	30	05	22	32
63	Shankar Rao K.	Shankar Rao 2/11/2020 K	Admission on 2/12/2020	63	10	30	28	0	20	30
64	~~Amhit~~	Ambika H.G.	Admission 23/12/2020	64	10	30	25	21	26	36
65		Triveni G.	Admission 23/12/2020	65	10	30	27	13	24	34
66		Pallavi O.	Admission on 23/12/2020	66	10	30	30	20	27	37
67		Harish S. D	Admission on 24/12/2020	67	10	17	16	6	13	23
68		Veena B Bharamgoudra	24/12/2020	68	10	30	30	02	21	31
69		Harsha K. N.	28/12/2020	69	10	30	30	17	26	36
70		Harish K.G.	28-12-2020	70	10	30	27	01	20	30
71		Trupthi S. Ballari	29/12/2020	71	10	30	30	04	22	32
72		Deepak L	31/12/2020	72	10	30	28	11	23	33
73		Firdosh Anjum H	31/12/2020	73	10	30	28	05	21	31

Initials of Teacher

Initials of H.O.D.

Initial of Principal

PRINCIPAL
Bapuji Institute of Engineering & Technology
DAVANGERE

Class : III B Section | Subject Code : 18CV35 | Subject : Basic Surveying | Total No. of Classes : 28

Sl No.	USN	NAME	10/9/20	14/9/20	15/9/20	16/9/20	21/9/20	23/9/20	28/9/20	30/9/20	01/10/20	05/10/20	07/10/20	07/10/20	12/10/20	14/10/20	15/10/20	21/10/20	22/10/20	28/10/20	29/10/20	04/11/20	05/11/20	09/11/20	11/11/20	18/11/20	19/11/20	23/11/20	25/11/20	26/11/20	No. of Days Present	%	Test Marks I	II	III	Average	Remarks
1	4BD19CV002	Abhishek K Chitragar	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
2	4BD19CV004	Ajay A Jajuri	1	2	3	4	5	6	7	8	A	A	9	10	A	11	12	13	A	14	15	A	16	A	A	A	17	A	A	A							
3	4BD19CV008	Akshay B M.	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
4	4BD19CV010	Ali Akbar	A	A	A	A	A	A	A	A	A	A	A	1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
5	4BD19CV012	Anusha S.	1	A	A	A	2	A	3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
6	4BD19CV014	B Sayyed Ismail Zabiulla	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
7	4BD19CV016	Bharathgouda K.N.	A	A	A	A	A	A	1	A	2	3	4	A	A	A	5	6	A	A	A	A	A	A	A	A	7	A	A	A							
8	4BD19CV018	Chandan B.V	A	A	1	2	3	A	4	5	A	A	A	A	A	A	A	6	A	A	A	A	7	A	A	A	A	A	8	A							
9	4BD19CV022	Deepa P	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							
10	4BD19CV024	Harish K.T.	A	A	A	A	A	1	2	A	3	A	4	A	5	6	7	8	9	A	A	A	A	A	A	10	A	A	11	A							
11	4BD19CV028	Karthik D Vernekar	1	2	3	4	5	6	7	A	A	A	A	A	A	A	8	A	A	A	A	A	A	A	A	A	A	A	A	A							
12	4BD19CV030	Lakshmi B.S	1	A	2	3	A	A	4	A	A	A	5	A	A	6	7	8	A	A	A	A	9	A	10	A	A	11	12	13							
13	4BD19CV032	Mallikarjun T.M.	1	2	3	4	5	6	7	8	9	10	A	11	A	A	12	13	A	A	A	14	A	15	A	A	A	A	16	A							
14	4BD19CV034	Manoj Swamy K.M	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	A	16	17	18	19	20	21	22	23	24	25	26	A							
15	4BD19CV036	Mohammed Ameer Khan D	1	2	3	4	A	A	A	A	A	A	A	A	A	5	6	A	A	A	A	7	A	A	A	A	A	A	A	A							
16	4BD19CV038	Mohit B V	1	2	A	A	A	3	4	5	A	A	A	A	6	7	8	A	9	10	11	A	12	13	14	15	16	A	A	17							
17	4BD19CV040	Namratha P Ram	A	A	1	2	A	3	4	5	6	A	7	A	A	A	A	9	A	A	A	A	A	A	A	A	A	A	A	A							
18	4BD19CV042	Nandini K.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	A	A	A	A	24							
19	4BD19CV044	P. N. Mohammed Salauddin	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
20	4BD19CV046	Pooja M.P.	A	1	2	3	4	5	6	7	8	9	10	11	A	12	13	14	A	15	16	A	17	18	A	19	20	A	21	22							
21	4BD19CV048	Pradeep K.B	A	A	1	2	A	3	4	5	A	A	6	A	A	7	8	9	A	10	A	11	12	A	13	14	15	16	17	18							
22	4BD19CV050	Prajwal G.T Matad	1	2	3	4	5	6	7	A	A	8	9	A	10	11	12	13	14	15	A	A	A	A	A	16	A	A	17	A							
23	4BD19CV052	Prerana V.	1	2	3	4	5	6	7	8	9	10	11	12	A	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27							
24	4BD19CV054	Raghu Doddamani	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
25	4BD19CV056	Rukhsar Banu A.K	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							
26	4BD19CV058	Sanjay G.A.	1	2	3	4	5	6	7	8	A	A	A	A	A	A	A	9	10	A	11	12	13	A	14	15	A	A	A	A							
27	4BD19CV060	Shashi Kiran C.R	1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
28	4BD19CV062	Siraj Ahamed Y.B	1	A	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	A	25	26	27							
29	4BD19CV064	Sunil N Rathod	A	1	A	A	A	A	2	A	A	3	4	A	5	A	6	7	A	A	8	A	9	A	10	11	A	12	13	A							
30	4BD19CV066	Tejaswini M.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							

Initials of Teacher

Initials of H.O.D.

Initial of Principal

PRINCIPAL
Bapuji Institute of Engineering & Technology
DAVANGERE.

Class : III B Section

Subject Code : 18CV35

Subject : Basic surveying

Total No. of Classes : 36

Sl No.	USN	NAME	DATE	02/12/20	14/12/20	16/12	21/12	23/12	28/12/20	30/12/20	31/12/20	4/01/21	5/01/21	7/1/21	19/1/21	17/1/21	21/1/21	01/2/21	3/2/21	4/2/21	10/2/21	11/2/21	15/2/21	17/2/21	17/2/21	18/2/21	18/2/21	19/2/21	23/2/21	25/2/21	26/2/21	No. of Days Present	%	Test Marks I	II	III	Average	Remarks
1	4BD19CV002	Abhishek K C	1	A	A	A	A	A	A	A	A	K	A	A	A	A	A	D	A	A	A	A	A	A	A	A	A	A	A	A	A	1	AB	AB	AB	AB	AB	AB
2	4BD19CV004	Ajay A Jaju	2	18 A	A	A	A	18	A	A	A	A	A	A	A	A	17	20	21	22	23	24	25	26	27	28	29	30	31	32	33	2	10	24	21	10	19	29
3	4BD19CV008	Akshay B M.	3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	L	A	A	A	A	A	A	A	A	A	A	A	A	3	10	21	23	9	18	28
4	4BD19CV010	Ali Akbar	4	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	4	10	25	16	3	15	25
5	4BD19CV012	Anusha S.	5	4	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	5	AB	AB	AB	AB	AB	AB
6	4BD19CV014	B Sayyed Isn	6	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	6	10	24	21	60	15	25
7	4BD19CV016	Bharathgouda	7	8	A	A	A	A	A	A	A	A	A	A	A	A	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	7	10	25	23	60	16	26
8	4BD19CV018	Chandan. B.V	8	29	A	A	A	10	A	A	A	A	A	A	A	A	11	12	13	14	15	A	A	A	A	A	A	16	17	18	19	8	10	26	30	12	23	23
9	4BD19CV022	Deepa P.	9	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	9	10	30	30	25	29	39
10	4BD19CV024	Harish K.T.	10	12 A	A	12	A	A	A	A	A	A	A	A	A	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	10	10	22	20	3	15	25
11	4BD19CV028	Karthik D Ver	11	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	11	AB	AB	AB	AB	AB	AB
12	4BD19CV030	Lakshmi. B.S	12	14 A	A	A	A	A	14	A	A	A	A	A	14	A	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	12	10	27	30	08	22	32
13	4BD19CV032	Mallikarjun.	13	A	A	19	A	18	19	20	21	A	A	A	A	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	13	10	24	23	11	20	30
14	4BD19CV034	Manoj Swamy	14	27	28	A	A	29	30	31	32	A	33	A	34	35	A	36	37	38	39	40	41	42	43	44	45	46	47	48	49	14	10	26	25	13	22	32
15	4BD19CV036	Mohammed Ame	15	A	A	A	A	A	A	A	A	A	A	A	A	A	A	10	11	12	13	14	15	16	17	18	19	20	21	22	23	15	10	22	14	01	13	23
16	4BD19CV038	Mohit B V	16	18	A	19	A	20	21	22	23	A	24	25	26	A	A	27	28	29	30	31	32	33	34	35	36	37	38	39	40	16	10	25	26	07	20	30
17	4BD19CV040	Namratha P E	17	10 A	A	A	A	A	A	A	A	A	A	A	A	A	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	17	10	22	30	07	20	30
18	4BD19CV042	Nandini. K.	18	25 A	25	26	27	A	28	29	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	18	10	[illegible]	30	21	27	37
19	4BD19CV044	P. N. Mohammed	19	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	19	10	20	18	6	13	23
20	4BD19CV046	Pooja. M. P	20	23 A	23	24	25	26	27	28	29	30	31	32	33	34	A	35	36	37	38	39	40	41	42	43	44	45	46	47	48	20	10	26	18	15	20	30
21	4BD19CV048	Pradeep. K. B	21	19	A	A	20	21	22	23	24	25	26	27	28	29	A	30	31	32	33	34	35	36	37	38	39	40	41	42	43	21	10	27	26	05	19	29
22	4BD19CV050	Prajwal G.T.	22	18 A	A	A	A	A	A	A	A	A	A	A	A	A	A	18	19	20	21	22	23	24	25	26	27	28	29	30	31	22	10	28	26	14	23	33
23	4BD19CV052	Prerana. V.	23	28	29	30	31	32	33	34	35	36	37	38	39	A	A	40	41	42	43	44	45	46	47	48	49	50	51	52	53	23	10	26	30	17	25	35
24	4BD19CV054	Raghu. Dodda	24	A	A	A	A	A	A	A	A	A	A	A	A	2	A	3	4	5	6	7	8	9	10	11	12	13	14	15	16	24	10	16	23	00	13	23
25	4BD19CV056	Rukkar Ban	25	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	25	10	30	30	26	29	39
26	4BD19CV058	Sanjay. G. F	26	16	A	A	A	A	A	A	A	A	A	A	A	A	A	17	18	19	20	21	22	23	24	25	26	27	28	29	30	26	10	25	23	17	22	32
27	4BD19CV060	Shashi Ki	27	2 A	A	A	A	A	A	A	A	A	A	A	A	2	A	3	4	5	6	7	8	9	10	11	12	13	14	15	15	27	10	22	23	10	20	30
28	4BD19CV062	Siraj Ahamed	28	28	A	A	29	A	30	31	A	A	32	33	34	35	A	36	37	38	39	40	41	42	43	44	45	46	47	48	49	28	10	30	26	10	22	32
29	4BD19CV064	Sunil N Ratt	29	14	A	15	16	17	A	A	A	A	18	19	A	A	A	20	21	22	23	24	25	26	27	28	29	30	31	32	33	29	10	28	23	05	19	29
30	4BD19CV066	Tejaswini. M.	30	29	A	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	30	10	30	30	23	38	28

Initials of Teacher

Initials of H.O.D.

Initial of Principal

PRINCIPAL
Jain Institute of Engineering & Technology
DAVANGERE.

Class: III 'B' Section | Subject Code: 18CV35 | Subject: Basic Surveying | Total No. of Classes: 28

Sl No.	USN	NAME	10/9/20	14/9/20	15/9/20	16/9/20	21/9/20	23/9/20	28/9/20	30/9/20	1/10/20	5/10/20	7/10/20	8/10/20	12/10/20	14/10/20	15/10/20	21/10/20	22/10/20	28/10/20	29/10/20	04/11/20	05/11/20	07/11/20	11/11/20	15/11/20	13/11/20	23/11/20	25/11/20	26/11/20	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
31	4BD19CV068	Vaishnavi V.	1	A	2	3	4	5	6	7	8	9	A	A	10	11	12	13	14	15	16	17	18	19	20	21	21	22	23	24							
32	4BD19CV070	Veeresh B. R. S. V	A	A	A	A	A	1	2	3	4	5	6	7	8	9	10	A	11	12	13	A	14	15	A	A	A	A	A	16							
33	4BD19CV072	Veman M Girvaddi	A	A	1	2	A	3	4	5	6	A	A	7	8	A	A	A	A	A	A	A	A	A	A	A	A	A	A	9							
34	4BD19CV074	Vikas D. Yadav	1	A	2	3	A	A	4	5	6	A	7	8	A	9	A	A	A	A	10	11	A	A	A	A	A	A	12	13							
35	4BD19CV076	Vivek A P.N	A	A	A	A	A	A	A	A	A	A	A	A	1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
36	4BD19CV078	Yashaswini M.U.	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
37	4BD19CV080	Zaiba Anjum	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							
38	4BD18CV090	Tejash B.R	—	—	1	2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
39	4BD17CV065	Pavan K.G.D.	12/9	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	1	A	2	3	4	5	A	A	A	A							
40	4BD18CV024	Ganesh B.G.	11/9/20	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	2	A	A	A	3	A	A	A							
41	4BD18CV047	Mohan A.D.	24/9/2020 →						A	A	A	A	A	A	A	A	1	2	3	4	A	A	5	A	A	A	A	A	6	A							
42	4BD18CV078	Siddesh Gowda M.S.	24/9/2020 →						A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
43	4BD18CV092	Uday K.H.	A — 1/10/2020 →								A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
44	4BD17CV025	Dishanth	A — 04/10/2020 →								A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
45	4BD17CV002	Adarsh N.G.	A — 5/10/2020 →										A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
46	[illegible]	Shreyas R.	A — 06/11/2020 →										A	A	A	A	1	2	A	3	A	4	A	5	A	6	A	A	A	7							
47	4BD18CV075	Shashank N.B	A — 23/10/20 →																	A	A	A	A	A	1	A	A	A	A	A							
48		Mohan Kumar S.B.	A — 29/10/2020 →																	A	A	A	A	A	A	1	A	A	A	A							
49		Sharath K.R.	A — 03/11/2020 →																				A	1	2	3	4	5	6	7							
50		Chetan G.	A — 06/11/2020 →																				A	A	A	A	A	A	A	A							
51		Chirudeep J.	A — 7/11/2020 →																					A	A	A	A	A	A	A							
52		Vinay K.	A — 9/11/2020 →																						A	A	A	A	A	A							
53		Hila swamy	A — 12/11/2020 →																							A	A	A	A	A							
54	Changed Branch	Rathan R Rathod	A — 18/11/2020 →																								1	2	3	A							
55		Hemanth H.Y.	A — 18/11/2020 →																								A	A	A	A							
56		Prajwal Kumar S.K.	A — 20/11/2020 →																									A	A	A							
57		Sohaan	A — Admission 20/11/2020 →																									A	A	A							
58		Rohith Kumar N.L	A — Admission on 23/11/2020 →																									A	1	2							
59		Vinay D.V.	A — Admitted on 24/11/2020 →																										A	A							
60		Darshan D Anugh H.G.	Admitted on 2/12/2020																																		
61		Dakshay D.	Admitted on 9/12/2020																																		
		Initials of Teacher																																			
		Initials of H.O.D.																																			
		Initial of Principal																																			

PRINCIPAL
Jain Institute of Engineering & Technology
DAVANGERE.

Class : III 'B' Section

Subject Code : 18CV35

Subject : Basic Surveying

Total No. of Classes : 56

Sl No.	USN	NAME	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
31	4BD19CV068	Vaishnavi	31	10	27	26	13	22	32
32	4BD19CV070	Veeresh B.	32	10	27	23	03	18	28
33	4BD15CV072	Veman M	33	10	22	22	11	19	29
34	4BD15CV074	Vikas D.	34	10	26	23	13	21	31
35	4BD15CV076	Vivek A P	35	10	18	26	13	19	29
36	4BD19CV078	Yashaswini	36	AB	AB	AB	AB	AB	AB
37	4BD15CV080	Zaiba Anji	37	10	20	30	20	27	37
38	4BD18CV090	Tejesh B.R	38	10	26	25	04	19	29
39	4BD17CV065	Pavan K.C	39	10	26	20	06	18	28
40	4BD18CV024	Ganesh B.C	40	10	19	15	15	17	27
41	4BD18CV047	Mohan D.D.	41	10	27	22	03	18	28
42	4BD18CV078	Siddesh Gowda	42	10	17	19	09	15	21
43	4BD16CV092	Uday K.H.	43	10	12	21	8	14	24
44	4BD17CV025	Dishanth	44	AB	AB	AB	AB	AB	AB
45	4BD17CV002	Adarsh N.G.	45	AB	AD	AD	AD	AD	AD
46	(Lst)	Shreyas R.	46	10	30	25	19	25	35
47	4BD18CV071	Shashank N.	47	10	23	23	07	18	28
48		Mohan Kumar	48	10	28	26	13	23	33
49		Sharath K.R.	49	10	30	27	14	24	34
50		Chetan G.	50	10	27	25	10	21	31
51		Chirudeep J	51	10	24	20	05	17	27
52		Vinay K.	52	10	26	17	13	19	29
53		Halaswamy	53	10	25	22	13	20	30
54	Change Branch	Rathan R	54	10	30	25	14	23	33
55		Hemanth H	55	10	26	30	23	27	37
56		Prajwal Kar	56	09	19	94	09	13 08	21
57		Sohaan	57	10	30	20	06	19	29
58		Rohith Kumar	58	10	30	26	16	24	34
59		Vinay D.V.	59	10	27	26	06	20	30
60		Darshan D A	60	10	26	25	17	23	33
61		Dakshay D.	61	10	27	29	05	21	31

Initials of Teacher

Initials of H.O.D.

Initial of Principal

PRINCIPAL
Jain Institute of Engineering & Technology
DAVANGERE.

Class: III B | Subject Code: 18CV35 | Subject: Basic Surveying | Total No. of Classes: 56

Sl No.	USN	NAME	02/12/20	14/12/20	16/12/20	21/12/20	23/12/20	28/12/20	30/12/20	31/12/20	4/1/21	5/1/21	7/1/21
62	1	Harshith. B. P 22.12.2020	Admission on 22.12.2020 →					1	2	3	A	A	4
63		Sandeep. K 23.12.2020	Admission on 23.12.2020 →					A	A	A	A	A	
64		Abhishek. H 23.12.2020	→					A	1	A	A	A	A
65		Vinay H. R 23.12.2020	→					A	1	A	A	A	A
66		Chidananda. H 23.12	→					A	1	A	A	A	2
67		Kallesh. M.N 24.12	→					A	A	A	A	A	A
68		Bhavana. M 30.12	→							A	A	A	1
69		Ganesh. L 31.12	Admission on 31.12.2020 →						1	2	3	A	4
70		Muralidhar. B 31.12	→								A	A	1
71		Mithun Chavan 31.12	→								A	A	A
72		Mohammed Shadab Azeez 31.12	→								1	A	A
73		Mohammed Thoufiq	→										

Sl No.	13/1/21	17/1/21	21/1/21	1/2/21	3/2/21	8/2/21	10/2/21	13/2/21	15/2/21	17/2/21	12/2/21	18/2/21	18/2/21	19/2/21	20/2/21	23/2/21	26/2/21	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
62	A	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20							
63	A	1	2	3	4	5	A	6	7	8	9	10	11	12	13	14	15							
64	A	1	2	3	4	5	A	6	7	8	9	10	11	12	13	14	15							
65	A	1	2	3	4	5	A	6	7	8	9	10	11	12	13	14	15							
66	A	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18							
67	A	1	2	3	4	5	A	6	7	8	9	10	11	12	13	14	15							
68	A	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17							
69	A	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20							
70	A	2	A	3	4	5	A	6	7	8	9	10	11	12	13	14	15							
71	A	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16							
72	A	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17							
73			→	1	2	3	4	5	6	7	8	9	10	11	12	13	14							

Initials of Teacher

Initials of H.O.D.

Initial of Principal

PRINCIPAL
...Institute of Engineering & Technology
DAVANGERE.

Class : III B Subject Code : 18CV35

Sl No.	USN	NAME
62		Harshith B P
63		Sandeep K
64		Abhishek H
65		Vinay H R
66		Chidananda H
67		Kallesh M N
68		Bhavana M
69		Ganesh L
70		Muralidhar B
71		Mithun Chavan
72		Mohammed Chadar
73		Mohammed [illegible]

Initials of Teacher

Initials of H.O.D.

Initial of Principal

Class : III B

Total No. of Classes : 56

No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
62	10	30	23	13	22	32
63	10	22	30	16	23	33
64	10	24	30	30	28	35
65	10	28	26	8	21	31
66	10	30	23	18	24	34
67	10	25	17	14	15	29
68	10	30	26	12	23	33
69	10	26	30	10	22	32
70	10	28	29	26	25	35
71	10	30	20	16	22	32
72	10	20	20	20	24	34
73	10	26	28	14	23	33

PRINCIPAL
Jain Institute of Engineering & Technology
DAVANGERE.

Class: III A Subject Code: 18CVL38

Subject: Basic Materials Testing lab Total No. of Classes: 10

Sl No.	USN	NAME	8/1/21	8/01/21	15/01/21	26/01/21	5/02/21	12/02/21	19/02/21	26/02/21	1/3/21	5/3/21	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
1.	4BD19CV001	Aban Sharif	1	2	A	4	5	6	7	8	A	9		1	20	+10	3+	=	30
2.	4BD19CV003	Afzal Noorsabnavar	A	4	2	3	4	A	5	6	7	8		2	22	+14		=	36
3	4BD19CV005	Akashdeep R Andanur	1	2	3	4	5	6	7	8	9	10		3	23	+15		=	38
4	4BD19CV006	Akhila C Akula.	1	2	3	4	5	6	7	8	9	10		4	24	+15		=	39
5	4BD19CV007	Akshatha Ashoka Oujjukar	1	2	3	4	5	6	7	8	9	10		5	24	+16		=	40
6	009	Akshaya kumara. L.M.	1	2	3	4	5	6	7	8	A	9		6	22	+13		=	35
7	011	Amith K.M.	A	1	A	2	3	4	A	5	A	5		7	22	+13		=	35
8	013	Arpitha Balanagouda Patil	1	2	3	4	A	A	5	6	7	8		8	24	+15		=	39
9	015	Basavaraj S Patil		A	A	A	A	A	A	A	A	A		9	19	+10		=	29
10	017	Bhumika P.	1	2	3	4	5	6	7	8	9	10		10	23	+15		=	38
11	019	Chinmayee.K.	1	2	3	4	5	6	7	8	9	11		11	24	+15		=	39
12	021	Darshan V.N.	1	2	A	4	5	A	A	6	7	8		12	20	+14		=	34
13	023	Ganesh U Shirigeri	1	2	A	3	4	5	A	6	7	8		13	24	+14		=	38
14	025	Hemanth kumar. D.V.	1	2	A	4	5	A	A	6	7	8		14	20	+14		=	34
15	4BD18CV099	Vinay Kumar M.	1	2	A		A	A	A	A	A	A		15	20	+13		=	33
16	4BD18CV027	Harshith N	1	2	3	4	5	6	A	7	A	8		16	21	+13		=	34
17		Bharath Reddy N	1	2	3	4	5	A	6	7	8	7		17	22	+14		=	36
18		Dhanush.R	A	1	2	3	4	5	6	7	8	10		18	23	+14		=	37
19		Vinod kumar Budhihal	1	A	2	3	4	5	6	7	8	9		19	22	+11		=	33
~~20~~	~~4BD17CV100~~	~~Sujith R.~~ left	A	A	A	A	A	A	A	A	A			20	left the college				
21		Suraj N. Raikar.	1	2	3	4	5	6	7	8	9	10		21	22	+15		=	37
22		Sandeep B.N	1	2	A	3	A	4	5	6	7	8		22	24	+15		=	39
23.		Triveni G.	1	2	3	4	5	6	7	8	9	10		23	23	+14		=	37
24		Veena B Bharamagoudar	1	2	A	3	4	5	6	7	8	9		24	23	+14		=	37
25.		Trupthi Balikai.	A	A	A	2	3	A	5	6	7	8		25	23	+14		=	37

Initials of Teacher

Initials of H.O.D.

Initial of Principal

PRINCIPAL
Bapuji Institute of Engineering & Technology
DAVANGERE.

Class : 3 A

Subject Code : 18CV32

Subject : Strength of Materials

Total No. of Classes : 94

Sl No.	USN	NAME	23/12/20	26/12/20	28/12/20	29/12/20	30/12/20	02/01/21	05/01/21	06/01/21	07/01/21	[illegible]	[illegible]	[illegible]	[illegible]	18/1/21	19/1/21	25/1/21	27/1/21	28/1/21	29/1/21	1/2/21	2/2/21	3/2/21	4/2/21	6/2/21	8/2/21	10/2/21	11/2/21	[illegible] 78	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
1	4BD19CV001		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	40							
2	003		42	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68							
3	005		49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	85							
4	006		53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	83							
5	007		54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	86							
6	009		29 A	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	66							
7	011		44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	80							
8	013		44 A	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	80							
9	015		31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58							
10	017		55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	91							
11	019		55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	91							
12	021		11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	47							
13	023		47 A	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	83							
14	025		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	42							
15	027		Change of Branch																																		
16	029		28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	65							
17	031		Left the college																																		
18	033		56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	93							
19	135		19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	55							
20	037		55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	91							
21	039		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	41							
22	041		45	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	82							
23	043		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	64							
24	047		6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	42							
25	049		23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	59							
26	051		42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69							
27	053		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32							
28	055		11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	47							
29	057		42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	78							
30	057		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	37							
31																																					
		Initials of Teacher																																			
		Initials of H.O.D.																																			
		Initial of Principal																																			

PRINCIPAL
Bapuji Institute of Engineering & Technology
DAVANGERE.

Class : 3rd   Subject Code : 18CV32

Subject : Strength of Materials   Total No. of Classes : 94

SI No.	USN	NAME	No. of Days Present	%	Test Marks I	II	III	Average	Remarks
31	4BD18CV061		40						
32	63		88						
33	65		92						
34	67		90						
35	69		90						
36	71		66						
37	73		83						
38	75		53						
39	77		57						
40	79		42						
41	4BD18CV099	Vinay Kumar. M.	45						
42	4BD17CV052	Mohammed Azhar Basith	56						
43		Trupthi. C. R.	32						
44	4BD18CV027	Harshith. N.	68						
45		Channesh. H. Patil	65						
46	4BD18CV076	Shivaraj. K. H.	56						
47		Bharath Reddy N	39						
48		Mohammed Khadir	39						
49		Abhilash. B. V	39						
50		Dhanush. R	42						
51		Surabhi S. Bharadwaj	37						
52		Chethan Kotraiah	43						
53		Vinod Kumar Budhihal	53						
54		Nandish M Mathad.	37						
55	Change of Branch	Santhosh S Bayoor	37						
56	4BD17CV160	Sujith. R	Left the college						
57		Rohith. A	35						
58	Change of Branch	Kiran. M. M	37						
59		Suraj. N. Raikar.	49						
60		Murugharajendra. H. V	38						
61		Shree Harsha. J. R.	41						

Initials of Teacher

Initials of H.O.D.

Initial of Principal

PRINCIPAL
Bapuji Institute of Engineering & Technology
DAVANGERE.

Class: 2nd B   Subject Code: 18CV32   Subject: Strength of Materials   Total No. of Classes: 94

Sl No.	USN	NAME	23/12/20	26/12/20	28/12/20	29/12/20	30/12/20	01/1/21	05/1/21	06/1/21	08/1/21	9/1/21	11/1/21	13/1/21	18/1/21	19/1/21	25/1/21	27/1/21	28/1/21	29/1/21	1/2/21	2/2/21	3/2/21	4/2/21	5/2/21	8/2/21	10/2/21	11/2/21	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
62		Sandeep B.N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	37						
63		Shankar Rao Kulkarni C.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	37						
64		Ambika H.J.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	x	26	24	37						
65		Triveni G.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	26	27	37						
66		Pallavi O.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	26	27	37						
67		Harisha S.D	24/12/2020	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	26	36						
68		Veena B Bharamgouda	24/12/2020	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	26	36						
69		Harsha C.N.	26/12/2020		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	35						
70		Harisha C.G.	27/12/2020		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25						
71		Trupthi S Belaikai	27/12/2020			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	32							
72		Deepak C	31/12/2020				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23						
73		Firdosh Anjum H.	31/12/2020				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	32						

Initials of Teacher
Initials of H.O.D.
Initial of Principal

PRINCIPAL
Bapuji Institute of Engineering & Technology
DAVANGERE.

LESSON PLAN

Subject : Subject Code : Class :

Period	Date	Topics Planned	Date	Topics Covered	Remarks
35	07.11.2020	Rankine Gordon's formula equation Problems.	07.11.2020	Rankine Gordon's formula equation Problems	covered
36	09.11.2020	Problems of Euler's Gordon's eq.	09.11.2020	Problems of Euler's Gordon's eq.	covered
37	11.11.2020	Module: 2 Compound Stress. Introduction	11.11.2020	Module: 2 Compound Stress Introduction	covered.
38	12.11.2020	General two dimensional Stress System Principal Stress & Planes	12.11.2020	General two Dimensional Stress System Principal Stress & Planes	covered
39	17.11.2020	Problems on Principal Stress & Planes	17.11.2020.	Problems on Principal Stress & Planes	covered.
40	18.11.2020	Problems on Principal Stress & Planes	18.11.2020	Problems on Principal Stress & Planes	covered
41	19.11.2020	Module: 3 Shear Force & Bending Moment Introduction	19.11.2020	Module: 3 Shear Force & Bending moment: Introduction	covered.
42	21.11.2020	Types of Beams, Loading supports,	21.11.2020	Types of Beam, Loading supports	covered
43	23.11.2020	Simply Supported Beam with Point load & eccentric loading with Problems	23.11.2020	Simply Supported Beam with Point load & eccentric loading with problems	covered.
44	24.11.2020	Simply supported Beam with udl with Problems	24.11.2020.	Simple Supported Beam with udl with Problems	covered
45	25.11.2020	Simply supported Beam with Problems	25.11.2020.	Simply Supported Beam	covered
46	26.11.2020	Problems on simply supported Beam with Different loading condition	26.11.2020	Problems on simply supported Beam	covered
47	28.11.2020	Problems.	28.11.2020	Problems	covered
48	30.11.2020	Overhanging beam Derivation for with Different loading	30.11.2020	Overhanging beam with different loading conditions	covered
49	1/12/2020	Problems	1/12/2020	Problems	covered
50	2/12/20	Problems	2/12/20.	Problems	covered
51	12/12/20	Cantilever beam with different loading conditions	12/12/20	Cantilever beam with different loading conditions	covered.

LESSON PLAN

Period	Date	Topics Planned	Date	Topics Covered	Remarks
52	14/12/20	problems	14/12/20	problems.	covered
53	15/12/20	module: 4 Bending stress Introduction	15/12/20	module: 4 Bending shear stress Introduction.	covered.
54	16/12/20	Derivation on equation for Bending stress $\frac{M}{I}=\frac{E}{R}=\frac{f}{y}$	16/12/20	Derivation on equation Bending stress $\frac{M}{I}=\frac{E}{R}=\frac{f}{y}$	covered
55	21/12/20	problem on Bending stress	21/12/20	problem on Bending stress	covered.
56	22/12/20.	problem on Bending stress	22/12/20	problem on Bending stress	covered.
57	23/12/20	problem on Bending stress.	23/12/20	problem on Bending stress	covered.
58	26/12/20	Deflection of Beams module 5	26/12/20	Deflection of Beams	covered
59	28/12/20	Derivation of Beams. simply supported beam with point.	28/12/20	Derivation of Beams simply supported beam with point	covered
60	28/12/20.	UDL UDV problems	29/12/20.	UDL, UVL problems	covered

Text Books :

1. B. S. Basavarajaiah, P. Mahadevappa. Strength of materials in SI units University of Press (India).
2. R subramanian. Strength of materials latest edition.

Reference Books :

1. R. K. Bansal, A Text book of Strength of materials. 4th edition Laxmi publication, 2010.
2. D. H. Young. S. P. Timoshenko. "elements of strength of materials.
3. S. Ramamrutham. Strength of materials.
4. S. S. Bhavikatti. by Strength of materials
5. ....

Signature of Faculty HOD

TUTORIAL CLASSES

Date	Topics Discussed	Remarks
61	Problems on deflection	covered
62	Problem on deflection	covered.
63	Problem on deflection	covered
64	Problem on deflection	covered.
65	Problem on deflection	covered.
66	Problem on deflection	covered
67	Module: 2 [For Diploma] Thick & Thin cylinders Derivation of hoop stress & longitudinal stress	covered
68	Problem on same	covered
69	Problem on Thick cylinders	covered
70	Thick cylinders Derivations	covered
71	Problems on Thick cylinders	covered
72	Problems on thick cylinders	

Test	Date	Class Strength	No. of Students Appeared	No. of Students Scored < 15	Signature of the HOD
T1	24/10/20	70	70	0	[signature]
T2	07.12.2020	70	70	0	[signature]
T3	22.02.2021	70	67	50	[signature]

LESSON PLAN

Subject : Basic surveying Subject Code : 18CV35 Class : III rd B

Period	Date	Topics Planned	Date	Topics Covered	Remarks
1	10/9/20	Module! I. Defination of surveying objectives & Importance	10/9/20	Module: I. Defination of surveying objectives & importance	covered
2	14/9/20	Classification of surveying.	14/9/20	Classification of surveying	covered
3	15/9/20	Principles of surveying	15/9/20	principles of surveying	covered
4	16/9/20	Applications of surveying unit of measurement	16/9/20	Applications of surveying unit of measurements	covered
5	21/9/20	Surveying measurement errors, types of errors Precision &	21/9/20	surveying measurement errors, types of errors, precision	covered
6.	23/9/20	Accuracy. classification of maps, map & Numbering	23/9/20	Accuracy, classification of maps. maps & Numbering	covered.
7	28/9/20	Measurement of Horizontal Distances: Measuring tape & types, measurement using tapes, Taping on	28/9/20	Measurement of Horizontal Distances. Measuring tape Measurement using tapes,	covered
8	30/9/20	Level ground. + Direct Ranging + InDirect Ranging	30/9/20	level ground. + Direct ranging + Indirect ranging.	covered
9	1/10/20	Sloping ground Direct & Indirect Ranging	1/10/20	sloping ground by Direct & Indirect ranging	covered
10	05/10/20	EDM, basic principles Booking of tape survey work	05/10/20	EDM, basic principles of Booking of tape survey work	covered
11	07/10/20	conventional symbols, obstacles in tape surveying	07/10/20	conventional symbols, obstacles in tape surveying	covered
12	08/10/20	Problems	08/10/20	Problems	covered.
13	12/10/20	Module! 4 Plane table surveying accessories	12/10/20	module! 4 Plane table surveying accessories	covered
14	14/10/20	Setting up the plane table surveying	14/10/20	setting up the plane table surveying	covered
15	15/10/20	methods of plane table surveying Radiation	15/10/20	methods of plane table surveying Radiation	covered
16	21/10/20	Intersection method. Traversing Advantages & Disadvantages of Plane Table surveying	21/10/20	Intersection method Traversing Advantages & Disadvantages Plane Table surveying	covered
17	22/10/20	Resection Two point Problems, Three Point Problem	22/10/20.	Resection - Two Point Problem & Three Point Problem	covered.

LESSON PLAN

Subject : Basic surveying Subject Code : 18CV35 Class : 3rd B

Period	Date	Topics Planned	Date	Topics Covered	Remarks
18	28.10.20	Three Point Problem & 7	28.10.20	Three Point Problem	covered
19	28.10.20	Module: 5. Areas & volume Different Area measuring calculation	28.10.20	Module: 5: Areas & volume. Introduction	Covered.
20	04.11.20	offsets at Regular intervals.	04.11.20	offsets at Regular intervals.	covered.
21	05.11.20	Area from co-ordinates with problems.	05.11.2020	Area from co-ordinates with problems	covered.
22	9.11.20	Problems on Areas by Different methods	9.11.2020	Problems on Areas by Different methods	covered
23	11.11.20	Volume: Different methods Problems on volume	11.11.2020	volume: Different methods & problems on volume	covered
24	18.11.2020	Problem on volume.	18.11.2020	Problems on volume	covered
25	15.11.2020	Module: 2 Compass surveying Introduction	15.11.2020	Module: 2 compass surveying Introduction	covered
26	23.11.2020	Definition of Fore bearing Back bearing, WCB, QB Problems	23.11.2020	Definition of Fore Bearing Back Bearing, WCB, QB Problems	covered.
27	25.11.2020	Magnetic Dip & Declination with problems Prismatic compass, surveyor compass with construction	25.11.2020	Magnetic Dip & Declination with problems. Prismatic compass. surveyor compass with construction.	covered.
28	26.11.2020	Problems on Interior angles	26.11.2020	Problem on Interior angles (Included angles)	covered
29	02/12/2020	Local attraction Introduction Problems	02/12/2020	Local attraction Problems	covered
30	14/12/2020	Problems on local attraction	14/12/2020	Problems on local attraction	covered
31	16/12/2020.	Traverse: computation Introduction	16/12/2020	Traverse computation	covered
32	21/12/2020	1. Dependent co-ordinates 2. Independent co-ordinates 3. closing error. with problems	16/12/2020	1. Dependent co-ordinates 2. Independent co-ordinates 3. closing error with problems.	covered
33	23/12/2020	1. Bowditch rule, 2. Transit rule with problems	23/12/2020	Problems	covered
34	28/12/2020.	omitted measurements problems	28/12/2020.	omitted measurements with problems	covered

LESSON PLAN

Subject : Basic surveying Subject Code : 18CV35 Class : 2nd B

Period	Date	Topics Planned	Date	Topics Covered	Remarks
35	30.12.20	Module 3 levelling: Basic definitions methods of levelling.	30.12.20	Module 3 levelling: Basic definitions Methods of levelling	covered
36	31.12.20	Dumpy level, Auto level, digital levelling & laser levelling	31.12.20	Dumpy level, Auto level, digital levelling & laser levelling	covered
37	4.1.21	Curvature and refraction corrections,	4.1.21	Curvature & refraction corrections	covered
38	5.1.21	Booking & reduction of levels. Problems	5.1.21	Booking & reduction of levels & Problems	covered
39	7.1.21	Problems on levelling	7.1.21	Problems on levelling	covered
40	13.1.21	Problems on levelling Differential levelling	13.1.21	problems on Differential levelling	covered.
41	17.1.21	problems on Differential levelling	17.1.21	problems on Differential levelling	covered
42	21.1.21	Profile levelling with problems	21.1.21	Profile levelling with problems	covered
43	01.2.21	fly levelling with problems	1.2.21	fly levelling with problems.	covered
44	3.2.2021	Reciprocal levelling	3.2.2021	Reciprocal levelling	covered
45	4.2.2021	problems on reciprocal levelling	4.2.2021	Problems on Reciprocal levelling.	covered
46	10.2.2021	module 4 Plane table surveying, accessories, setting up plane table surveying	10.2.2021	module: 4 Plane table surveying accessories setting up plane table surveying	covered
47	11.2.2021	method of plane table surveying	11.2.2021	methods of plane table surveying	covered.
48	15.2.2021	Advantages & Disadvantages of plane table surveying Resection of two-point Problems, three-point Problems	15.2.2021	Advantages & Disadvantages of plane table surveying Resection of two-point, three point Problems	covered
49	17.2.2021	Three point Problems	17.2.2021	Three point Problems	covered
50.	17.2.2021	module: 5 Area & Volume Area - methods of Area calculation, offsets at regular intervals.	17.2.2021	module: 5 Area & Volume Area - methods of area calculation, offsets at regular intervals	covered
51	18.2.2021	Area from co-ordinates with Problems, by Different methods, volumes: Different methods	18.2.2021	Area from co-ordinates with Problems, by different methods, volume Different methods.	covered

LESSON PLAN

Period	Date	Topics Planned	Date	Topics Covered	Remarks

Text Books :

1. B.C. Punmia, "Surveying Vol-1. Laxmi Publications Pvt. Limited New Delhi - 2005.

2. Kanetkar T.P. & S.V. Kulkarni. Surveying & Leveling.

Reference Books :

1. S.K. Duggal 'Surveying Volume 1.

2. K.R. Arora. Surveying Volume 1

3. R. Subramanian. Surveying & Leveling.

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Signature of Faculty

HOD

TUTORIAL CLASSES

Date	Topics Discussed	Remarks

Test	Date	Class Strength	No. of Students Appeared	No. of Students Scored < 15	Signature of the HOD
T1	23.10.2020	67	67	00	
T2	09.12.2020	67	67	00	
T3	23.02.2021	67	67	[illegible]	

TIME TABLE Raghu M.E

Day / Time	1 8.00 - 9.00	2 9.00 - 10.00	10.00 - 10.30	3 10.30 - 11.30	4 11.30 - 12.30	12.30 - 2.00	5 2.00 - 3.00	6 3.00 - 4.00	7 4.00 - 5.00
MONDAY	18CV32-A		SHORT BREAK			LUNCH BREAK	18CV35 - B		18CVL57 - T (B)
TUESDAY		18CV32-A							
WEDNESDAY	18CV35-B				18CV32-B		← 18CVL57 - A3 (MEET SH)		
THURSDAY		18CV35-B		18CV32-A			← 18CVL57 - B1 (MEERTAN)		
FRIDAY		← 18CVL38 A1 (MER+CPA)							
SATURDAY		18CV32-A							

3rd A - Section
= Strength of Materials
3rd B - Section
= Basic Surveying
18CVL57-T (B)
= Surveying Practice
18CVL57 - B1 & A3
- Surveying Practice.
18CVL38 - A1
Building Materials Lab

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B. E. CIVIL ENGINEERING Choice Based Credit System (CBCS) and Outcome Based Education (OBE) SEMESTER - III			
STRENGTH OF MATERIALS			
Course Code	**18CV32**	CIE Marks	40
Teaching Hours/Week (L:T:P)	(3:2:0)	SEE Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives: This course will enable students

1. To understand the basic concepts of the stresses and strains for different materials and strength of structural elements.
2. To know the development of internal forces and resistance mechanism for one dimensional and two-dimensional structural elements.
3. To analyse and understand different internal forces and stresses induced due to representative loads on structural elements.
4. To determine slope and deflections of beams.
5. To evaluate the behaviour of torsion members, columns and struts.

Module-1

Simple Stresses and Strain: Introduction, Definition and concept and of stress and strain. Hooke's law, Stress-Strain diagrams for ferrous and non-ferrous materials, factor of safety, Elongation of tapering bars of circular and rectangular cross sections, Elongation due to self-weight. Saint Venant's principle, Compound bars, Temperature stresses, Compound section subjected to temperature stresses, state of simple shear, Elastic constants and their relationship.

Module-2

Compound Stresses: Introduction, state of stress at a point, General two dimensional stress system, Principal stresses and principal planes. Mohr's circle of stresses. Theory of failures: Max. Shear stress theory and Max. principal stress theory.

Thin and Thick Cylinders: Introduction, Thin cylinders subjected to internal pressure; Hoop stresses, Longitudinal stress and change in volume. Thick cylinders subjected to both internal and external pressure; Lame's equation, radial and hoop stress distribution.

Module-3

Shear Force and Bending Moment in Beams: Introduction to types of beams, supports and loadings. Definition of bending moment and shear force, Sign conventions, relationship between load intensity, bending moment and shear force. Shear force and bending moment diagrams for statically determinate beams subjected to points load, uniformly distributed loads, uniformly varying loads, couple and their combinations.

Module-4

Bending and Shear Stresses in Beams: Introduction, pure bending theory, Assumptions, derivation of bending equation, modulus of rupture, section modulus, flexural rigidity. Expression for transverse shear stress in beams, Bending and shear stress distribution diagrams for circular, rectangular, 'I', and 'T' sections. Shear centre (only concept).

Torsion in Circular Shaft: Introduction, pure torsion, Assumptions, derivation of torsion equation for circular shafts, torsional rigidity and polar modulus Power transmitted by a shaft.

Module-5

Deflection of Beams: Definition of slope, Deflection and curvature, Sign conventions, Derivation of moment-curvature equation. Double integration method and Macaulay's method: Slope and deflection for standard loading cases and for determinate prismatic beams subjected to point loads, UDL, UVL and couple.

Columns and Struts: Introduction, short and long columns. Euler's theory; Assumptions, Derivation for Euler's Buckling load for different end conditions, Limitations of Euler's theory. Rankine-Gordon's formula for columns.

Course outcomes: After studying this course, students will be able;

1. To evaluate the basic concepts of the stresses and strains for different materials and strength of structural elements.
2. To evaluate the development of internal forces and resistance mechanism for one dimensional and two dimensional structural elements.
3. To analyse different internal forces and stresses induced due to representative loads on structural elements.
4. To evaluate slope and deflections of beams.
5. To evaluate the behaviour of torsion members, columns and struts.

Question paper pattern:

- The question paper will have ten full questions carrying equal marks.
- Each full question will be for 20 marks.
- There will be two full questions (with a maximum of four sub- questions) from each module.
- Each full question will have sub- question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbooks:

1. B.S. Basavarajaiah, P. Mahadevappa "Strength of Materials" in SI Units, University Press (India) Pvt. Ltd., 3rd Edition,2010
2. Ferdinand P. Beer, E. Russell Johnston and Jr. John T. De Wolf "Mechanics of Materials", Tata McGraw-Hill, Third Edition, SI Units

Reference Books:

1. D.H. Young, S.P. Timoshenko "Elements of Strength of Materials" East West Press Pvt. Ltd., 5th Edition (Reprint2014).
2. R K Bansal, "A Textbook of Strength of Materials", 4th Edition, Laxmi Publications, 2010.
3. S.S. Rattan "Strength of Materials" McGraw Hill Education (India) Pvt. Ltd., 2nd Edition (Sixth reprint2013).
4. Vazirani, V N, Ratwani M M. and S K Duggal "Analysis of Structures Vol. I", 17th Edition, Khanna Publishers, New Delhi.

m: II. Course title: Strength of materials [15CV32]

Modules 1

M. E. Raghu.
Assistant Professor.
B.I.E.T. Davangere.

Simple stresses & strain:

Introduction:

When an External force acts on a body, the body tends to undergo some deformation. Due to cohesion b/w the molecules, the body resists deformation. The resistance by which materials of the body opposes the deformation is known as "strength of materials."

Engineering Mechanics
- Mechanics of solids.
  - Mechanics of Rigid bodies
    - Statics
    - Dynamics
  - Mechanics of Deformable bodies
    - Strength of materials
    - Theory of elasticity
    - theory of plasticity
- Mechanics of fluids.

→ Change in shape, size, geometry is known as Deformation.

Materials are classified into

1. elastic - [tennis | rubber ball]
2. plastic - [chewing gum]
3. Rigid - [stone]

] Deformation.

1. Elasticity :

When an External force acts on a body, the body tends to undergo some deformation. If the External force is removed, then the body comes back to its original shape & size. [which means the deformation disappear completely]. The body is known as "elastic body". Then that material is reffered as elastic & this property is called elasticity. [$\delta = \checkmark$ | $\delta = 0$]

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(1) Plastic : Due to External loading. If there is Permanent deformation in the material. (i.e. material will not regain original size (or) shape (or) dimension) even after the removal of the load. Then the material is said to be plastic & this property is called Plasticity.

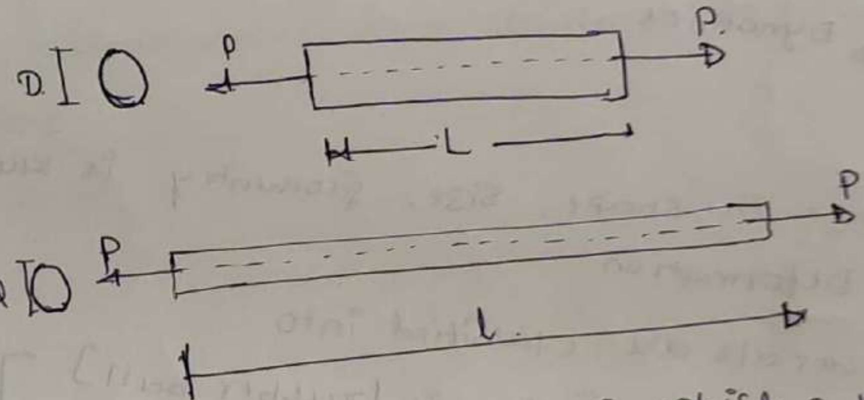
A Rigid material is one in which deformation is not seen when subjected to External loading [$\delta = 0$]

other properties of Materials are.

1. Ductility. 2. Brittleness 3. Malleability. 4. Toughness, 5. Hardness, 6. Fatigue, and 7. Creep.

1. Ductility: It is the property of the material by which it can be drawn into a small section due to tensile force. Hence considerable deformation are seen before the failure takes place.

Ex: Steel



(2) Brittleness:- Brittleness is a property in which a material breaks without any significant deformation under the action of External load. A brittle material shows little (negli-gible) plastic deformation before the fracture takes place.

Ex: Glass, ceramic materials.

(or)

when a material cannot be drawn into a smaller section due to a tensile force, then it is referred as brittle. Brittleness is therefore called as a lack of ductility. In such type of materials failure takes place even at small deformation. Which is highly undesirable for engineering application ~ no application Ex: Cast Iron.

③ Malleability: It is the property by which a material can be uniformly extended in a direction without rapture due to a tensile force. Hence a malleable will have high degree of plasticity.

Ex: Gold [due to this it may be drawn into wire (or) sheets]

④ Toughness: It is the property of the material which enables it to absorb energy without failure

Ex: Impact loading.

⑤ Hardness: It is the ability of a material to resist indentation (or) scratching (or) surface abrasion.

⑥ Fatigue: It is the phenomenon of a material failing under very small load due to repeated cycle of loading.

⑦ Creep: It is the property by which a material undergoes deformation at a constant load over a period of time.

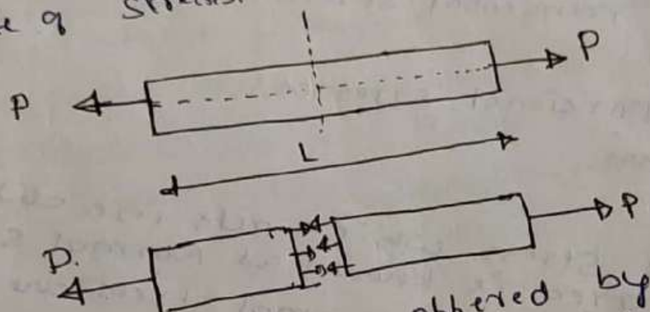
longitudinal strain.

Strength of materials

when an External force acts on a body, the body tends to undergo some deformation. Due to cohesion b/w the molecules, the body resists deformation. This resistance by which materials of the body opposes the deformation is known as strength of materials.

Stress:

when a material is subjected to load, internal resisting forces are developed and then it is said to be in a state of stress.



∴ Stress is the resistance offered by the body to the deformation" and is measured as the intensity of load per unit area and is denoted by f, (or) σ with unit as N/mm² or KN/m² (or) pascal

[1 pascal = 1 N/m²

Stress = $\frac{\text{load}}{\text{Area}}$, $f = \frac{P}{A}$

f, σ = Stress [also called Intensity of stress]

P = External force (or) load

A = Area of cross section.

Unit of Stress

1 Pa = 1 N/m²

1 kPa = 1 × 1000 N/m² = 1×10^3 N/m²

1 MPa = 1 × 1000 × 1000 N/m² = 1×10^6 N/m²

1 GPa = 1 × 1000 × 1000 × 1000 N/m² = 1×10^9 N/m²

1 TPa = 1 × 1000 × 1000 × 1000 × 1000 N/m² = 1×10^{12} N/m²

$1 \text{ mpa} = 1 \times 10^6 \frac{N}{m^2} = \frac{1 \times 10^6}{(1000)^2} = \frac{N}{mm^2}$

$1 \text{ mpa} = 1 \text{ N/mm}^2$

$1m = 1000mm$

Based on nature of forces, stresses are classified as (or)

Types of Stresses.

The following are the different types of stress

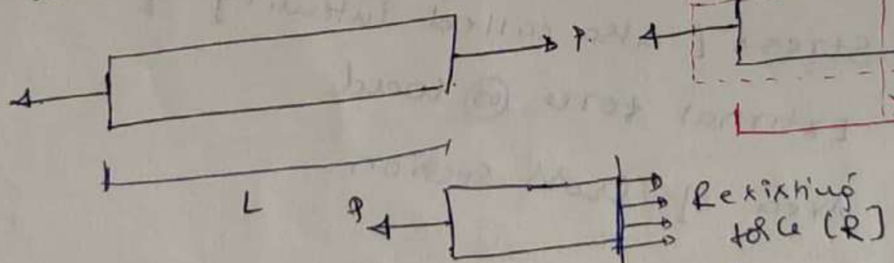
1. Normal stress.
   - (a) Tensile stresses
   - (b) compressive stresses.
2. shear stress (or) Tangential stresses.
3. Bending stress
4. Twisting (or) Torsional stresses.
5. Bearing stresses.

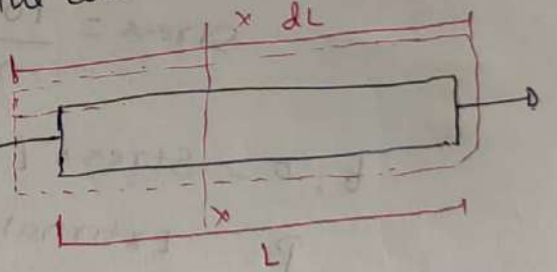
(1) Normal stress:

The stress which acts in a direction perpendicular to the area is known as Normal stress. It is denoted by sigma [ie σ]. The normal stress are further divided into Tensile stress and compressive stress

(a). Tensile stress:

The stress induced in a body, when subjected to two equal and opposite pull as shown in fig. as a result of which there is an increase in length is known as "tensile stress". The tensile stress acts normal to the area & it pulls on the area.





Let P = pull (or) force acting on the body.

A = ~~Area~~ cross-sectional area of the body.

L = original length of the body.

dL = Increase in length of the body due to pull P acting on the body

e : strain [i.e. tensile strain]

σ : stress induced in the body.

Tensile stress: $\sigma = \frac{\text{Resisting force (R)}}{\text{Cross sectional area (A)}}$ (or) = $\frac{\text{Tensile load P}}{\text{Area (A)}}$

$$\boxed{\sigma = \frac{P}{A}}$$ $\because (R = P)$

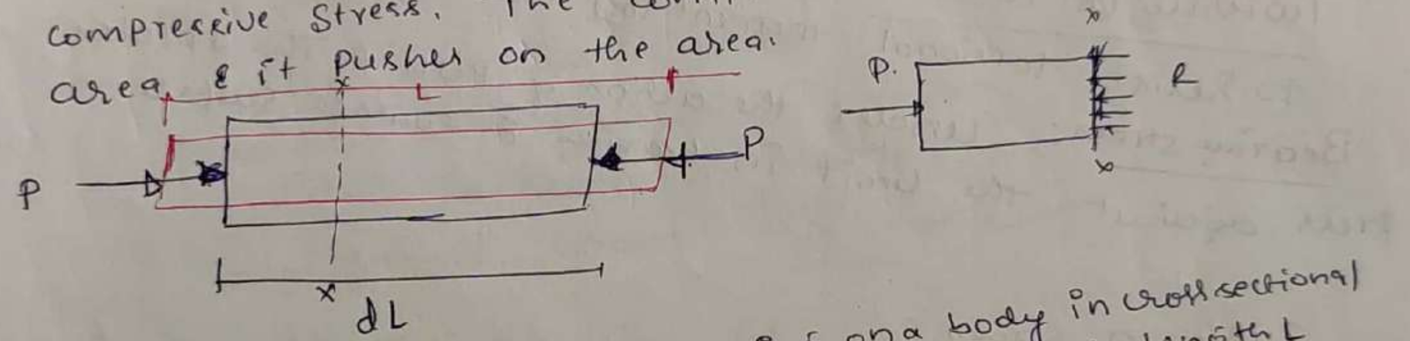
Tensile strain is given by

$$e = \frac{\text{Increase in length}}{\text{original length}}$$

i.e. $\boxed{e = \frac{dL}{L}}$ $\boxed{e = \frac{dL}{L}}$,

② Compressive stress:

The stress induced in a body when subjected to two equal & opposite pushes as shown in fig as a result of which there is a decrease in length of the body is known as compressive stress. The compressive stress acts normal to the area & it pushes on the area.



Let an axial push 'P' acting on a body in cross sectional Area 'A' Due to external push P. Let the original length L of the body decreases by dL.

Then compressive stress = $\sigma = \frac{\text{Resisting force (R)}}{\text{Area (A)}} = \frac{\text{Push (P)}}{\text{Area}}$

$$\boxed{\sigma = \frac{P}{A}}$$

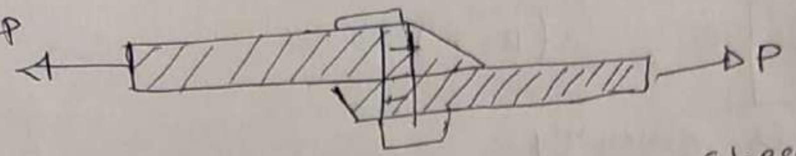
compressive strain is given by $e = \frac{\text{Decrease in length}}{\text{original length}}$

$$\boxed{e = \frac{dL}{L}}$$

3) Shear stress (or) tangential stress:

The stress induced in a body when subjected to two equal & opposite forces which are acting tangentially across the resisting section as shown in fig. as a result of which the body tends to shear off across the section is known as shear stress & the corresponding strain is known as shear ~~strain~~ stress strain

~~& the~~ It is represented by τ (Tow)



The shear stress is defined as shear force per unit area
(or) It is the ratio of shear resistance to shear area is called
Shear stress. It is denoted by τ [tow]

Shear stress = Shear force / Shear Area = F/A

Bending stress: The stress produced at the section to resist the bending moment in beam is known as Bending stress.

Twisting (or) Torsion: The stress produced at the section to resist torsional moment (or) twisting moment in shaft.

Bearing stress: under the action of pull P the 2 plates press against the limit in bearing & contact surface.

Types of strain:

Longitudinal strain:

When a body is subjected to an axial tensile load. There is an increase in the length of the body. But at the same time there is a decrease in other dimension of the body at the right angles to the line of action of the applied load. Thus the body is having axial deformation & also deformation at right angles to the line of action of the applied load.

The ratio of axial deformation to the original length of the body is known as longitudinal (or) linear strain (or)

The longitudinal strain is also defined as the deformation of the body per unit length in the direction of the applied load.

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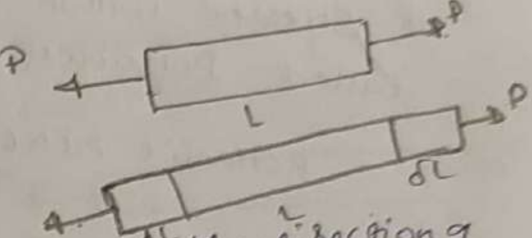
Let. L = length of the body,

P = Tensile force acting on the body.

δL = Increase in length of the body in the direction of P.

longitudinal strain $= \frac{\delta L}{L}$



lateral strain:

The strain at right angles to the direction of applied load is known as lateral strain. Let a rectangular bar of length L, breadth b, & depth d is subjected to an axial load P as shown in fig. The length of the bar will increase while the breadth & depth will decrease.

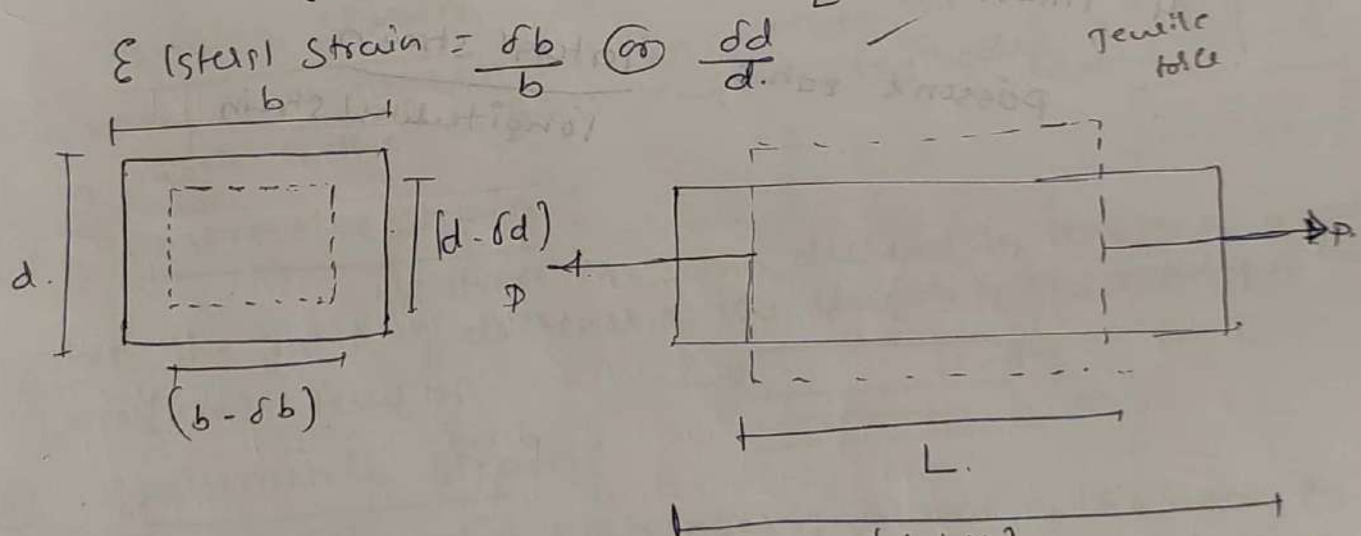
Let δL = Increase in length

δb = ~~Dec~~ Decrease in breadth,

δd = Decrease in depth.

longitudinal strain $= \frac{\delta L}{L}$

& lateral strain $= \frac{\delta b}{b}$ (or) $\frac{\delta d}{d}$



Note: If longitudinal strain is tensile, the lateral strain will be compression.

If longitudinal strain is compression & the lateral strain will be tensile.

Poisson's Ratio:

The ratio of lateral strain to the longitudinal strain is a constant for a given material, when the material is stressed within the elastic limit, This ratio is called Poisson's ratio & generally denoted by "μ".

Poisson's ratio $\mu = \frac{\text{lateral strain}}{\text{longitudinal strain}}$

(or) lateral strain = $\mu \times$ longitudinal strain.

As lateral strain is opposite in sign to longitudinal strain hence algebraically lateral strain is written as

lateral strain = $-\mu \times$ longitudinal ~~stress~~ strain.

(or)

Poisson's ratio is defined as the ratio of lateral strain to the longitudinal strain & is denoted by μ (mu).

$\therefore$ poisson's ratio = $\frac{\text{lateral strain}}{\text{longitudinal strain}}$

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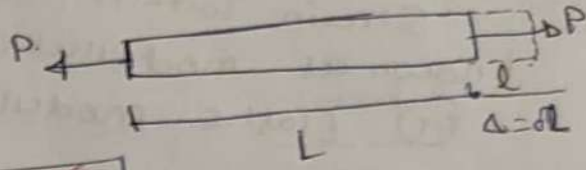
Strain

when a body is subjected to some external force, there is some change of dimension of the body. the ratio of change of dimension of the body to the original dimension is known as strain.

strain can be represented or denoted by ϵ or e

strain is unit-less or dimensionless.

$$\epsilon = \frac{\text{Change in dimension}}{\text{original dimension}}$$



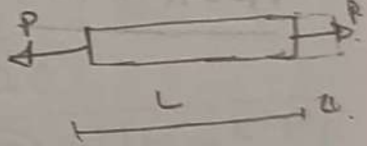
$$\epsilon = \frac{(L+\Delta) - l}{L}$$

$$\epsilon = \frac{\Delta}{L} = \frac{\delta l}{L}$$

strain may be.

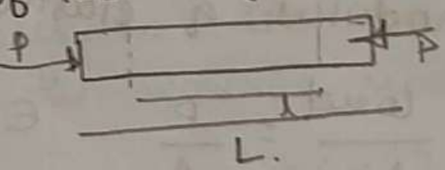
1. Tensile strain
2. compressive strain.
3. volumetric strain and
4. Shear strain.

1. **Tensile strain**: If there is some increase in length of a body due to External force, then the ratio of increase in length to the original length of the body.



(2) **compressive strain**:

If there is some decrease in length of a body, then the ratio of decrease of the length of the body to the original length.



(3) **volumetric strain**:

The ratio of change of volume of the body to the original volume.

(4) **Shear Strain**:

The strain produced by the ~~shear~~ Shear stress is known as Shear strain.

Hook's law and Elastic modulii

When a material is loaded within elastic limit, the stress is proportional to the strain produced by the stress.

That means stress is directly proportional to the strain within the elastic limit. This constant is known as modulus of Elasticity, (or) modulus of Rigidity (or) Elastic modulii.

modulus of Elasticity [or young's modulus]

The ratio of tensile stress (or) compressive stress to the corresponding strain is a constant. This ratio is known as young's modulus (or) modulus of Elasticity and is denoted by E.

$$E = \frac{\text{Tensile stress}}{\text{Tensile strain}} \quad (\text{or}) \quad \frac{\text{compressive stress}}{\text{compressive strain}}$$

$$E = \frac{\sigma}{\epsilon}$$

Hook's law

Stress ∝ strain.

$$f \propto \epsilon$$

$$f = E\epsilon$$

where E = constant is known as young's modulus (or) modulus of elasticity.

$$f = \frac{\text{load}}{\text{Area}} = \frac{P}{A} \qquad \epsilon = \frac{\delta L}{L} = \frac{\Delta}{L}$$

$$\frac{P}{A} = E\frac{\Delta}{L}$$

$$\frac{PL}{A\Delta} = E$$

$$\boxed{E = \frac{PL}{A\Delta}} \quad N/mm^2.$$

Where E = young's modulus

P = load N (or) kN.

L = length in M (or) mm

A = Area of cross section. mm^2.

Δ = change in length mm

For a given material youngs modulus E remains constant E it varies from material to materials.

Problem

1. A circular rod of steel 10mm diameter is subjected too tensile load of 11KN. for which the total extension on a 300mm length was 0.20mm. find the value of young's modulus.

→ diameter d = 10mm

$A = \frac{\pi (10)^2}{4} = 78.53\ mm^2$

$P = 11 \times 10^3\ N.$

$L = 300mm.$

$\Delta = 0.20mm.$

$E = ?$

$Stress = \frac{load}{Area}$

$= \frac{11 \times 10^3\ N}{78.53\ mm^2}$

Stress f = 140.05 N/mm²

$Strain = \frac{\Delta}{L} = \frac{0.20\ mm}{300\ mm}$

$\epsilon = 6.66 \times 10^{-4}$

$E = \frac{PL}{A\Delta} = \frac{11 \times 10^3 \times 300}{78.53 \times 0.20}$

$E = 2.10 \times 10^5$ mpa (or) N/mm²

02) length of an aluminium rod is 400mm with diameter as 10mm. when it is subjected to a tensile force of 2KN. the length increases to 400.15 mm. Find the Stress in the bar and the youngs modulus.

→ length of rod L = 400mm.

diameter of rod d = 10mm.

$P = 2KN = 2 \times 10^3 N.$

$E = ?\quad f = ?$

$A = \frac{\pi (d)^2}{4} = \frac{\pi (10)^2}{4}$

$A = 78.53 mm^2$

L' (final length) = 400.15mm   L (original length) = 400mm

$\Delta = L' - L = 400.15 - 400$

$\Delta = 0.15mm.$

Stress - Strain Relation for Structural Steel

Stress $f = \frac{P}{A} = \frac{2\times10^3}{78.55} = 25.46$ N/mm2 [Tensile stress]

Strain: $\frac{\Delta}{L} = \frac{0.15}{400} = 3.75\times10^{-4}$

$E = \frac{f}{e} = \frac{PL}{A\Delta} = \frac{2\times10^3\times400}{78.55\times0.15} =$

$E = 67897.30$ N/mm2

$E = ~~67.789~~ \times 10^3$ mpa
67.897×10^3 N/mm2

(3) A uniform steel rod 6mm diameter & 0.5m length is subjected to a tensile force of 3KN. find stress in the bar & its elongation if E = 200 GPa.

$D = 6$ mm

$L = 0.5$ m $= 0.5\times1000 = 500$ mm

$P = 3\times10^3$ N.

$E = 200$ GPa $= 200\times10^9$ Pa.

$f = ?$ $\Delta = ?$

1 M = 1000 mm

$E = 200\times10^9$ N/m2

$= \frac{200\times10^9}{(1000)^2}$

$= 200\times10^3$ mpa (or) N/mm2

$E = 200\times10^3$ N/mm2

(or) 200 GPa
$\frac{10^3\times10^6}{10^3}$ × MPa (or) N/mm2
$= 200\times10^3$ N/mm2

Stress $f = \frac{Load}{Area}$

$A = \frac{\pi(d)^2}{4} = \frac{\pi\times(6)^2}{4} = 28.274$ mm2.

$E = \frac{PL}{A\Delta} = 200\times10^3 = \frac{3\times10^3\times500}{28.274\times\Delta}$

$\Delta = \frac{3\times10^3\times500}{28.274\times200\times10^3}$

$\Delta = 0.265$ mm

$\Delta = \frac{kN\times mm}{mm^2\times N/mm^2}$

$\Delta =$ mm

Stress $f = \frac{P}{A} = \frac{3\times10^3 \text{ N}}{28.274 \text{ mm}^2} = 106.104$ N/mm2

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Stress - Strain Relation for Structural Steel
[Mild Steel (or) Ductile material]
[ferrous material]

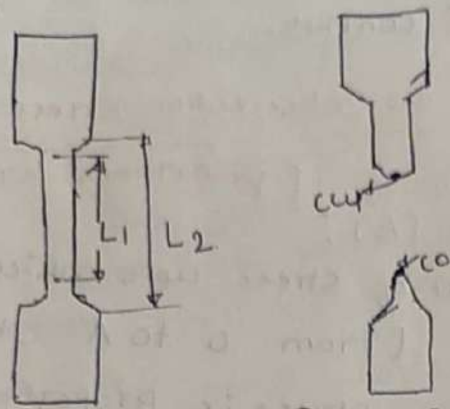
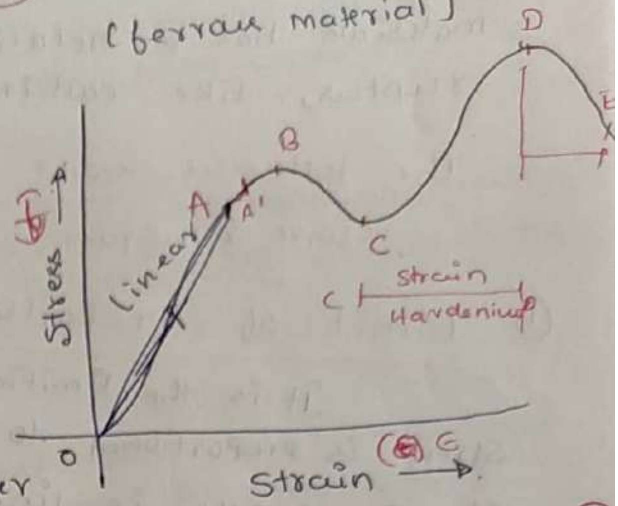
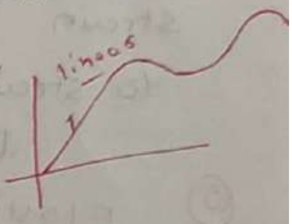


Fig (a) Test specimen Fig (b) specimen after breaking





A = Proportionality limit , A' = elastic limit .
B = upper yield point .
C = yield Point | lower yield point .
D = ultimate strength | ultimate stress .
E : Breaking Point | Rupture strength .

Fig (a) shows a typical tensile test specimen of mild steel. Its ends are gripped into universal testing machine. Extensometer is fitted to the test specimen which measures extension over the length L_1 as shown in fig (a). The length over which extension is measured is called gauge length. The load is applied gradually & at regular interval of loads extension is measured the process is continued until failure of the specimen takes place.

load divided by original cross-sectional Area will give the stress (σ) similarly strain is obtained by dividing the extensometer reading by gauge length of extensometer (L_1) & by dividing scale reading by grip to grip (L_2). knowing the original cross-sectional Area & length of the specimen, the normal stress (σ) & the strain (ε) can be obtained. the graph of these quantities ie stress (σ) along y-axis & strain along x-axis is called the stress-strain diagram.

The stress strain diagram differs in form for various materials. The engineering materials are classified as either ductile (or) brittle materials. A ductile material is one having relatively large tensile strains upto the point of rupture.

like structural steel & alluminium, whereas brittle materials has a relatively small strain upto the point of rupture like cast iron. & concrete.

The following salient points are observed on stress - strain curve diagram. [proportional limit]

① Limit of Proportanility [A]:

It is the limiting value of stress upto which the stress is proportional to strain [From 'O' to 'A' stress-strain curve is linear i.e stress is proportional to strain upto Point A & is called proportionality limit]

stress ∝ strain

$f \propto e$

$f = Ee$

E = youngs modulus [N/mm^2]

② Elastic limit [A']

The elastic limit is the limit beyond which the material will no longer go back to its original shape when the load is removed. (or)

This is the limiting value of stress upto which if the material is stressed & then released [unloaded] strain [deformation] disappears completely & the original length is regained. This point is slighty beyound the limit of proportanility.

③ upper yield point [B]

This is the stress at which the load starts reducing & the extension increases. This phenomeon is known as yielding of materials.

④ lower yield point (C)

At this stage the stress remains same but strain increases for some time.

Yield point: It is a point at which the material will have appreciable elongation (or) yielding without any increase in load, & diagram becomes a curve at C. The stress corresponding to the point C is called yield stress [lower yield point]

...ith steel.

(5) Ultimate Strength (D)

This is the maximum stress the material can resist. At this stage C/S area at a particular section starts reducing rapidly. This is called neck formation.

(6) Break Point (E)

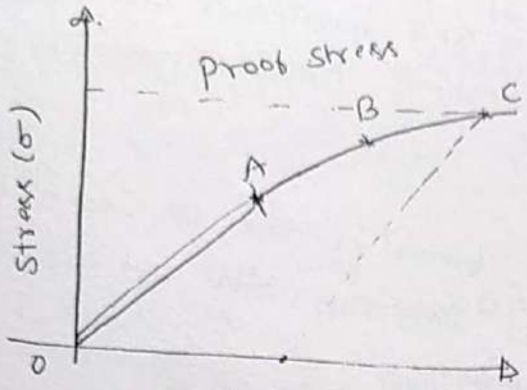
The stress at which finally the specimen fails is called Breaking point (or) It is the point at which the specimen fails (or) Breaks.

The load corresponding to breaking is called breaking load & the stress corresponding to breaking load is taken as Nominal breaking stress (or) ~~atto~~ actual breaking stress.

$$\text{Nominal breaking stress} = \frac{\text{Breaking load}}{\text{original C/S Area}}$$

$$\text{breaking stress} = \frac{\text{Breaking load}}{\text{final C/S area}}$$

Stress- strain curve for non-ferrous materials



A = proportanility limit.
B = elastic limit.
C = proof stress.

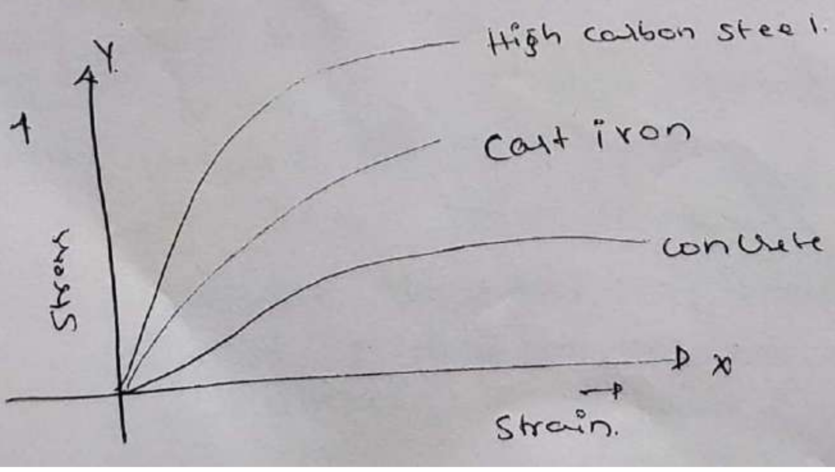
From the curve it is observed that the stress is proportional to strain upto point 'A' & is called proportanility limit. i.e Hook's law is valid up to point 'A'. But the matrial retains its elastic property upto point 'B' & is called as "stress at elastic limit".

To decide a failure stress for non-ferrous material as per Indian standard [I.S] we consider 0.2% of strain along x-axis. From that point we draw the line parallel to linear portion of curve. The line meets the curve at point c is called as proof stress [failure stress]".

Non Ferrous materials (or) non-elastic materials / brittle materials

These materials donot show specific yield point & their failure is sudden.

Ex: Copper, zinc, concrete, alluminium, cast iron etc.



Stress - strain relation in aluminium & high strength steel.

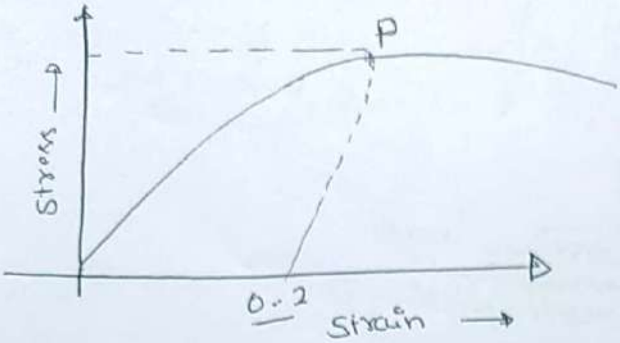


fig.

In These elastic materials there is no clear cut yield point. The necking takes place at ultimate stress & eventually the breaking point is lower than the ultimate point.

The stress 'p' at which if unloading is made there will be 0.2%. permanent set is known as 0.2% proof stress & this point is treated as yield point for all practical purposes.

Stress - Strain Relation in brittle Materials :

The typical stress - strain relation in a brittle material like cast iron. is as shown in fig(2)

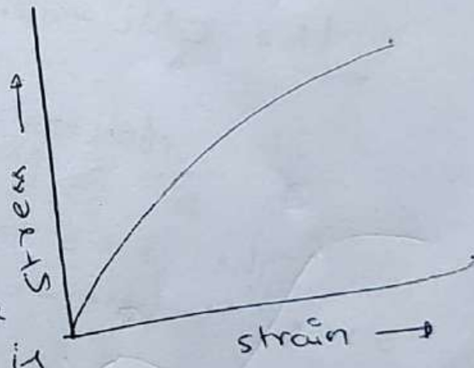


fig 2.

In these materials there is no appreciable change in rate of strain. There is no yield point & no necking takes place. ultimate & Breaking point are one & the same. The strain at failure is very small.

Important Definitions

Yield stress : It is the ratio of yield load to the cross sectional Area is known as yield stress.

$$\text{Yield Stress} = \frac{\text{Yield load}}{\text{Cross sectional area}}$$

ultimate stress : It is the ratio of ultimate load (or) Maximum load to the cross sectional area.

$$\text{ultimate Stress} = \frac{\text{ultimate load}}{\text{Cross-sectional Area}}$$

working stress (or) allowable stress (or) safe stress

It is the ratio of working load (or) service lo[ad] to the cross sectional area.

The working stress is also known as allowabl[e] stress & safe stress.

$$\text{working stress} = \frac{\text{working load}}{\text{cross - sectional Area}}$$

Factor of safety [FOS]

It is the ratio of yield stress (or) ultimate stre[ss] to the working stress is known as F.O.S (or) (or)

The greatest stress to which a material may [be] subjected in pratice must be less than the ultimate str[ess] this corresponding stress is called working stress.

$$\text{factor of safety} = \frac{\text{ultimate stress}}{\text{working stress}} > 1$$

The F.O.S must always be such that the working stress is below elastic limit.

load factor :

It is the ratio of load at failure to working load is called load factor.

$$\text{load factor} = \frac{\text{load failure}}{\text{working load.}}$$

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Percentage reduction in Area:

It is the ratio of change in area to the total area is known as % of reduction in Area.

$$\% \text{ of reduction in Area} = \frac{\text{Change in Area}}{\text{total Area}} \times 100$$

$$= \frac{\delta A}{A} \times 100$$

Subjected to compressive force:

$$\% \text{ of reduction in Area} = \frac{\text{original Area} - \text{final Area}}{\text{original Area}}$$

Subjected to tensile force:

$$\% \text{ of reduction in Area} = \frac{\text{final Area} - \text{original Area}}{\text{original Area}}$$

Modulus of Rigidity (or) Shear modulus:

It is the ratio of shear stress to the corresponding shear strain within elastic limit is known as elastic modulus of Rigidity (or) shear modulus.

It is denoted by C (or) G (or) N

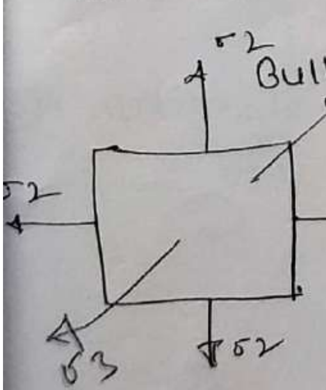
$$\therefore C \text{ (or) } G \text{ (or) } N = \frac{\text{shear stress}}{\text{shear strain}} = \frac{\tau}{\phi}$$

$$C = \frac{\tau}{\phi}$$

Bulk modulus:

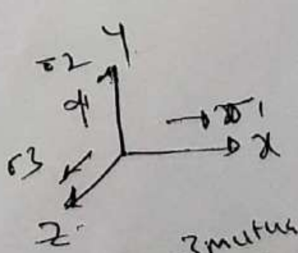
It is defined as the ratio of direct stress to the corresponding volumetric strain. when the body is subjected to 3 mutual perpendicular stress of same intensity is known as bulk modulus. It is denoted by K.

$$\text{Bulk modulus} = \frac{\text{Direct Stress}}{\text{volumetric strain}}$$



$$\therefore \boxed{K = \frac{\sigma}{e_v}}$$

$$\sigma_1 = \sigma_2 = \sigma_3$$



3 mutual perpendicular directions

The following data refered to a mild steel specimen tested in a laboratory.

① Diameter of the specimen = 25mm.
② Length of the specimen = 300mm
③ Extension under a load of 15KN = 0.045mm
④ load at yield point = 127.65KN.
⑤ maximum load = 208.6 KN
⑥ Length of the specimen after failure = 375mm.
⑦ Neck diameter = 17.75mm.

Determine youngs modulus, yield point, ultimate stress, percentage of elongation percentage of reduction in area, safe stress adopting factor of safety.

Given. $d = 25mm$, $l = 300m$, $\delta l = 0.045mm$, $P = 15KN$, $P = 15\times10^3 N$

$E = \frac{\text{stress}}{\text{strain}} = \frac{\sigma}{\epsilon}$

$\text{stress} = \frac{\text{load}}{\text{Area}} = \frac{15\times10^3}{\frac{\pi}{4}(25)^2} = 30.55\ N/mm^2$

$\text{Strain} = \frac{\text{Change in length}}{\text{original length}} = \frac{\delta L}{L} = \frac{0.045}{300} = 1.5\times10^{-4}$

$E = \frac{\text{stress}}{\text{strain}} = \frac{30.55}{1.5\times10^{-4}} = 2.03\times10^5\ N/mm^2$

stress at yield point (or) yield stress

$f_y = \frac{\text{yield load}}{\text{Area}} = \frac{127.65\times10^3}{\frac{\pi\times(25)^2}{4}}$

$f_y = 260.04\ N/mm^2$

ultimate stress

$f_u = \frac{\text{ultimate load (or) maximum load}}{\text{Area}} = \frac{208.6\times10^3}{\frac{\pi\times(25)^2}{4}}$

$f_u = 424.95\ N/mm^2$

Percentage of Elongation $= \frac{375-300}{300} \times 100$ final length

final length - initial length / original length $\times 100$

$= 25\%$.

Percentage reduction in Area.

d : 25

d_1 :

$$= \frac{\frac{\pi}{4}(d^2 - d_1^2)}{\frac{\pi}{4} \times d^2} \times 100$$

$d = 25$
$d_1 = 17.75$
neck diameter

$$= \frac{d^2 - d_1^2}{d^2} \times 100$$

$$= \frac{(25)^2 - (17.75)^2}{~~17.75^2~~ \; 25^2} \times 100$$

$= 0.4959 \times 100$

$= 49.59\%$.

stress $= \frac{\text{yield stress}}{F.S} = \frac{260.17}{2} = 130.085$ N/

(2) In a tension testing Machine the following result obtained

(1) Dia of the specimen = 12mm.
(2) Tensile load = 100KN.
(3) change in length = 0.012mm
(4) length of specimen = 240mm
(5) ultimate load = 260kN.
(6) Breaking load = 230kN.
(7) The load behind the stress is not proportional to strain = 100kN.
(8) Extension of bar was 62.5mm & pla was 6.5mm at fracture.

estimate (a) young's modulus (b) ultimate stress (c) Break stress (d) % of elongation (e) % of reduction area (f) working ~~stes~~ stress if FOS is 2

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Given

$d = 12\,mm$. $P = 100\times10^3\,N$ $\Delta L = 0.012\,mm$.

$L = 240\,mm$, Ultimate load $= 260\,kN$, Breaking load $= 230\,kN$

Extension of bar $= 62.5\,mm$.

Dia $= 6.5\,mm$ at fracture $A = \frac{\pi}{4}(6.5)^2 = 33.18\,mm^2$

Area of the specimen $= \frac{\pi}{4}(12)^2 = 113.097\,mm^2$

stress $\sigma = \frac{P}{A} = \frac{100\times10^3}{113.09} = 884.4\,N/mm^2$

strain $e = \frac{\delta L}{L} = \frac{0.012}{240} = 5\times10^{-5}$

(a) Young's modulus (E)

$E = \frac{\sigma}{e} = \frac{884.4}{5\times10^{-5}}$

$E = 17.68\times10^{6}\,N/mm^2$

(b) Ultimate stress

$$\text{Ultimate stress} = \frac{\text{Ultimate load}}{\text{Cross sectional Area}}$$

$$= \frac{260\times10^3}{113.09} = 2.299\times10^3\,N/mm^2$$

(c) % elongation $= \frac{\text{Total increase in length}}{\text{original length}} \times 100$

$$= \frac{62.5}{240}\times100$$

% elongation $= 26.04\,\%$.

% of Area reduction $= \frac{\text{Initial Area} - \text{Final Area}}{\text{Initial Area}}\times100$

$$= \frac{113.11 - 33.18}{113.11}\times100$$

$$= 70.66\,\%$$

Breaking stress.

i.e. Breaking stress $= \frac{\text{Breaking load}}{\text{Area}}$

$$= \frac{230\times10^3}{113.18} = 2.032\times10^3\,N/mm^2$$

(6) working stress if FOS = 2.

$$F.OS = \frac{\text{yield stress}}{\text{working stress}}$$

$$\text{yield stress} = \frac{\text{yield load}}{\text{Area}} = \frac{~~884~~ 100 \times 10^3}{113.11}$$

yield stress = 884.09 N/mm2

$$\text{working stress} = \frac{\text{yield stress}}{F.OS}$$

$$= \frac{884.09}{2}$$

working stress = 442.047 N/mm2

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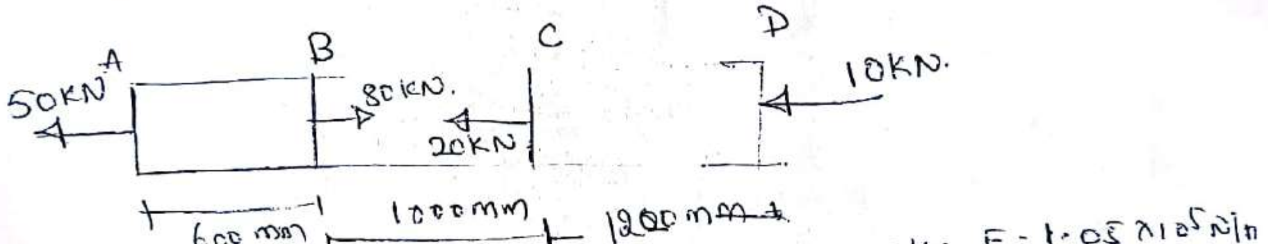
Principle of Superposition:

When a no of loads are acting on a body, the resulting strain, according to the principle of superposition will be the algebraic sum of strains caused by the individual loads.

While using this principle for an elastic body which is subjected to a number of direct forces [tensile (or) compressive] at different sections along the length of the body. First the free body diagram of individual section is drawn. Then the deformation of each section is obtained. The total deformation of the body will be then equal to the algebraic sum of deformation of the individual sections.

Problems

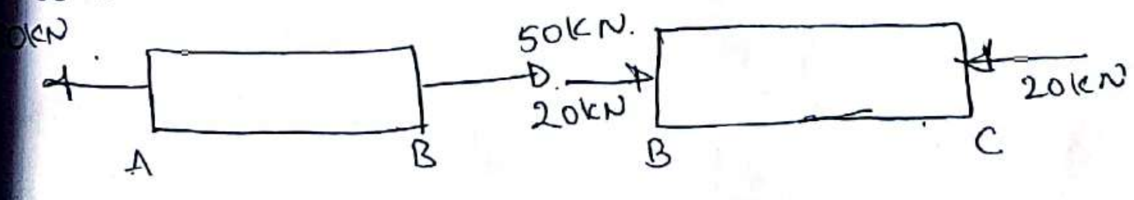
1) A brass bar, having cross-sectional area of 1000mm², is subjected to axial forces as shown in fig.

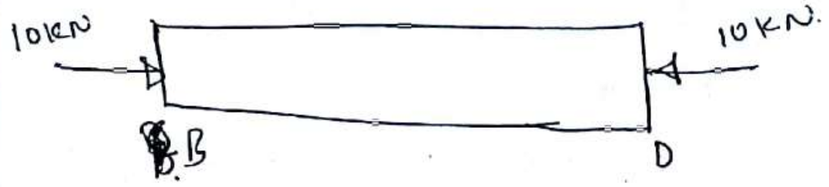


Find the total elongation of the bar. Take $E = 1.05 \times 10^5 N/mm^2$

$A = 1000mm^2$, $E = 1.05 \times 10^5 N/mm^2$, dL = Total elongation of the bar.

The force of 80KN acting at B is split up into three forces of 50KN, 20KN, and 10KN. Then the part AB of the bar will be subjected to a tensile load of 50KN part BC is subjected to a compressive load of 20KN. and part BD is subjected to a compressive load of 10KN as shown in fig.





The Part AB is subjected to a tensile load of 50kN. Hence there will be ~~subjected to a tensile load of 50kN~~ increase in length of this pa ~~Part BC is subjected~~ to a increase in length of this part

Increase in length of AB :

$$\Delta = \frac{P_1}{AE} \times L_1$$

$P_1 = 50,000 N.$

$L_1 = 600mm$

$$= \frac{50 \times 1000}{1000 \times 1.05 \times 10^5} \times 600$$

$$\boxed{\Delta_1 = 0.2857 mm}$$ +ve Tension Incr len

The Part BC is subjected to a compressive load of 20kN or 20,000N. Hence there will be decrease in length of the Part

Decrease in length

$$\Delta = \frac{P_2}{A_2 E} \times L_2$$

$P_2 = 20,000 N$

$L_2 = 1m = 1000$

$$\Delta_2 = \frac{20,000}{1000 \times 1.05 \times 10^5} \times 1000$$

−ve (Decrease in length)

$$\boxed{\Delta_2 = 0.1904mm.}$$

The part BD: This Part is subjected to a compressive load 10kN. Hence there will be decrease in length

$$\Delta_3 = \frac{P_3}{AE} \times L_3$$

$P_3 = 10,000 N.$

$L_3 = 1.2 + 1 = 2.2$

$L_3 = 2200mm$

$$\Delta_3 = \frac{10,000}{1000 \times 1.05 \times 10^5} \times 2200$$

−ve [Decrease in length

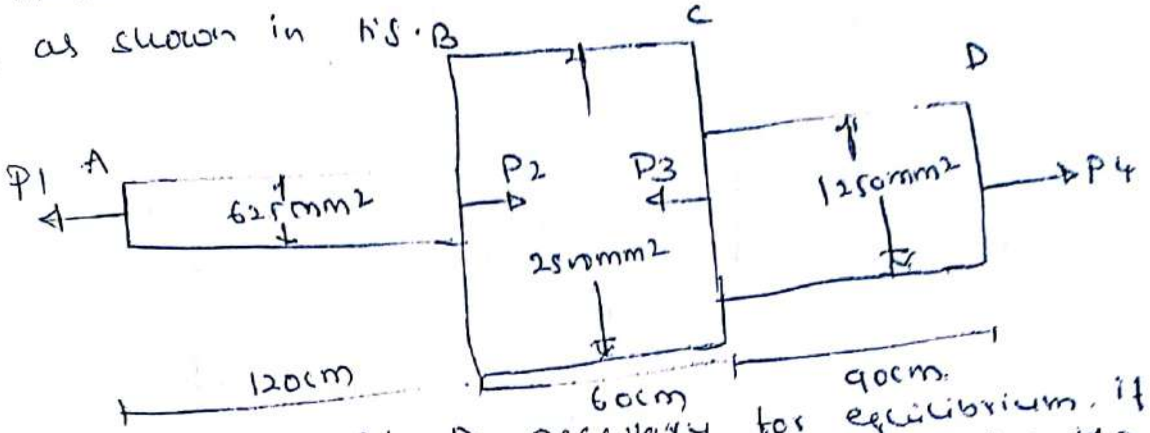
$$\boxed{\Delta_3 = 0.2095m}$$

Total elongation of the bar = 0.2857 − ~~0.2857~~ 0.1904 −

$$\boxed{\Delta = -0.1142mm}$$

Negative sign shows that there will be decrease in length of the bar.

A member ABCD is subjected to point loads P_1, P_2, P_3 & P_4 as shown in fig. B



calculate the force P_2 necessary for equilibrium, if $P_1 = 45KN$, $P_3 = 450KN$ and $P_4 = 130KN$. Determine the total elongation of the member, assuming the modulus of elasticity to be $2.1 \times 10^5 N/mm^2$

Part AB $A_1 = 625 mm^2$ $L_1 = 120cm = 1200mm$ $E = 2.1 \times 10^5 N/mm^2$

Part BC $A_2 = 2500mm^2$ $L_2 = 60cm = 600mm$

Part CD $A_3 = 1250mm^2$ $L_3 = 90cm = 900mm.$

Value of P_2 is necessary for equilibrium.

Resolve the forces on the rod along its axis [i.e. equating the forces acting towards right to those acting towards left]. we get.

$$P_1 + P_3 = P_2 + P_4.$$

But $P_1 = 45KN$, $P_3 = 450KN$, $P_4 = 130KN.$

$$45 + 450 = P_2 + 130$$

$$495 = P_2 + 130$$

$$495 - 130 = P_2$$

$$\boxed{P_2 = 365 KN.}$$

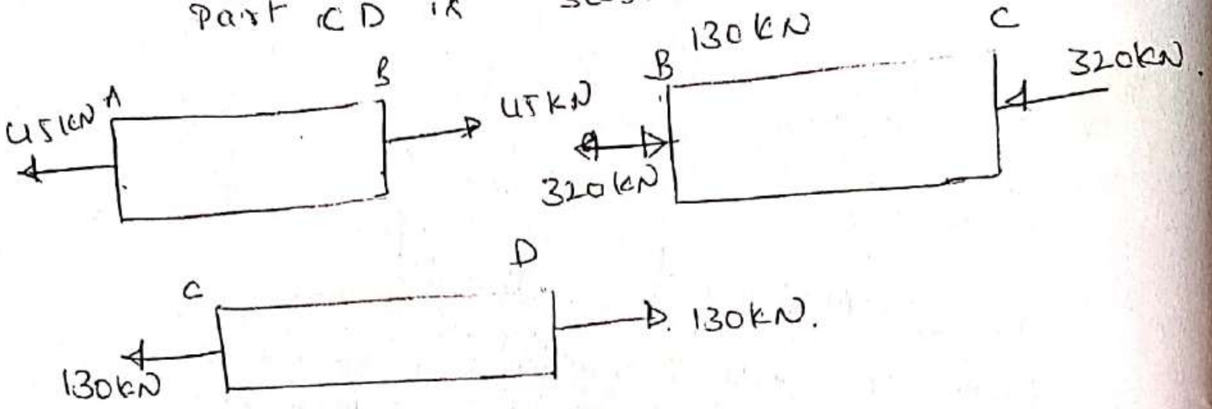
The force of 365KN acting at B is split into two forces of ~~320KN~~ 45KN and 320KN [i.e. 365 − 45 = 320KN.]

The force of 450KN acting at C is split into two forces of 320KN and 130KN. [ie 450 − 320 = 130KN]

It is clear that part AB is subjected to tensile ~~force~~ load

Part BC is subjected to compressive ~~force~~ load

Part CD is subjected to Tensile ~~force~~ Load



Part AB

$$\Delta_1 = \frac{P_1}{A_1 E} \times L_1 = \frac{45000}{625 \times 2.1 \times 10^5} \times 1200$$

$$\boxed{\Delta_1 = 0.4114\,mm}$$ (+ve)

(Increase in le

Part BC

$$\Delta_2 = \frac{P_2}{A_2 E} \times L_2 = \frac{320,000}{2500 \times 2.1 \times 10^5} \times 600$$

$$\boxed{\Delta_2 = 0.3657\,mm}$$ (−)ve

Part CD

$$\Delta_3 = \frac{P_3}{A_3 E} \times L_3 = \frac{130,000}{1250 \times 2.1 \times 10^5} \times 900$$

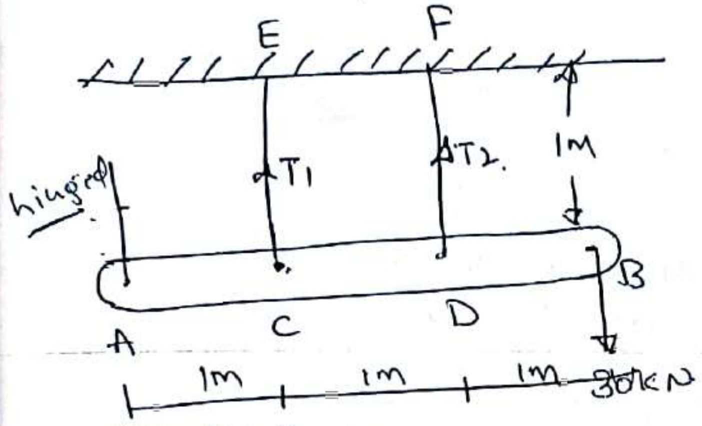
$$\boxed{\Delta_3 = 0.4457\,mm}$$ +ve.

Total change in length $\Delta = \Delta_1 - \Delta_2 + \Delta_3$

$= 0.4114 - 0.3657 + 0$

$$\boxed{\Delta = 0.4914\,MM}$$ ExH

A rigid bar ACDB is hinged at A and supported in a horizontal position by two identical steel wires as shown in fig. A vertical load of 30kN is applied at B. Find the tensile forces T_1 and T_2 induced in these wires by the vertical load.



Before applying load fig 1

After applying load

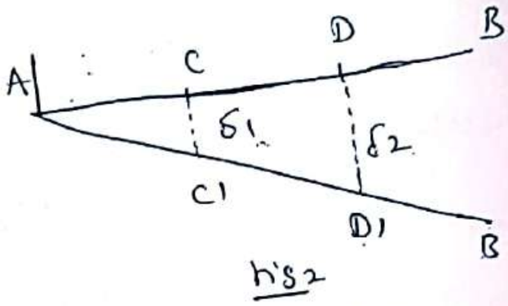


fig 2

Two identical steel wires means the area of the cross-sections, lengths and value of E for both wires is same.

$A_1 = A_2 \quad L_1 = L_2 \;\&\; E_1 = E_2$

Load at B = 30kN = 30,000 N.

fig (2) T_1 = Tension in the first wire δ_1 = Extension of first wire

T_2 = Tension in the second wire δ_2 = —11— second —11

Since the rigid bar remains straight. hence extensions δ_1 & δ_2 are given by

$$\frac{\delta_1}{\delta_2} = \frac{AC}{AD} = \frac{1}{2}$$

$$\boxed{2\delta_1 = \delta_2} \quad \text{---(1)}$$

But δ_1 is the extension of the wire EC

$$\delta_1 = \frac{\text{Stress in } EC \times L_1}{E_1}$$

$$= \frac{\left(\frac{T_1}{A_1}\right) \times L_1}{E_1}$$

$$\boxed{\delta_1 = \frac{T_1 \times L_1}{A_1 \times E_1}}$$

$$\boxed{\delta_2 = \frac{T_2 \times L_2}{A_2 \times E_2}}$$

Substituting values of δ_1 & δ_2 in equation(i)

$$2\delta_1 = \delta_2 \quad \rightsquigarrow (1)$$

$$2 \times \frac{T_1 \times L_1}{A_1 \times E_1} = \frac{T_2 \times L_2}{A_2 \times E_2}$$

But $A_1 = A_2$ $L_1 = L_2$ $E_1 = E_2$, Hence above equation becomes

$$2T_1 = T_2 \quad — (2)$$

Now taking the moments of all the forces on the rigid bar about A, we get

$$T_1 \times 1 + T_2 \times 2 = 30 \times 3$$

$$T_1 + 2T_2 = 90 \quad \rightsquigarrow (3)$$

Substituting the value of T_2 from equation (2) into equation (3) we get

$$T_1 + 2(2T_1) = 90$$

$$5T_1 = 90$$

$$\boxed{T_1 = 18 kN}$$

from equation

$$2T_1 = T_2$$

$$2 \times 18 = T_2$$

$$\boxed{T_2 = 36 \ kN}$$

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Analysis of Bars of varying sections.

A bar of different lengths & of different diameters [and hence of different Cross sectional areas] is shown in fig (a). Let this bar is subjected to an axial load P.

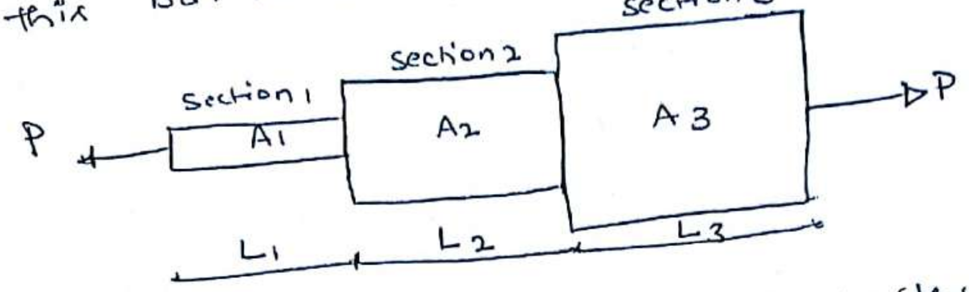


fig. a

The stresses, strains and change in length will be different. The total change in length will be obtained by adding the changes in length of individual section.

Let P = Axial load acting on the bar.

L_1 & A_1 = Length and Area of Cross section 1

L_2 & A_2 = length and Area of Cross section 2

L_3 & A_3 = Length and Area of Cross section 3

E = Youngs modulus for the bar.

Then Stress for the section 1 $= \frac{P}{A_1}$

$$\sigma_1 = \frac{\text{load}}{\text{Area of cross section 1}}$$

$$\boxed{\sigma_1 = \frac{P}{A_1}}$$

Similarly (2) & (3)

$$\sigma_2 = \frac{\text{load}}{\text{Area of Cross section}} = \frac{P}{A_2}$$

$$\boxed{\sigma_2 = \frac{P}{A_2}} \quad \boxed{\sigma_3 = \frac{P}{A_3}}$$

$$E = \frac{\sigma}{e}$$

$$\text{Youngs modulus} = \frac{\text{Tensile Stress}}{\text{Tensile Strain}} = \frac{\sigma}{e}$$ The strains in different sections are obtained.

Strain of section 1 $e_1 = \frac{\sigma_1}{E} = \frac{P}{A_1 E}$ $\sigma_1 = \frac{P}{A_1}$

$$e_1 = \frac{P}{A_1 E}$$

Strain of section (2) & (3)

$$e_2 = \frac{P}{A_2 E}$$ $$e_3 = \frac{P}{A_3 E}$$

But strain in section (1) = $\frac{\text{change in length of section (1)}}{\text{Length of the section (1)}}$

$$e_1 = \frac{dL_1}{L_1}$$

where dL_1 = change in length of section (1)

$e_1 = \frac{dL_1}{L_1}$ $dL_1 = e_1 L_1$ where $e_1 = \frac{P}{A_1 E}$

$$dL_1 = \frac{PL_1}{A_1 E}$$

Similarly strain in section (2) & (3)

$$dL_2 = \frac{PL_2}{A_2 E}$$ $$dL_3 = \frac{PL_3}{A_3 E}$$

Total change in length of the bar

$$dL = dL_1 + dL_2 + dL_3$$

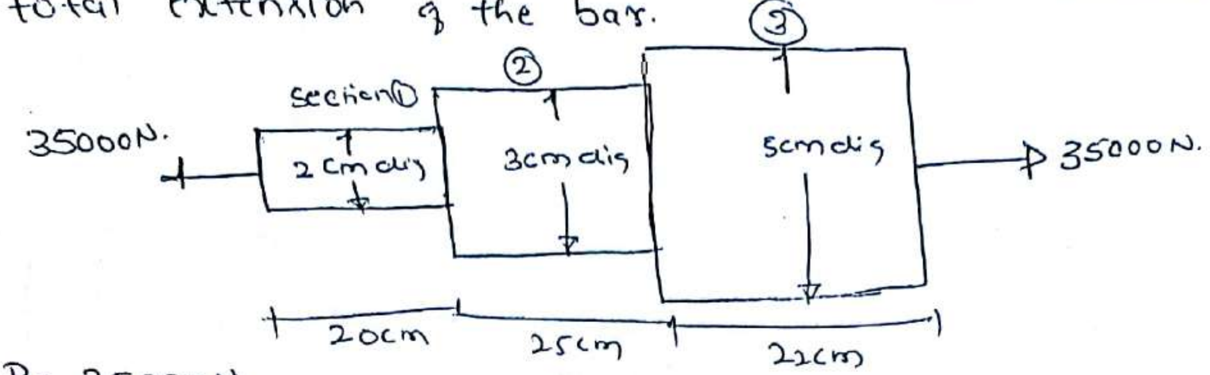
$$= \frac{PL_1}{A_1 E} + \frac{PL_2}{A_2 E} + \frac{PL_3}{A_3 E}$$

$$dL = \frac{P}{E}\left[\frac{L_1}{A_1} + \frac{L_2}{A_2} + \frac{L_3}{A_3}\right]$$

This equation is used when the young's modulus of a section is same. If the young's modulus of different section different, then total change in length of the bar is given by

$$dL = P\left[\frac{L_1}{A_1 E_1} + \frac{L_2}{A_2 E_2} + \frac{L_3}{A_3 E_3}\right]$$

... axial pull of 35000 N is acting on a bar consisting of three lengths as shown in fig. If the youngs modulus $= 2.1\times10^5$ N/mm2. determine: ① Stresses in each section and ② total extension of the bar.



Given $P = 35000N$

$L_1 = 20cm = 200mm$ $L_2 = 25cm = 250mm$

$D_1 = 2cm = 20mm$ $D_2 = 3cm = 30mm$

$A_1 = \frac{\pi D_1^2}{4} = \frac{\pi(20)^2}{4} = 314.15mm^2$ $A_2 = \frac{\pi D_2^2}{4} = \frac{\pi(30)^2}{4} =$ ~~490.87~~ 706.85 m

$L_3 = 22cm = 220mm$

$D_3 = 5cm = 50mm$ $E = 2.1\times10^5$ N/mm2

$A_3 = \frac{\pi D_3^2}{4} = \frac{\pi(50)^2}{4} = 1963.49mm^2$

① Stresses in each section

section ① $\sigma_1 = \frac{\text{Axial load}}{\text{Area of section①}} = \frac{35000\,N}{314.15\,mm^2} = 111.41$ N/mm²

Section② $\sigma_2 = \frac{\text{Axial load}}{\text{Area of section②}} = \frac{35000N}{\text{~~490.87~~ } 706.85\,mm^2} = 49.51$ N/mm²

Section③ $\sigma_3 = \frac{35000}{1963.49} = 17.825$ N/mm²

② Total Extension of the bar

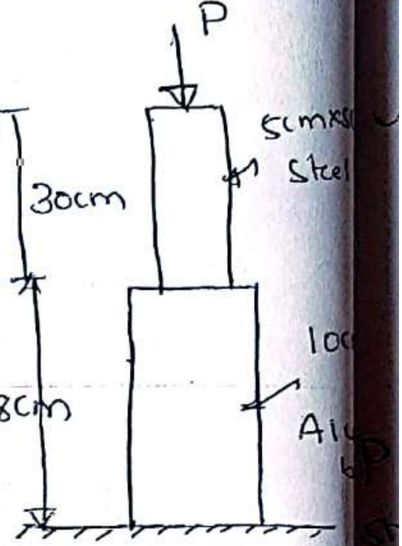
Total Extension $\Delta = \frac{P}{E}\left[\frac{L_1}{A_1} + \frac{L_2}{A_2} + \frac{L_3}{A_3}\right]$

$\Delta = \frac{35000}{2.1\times10^5}\left[\frac{200}{314.15} + \frac{250}{706.85} + \frac{220}{1963.49}\right]$

$\Delta =$ ~~1.667×10⁹~~ 0.1667 $[0.636 + 0.353 + 0.1120]$

$\Delta =$ ~~1.835mm~~ 0.1835 mm

(2) A member formed by connecting a steel [bar to an alum]inium bar is shown in fig. Assuming that the bars are preve[nted] from buckling sideways, calculate the magnitude [of] force P that will cause the total length of the member [to] decrease 0.25mm. The values of elastic modulus for st[eel] and aluminium are 2.1×10^5 N/mm² & 7×10^4 N/m[m²] respectively.



Given

Length of steel bar $L_1 = 30cm = 300mm$

Area of steel bar $A_1 = 5cm \times 5cm$

$= 50mm \times 50mm$ ~~50mm×500mm~~

$= 2500mm^2$ ~~= 2500 25cm²~~

elastic modulus

$A_1 = 2500mm^2$

$E_1 = 2.1\times10^5$ N/mm²

Length of aluminium $L_2 = 38cm = 380mm$

Area of Aluminium $A_2 = 10cm \times 10cm$

$=$ ~~100cm~~ 100×100 mm

$A_2 = 10000mm^2$ $= 10000mm^2$

elastic modulus

$E_2 = 7\times10^4$ N/mm²

Total decrease in length, $dL = 0.25mm$

P = Required force.

$$dL = P\left[\frac{L_1}{A_1E_1} + \frac{L_2}{A_2E_2}\right]$$

$$0.25 = P\left[\frac{300}{2500\times2.1\times10^5} + \frac{380}{10000\times7\times10^4}\right]$$

$$0.25 = P\left[5.714\times10^{-7} + 5.428\times10^{-7}\right]$$

$$0.25 = P\left[1.114\times10^{-6}\right]$$

$$P = \frac{0.25}{1.114\times10^{-6}}$$

$P = 224376.23$ N.

$P = 2.243\times10^5$

P = 224.37 KN

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) The bar shown in fig. is subjected to a tensile load of 160kN. If the stress in the middle portion is limited to 150 N/mm². determine the diameter of the middle portion. Find also the length of the middle portion. If the total elongation of the bar is to be 0.2mm. Young's modulus given as equal to 2.1×10^5 N/mm²

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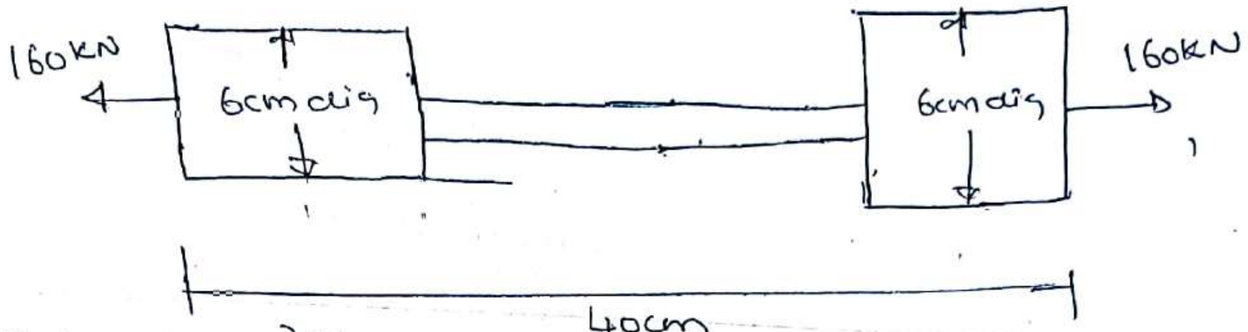

= 160kN = 160×10^3 N,

Stress in middle portion = 150N/mm²

Total elongation dL = 0.2mm.

Total length of the bar L = 40cm = 400mm

$E = 2.1\times10^5$ N/mm²

D_1 = 6cm = 60mm.

$$A_1 = \frac{\pi D_1^2}{4} = \frac{\pi(60)^2}{4} = 2827.43\,mm^2$$

D_2 = Diameter of the middle portion.

L_2 = length of the middle portion in mm.

Length of both end portions of the bar

$L_1 = (400 - L_2)$ mm.

$$\text{Stress} = \frac{\text{Load}}{\text{Area}}$$

Middle portion

$$\sigma_2 = \frac{P}{A_2}$$

$$150 = \frac{160\times10^3}{\frac{\pi}{4}(D_2)^2}$$

$$D_2^2 = \frac{4\times160\times10^3}{150\times\pi}$$

$$D_2^2 = 1358.12\,mm^2$$

$$\boxed{D_2 = 36.85\,mm}$$

$D_2 = 3.68$ cm

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Area of cross section of middle Portion

$A_2 = \frac{\pi}{4} \times D_2^2$

$A_2 = \frac{\pi}{4} \times 36.85^2$

$A_2 = 1066.6 mm^2$

Total extension $dL = \frac{P}{E}\left[\frac{L_1}{A_1} + \frac{L_2}{A_2}\right]$

$0.2 = \frac{160 \times 10^3}{2.1 \times 10^5}\left[\frac{(400 - L_2)}{2827.43} + \frac{L_2}{1066}\right]$

$\frac{0.2 \times 2.1 \times 10^5}{160 \times 10^3} = \frac{(400 - L_2)}{2827.43} + \frac{L_2}{1066}$

$0.2625 = \frac{1066(400 - L_2) + 2827.43 L_2}{2827.43 \times 1066}$

$791185.59 = 426400 - 1066 L_2 + 2827.43 L_2$

$791185.59 = 426400 - 1066 L_2 + 2827.43 L_2$

$791185.59 - 426400 = L_2[2827 - 1066]$

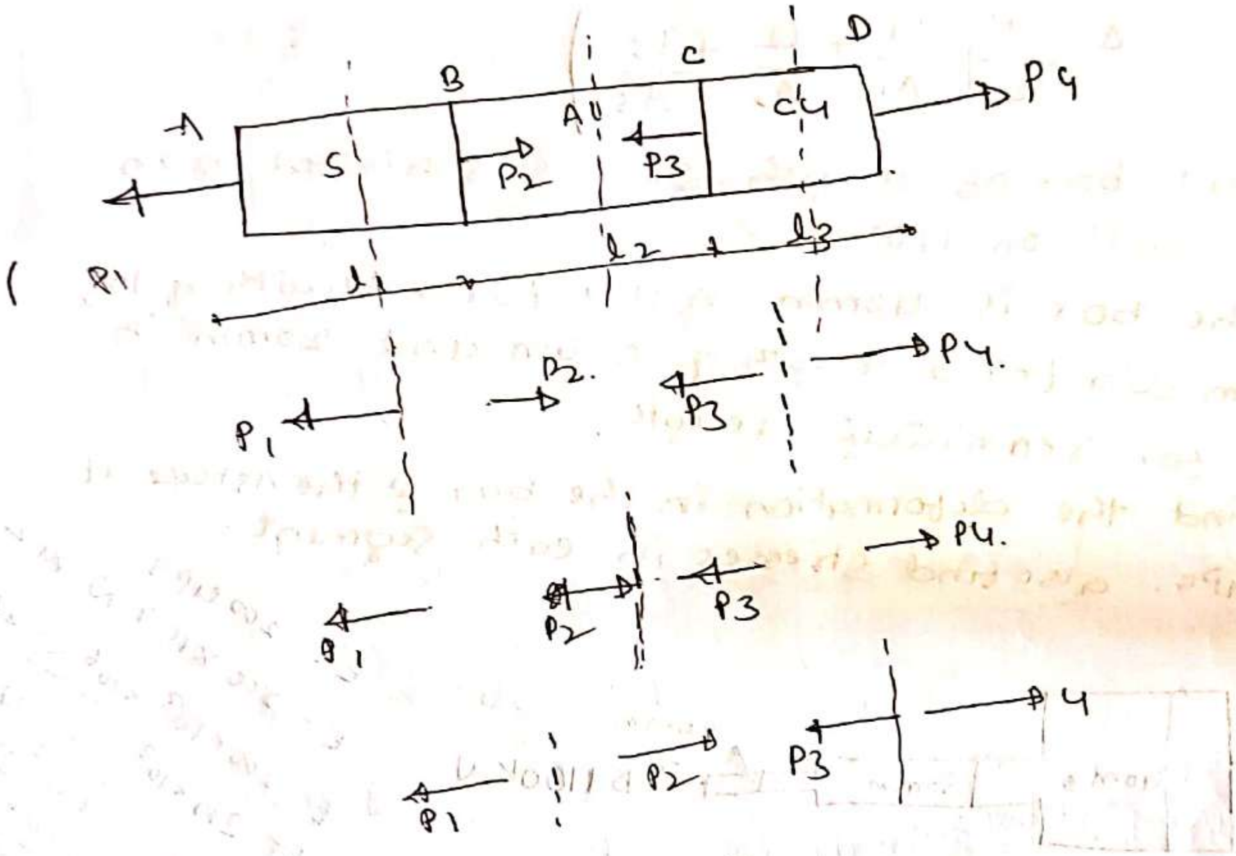
$364785.59 = 1761 L_2$

$L_2 = 207.14 mm$

$L_2 = 20.714 cm$

Principle of super position :

"When a number of loads are acting on a body in equilibrium, The resulting strain will be the algebraic sum of the strain caused by Individual force." and is known as principle of super position.

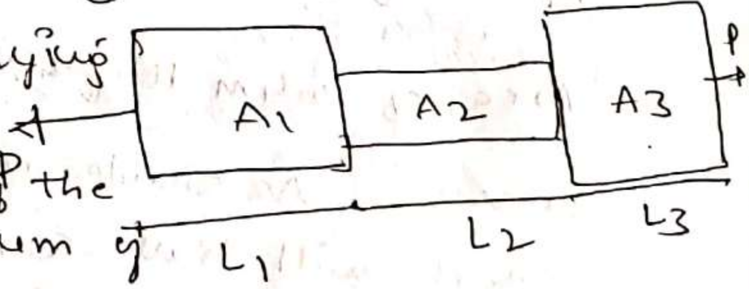


Young's modulus $\epsilon = \pm \epsilon_{AB} \pm \epsilon_{BC} \pm \epsilon_{CD}$

Strain elongation $\Delta = \pm \Delta_{AB} \pm \Delta_{BC} \pm \Delta_{CD}$

Bars of varying sections

If an axile force P (tensile or compressive) is acting on a bar of varying cross section, The total elongation or contraction of the bar will be equal to the sum of elongation or contraction of each section under the action of axile force P.



Thus referring fig.

The total elongation Δ will be given by

$$\Delta = \Delta_1 + \Delta_2 + \Delta_3$$

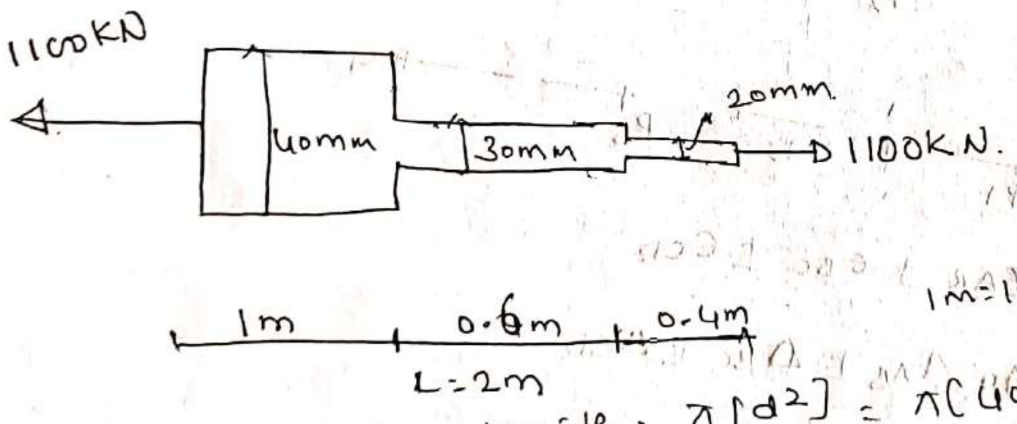
where Δ_1, Δ_2 & Δ_3 are the the elongations of the three portions.

Thus $$\Delta = \frac{P}{E}\left[\frac{L_1}{A_1} + \frac{L_2}{A_2} + \frac{L_3}{A_3}\right]$$

(1) A steel bar of length 2m is subjected to an axial pull of 1100KN.

(a) The bar is 40mm in dia for a length of 1m, 30mm dia for a length of 0.6m and 20mm in dia for reamining length.

(b) find the deformation in the bar & the nsteere if $E = 200$ GPa. also find stresses in each segment..



$E = 200$ GPa
$E = 200 \times 10^9\ N/m^2$
$E = 200 \times 10^3 \times 10^6\ N/m^2$
$E = 200 \times 10^3 \times \frac{10^6\ N}{(1000)^2\ mm^2}$
$E = 200 \times 10^3\ N/mm^2$
$10^6\ N/m^2$
$\therefore$ 1 MPa = 1 N/mm^2
$E = 200 \times 10^3\ N/mm^2$

1m = 1000mm

1. Area of 1m length $= \frac{\pi[d^2]}{4} = \frac{\pi[40]^2}{4} = 1256.63\ mm^2$

2. Area of 0.6m length $= \frac{\pi[30]^2}{4} = 706.85\ mm^2$

3. Area of 0.4m length $= \frac{\pi[20]^2}{4} = 314.15\ mm^2$

Stresses - As single tensile force is acting, each segment will have same load.

i.e $P_1 = P_2 = P_3 = 1100 \times 10^3\ N$

Stress in each segment $\sigma_1 = \frac{P_1}{A_1} = \frac{1100\times10^3}{1256.6} = 875.37\ N/mm^2$

Stress in 2nd segment $\sigma_2 = \frac{P_2}{A_2} = \frac{1100\times10^3}{706.8} = 1556.31\ N/mm^2$

Stress in 3rd segment $\sigma_3 = \frac{P_3}{A_3} = \frac{1100\times10^3}{314.15} = 3501.5$ ~~3497.6~~ N/mm^2

(5) Deformation in segment

$$\Delta_{AB} = \left[\frac{PL}{AE}\right]_{AB} = \left[\frac{1100\times1000\times10^3}{1256.6\times200\times10^3}\right] = 4.37\ mm$$

$$\Delta_{BC} = \left[\frac{PL}{AE}\right]_{BC} = \left[\frac{1100\times10^3\times600}{706.8\times200\times10^3}\right] = 4.67\ mm$$

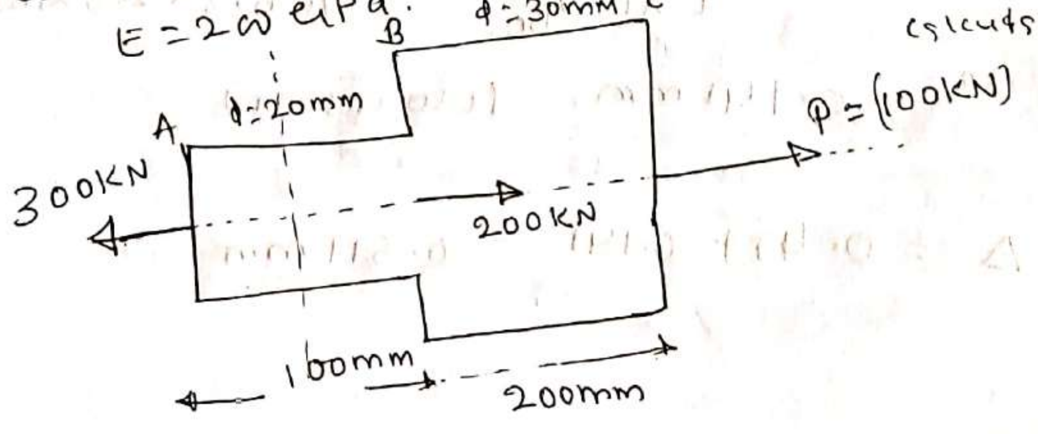
$$\Delta_{CD} = \left[\frac{PL}{AE}\right]_{CD} = \left[\frac{1100\times10^3\times400}{314.15\times200\times10^3}\right] = 7.00\ mm$$

$\Delta = \Delta_{AB} + \Delta_{BC} + \Delta_{CD}$

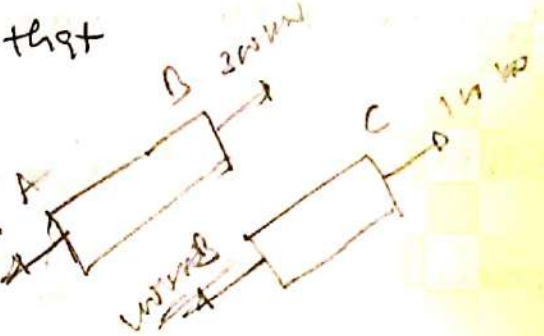
$\Delta = +4.37 + 4.67 + 7.00$

$\boxed{\Delta = 16.04\ mm}$ ∴ Total elongation.

(2) Determine the stress in different segments of a circular bar shown in fig. Compute the total deformation of the part if $E = 200\ GPa$. (9) calculated.



For equillibrium we know that



$\xrightarrow{+ve} \sum H = 0$ $\quad -300 + 200 + P = 0$

$$\boxed{P = 100\,kN}$$

Area $A_{AB} = \frac{\pi d^2}{4} = \frac{\pi (20)^2}{4} = 314.15\,mm^2$

$A_{BC} = \frac{\pi (30)^2}{4} = 706.8\,mm^2$

Stress in segment AB

$f_{AB} = \frac{P}{A_{AB}} = \frac{300 \times 10^3}{314.15} = 955.10\,N/mm^2$ [T]

300kN ← ¦ → 300kN

$\Delta_{AB} = \left[\frac{PL}{AE}\right]_{AB} = \frac{300 \times 10^3 \times 100}{314.15 \times 200 \times 10^3} = 0.47\,mm$

$$\boxed{\Delta_{AB} = 0.47\,mm}$$ Elongation

Stress in segment BC $\quad f_{BC} = \frac{P_{BC}}{A} = \frac{100 \times 10^3}{706.8} = 141.48\,N/mm^2$ [T]

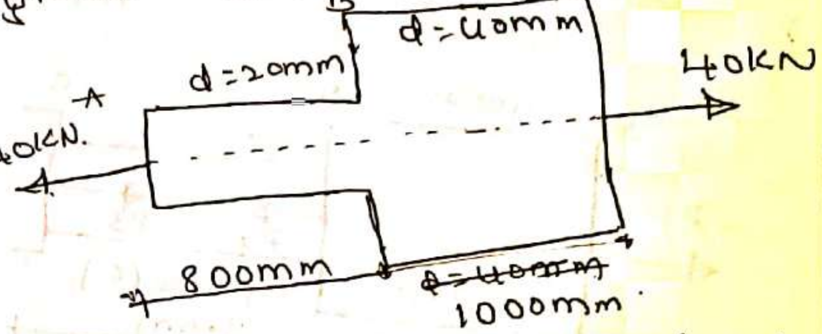
300kN ← 200kN → ¦ 100kN → ⇒ 100kN ← | → 100kN

$\Delta_{BC} = \left[\frac{PL}{AE}\right]_{BC} = \frac{100 \times 10^3 \times 200}{706.8 \times 200 \times 10^3}$

$\Delta_{BC} = 0.141\,mm$ (Elongation)

$\Delta = 0.47 + 0.141 = 0.611\,mm$

(3) A steel rod 20mm dia and 800mm long is rigidly attached to an alluminum rod, 40mm dia and 1m long. The combination is subjected to a tensile load of 40KN. find the stress in the material and total Elongation of the bar. given Esteel = 200 GPa, C



E alluminum = 70 GPa.

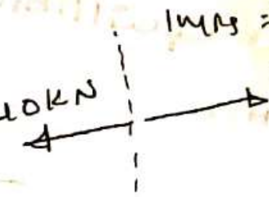
E = 200×10⁹ N/m².

⇒ = 200×10³ N/mm²

1MPa = 10⁶ N/m²
1MN = 10⁶ N
1MN = (1000)² N/mm²

$E_S = 200\times10^3$ N/mm²

$E_{al} = 70\times10^3$ N/mm²



$A_{AB} = \frac{\pi(20)^2}{4} = 314.15\ mm^2$

$A_{BC} = \frac{\pi(40)^2}{4} = 1256.63\ mm^2$

Stress in segment AB is

$\sigma: f_{AB} = \frac{P_{AB}}{A_{AB}} = \frac{40\times10^3}{314.15}$

$f_{AB} = 127.34\ MPa$

Deformation in AB

$\Delta_{AB} = \left[\frac{PL}{AE}\right]_{AB} = \left[\frac{40\times10^3\times 800}{314.15\times 200\times10^3}\right]$

$\Delta AB = \left[\frac{40\times10^3\times800}{314.15\times200\times10^3}\right]$

$\Delta AB = 0.509\ mm$. Elongation

Stress in segment BC is

$f_{BC} = \frac{P_{BC}}{A_{BC}} = \frac{40\times10^3}{1256.63} = 31.83\ N/mm^2$.

Deformation in BC

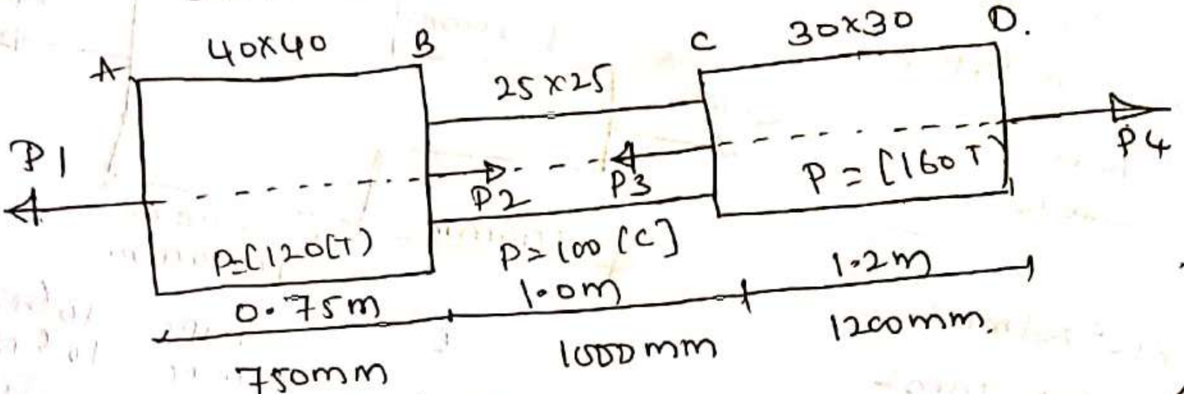
$\Delta BC = \left[\frac{PL}{AE}\right]_{BC} = \left[\frac{40\times10^3\times1000}{1256.63\times70\times10^3}\right] = 0.45mm$

Total ~~Deflecti~~ Deformation

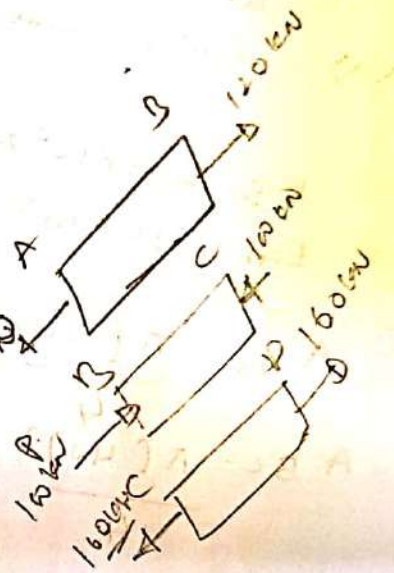
$\Delta = \Delta AB + \Delta BC = 0.509 + 0.45$

$\Delta = 0.963mm$ Elongation.

(4) A member ABCD is subjected to point load P_1, P_2, P_3 & P_4 as shown in fig. calculate the force P_3 for equilibrium if $P_1 = 120 KN$, $P_2 = 220 KN$, $P_4 = 160 KN$. Determine also the net change in length of the bar take $E = 2 \times 10^5 \, N/mm^2$.



For equilibrium



+ve $\sum H = 0$ $\quad -P_1 + P_2 - P_3 + P_4 = 0$

$-120 + 220 - P_3 + 160 = 0$

$$\boxed{P_3 = 260 KN}$$

Deformation in AB

$$\Delta_{AB} = \left[\frac{P_1 L}{AE}\right]_{AB} = \frac{120 \times 750}{40 \times 40 \times 200 \times 10^3}$$

$A_{AB} = 40 \times 40 = 1600 \, mm^2$

$$\boxed{\Delta_{AB} = 0.281 mm}$$ Elongation.

$$\Delta_{BC} = \left[\frac{P_2 L}{AE}\right]_{BC} = \frac{100 \times 10^3 \times 1000}{25 \times 25 \times 200 \times 10^3}$$

$$\boxed{\Delta_{BC} = -0.8 mm}$$ [Compression]

$$\Delta_{CD} = \left[\frac{PL}{AE}\right]_{CD} = \frac{160 \times 10^3 \times 1200}{900 \times 200 \times 10^3}$$

$A_{CD} = 30 \times 30 = 900 mm^2$

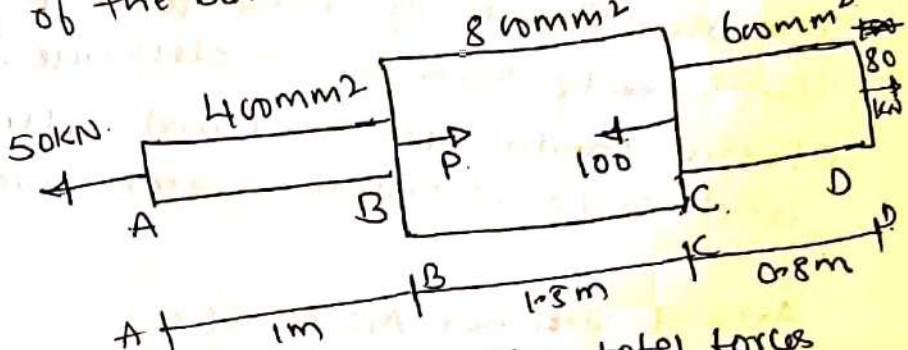
$$\boxed{\Delta_{CD} = 1.066 mm}$$

$\Delta = 0.281 - 0.8 + 1.066$

Total Deformation $\Delta = 0.547 mm$

5. A steel bar ABCD of varying sections is subjected to the axial forces as shown in fig. Find out the value of P necessary for equilibrium. If $E = 210\ kN/mm^2$, determine the total Elongation of the bar.

$E = 210\ kN/mm^2$
$= 210 \times 10^3\ N/mm^2$

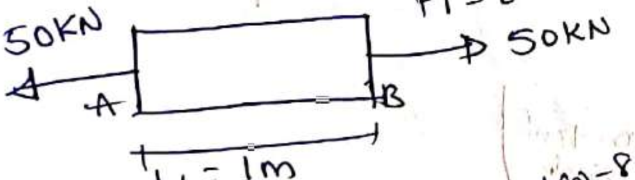


For the equilibrium of the bar equate the total forces acting towards right to the total forces acting to the left

$$-50 + P - 100 + 80 = 0$$

$$\boxed{P = 70KN.}$$

Now consider equilibrium of each of the parts AB, BC, and CD.



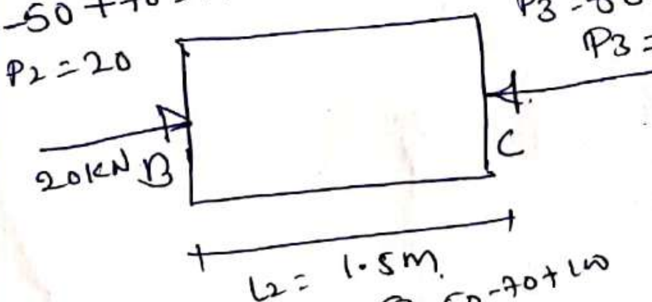
$P_1 = [70 - 100 + 80]$ → 50KN

$$\Delta_{AB} = \frac{P_1 L_1}{A_1 E}$$

$$\Delta AB = \frac{50 \times 10^3 \times 1000}{400 \times 210 \times 10^3} = 0.595mm\ [T]$$

$-50 + 70 = P_2$

$P_2 = 20$



100-80

$P_3 = 80 - 100$

$P_3 = 20\ kN$

$P_3 = 20kN.$

$$\Delta BC = \frac{P_2 L_2}{A_2 E}$$

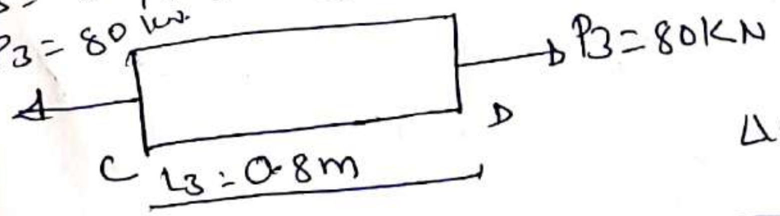
$$\Delta BC = \frac{20 \times 10^3 \times 1500}{800 \times 210 \times 10^3}$$

$$\boxed{\Delta BC = 0.178\ mm}$$

[compression]

$P_3 = -50 + 70 + 100$ (or) $50 - 70 + 100$

$P_3 = 80\ kN$



$$\Delta CD = \frac{P_3 L_3}{A_3 E}$$

$$\Delta CD = \frac{80 \times 10^3 \times 800}{600 \times 210 \times 10^3}$$

$$\boxed{\Delta CD = 0.507\ mm}\ [T]$$

Total Deformation $\Delta = \Delta_{AB} - \Delta_{BC} + \Delta_{CD} = 0.595 - 0.178 + 0.507$

$$\boxed{\Delta = 0.924mm}$$

Expression for deformation in case of uniformly tapering sections.

Case: 1 Uniformally tapering rod (or) Circular bar

Consider a uniformally tapering rod (or) Circular bar from d_1 to d_2 over a length 'L' subjected to Pull 'P' as shown in fig with E as youngs modulus.

M. E. Raghu.
Assistant Professor.
B. I. E. T.
Davanagere

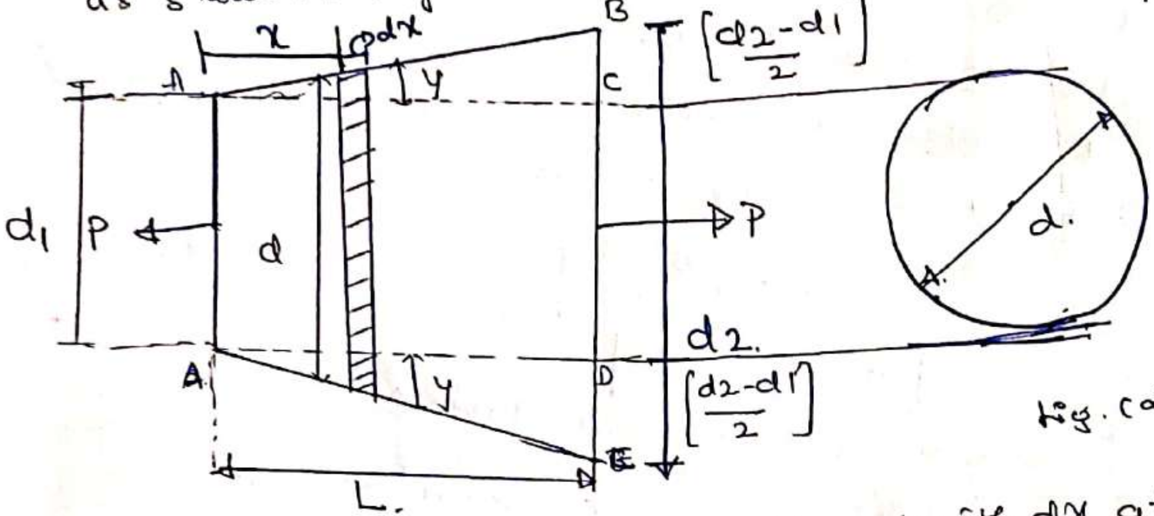
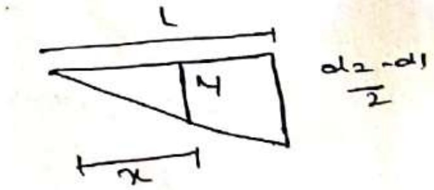


fig. (a)

Consider an elemental strip of length dx at a distance x as shown and Let the diameter of the section be d, as the section is uniformally tapering.

$$d = d_1 + y + y$$

$$d = d_1 + 2y.$$



From similar triangles;

$$\frac{\frac{d_2-d_1}{2}}{y} = \frac{L}{x}.$$

$$\boxed{y = \frac{d_2-d_1}{2L} \times x.}$$

$$d = d_1 + 2y$$

$$d = d_1 + 2\left[\frac{d_2-d_1}{2L}\right] \times x$$

Let $K = \frac{d_2-d_1}{L}$

$$d = d_1 + \left[\frac{d_2-d_1}{L}\right] \times x$$

$$\boxed{d = d_1 + K(x)} \quad \text{--- (1)}$$

Let 'P' be the axial load on a circular bar of length 'L' as shown in fig. The bar of length 'L' has a diameter d_1 at one end & d_2 at the other end.

Consider an elementary strip of Thickness dx at a distance 'x' from end A.

Let d_1 = Diameter at the smaller end.

d_2 = Diameter at the larger end.

L = length of the bar.

E = Young's modulus.

From fig & by considering similar triangles we get

$$d = d_1 + \left[\frac{d_2 - d_1}{L}\right] \cdot x \qquad K = \frac{d_2 - d_1}{L}$$

$$\boxed{d = d_1 + K \cdot x}$$

Area of section at distance 'x' from A

i.e $A = \frac{\pi d^2}{4}$ (circular section)

Length of ~~lettq~~ section $L = dx$.

w.k.T. $\Delta = \frac{PL}{AE}$ Let δ (or) Δ = deformation in the elementary strip.

∴ Extension in the elementary strip $= \frac{P \cdot dx}{\frac{\pi d^2}{4} \cdot E}$

Extension in the elementary strip: $\boxed{\frac{4P \cdot dx}{\pi d^2 \cdot E}}$

Total Extension of the bar is obtained by integrating the above equation b/w the limits 0 to L

i.e. $\Delta = \int_0^L \frac{4P \cdot dx}{\pi d^2 \cdot E}$

$$\Delta = \int_0^L \frac{4P \cdot dx}{\pi \cdot (d_1 + K \cdot x)^2 \cdot E}$$

$$\Delta = \frac{4P}{\pi E} \int_0^L \frac{dx}{(d_1 + Kx)^2}$$

w.o.n.s

$$\int (ax+b)^n \cdot dx$$

$$= \frac{1}{a} \frac{(ax+b)^{n-1}}{n+1}$$

$n \neq -1$

(or)

$$\int_0^L \frac{1}{(a+bx)^2} dx.$$

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$$\Delta = \frac{4P}{\pi E}\left[-\frac{1}{k}\left[\frac{1}{d_1+kx}\right]\right]_0^L$$

$$= \left(-\frac{1}{b}\right)\left[\frac{1}{a+bx}\right]_0^L$$

$$\Delta = \frac{-4PL}{\pi E(d_2-d_1)}\left[\frac{1}{d_1+\frac{[d_2-d_1]x}{L}}\right]_0^L$$

$$= \frac{-4PL}{\pi E[d_2-d_1)}\left[\frac{1}{d_1+\frac{[d_2-d_1]L}{L}} - \frac{1}{d_1+0}\right]$$

$$\Delta = \frac{-4PL}{\pi E[d_2-d_1]}\left[\frac{1}{d_2}-\frac{1}{d_1}\right]$$

$$= \frac{-4PL}{\pi E[d_2-d_1]}\left[\frac{d_1-d_2}{d_2 d_1}\right]$$

taking -ve inside.

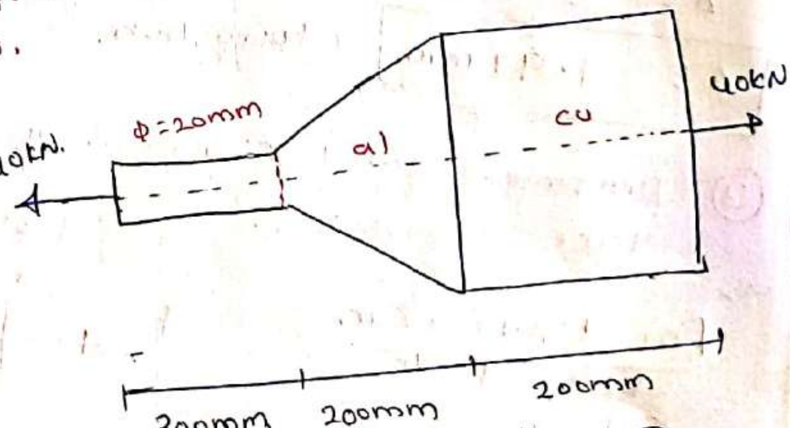
$$\frac{4PL}{\pi E[d_2-d_1]}\left[\frac{d_2-d_1}{d_1 d_2}\right]$$

$$\boxed{\Delta = \frac{4PL}{\pi E d_1 d_2}}$$

$d_1 = d_2 = d$

$$\boxed{\Delta = \frac{4PL}{\pi E d^2}}$$

1. A stepped bar is subjected to an external loading as shown in fig. calculate the change in length of the bar. $E_s = 200GPa$, $E_{al} = 70GPa$, $E_{cu} = 100GPa$.



$$\Delta = \Delta_s + \Delta_{al} + \Delta_{cu}$$

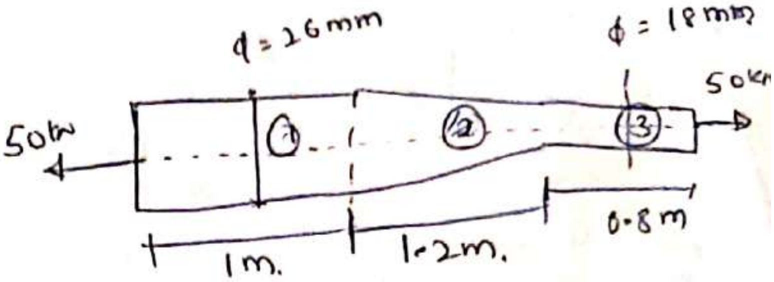
$$\Delta = \frac{PL}{AE} + \frac{4PL}{\pi E d_1 d_2} + \frac{PL}{AE}$$

$$= P\left[\frac{L}{AE} + \frac{4L}{\pi E d_1 d_2} + \frac{L}{AE}\right]$$

$$\Delta = 40\times10^3\left[\frac{300}{\pi\frac{[20]^2}{[4]}\times(200\times10^3)} + \frac{4\times200}{\pi\times70\times10^3\times20\times50} + \frac{200}{\frac{\pi[50]^2}{4}[100\times10^3)}\right]$$

$$\Delta = 0.375mm$$

② Find the total elongation of the bar shown in fig. subjected to an axial load of 50kN. Take $E = 2.1\times10^5$ MPa.



→ $P = 50\times10^3 N$. $d_1 = 26mm$

$E = 2.1\times10^5$ MPa $d_2 = 18mm$

$E = 2.1\times10^5 N/mm^2$.

1m = 1000mm

1.2 = 1200mm

$A_1 = \frac{\pi d_1^2}{4} = \frac{\pi [26]^2}{4} = 530.92 mm^2$

$A_2 = \frac{\pi d_2^2}{4} = \frac{\pi [18]^2}{4} = 254.46 mm^2$

The total elongation $\Delta = \Delta_1 + \Delta_2 + \Delta_3$

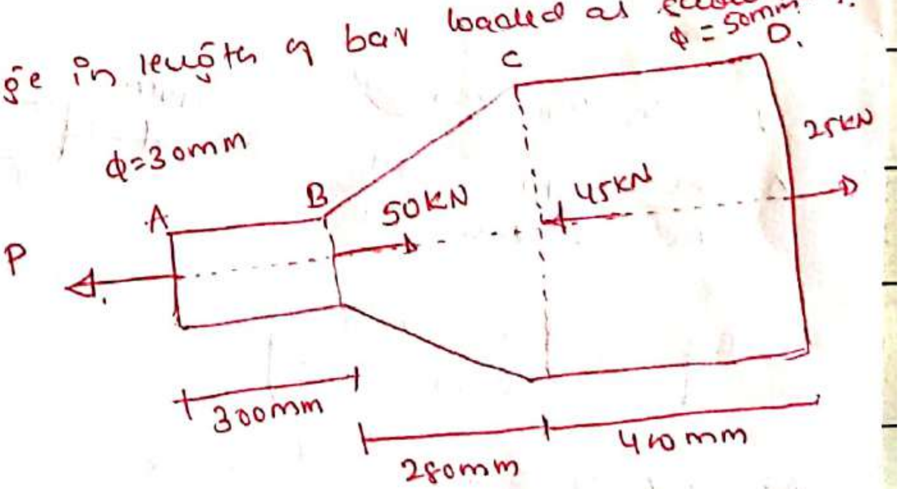
$$\Delta = \left(\frac{PL}{A_1 E}\right)_1 + \left[\frac{4PL}{\pi E d_1 d_2}\right]_2 + \left[\frac{PL}{A_2 E}\right]_3$$

$$\Delta = \left[\frac{50\times10^3 \times 1\times10^3}{530.9\times2.1\times10^5}\right] + \left[\frac{4\times50\times10^3\times1.2\times10^3}{\pi\times2.1\times10^5\times26\times18}\right] + \left[\frac{50\times10^3\times0.8\times10^3}{254.46\times2.1\times10^5}\right]$$

$\Delta = 0.448 + 0.777 + 0.748$.

$\Delta = 1.97 mm.$ Elongation.

③ Determine total change in length of bar loaded as shown in fig. Take E = 200GPa.



→ For Equilibrium

→ +ve ← -ve

$\Sigma H = 0$

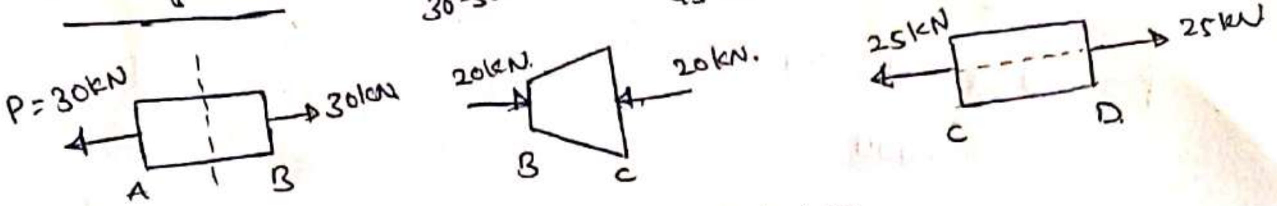
$-P + 50 - 45 + 25 = 0$

$-P + 30 = 0$

$P = 30kN.$

At segment ①

30-50=-20 45-25=20



total Deformation $\Delta = \pm \Delta AB \pm \Delta BC \pm \Delta CD$

$$\Delta = \left[\frac{PL}{AE}\right]_{AB} \pm \left[\frac{4PL}{\pi E d_1 d_2}\right]_{BC} \pm \left[\frac{PL}{AE}\right]_{CD}.$$

Tension = +ve
compression = -ve

200 GPa
200×10^9 N/mm²
GPa = 10^3 (MPa)
$E = 200\times10^3$ N/mm²

$$A_1 = \frac{\pi (d_1)^2}{4} = \frac{\pi[30]^2}{4} = 706.85\,mm^2,$$

$$A_2 = \frac{\pi[d_2]^2}{4} = \frac{\pi[50]^2}{4} = 1963.49\,mm^2$$

$$\Delta = \left[\frac{30\times10^3\times300}{706.85\times200\times10^3}\right]_{AB} - \left[\frac{4\times20\times10^3\times280}{\pi\times200\times10^3\times30\times50}\right]_{BC} + \left[\frac{25\times10^3\times400}{1963.49\times200\times10^3}\right]_{CD}$$

$$\Delta = (0.063)_{AB} - (0.023)_{BC} + [0.025]_{CD}$$

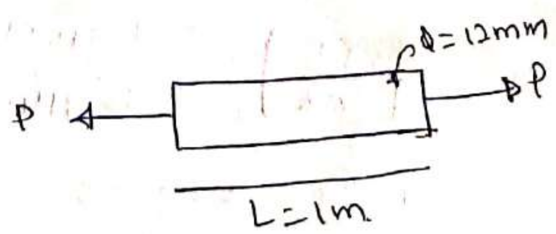
Δ = Elongation - shortening + Elongation

$\Delta = 0.065\,mm$

(4) A rod of 12mm dia and 1m long is subjected to a tensile load of P in such a way that elongation should not be more than 0.4mm. find the value of P if $E = 2\times10^5$ N/mm²

ws $d = 12mm$, $L = 1m = 1000mm$ $P = ?$ $\Delta = 0.4mm$

$E = 2\times10^5$ N/mm²



$$\Delta = \frac{PL}{AE}$$

$$0.4\,mm = \frac{P\times1000mm}{113.09\,mm^2\times2\times10^5\,N/mm^2}$$

$$A = \frac{\pi(12)^2}{4} = 113.09\,mm^2$$

$$P = \frac{\Delta AE}{L}$$

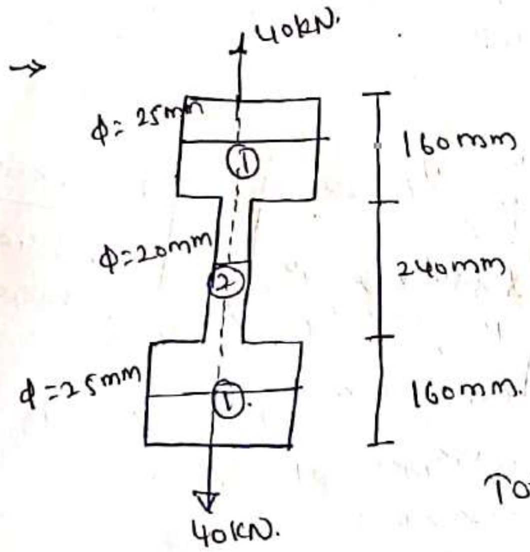
$$P = \frac{0.4 \times 113.09 \times 2 \times 10^5}{1000}$$

$P = 9047.2 N$

$P = 9.047 \times 10^3 N$

$$\boxed{P = 9.047 kN}$$

(15) A bar shown in fig is tested in UTM, it is observed that a load of 40kN total Extension is 0.285mm. Determine young's modulus.



$P = 40kN$. $\Delta = 0.285$ (mm) $E = ?$

$$A_1 = \frac{\pi [d_1]^2}{4} = \frac{\pi (25)^2}{4} = 490.87 mm^2$$

$$A_2 = \frac{\pi (d_2)^2}{4} = \frac{\pi (20)^2}{4} = 314.15 mm^2$$

$L_1 = L_3 = 160mm$, $d_1 = 25mm$

$L_2 = 240mm$, $d_2 = 20 mm$.

Total Deformation $\Delta = \Delta_{AB_1} + \Delta_{BC_2} + \Delta_3$

$\Delta = 0.285mm$

but $E = ?$

$$\Delta = \frac{PL}{AE}$$

$$1 = E_3 = E = \left(\frac{PL}{A\Delta}\right)_1 = \left[\frac{40 \times 10^3 \times 160}{490.8 \times 0.285}\right]_1 = 45754.15 N/mm^2$$

$$E_2 = \left[\frac{PL}{A\Delta}\right]_2 = \left[\frac{40 \times 10^3 \times 240}{314.15 \times 0.285}\right]_2 = 107223.33 N/mm^2$$

$E = E_1 + E_2 + E_3$

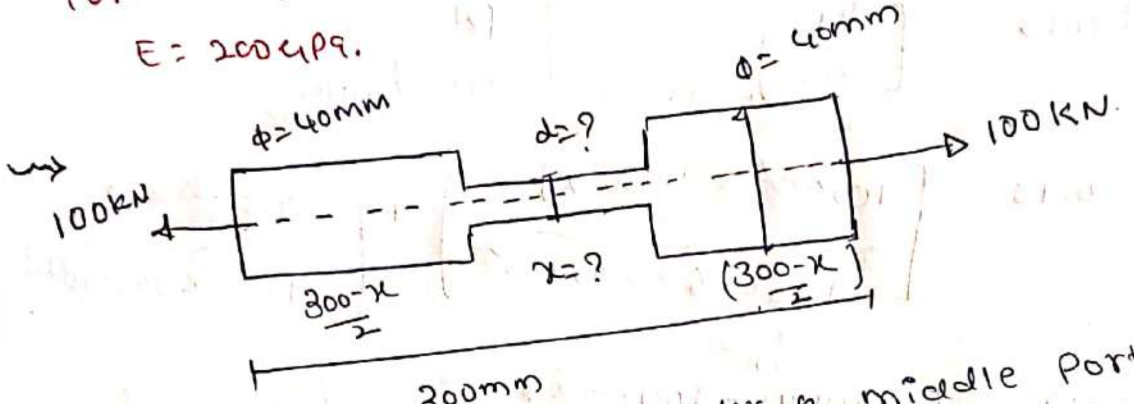
$E = 45754.15 + 107223.33 + 45754.15$

$E = 198731.63 MPa$.

$$\boxed{E = 1.98 \times 10^5 N/mm^2}$$

(5) A bar shown in fig is subjected to loading. find the diameter of the middle portion. if the stress their is to be limited to 100 kN/mm2. Also find the length of the middle portion. if total extension of the bar is to be 0.13mm. give

E = 200GPa.



case: 1 Let 'd' be the diameter of middle portion

if $f = 100\ N/mm^2$ $P = 100kN$.

$$f = \frac{P}{A} = \frac{100\,kN \times 10^3}{\frac{\pi d^2}{4}}$$

$$100 = \frac{100 \times 10^3 \times 4}{\pi d^2}$$

$$d^2 = \frac{100 \times 10^3 \times 4}{100 \times \pi}$$

$$d^2 = 1273.2.$$

$$d = \sqrt{1273.2}$$

$$\boxed{d = 35.68\ mm}$$

$$A_1 = \frac{\pi [40]^2}{4} = 1256.63\ mm^2$$

$$A_2 = \frac{\pi [35.68]^2}{4} = 999.86\ mm^2$$

$= 1000\ mm^2$

case: 2

Let x be the length of the middle portion

$\delta = \delta_1 + \delta_2 + \delta_3 = 0.13m$ $E = 200\ GPa = 200 \times 10^3\ N/mm^2$

total elongation $\Delta = \left[\begin{array}{c}\text{Elongation of}\\ \text{outer segments}\end{array}\right] + \left[\begin{array}{c}\text{Elongation of}\\ \text{middle segment}\end{array}\right]$

$$0.13 = \left[\frac{PL}{AE}\right]_{outer} + \left[\frac{PL}{AE}\right]_{Inner\ (middle)}$$

$$0.13 = \left[\frac{100\times10^3 \times [300-x]}{1256.6\times200\times10^3}\right] + \left[\frac{100\times10^3\times x}{1000\times200\times10^3}\right]$$

$$0.13 = \left[\frac{(30000\times10^3 - 100\times10^3\times x)}{1256.6\times200\times10^3}\right] + \left[\frac{100x\times10^3}{1000\times200\times10^3}\right]$$

check

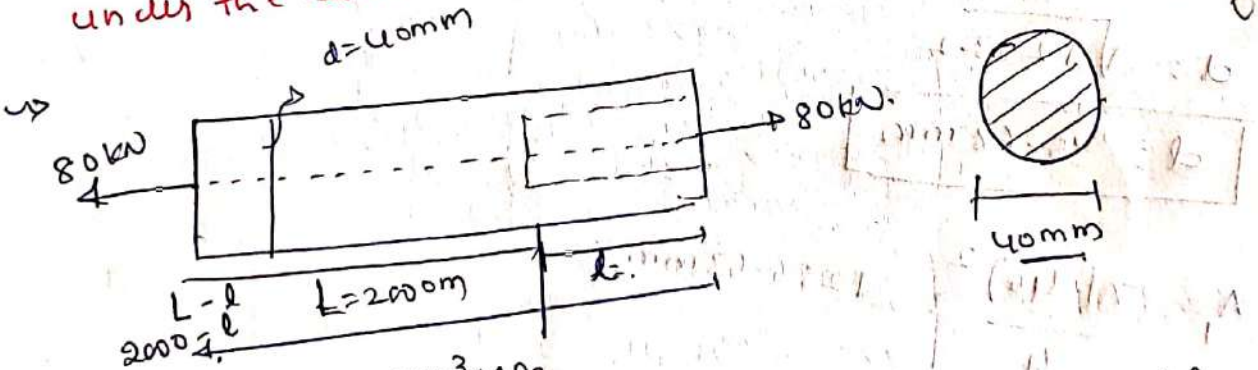
$$0.13 = \left(\frac{30000 - 100x}{251320}\right) + \left[\frac{100x}{2\times10^5}\right]$$

~~0.0115x +~~

$x = 106.8\,mm$ (Tension)

⑥ A steel tie bar of 40mm diameter and 2m long is subjected to a pull of 80kN. Calculate length of hole of diameter 20mm to be drilled in the rod so that final extension of the entire bar increased by 20%. E = 200GPa under the same pull.

$E = 2\times10^5\ N/mm^2$



$E = 200\ GPa = 200\times10^3\ MPa$

Case:1 Deformation in the solid bar [before hole drilling]

$$\Delta = \frac{PL}{AE} = \frac{80\times10^3[2000]}{\frac{\pi(40)^2}{4}\times[200\times10^3]} = 0.63\,mm$$

$\boxed{\Delta = 0.63\,mm}$

Case: 2 Deformation in the bar due to a of dia 20mm.

$$\Delta' = \frac{PL}{AE} =$$

$$\Delta = \Delta + (20\% (\Delta))$$

$$= 0.63 + 20\% (0.63)$$

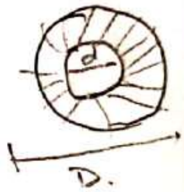
$$\Delta = 0.63 + 0.126$$

$$\boxed{\Delta = 0.756 \text{mm}}$$

Let x be the length of the bore drilled

[Deformation in undrilled portion (solid portion)] + [Deformation in drilled portion] = 0.756

$$\frac{P[2000 - l]}{\frac{\pi}{4}(40)^2 \times 200\times10^3} + \frac{P(l)}{\frac{\pi}{4}(40^2 - 20^2) \times 200\times10^3} = 0.756$$



$P = 80\times10^3$

$$A = \frac{\pi D^2}{4}$$

$$A = \frac{\pi d^2}{4}$$

$$A = \frac{\pi}{4}[D^2 - d^2]$$

$$\frac{80\times10^3(2000 - l)}{\frac{\pi}{4}(40)^2 \times 200\times10^3} + \frac{80\times10^3 l}{\frac{\pi}{4}(40^2 - 20^2) \times 200\times10^3} = 0.756$$

$$\frac{160\times10^6 - 80\times10^3 l}{1256 \times 200\times10^3} + \frac{80\times10^3 l}{942.477 \times 200\times10^3} = 0.756$$

$$\frac{160\times10^6 - 80\times10^3 l}{1256\times200\times10^3} + 4.244\times10^{-4} l = 0.756$$

$$0.6366 - 3.1847\times10^{-4} l + 4.244\times10^{-4} l = 0.756$$

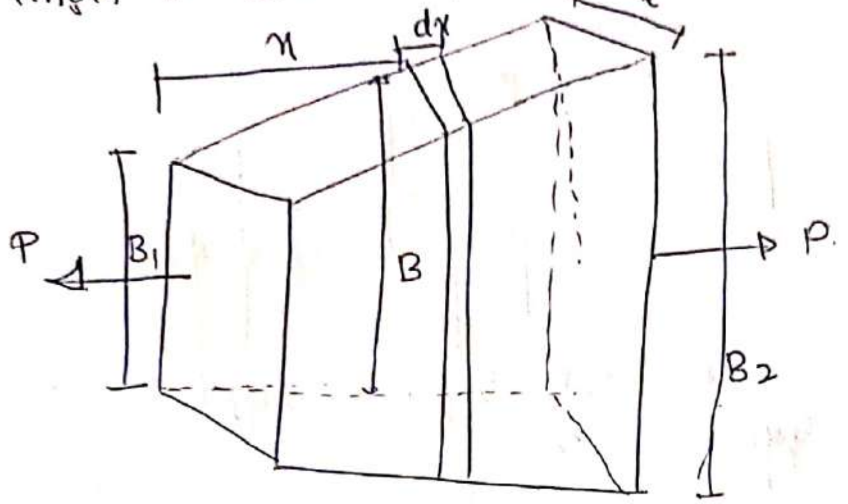
$$7.4287\times10^{-4} l = 0.756 - 0.6366$$

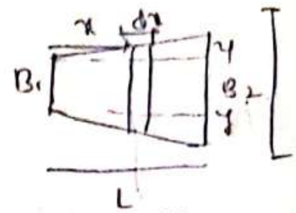
$$l = \frac{0.1194}{7.4287\times10^{-4}}$$

$l =$ ___ .

* Deformation in case of a uniformly tapering plate (Rectangular section)

Consider a plate of constant thickness 't' tapering uniformally from breadth B_1 to B_2 subjected to an axial pull 'P' over a length 'L' with E young's modulus as shown in fig.



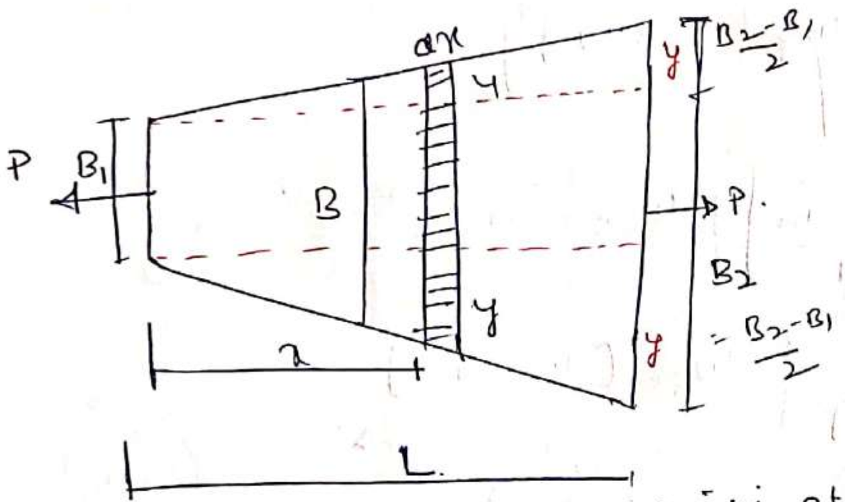


~~$B = B_1 + B_2$~~

$B = B_1 + y + y$

$$B = B_1 + 2y$$

$$y = \frac{B_2 - B_1}{2}$$



$L \Rightarrow \left(\frac{B_2 - B_1}{2}\right)$

$x \Rightarrow y$.

$$y = \left(\frac{B_2 - B_1}{2}\right)\left(\frac{x}{L}\right)$$

$$y = \left(\frac{B_2 - B_1}{2}\right)\frac{x}{L}$$

Consider an elemental length 'dx' at a distance 'x' ~~in which~~ from the B_1. Let deformation 'δ' (or) Δ and breath as B.

from the fig

$$B = B_1 + 2y$$

$B = B_1 + y + y$

$$= B_1 + 2\left[\frac{B_2 - B_1}{2}\right]\frac{x}{L}$$

$$= B_1 + \left[\frac{B_2 - B_1}{L}\right]x.$$

where $K = \frac{B_2 - B_1}{L}$

$$B = B_1 + Kx$$

Hence $\delta = \frac{PL}{AE}$ $\delta = \frac{P \times (dx)}{(B \times t) E} = \frac{P\,dx}{(t \times E)(B)}$

Area of Rectangular section $A = B \times t$ = Breadth × thickness

Substituting the B in this equation

$$\delta = \frac{P\,dx}{Et[B_1+Kx]}$$ δ for Elemental area

Hence Deformation for complete plate.

$$\Delta = \int_0^L \frac{P}{Et[B_1+Kx]}\,dx = \frac{P}{Et}\int_0^L \frac{1}{(B_1+Kx)}\,dx$$

w.k.T.

$$\int_0^L \frac{1}{(a+bx)}\,dx = \frac{1}{b}\log[a+bx]$$

$$\Delta = \frac{P}{Et}\left[\frac{1}{K}\log[B_1+Kx]\right]_0^L$$

$$\Delta = \frac{P}{Et}\left[\left(\frac{1}{\frac{B_2-B_1}{L}}\right)\right)\log_e\left[B_1+\left[\frac{B_2-B_1}{L}\right]x\right]$$

$$\Delta = \frac{PL}{Et[B_2-B_1]}\left[\log_e[B_2-B_1]\right]$$

$$\Delta = \frac{P}{Et}\left[\frac{L}{(B_2-B_1)}\right]\log_e\left(B_1+\frac{(B_2-B_1)}{L}L\right)$$

$$\Delta = \frac{PL}{Et(B_2-B_1)}\log_e\left(\frac{B_2}{B_1}\right)$$

$$- \log_e B_1$$

$$= \frac{PL}{Et(B_2-B_1)} \times \log_e(B_2 - \log_e(B_1)$$

$$= \frac{PL}{Et(B_2-B_1)} \times \log_e[B_2-B_1)$$

$$\log_e\left[\frac{B_2}{B_1}\right]$$

$$\Delta = \frac{PL}{AEt(B_2-B_1)}$$

$$\boxed{\Delta = \frac{2.303PL}{Et[B_2-B_1]}\log_{10}\left(\frac{B_2}{B_1}\right)}$$

$A = b \times t$ ...... where $b = b_1 + Kx$.

$A = [b_1 + K \cdot x] t$

length of elementary section $l = dx$.

w.k.t. $\Delta = \frac{PL}{AE}$ $\qquad K = \frac{b_2 - b_1}{L}$

$$\Delta = \frac{P \cdot dx}{(bxt) \cdot E}$$

$$\boxed{\Delta = \frac{P \cdot dx}{(b_1 + K \cdot x) \cdot t \cdot E}}$$

Total Extension of the bar is obtained by integrating the above equation b/w the limits 0 to L

$$\Delta = \int_0^L \frac{P \cdot dx}{(b_1 + K \cdot x) t \cdot E}$$

$\int \frac{1}{(a+bx)} dx = \frac{1}{b} \log(a+$

$= \frac{1}{b} \log [a + bx]$

$$\Delta = \frac{P}{t \cdot E} \int_0^L \frac{dx}{(b_1 + K \cdot x)}$$

$$\Delta = \frac{P}{t \cdot E} \left[\frac{1}{K} \times \log [b_1 + Kx]_0^L \right]$$

$\log (a-b) = \log \left[\frac{a}{b}\right]$

$$\Delta = \frac{P}{t \cdot E \cdot K} \left[\log_e b_1 + K \cdot L - \log_e b_1 + \cancel{K \cdot 0} \right]$$

$$\Delta = \frac{P}{t \cdot E \cdot K} \left[\log_e \left[\frac{b_1 + K \cdot L}{b_1} \right] \right]$$

$$\Delta = \frac{P}{t \cdot E \cdot K} \left[\log_e \left[\frac{\cancel{b_1} + \frac{b_2 - \cancel{b_1}}{\cancel{L}} \times \cancel{L}}{b_1} \right] \right]$$

$$\Delta = \frac{P}{t \cdot E K} \left[\log_e \left[\frac{b_2}{b_1} \right] \right] \quad \text{(or)} \quad \Delta = \frac{P}{t \cdot E \left(\frac{b_2 - b_1}{L} \right)} \left[\log_e \left[\frac{b_2}{b_1} \right] \right]$$

$$\Delta = \frac{PL}{t \cdot E \times (b_2 - b_1)} \times \log_e \left[\frac{b_2}{b_1} \right]$$

$$\Delta = \frac{2.303\, PL}{t \cdot E (b_2 - b_1)} \log_{10} \left[\frac{b_2}{b_1} \right]$$

1. A brass plate of uniform thickness 6mm varies in width from 100mm to 180mm over a length of 600mm with a tensile load of 40kN. Find the elongation of the bar if E = 82 GPa.

ans> $t = 6mm$

$B_1 = 100mm$

$B_2 = 180mm$

$L = 600mm$

$E = 82 GPa = 82\times10^3 MPa = 82\times10^3 N/mm^2$

$P = 40kN$

$\Delta = ?$

$$\Delta = \frac{2.303 PL}{Et[B_2 - B_1]} \log\left[\frac{B_2}{B_1}\right]$$

$$\Delta = \frac{2.303\times40\times10^3\times600}{82\times10^3\times6\times[180-100]} \log\left[\frac{180}{100}\right]$$

$$\boxed{\Delta = 0.358 mm}$$

② A rectangular bar made of steel is 2.8m long & 15mm thick. The rod is subjected to an axial tensile load of 40kN. The width of the rod varies from 75mm at one end to 30mm at the other. Find the extension of the rod if $E = 2\times10^5 N/mm^2$

ans> $L = 2.8m = 2800mm$

$t = 15mm$

$P = 40kN = 40,000N$

$B_2 = 75m.$

$B_1 = 30mm$

$\Delta = ?$

$E = 2\times10^5 N/mm^2$

$$\Delta = \frac{2.303\times PL}{Et[B_2 - B_1]} \log\left[\frac{B_2}{B_1}\right]$$

$$\Delta = \frac{2.303\times40,000\times2800}{2\times10^5\times15[75-30]} \log\left[\frac{75}{30}\right]$$

$$\boxed{\Delta = 0.76mm}$$

③ The extension of a rectangular steel bar of length 400mm & thickness 10mm, is found to be 0.21mm. The bar tapers uniformly in width from 100mm to 50mm. If E for the bar is $2\times10^5 N/mm^2$. determine the axial load on the bar

* $L = 400mm$

$t = 10mm$

$\delta l = 0.21mm$

$B_2 : 100mm$

$B_1 : 50mm$

$E = 2\times10^5 N/mm^2$

$P = ?$

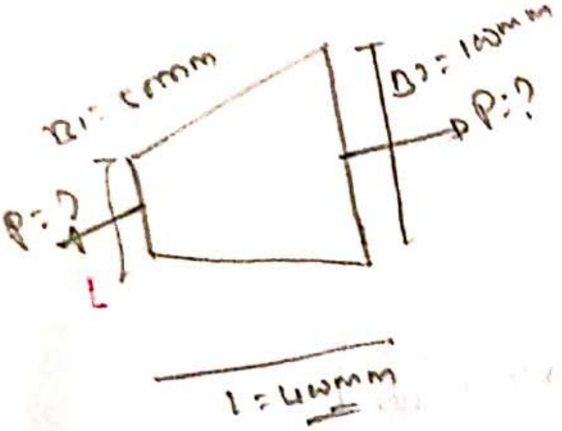
$$\delta l = \frac{2.303 PL}{Et(B_2 - B_1)} \log_{10}\left[\frac{B_2}{B_1}\right]$$

$$0.21 = \frac{2.303 \times P \times 400}{2\times10^5 \times 10(100-50)} \log 10\left[\frac{100}{50}\right]$$

$$0.21 = \frac{921.2 P}{100\times10^6} \times 0.30$$

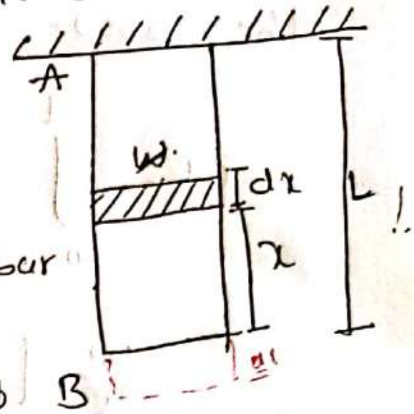
$$0.21 = \left[9.212\times10^{-6}\right] P \times 0.30$$

$$P = 75.98 kN$$



Elongation of a Bar due to its own weight

Fig shows a bar AB fixed at end A & hanging freely under its own weight



Let L = length of the bar

A = Area of cross section.

E = young's modulus for the bar material.

w = weight per unit volume of B the bar material.

Consider a small strip of thickness dx at a distance x from the lower end (B).

weight of the bar for a length of x is given by

weight of the bar for a length x = Specific weight × volume of bar upto length x

$P = \text{Specific weight} \times \text{volume of}$

$P = w \times A \times x$

This means that on the strip, a weight of $w \times A \times x$ is acting in the downward direction. Due to this weight, there will be some increase in the length of element. But length of the element is dx.

Now stress on the element $= \dfrac{\text{weight acting on element}}{\text{Area of cross section}}$

$$= \frac{w \times A \times x}{A} = w \cdot x.$$

The above equation shows the stress due to self weight is not uniform. It depends on x. The stress increases with increase of x.

$$\text{Strain in the element} = \frac{\text{Stress}}{E} = \frac{w \times x}{E}$$

∴ Elongation of the element

$= \text{strain} \times \text{length of element}$

$$= \frac{w \times x}{E} \times dx$$

$$= \frac{w x}{E} \cdot dx.$$

Total elongation of the bar is obtained by integrating the above equation b/w limits 0 to L

$$\delta L = \int_0^L \frac{w \times x}{E} dx = \frac{w}{E}\int_0^L x \cdot dx$$

$$= \frac{w}{E}\left[\frac{x^2}{2}\right]_0^L$$

$W = w \times L$

$$= \frac{w}{E}\left[\frac{L^2}{2}\right]$$

$$\boxed{\delta L = \frac{WL}{2E}}$$

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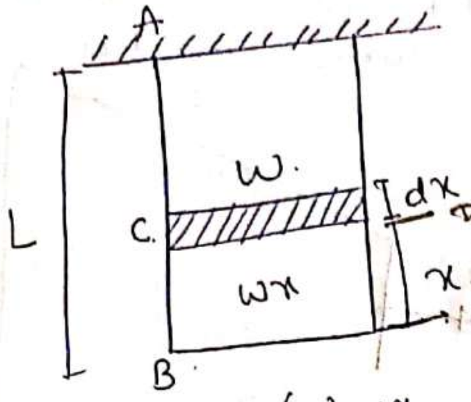
Elongation due to self weight :

Consider a bar AB of length 'L' hanging freely under its own weight 'W' as shown in fig. Let 'A' be the uniform cross section.



Consider a small strip dx at a distance x from 'B', with the weight of the portion as Wx. The deformation in this element strip:

$$\delta = \frac{PL}{AE} = \frac{(Wx)(dx)}{A.E}$$

$\rho = \frac{wt}{Volume}$

w.k.T.

$wt = volume \times \rho$

Specific weight $= volume \times density$

$W = V\rho$

$W = (A \times L)\rho$

$W_x = (A \times x)(\rho)$

$\rho = \frac{W_x}{V}$

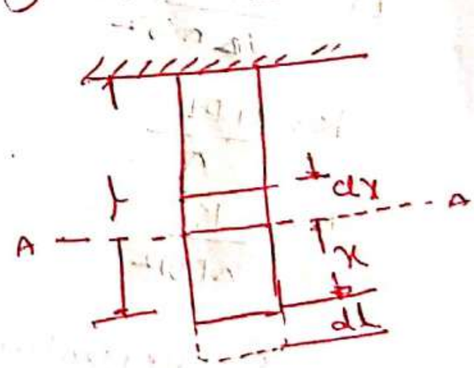
$$\delta = \frac{(A \times x)(\rho)\,dx}{AE}$$

$$\delta = \frac{\rho x . dx}{E}$$

Deformation in complete bar.

$$\Delta = \int_0^L \frac{\rho x . dx}{E} \qquad \int_0^L \frac{\rho . x . dx}{E}$$

$$\Delta = \frac{\rho}{E}\left[\frac{x^2}{2}\right]_0^L = \frac{\rho L^2}{2.E} \qquad \rho = \frac{wt}{V}$$



$$\Delta = \frac{WL^2}{2EV} = \frac{WL^2}{2E(A.L)}$$

volume of the bar $= A \times L$

$$\boxed{\Delta = \frac{WL}{2AE}}$$

Thus the deformation of the bar under its own weight is equal to half the deformation, if the body is subjected to the direct load equal to the weight of the body.

$$\boxed{\Delta = \frac{1}{2}\frac{PL}{AE}}$$

$$\Delta = \frac{1}{2}\frac{PL}{AE}$$

Analysis of Bars of composite sections :

A bar made up of two (or) more bars of equal lengths but of different materials rigidly fixed with each other and behaving as one unit for extension (or) compression when subjected to an axial tensile (or) compressive loads is called a composite bar.

Let P = total load on the composite bar

L = length of composite bar.

A_1 = Area of cross sectional of bar 1

A_2 = — " — bar 2

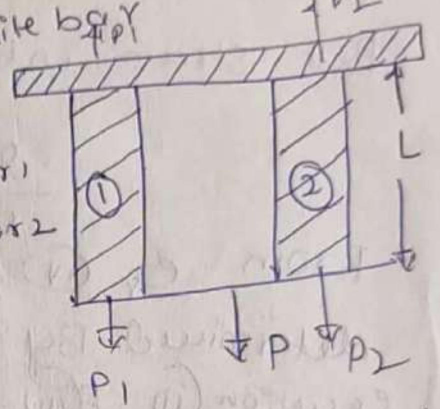
E_1 = youngs modulus of bar 1

E_2 = youngs modulus of bar 2

P_1 = load shared by bar 1.

P_2 = load shared by bar 2.

σ_1 = stress induced in bar (1) σ_2 = stress induced bar (2)



Now the total load on the composite bar is equal to the sum of the load carried by the two bars.

$$P = P_1 + P_2 \rightarrow (i)$$

The stress in bar (1) $\sigma_1 = \frac{\text{Load carried by bar 1}}{\text{Area of cross sectional of bar 1}} = \frac{P_1}{A_1}$

$$\boxed{P_1 = \sigma_1 A_1} \rightarrow (ii)$$

The stress in bar (2)

$$\sigma_2 = \frac{P_2}{A_2} = \boxed{P_2 = \sigma_2 A_2} \rightarrow (iii)$$

Substituting the value of P_1 and P_2 in eq (1)

we get

$$P = P_1 + P_2$$

$$\boxed{P = \sigma_1 A_1 + \sigma_2 A_2} \rightarrow (iv)$$

Since the ends of the two bars are rigidly connected each bar will change in length by same amount. also the length of each bar is same and hence the ratio of change in length to the original length.

But strain in bar 1 $= \frac{\text{stress in bar (1)}}{\text{Youngs modulus of bar (1)}}$

$= \frac{\sigma_1}{E_1}$

Strain in bar $2 = \frac{\sigma_2}{E_2}$.

But strain in bar 1 = strain in bar 2

$$\frac{\sigma_1}{E_1} = \frac{\sigma_2}{E_2} \longrightarrow (V)$$

From eq (IV) & V, the stresses σ_1 & σ_2 can be determined By substituting the values of σ_1 & σ_2 in equation (ii) & (iii). the load carried by different materials may computed.

Modular ratio.:

It is the ratio of Youngs modulus of one material to another [i.e E_1/E_2] & is denoted by M & is constant.

From compatability condition.

We have $\frac{\sigma_1}{E_1} = \frac{\sigma_2}{E_2}$

$$\sigma_1 = \sigma_2\left[\frac{E_1}{E_2}\right]$$

$$\boxed{M = \frac{E_1}{E_2}}$$

Problems on composite sections:

① A steel rod of 3 cm diameter is enclosed centrally in a hollow copper tube of External diameter 5 cm and internal diameter of 4 cm. The composite bar is then subjected to an axial pull of 45000N. If the length of each bar is equal to 15 cm, determine.

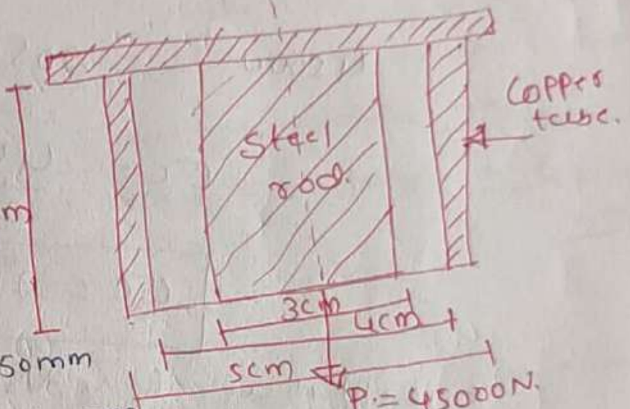
1. Stresses in the rod and tube and.
2. Load carried by each bar.

take E of steel = 2.1×10^5 N/mm², E for copper = 1.1×10^5 N/mm²

Given
⇒ Diameter of steel rod = 3 cm = 30 mm

Area of steel rod $A_s = \frac{\pi (30)^2}{4}$

$A_s = 706.85\ mm^2$



External Dia of copper tube = 5 cm = 50 mm

Internal Dia of copper tube = 4 cm = 40 mm

Area of copper tube $A_c = \frac{\pi}{4}[50^2 - 40^2] = 706.85\ mm^2$.

Axial pull of composite bar P = 45000N.

Length of Each bar L = 15 cm = 150 mm.

Youngs modulus of steel $E_s = 2.1 \times 10^5$ N/mm².

Youngs modulus of copper $E_c = 1.1 \times 10^5$ N/mm².

① Stress in the rod and tube.

Let σ_s = Stress in steel. σ_c = stress in copper

P_s = Load carried by steel rod P_c = Load carried by copper tube.

Now Strain in steel = Strain in copper

$\frac{\sigma}{E}$ = Strain

$$\frac{\sigma_s}{E_s} = \frac{\sigma_c}{E_c}$$

$\frac{\sigma}{e} = E$

$$\sigma_s = \frac{E_s}{E_c}\sigma_c$$

$$\sigma_s = \frac{2.1 \times 10^5}{1.1 \times 10^5} \times \sigma_c$$

$$\sigma_s = 1.909\ \sigma_c \quad \rightarrow (1)$$

Now stress = $\frac{\text{Load}}{\text{Area}}$ Load = stress × Area

Total Load = Load on steel + Load on copper.

P = $\sigma_s \times A_s + \sigma_c \times A_s$

P = $1.909\sigma_c \times 706.86 + \sigma_c \times 706.86$

45000 = $(1.909\sigma_c \times 706.86) + (\sigma_c \times 706.86)$

= $1349.395\sigma_c + 706.86\sigma_c$

45000 = $2056.25\sigma_c$

$\sigma_c = \frac{45000}{2056.25} = 21.88$

$\sigma_c = 21.88\ N/mm^2$

Substituting this value in eq ①

we get

$\sigma_s = 1.909\sigma_c$

$\sigma_s = 1.909 \times 21.88$

$\sigma_s = 41.77\ N/mm^2$

② Load carried by each bar.

As Load = Stress × Area.

Load carried by steel rod.

P_s = Stress (σ_s) × AS.

$P_s = 41.77 \times 706.86$

P_s = ~~29530~~ 29525.54N.

$P_s = 29.525\ kN$

Load carried by copper tube.

P_c = Stress (σ_c) × Ac.

= 21.88×706.86

PC = 15466.09 N

PC = 15.466 kN.

(Q2) A compound tube consists of a steel tube 140mm internal diameter and 160mm External diameter and an outer brass tube 160mm internal diameter and 180mm External diameter. The The two tubes are of the same length. The compound tube carries an axial load of 900 kN, Find the stresses and the load carried by each tube and the amount it shortens. Length of each tube is 140mm. Take E for steel as 2×10^5 N/mm2 and for brass as 1×10^5 N/mm2.

→ Internal dia of steel = 140mm.
outer dia of Steel = 160mm

Area of steel tube = $\frac{\pi}{4}(160^2 - 140^2)$ =

Area of steel tube = 4712.38 mm^2

Internal dia of brass = 160mm
outer dia of brass = 180mm

Area of brass tube = $\frac{\pi}{4}(180^2 - 160^2)$

Area of brass tube = 5340.70 mm^2

Axial load P = 900kN = 900×10^3 N.

length of Each tube = 140mm. $E_s = 2\times10^5$ N/mm2 $E_b = 1\times10^5$ N/mm2

let σ_s = stress in steel, σ_b = stress in brass

Now strain in steel = strain brass

Strain = $\frac{\text{Stress}}{E}$

$$\frac{\sigma_s}{E_s} = \frac{\sigma_b}{E_b}$$

$$\sigma_s = \frac{E_s}{E_b}\cdot\sigma_b$$

$$\sigma_s = \frac{2\times10^5}{1\times10^5}\sigma_b$$

$$\sigma_s = 2\sigma_b \rightarrow (1)$$

Stress = $\frac{\text{Load}}{A}$

Stress × A

Now, Load in Steel + Load in brass = total load.

$$\sigma_s \times A_s + \sigma_b \times A_B = 900\times10^3$$

$$2\times\sigma_b\times 4712.38 + \sigma_b\times 5340.70 = 900\times10^3$$

$$9424.76\,\sigma_b + 5340.70\,\sigma_b = 900\times10^3$$

$$\sigma_b = 60.95 \text{ N/mm}^2$$

Stress in brass σ_b = 60.95 N/mm2

Substituting this σ_b in eq (1) we get.

$\sigma_s = 2 \times 60.95$

$\sigma_s = 121.9\ N/mm^2$

Load carried by brass tube = Stress × Area

$= \sigma_b \times A_b$

$= 60.95 \times 5340.7$

$= 325515.66\ N$

$P_b = 325.515\ kN$

Load carried by steel tube = stress × area

$= \sigma_s \times A_s$

$= 121.9 \times 4712.4$

$= 574441.56\ N$

$P_s = 574.441\ kN$

Decrease in length of compound tube

= Decrease in length of either of the tubes.

= Decrease in length of brass tube

= Strain in brass tube × original length

$= \frac{\sigma_b}{E_b} \times L$ (or) $\frac{\sigma_s}{E_s} \times L$

$= \frac{60.95}{1\times10^5} \times 140$; $\frac{121.9}{2\times10^5} \times 140 = 0.0853\ mm$

$= 0.0853\ mm$

Strain $= \frac{\delta L}{L}$

δL = strain × length (original)

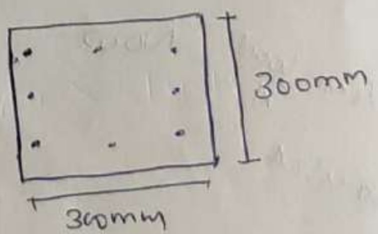
$\frac{\delta L}{L}$ = strain

δL = strain × L

$\delta L = \frac{stress}{E_b} \times L$

$\delta L = \frac{stress\ in\ brass}{E_b} \times L$

(3) A reinforced concrete column is 300mm × 300mm in section. The column is provided with 8 bars of 20mm dia. The column carries a load of 360kN. Find the stress in concrete and steel if $E_s = 2.1\times10^5\ N/mm^2$ and $E_c = 0.14\times10^5\ N/mm^2$



→ Area of column = 300 × 300

$= 90000\ mm^2$

A_s = Area of steel $= 8 \times \frac{\pi}{4}(20)^2$

$A_s = 2513.27\ mm^2$

Area of concrete $= A - A_s$

$= 90000 - 2513.27$

A_c = Area of concrete $= 87486.72\ mm^2$

W.K.T.

For equilibrium condition

$$P = P_s + P_c \rightarrow (1)$$

$$360 \times 10^3 = \sigma_s \times A_s + \sigma_c \times A_c$$

$\sigma = \frac{P}{A}$

$P = \sigma \times A$

Strain: $\frac{\text{stress}}{E}$

strain in steel = strain concrete

$$\frac{\sigma_s}{E_s} = \frac{\sigma_c}{E_c}$$

$$\sigma_s = \sigma_c \left[\frac{E_s}{E_c}\right]$$

$$\sigma_s = \sigma_c \left[\frac{2.1 \times 10^5}{0.14 \times 10^5}\right]$$

$$\boxed{\sigma_s = 15\sigma_c} \rightarrow (2)$$

substituting the σ_s in eq (1) we get

$$360 \times 10^3 = 15\sigma_c \times 2513.27 + \sigma_c \times 87486.72$$

$$360 \times 10^3 = \sigma_c [125185.77]$$

$$\sigma_c = \frac{360 \times 10^3}{125185.77}$$

$$\boxed{\sigma_c = 2.87 \text{ N/mm}^2}$$ stress in concrete

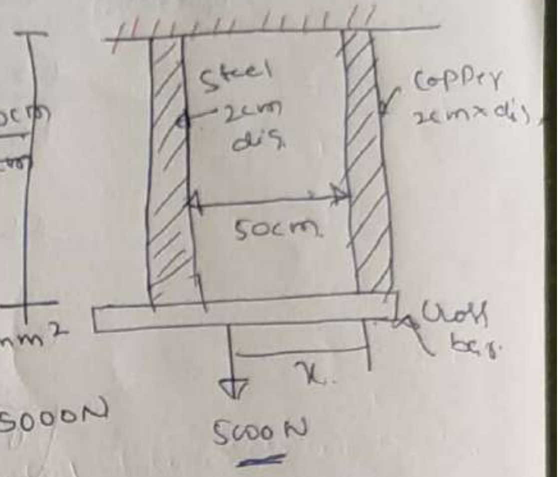
$$\sigma_s = 15 \times \sigma_c = 15 \times 2.87$$

$$\boxed{\sigma_s = 43.13 \text{ N/mm}^2}$$ stress in steel.

(4) Two vertical rods one of steel and the other of copper are each rigidly fixed at the top and 50 cm apart. Diameters and lengths of each rod are 2 cm and 4 m respectively. A cross bar fixed to the rods at the lower ends carries a load of 5000 N such that the cross bar remains horizontal even after loading. Find the stress in each rod the position of the load on the bar. Take E for steel 2×10^5 N/mm² and E for copper = 1×10^5 N/mm².

us Distance b/w the rods = 50 cm
= 500 mm

Dia of steel rod = Dia of copper rod
= 2 cm = 20 mm



Area of steel rod = Area of copper rod

$A_s = A_c = \frac{\pi}{4}(20)^2 = 314.15\,mm^2$

Length of Each rod = 4m = 4000 mm P = 5000N

Total $P = P_s + P_c$

$5000N = \sigma_s \times A_s + \sigma_c \times A_c$ → (1)

Stress = $\frac{Load}{Area}$

Stress × Area = load

σ_s = stress in steel, σ_c = stress in copper,

Cross bar remains horizontal, the extensions of the steel and copper rod are equal. Also these rods have the same original length the strains of these rod are equal

Hence

Strain in steel = strain in copper

$E = \frac{Stress}{Strain}$

Strain = $\frac{\sigma}{E}$

$\frac{\sigma_s}{E_s} = \frac{\sigma_c}{E_c}$

$\sigma_s = \left(\frac{E_s}{E_c}\right)\sigma_c$

$\sigma_s = \left[\frac{2\times10^5}{1\times10^5}\right]\sigma_c$

$\boxed{\sigma_s = 2\sigma_c}$ → (2)

Substituting the σ_s in eq (1) we get

$5000 = 2\sigma_c \times 314.15 + \sigma_c \times 314.15$

$5000 = \sigma_c[942.46]$

$\sigma_c = 5.30 \, N/mm^2$

Substituting σ_c in eq (2)

$\sigma_s = \sigma_c \times 2$

$\sigma_s = 2 \times 5.30$

$\sigma_s = 10.61 \, N/mm^2$

Position of load of 5000N on cross bar

Let x = The distance of 5000N load from the copper rod. i.e. from the from rigid rod right hand.

Load carried by each rod

Load = stress × Area

Steel rod. $P_s = \sigma_s \times A_s$

$= 10.61 \times 314.15$

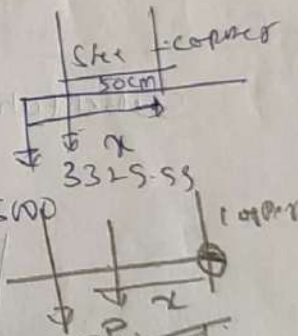
$P_s = 3329.99 \, N.$

Copper rod $P_c = \sigma_c \times A_c$

$= 5.3 \times 314.15$

$P_c = 1664.99 \, N.$

Taking moment about the copper rod and equating the same we get

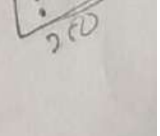


$5000 \times x = P_s \times 50$

$5000 \times x = 3329.99 \times 50$

$x = 33.29 \, cm.$

) A reinforced short column 250mm × 250mm in section is reinforced with 8 steel bars. The total area of steel bars is 2500mm². The column carries a load of 390kN. If the modulus of elasticity for steel is 15 times that of concrete. Find the stresses in concrete and steel.



→ Area of concrete column = Area of column A_c = $250 \times 250 = 62,500 \, mm^2$

Area of steel bars $A_s = 2500 \, mm^2$.

Area of concrete $A_c = 62,500 - 2500 = 60,000 \, mm^2$

Total load on column $P = 390 kN = 390,000 N$.

E for steel = 15 × E for concrete

$E_S = 15 E_C$.

$\frac{E_S}{E_C} = 15$

let σ_s = Stress in steel N/mm²

σ_c = Stress in concrete N/mm²

Now Strain in steel = Strain in concrete

$\frac{stress}{strain} = E$

$\frac{stress}{E} = strain$

$\frac{\sigma}{E} = \epsilon$

$$\frac{\sigma_s}{E_s} = \frac{\sigma_c}{E_c}$$

$$\sigma_s = \left(\frac{E_s}{E_c}\right)\sigma_c$$

$$\boxed{\sigma_s = 15\,\sigma_c} \rightarrow (1)$$

Also we know that

Load = stress × Area

Total Load = load on steel + load on concrete

$P = \sigma_s \times A_s + \sigma_c \times A_c$

$390,000 = 15\sigma_c \times 2500 + \sigma_c \times 60,000$

$390,000 = 97500\,\sigma_c$

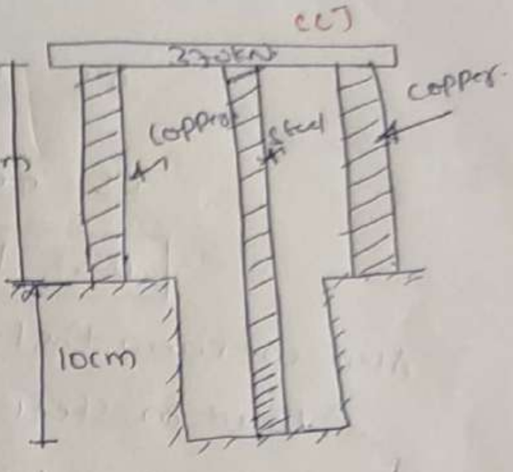
$$\boxed{\sigma_c = 4.0 \ N/mm^2} \rightarrow (2).$$

Substituting the σ_c in eq (1) we get

$\sigma_s = 15 \times 4.0$

$$\boxed{\sigma_s = 60 \ N/mm^2}$$

⑥ A steel rod and two copper rods together support a load of 370kN as shown in fig. The cross-sectional area of steel rod is 2500mm² and of each copper rod is 1600mm². Find the stresses in the rods. Take E for steel = 2×10⁵ N/mm² and for copper = 1×10⁵ N/mm².



→ Given $P = 370\,kN = 370,000\,N$

Steel $A_s = 2500\,mm^2$

Copper $A_c = 2 \times 1600$

$A_c = 3200\,mm^2$

E for steel $E_s = 2 \times 10^5\,N/mm^2$

E for copper $E_c = 1 \times 10^5\,N/mm^2$

Length of the steel rod = 15cm + 10cm = 25cm = 250mm

Length of the copper rod = 15cm = 150mm.

Let σ_s = stress in steel N/mm², σ_c = stress in copper N/mm²

We know that decrease in length of steel rod is equal to the decrease in length of copper rods.

the decrease in length of the steel rod.

But decrease in length of the steel rod.

$\therefore$ Strain = $\frac{\text{Stress}}{E}$

= strain in steel rod × length of steel rod.

$\varepsilon = \frac{\delta L}{L}$

$\delta L = \varepsilon L$

Deformation δL = $\frac{\text{stress in steel}}{E_s} \times L_s$

Strain = $\frac{\text{Stress}}{E}$

$\frac{\delta L}{L} = \left(\frac{\text{Stress}}{E}\right)$

$= \frac{\sigma_s}{2 \times 10^5} \times 250 \longrightarrow (1)$

Illy Decrease in length of the copper rod.

= strain in copper rod × length of copper rod

$= \frac{\text{stress in copper}}{E_c} \times L_c$

$= \frac{\sigma_c}{1 \times 10^5} \times 150 \longrightarrow (2)$.

Equating the decrease in length of steel rod to the decrease in the length of copper rods, we get

$$\frac{\sigma s}{2\times10^5}\times 250 = \frac{\sigma c}{1\times10^5}\times 150$$

$$\sigma s = \sigma c \times \left(\frac{2\times10^5}{1\times10^5}\right)\times\left[\frac{150}{250}\right]$$

$$\sigma s = \sigma c \times 1.2$$

$$\boxed{\sigma s = 1.2\sigma c} \longrightarrow (3)$$

Also we know that

Load on steel + load on copper = Total load applied

(load = stress × area)

$$\sigma s \times As + \sigma c \times Ac = 370,000$$

$$\sigma s \times As + \sigma c \times Ac = 370,000$$

$$1.2\times\sigma c\times 2500 + \sigma c\times 3200 = 370,000$$

$$\sigma c = \frac{370,000}{6200}$$

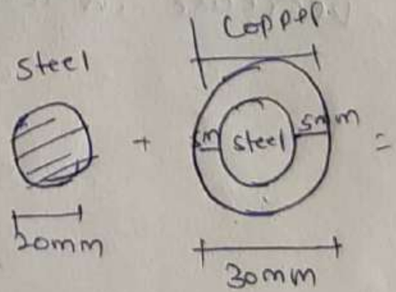
$$\boxed{\sigma c = 59.67\ N/mm^2}$$

Substituting σc in eq (3) we get.

$$\sigma s = 1.2\times 59.67$$

$$\boxed{\sigma s = 71.612\ N/mm^2}$$

(7) A compound bar consist of a circular rod of steel of dia 20mm rigidly fitted into a copper tube of internal diameter 20mm & thickness 5mm. If the bar is subjected to a load of 100kN. find the stress developed. Es = 200GPa and Ecu = 120GPa.



$$Es = 200\times10^3\ N/mm^2$$

$$Ecu = 120\times10^3\ N/mm^2$$

$$P = 100\ kN = 100,000\ N.$$

$$As = \frac{\pi}{4}(20)^2 = 314.15\ mm^2 \qquad Acu = \frac{\pi}{4}\left[30^2 - 20\right]^2$$

$$\boxed{Acu = 392.69\ mm^2}$$

We know that

Load on steel + load on copper = Total load → ①

$\sigma_s \times A_s + \sigma_{cu} + A_{cu} = P$

Stress = Load / Area

Load = Stress × Area

Now Strain in steel = Strain in copper

Strain = Stress / E

$$\frac{\sigma_s}{E_s} = \frac{\sigma_c}{E_c}$$

$$\sigma_s = \left[\frac{E_s}{E_c}\right]\sigma_c$$

$$\sigma_s = \left[\frac{200\times10^3}{120\times10^3}\right]\sigma_c$$

$$\boxed{\sigma_s = 1.667\,\sigma_c} \rightarrow ②$$

Substituting σ_s in eq ① we get

$1.667 \times \sigma_c \times 314.15 + \sigma_{cu} \times 392.69 = 100{,}000$

$$\boxed{\sigma_c = 109.12\ N/mm^2}$$

Substituting σ_c in eq ② we get

$\sigma_s = 1.667 \times 109.12$

$\sigma_s = 181.91\ N/mm^2$

$P_c = \sigma_c \times A_c$

$= 109.12 \times 392.69$

$\boxed{P_c = 42.85\ kN}$

$P_s = \sigma_s \times A_s$

$P_s = 181.91 \times 314.15$

$\boxed{P_s = 57.147\ kN}$

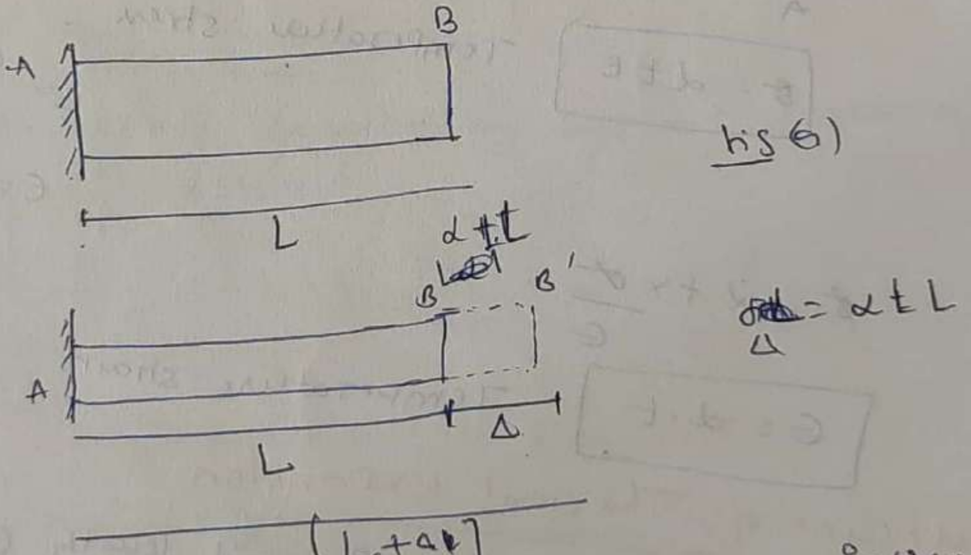
Raghu. M.E.
Assistant professor.

Temperature stress. :

Most of the Engineering materials when subjected to Variation of Temperature either expands (or) contracts. If the expansion (or) contraction is restricted thermal stress are developed. If bar is allowed to expand (or) contract freely thermal stress donot develop.

Thermal stress are the stress Induced in a body due to the change in temperature. Thermal stress are set up in a body when a temperature of a body is raised (or) lower. [Expansion (or) contraction] & the body is not allowed to expand (or) contract freely. But if the body is allowed to expand (or) contract freely than no temperature stress is induced (or) set up in the body.

The change in length due to change in temperature is found to be directly proportional to length of the member & also to change in temperature.



Consider a bar of length 'L' subjected to an increase in Temperature 't'c. If the bar is free to expand then the Increase in length (Δ) is given by

Change in length $\Delta = \alpha t L$ $\quad 1 / {}^\circ C \times mm$

$\alpha =$ co-efficient of Thermal Expansion.

$t =$ Rise in temperature | change in temprature.

$L =$ original length.

$\Delta =$ change in length.

① If full Expansion is prevented

case:1

If the changes due to temperature are permitted freely no stress develop in the member as shown in fig 9. Due to increase in temperature by ($t^\circ C$) the bar will Extend by "$\alpha L t$" & due to this change no stress is Induced.

W.K.T $\Delta = \frac{PL}{AE}$

$\alpha L t = \frac{P}{A} \times \frac{L}{E}$

$\frac{\alpha L t E}{L} = \frac{P}{A}$

$\frac{P}{A} = \alpha t E$

$\boxed{\sigma = \alpha t E}$ Temperature stress

$E = \frac{\sigma}{\epsilon}$ $\frac{\text{stress}}{\text{strain}}$

$\epsilon = \frac{\sigma}{E}$

$\epsilon = P/A$. $\epsilon = \frac{\sigma}{E}$

$\Delta = \alpha L T$

$E = \frac{\text{stress}}{\text{strain}} = \frac{\sigma}{\epsilon}$

$\epsilon = \frac{\sigma}{E}$

$\therefore \epsilon = \frac{\sigma}{E}$

(or)

$\sigma = \alpha . t \times \frac{\sigma}{\epsilon}$

$\boxed{\epsilon = \alpha . t}$ Temperature strain //

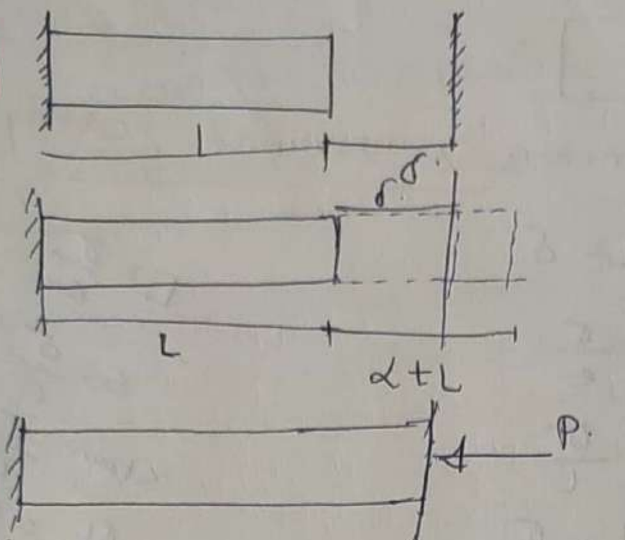
co-efficient of Thermal Expansion.

It is defined as change in unit length of the member/material due to unit change in temperature. This value is different for different materials.

co-efficient of thermal Expansion for some of the commonly used engineering materials are

	materials	co-efficient of thermal Expansion α
		$12 \times 10^{-6}/^\circ C$
1.	Steel	$17.5 \times 10^{-6}/^\circ C$
2.	Copper	$18 \times 10^{-6}/^\circ C$
3.	Stainless steel	$19 \times 10^{-6}/^\circ C$
4.	Brass, Bronze. 5. Aluminimum	$23 \times 10^{-6}/^\circ C$.

Case: II. If free Expansion is prevented partly. $\delta = \frac{\sigma}{E}$



$\Delta = \alpha tL - \delta$

w.k.T. Strain $\delta L = \frac{\sigma}{E}$

$\delta L = L \cdot \frac{\sigma}{E}$

$\Delta = \delta L$

$\alpha tL - \delta = L \cdot \sigma$

$(\alpha tL - \delta)\frac{E}{L} = \sigma$

$\Delta = \alpha tL - \delta$

$= \alpha tL - \delta$

$\frac{PL}{AE} = \alpha tL - \frac{\sigma}{E}$

$\frac{PL}{AE} = \alpha tL - \frac{\sigma E}{EL}$

$= \frac{\alpha tL}{E}$

$\frac{P}{A} \times \frac{L}{E}$

σ

If the bar is free to extend when temperature is increased by 't' degree its extension [free Expansion] would have been "αtL". But this extension is completely prevented by forces developed at supports. This support in this case by forces developed at supports this support force p is such that it causes shortening [Δ] of the bar by "αtL"

Thus shortening caused by support reaction p is given by $\Delta = \alpha tL - \delta$

w.k.T $\Delta = \frac{PL}{AE}$ $\therefore \frac{PL}{AE} = \alpha tL - \delta$.

(or)

Case I If full Expansion is prevented

w.k.t $\Delta = \alpha tL$

Also $E = \frac{\sigma}{\epsilon} = \frac{\text{Stress}}{\text{Strain}}$

$\epsilon = \frac{\sigma}{E}$ but strain $\epsilon = \frac{\delta L}{L}$

$\frac{\delta L}{L} = \frac{\sigma}{E}$

$\delta L = L \cdot \frac{\sigma}{E}$ $[\delta L = \Delta]$

$\Delta = L \cdot \frac{\sigma}{E}$

$\alpha tL = L \cdot \sigma$

$$\frac{\alpha t L}{L} = \frac{\sigma}{E}$$

$$\boxed{\sigma = \alpha . t E}$$

Case: 2 Free Expansion is Prevented partly

$$\Delta = \alpha t L - \delta$$

$E = \frac{\sigma}{\epsilon}$

$\epsilon = \frac{\sigma}{E}$

Strain $= \frac{\sigma}{E}$

$\frac{\delta L}{L} = \frac{\sigma}{E}$

$\Delta L = L . \frac{\sigma}{E}$

w.k.T $\delta L = L . \frac{\sigma}{E}$

$$\Delta = L . \frac{\sigma}{E}$$

$$\alpha t L - \delta = L . \frac{\sigma}{E}$$

$\left[\frac{\alpha t L - \delta}{L}\right] E = \sigma$

$$\sigma = \left(\frac{\alpha t L - \delta}{L}\right) . E$$

$\sigma = [\alpha t L - \delta]\left[\frac{E}{L}\right]$

$$\boxed{\sigma = \left(\alpha t - \frac{\delta}{L}\right) E}$$

Problems

① A rod is 2m long at 10° c. find the Expansion of the rod. when temperature is raised to 80° c. If this Expansion is prevented, find the stress in the material. Given $E = 1 \times 10^5$ mPa. $\alpha = 0.000012/°c$

⇒ $L = 2m = 2000mm$

$E = 1 \times 10^5 \ N/mm^2$.

$\alpha = 0.000012/°c$

$t = T_f - T_i = 80° - 10° = 70°c$

$t_c = 70°c$.

Change in Temperature

t_c = final Temperature - Initial temp - erth

$t_c = 80° - 10°$

$t_c = 70°c$

① case

Expansion of the rod $\Delta = \alpha t L$

$= 0.000012 \times 70 \times 2000$

$$\boxed{\Delta = 1.68mm}$$

Case: 2 Stresses due to prevention of Expansion

$\sigma = \alpha . tE$

$= 0.000012 \times 70 \times 1 \times 10^5$

$\sigma = 84$ mpa. compressive.

(2) A road of steel is 20m at 10°C. find free Expansion of rod when temperature is raised to 65°C. find temperature stress produced when Expansion is prevented & when the rod is permitted to expand by 5.8mm $E = 2\times10^5$ mpa. $\alpha = 12\times10^{-6}$ /°C

Jan: 2018

→ $L = 20m = 20\times10^3$ mm.

$t_{in} = 10°C$

$t_{final} = 65°C$

$\Delta = 5.8mm$

$E = 2\times10^5$ mpa.

$\alpha = 12\times10^{-6}$ /°C

$t_f = t_{final} - t_{inal}$

$= 65 - 10$

$t = 55$

(1) $\Delta = L\alpha t$

$\Delta = 20\times10^3 \times 12\times10^{-6} \times 55$

$\Delta = 13.2$mm

Case 2: stresses due to prevention of Expansion

$\sigma = \alpha . TE$

$\sigma = 12\times10^{-6} \times 55 \times 2\times10^5$

$\sigma = 132$ mpa

$\sigma = (L\alpha T - \Delta)\left(\frac{E}{L}\right)$

$= [20\times10^3 \times 12\times10^{-6} \times 55 - 5.8]\left[\frac{2\times10^5}{20\times10^3}\right]$

$\sigma = 74$ mpa.

(3) Explain the reason for development of stress in bars, when their temperature rises (or) falls. Accordingly calculate the nature & magnitude of stress induced in the rod of 2m length & 20mm diameter when both ends constrained. its temperature raised by 70°C $\alpha = 1.2\times10^{-5}$ /°C Take $E = 1\times10^5$ mpa

→ $L = 2m = 2\times10^3$ mm

$T = 70°C$

$E = 1\times10^5$ N/mm2

$\alpha = 1.2\times10^{-5}$ /°C.

$d = 200$mm.

$\sigma = \alpha T E$

$= 1.2 \times 10^{-5} \times 70 \times 1 \times 10^{5}$

$\sigma = 84 \text{ MPa}$ (compressive)

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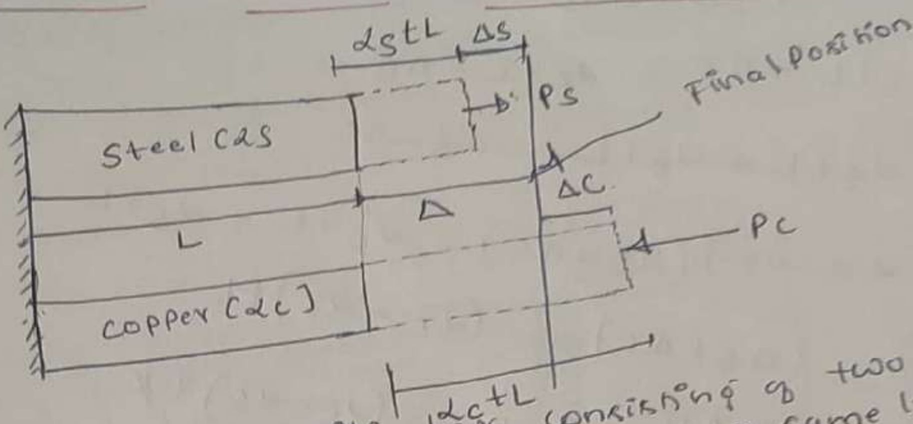
Temperature Stress in Compound Bars :- [Composite]



① fig

Fig shows a composite bar consisting of two members. A bar of Steel & another bar of copper of same length rigidly connected at their ends. having different co-efficient of expansion.

Let the composite bar is subjected to a temperature rise of t°C. Then the opposite kinds of stress. ie tensile & compressive will be set up in the two materials. If the bars are free to expand increase in length of copper [$\alpha_c t L$]. will be more than the steel [$\alpha_s t L$]. This is because of copper is having more co-efficient of thermal Expansion (α_c) than that of steel (α_s). & it will elongate more than the steel.

[But both the members are rigidly connected to form a composite bar, the composite bar should expand as a whole by the same amount 'Δ'. In order to compensate this there will be slightly increase in length of the steel (Δs) due to compensative force is induced in the steel & slightly decrease in the length of the copper (Δc) due to the force 'Pc' induced in the copper].

In order to have common Expansion 'Δ'. tensile force will be developed in steel & compressive force in copper.

∴ Tensile force in steel = compressive force in copper

$$P_S = P_C = P \text{ (say)}$$

From compatability equation

final Extension of copper = final extension of steel

$$\Delta c = \Delta s = \Delta \text{ (say)}$$

from fig ①

$$\Delta = \alpha_s t L + \Delta s \rightarrow ① \text{ for steel}$$

$$\Delta = \alpha_c t L - \Delta c \rightarrow ② \text{ for copper.}$$

From eq ① & ② we get

$$\alpha_s tL + \Delta s = \alpha_c tL - \Delta c$$

~~$\alpha_s tL - \alpha_c tL = \Delta s - \Delta c$~~

~~$\alpha_c - \alpha_s)$~~ $(\Delta s + \Delta c) = \alpha_c tL - \alpha_s tL$

$$(\Delta s + \Delta c) = (\alpha_c - \alpha_s) tL$$

$$\frac{P_s L}{A_s . E_s} + \frac{P_c . L}{A_c . E_c} = (\alpha_c - \alpha_s) tL$$

since $P_s = P_c = P$

$$\frac{P}{A_s . E_s} + \frac{P}{A_c . E_c} = (\alpha_c - \alpha_s) t \rightarrow (9)$$

$$(\alpha_c - \alpha_s) t = P \left[\frac{1}{A_s . E_s} + \frac{1}{A_c . E_c} \right] \rightarrow (1)$$

$$P = \frac{t (\alpha_c - \alpha_s)}{\frac{1}{A_s . E_s} + \frac{1}{A_c . E_c}} \rightarrow (2)$$

If we know the value of P then equation (9) reduces to

i.e $\sigma_s = \frac{P_s}{A_s}$ & $\sigma_c = \frac{P_c}{A_c}$ $P_s = \sigma_s . A_s$, $P_c = \sigma_c A_c$.

$$(\alpha_c - \alpha_s) t = \left[\frac{\sigma_s . A_s}{A_s . E_s} + \frac{\sigma_c . A_c}{A_c . E_c} \right]$$

$$(\alpha_c - \alpha_s) t = \left(\frac{\sigma_s}{E_s} + \frac{\sigma_c}{E_c} \right)$$

But $\frac{\sigma}{E} = \epsilon$ $\therefore \frac{\sigma_s}{E_s} = \epsilon_s$ strain in steel]

lit y $\frac{\sigma_c}{E_c} = \epsilon_c$ [strain in copper]

$$(\alpha_c - \alpha_s) t = \epsilon_s + \epsilon_c$$

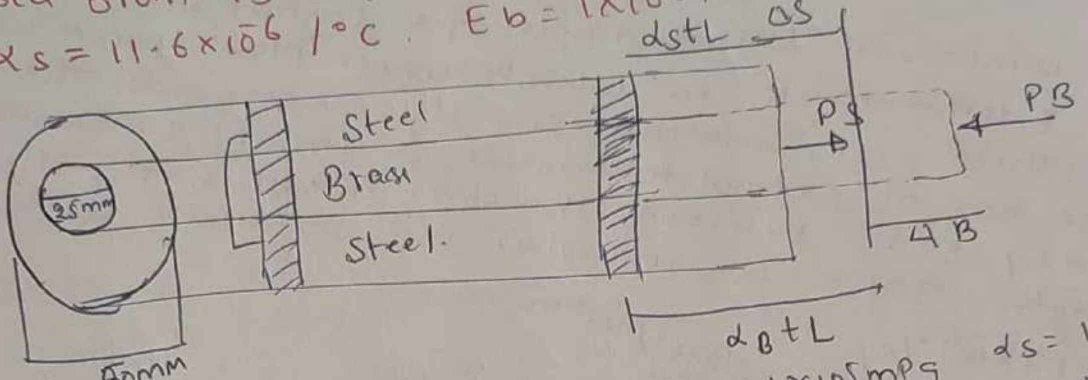
The above equation (3) gives strain developed in the two materials

$$\epsilon_s + \epsilon_c = (\alpha_c - \alpha_s) t \rightarrow (3)$$

Dec 2013 - Jan 2014

① A bar of brass 25mm dia is enclosed in a steel tube of 25mm internal dia & 50mm External diameter. The bar & the tube are rigidly connected at both ends. Find the stress in two materials. if the temperature of the system is raised from 15°c to 95°c. Assume $E_s = 2\times10^5$ mPa. $E_b = 1\times10^5$ mPa. $\alpha_b = 18.7\times10^{-6}$ °/C. $\alpha_s = 11.6\times10^{-6}$ /°C.

Sol:



$\alpha_s = 11.6\times10^{-6}$ /°C
$\alpha_b = 18.7\times10^{-6}$ °/C
$E_b = 1\times10^5$ mPa
$E_s = 2\times10^5$ mPa
$t_1 = 15$°c $t_2 = 95$°C
$t = 95 - 15 = 80$°C

Area of Bar:

$A_B = \frac{\pi}{4}[25]^2 = 490.87\,mm^2$

area of steel $A_s = \frac{\pi}{4}[50^2 - 25^2] = 1472.62\,mm^2$

$P_b = P_s = P$.

$L_b = L_s = L$

From fig

Elongation of steel $= \alpha_s tL + \Delta s$ → ①

elongation of Brass $= \alpha_B tL - \Delta c$ → ②

eq ① & ②

$\alpha_s tL + \Delta s = \alpha_B tL - \Delta B$

$\Delta B + \Delta s = \alpha_B tL - \alpha_s tL$

$\Delta B + \Delta s = (\alpha_B - \alpha_s)tL$

$(\alpha_B - \alpha_s)tL = \frac{P_B\times L_B}{A_B.E_B} + \frac{P_s.L_s}{A_s.E_s}$ since $P_B = P_s = P$ ($L_B = L_s = L$)

$(\alpha_B - \alpha_s)t = P\left[\frac{1}{A_B.E_B} + \frac{1}{A_s.E_s}\right]$

$[18.7 - 11.6]\times10^{-6}\times80 = P\left[\frac{1}{490.87\times2\times10^5} + \frac{1}{1472.62\times10^5}\right]$

P = 23.89 kN

$(\alpha_B - \alpha_s)t = P\left[\frac{1}{A_B.E_B} + \frac{1}{A_s.E_s}\right]$

$(18.7\times10^{-6} - 11.6\times10^{-6})80 = P\left[\frac{1}{490.87\times1\times10^5} + \frac{1}{1472.62\times2\times10^5}\right]$

$5.68\times10^{-4} = P[2.376\times10^{-8}]$

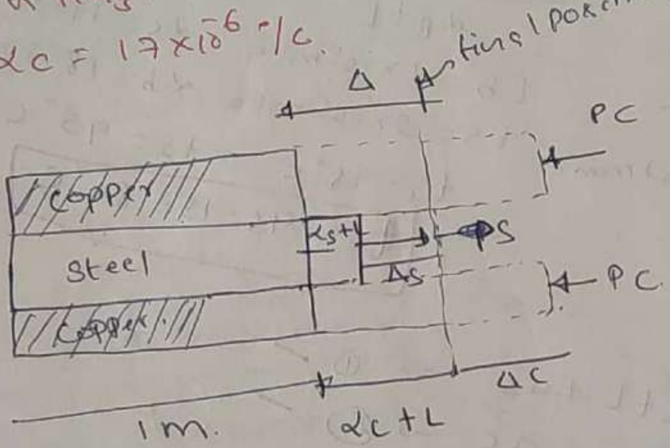
P = 23.89 kN

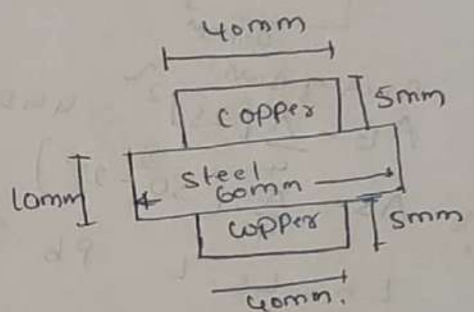
Stress in steel $\sigma_s = \frac{P}{A_s} = \frac{23.89 \times 10^3}{1472.62} = 16.22 \, N/mm^2$

Stress in Brass $\sigma_B = P/A_B = \frac{23.89 \times 10^3}{490.87} = 48.68 \, N/mm^2$

(Q2) A compound bar is made of a Central Steel Plate 60mm wide & 10mm thick to which copper plate 40mm wide and 5mm thick are connected rigidly on each side. The length of the bar at Normal temperature is 1m. If the temperatures raised by 80°C. Determine the stress in each bar & the change in length. take $E_S = 200 GN/m^2$. $E_C = 100 GN/m^2$. $\alpha_S = 12 \times 10^{-6} /°C$

$\alpha_C = 17 \times 10^{-6} /°C$.





(3) A steel rail is 12.6 m long & is laid at a temperature of 24°C. The maximum temperature expected is 44°C.

(i) Estimate the min gap b/w two rails to be left so that temperature stress do not develop.

(ii) Calculate the thermal stress developed in the rails if

(a) No expansion joint is prevented.

(b) If a 2mm gap is provided for expansion.

(3) if the stress developed is 20 MN/m². what is the gap b/w the rails. ?

Take $E = 2\times10^5$ MN/m² & $\alpha = 12\times10^{-6}/°C$

→ Given

$L = 12.6 m = 12.6\times10^3$ mm

$t_1 = 24°C$. $t_2 = 44°C$.

$t = t_2 - t_1 = 44°C - 24°C = 20°C$

$E = 2\times10^5$ MN/m². $\alpha = 12\times10^{-6}/°C$

$= 2\times10^5\times10^6$ N/m².

$= 2\times10^5\times\frac{10^6}{10^6}$ N/mm².

$E = 2\times10^5$ N/mm².

$E = 2\times10^5$ MN/m²
$= 2\times10^5\times10^6$ N/m²
$= 2\times10^5\times\frac{10^6}{10^6}$ N/mm²
$= 2\times10^5$ N/mm²

(i) Free Expansion of rail $\Delta = \alpha t L$

$\Delta = 12\times10^{-6}\times 20\times 12.6\times10^3$

$\Delta = 3.024$ mm

(ii)(a) If no Expansion Joint is provided, free expansion prevented is equal to 3.024 mm.

i.e. $\Delta = 3.024$ mm

$\sigma \alpha E$

$\sigma = E\epsilon$

$\frac{P}{A} = E\frac{\Delta}{L}$

$\frac{PL}{AE} = 3.024$

$\frac{P}{A} = \frac{3.024\times E}{E}$

$\frac{P}{A} = \frac{3.024\times2\times10^5}{12.6\times10^3}$

$\frac{P}{A} = 48$ N/mm²

$\sigma_t = 48$ N/mm².

(or) $\sigma = \alpha t E$

$\sigma = 12\times10^{-6}\times 20\times 2\times10^5$

$\sigma = 48$ N/mm²

② If a gap of 2mm is provided, free expansion is prevented is

$\Delta = \alpha t L - \delta$

$\Delta = 3.024 - 2 = 1.024mm$

$\frac{PL}{AE} = 1.024$

$\frac{P}{A} = \frac{1.024 \times E}{L}$

$\sigma = \frac{1.024 \times 2 \times 10^5}{12.6 \times 10^3}$

$\sigma_t = 16.253 \ N/mm^2$

③ Given $\sigma_t = 20 N/mm^2$, $\Delta = ?$

W.K.that $\Delta = \frac{PL}{AE}$

$\frac{P}{A} = \frac{\Delta E}{L}$

$(\sigma_t) = \frac{\Delta \times E}{L}$

$\Delta = \frac{\sigma_t \times L}{E} = \frac{20 \times 12.6 \times 10^3}{2 \times 10^5}$

$\Delta = 1.26mm$

Also $\Delta = \alpha t L - \delta$

$\Delta = 3.024 - \delta$

$\delta = ~~1.26~~ \ 3.024 - 1.26$

$\delta = 1.764mm$

$\Delta = \frac{PL}{AE}$

$\frac{\Delta \times E}{L} = \frac{P}{A}$

$\frac{\Delta \times E}{L} = \sigma$

$\Delta = \frac{\sigma \times L}{E}$

$\Delta = \frac{20 \times 12.6 \times 10^3}{2 \times 10^5}$

$\Delta = 1.26mm$

$\Delta = \alpha t L - \delta$

$\Delta = 3.024 - \delta$

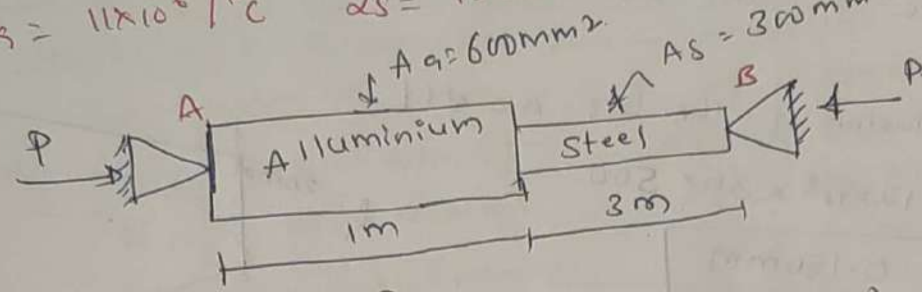
$= 3.024 - 1.26$

$= 3.024 - 1.26$

$\Delta = 1.764mm$

(4) A composite bar is Rigidly fitted at the supports A & B as shown in fig. Determine the reaction at the supports when temperature is 20°c. Take $E_a = 70$ GN/m², $E_s = 200$ GN/m², $\alpha_a = 11\times10^{-6}/°c$, $\alpha_s = 12\times10^{-6}/°c$.

→



Ea = 70 N/mm² ×10³
Es = 200×10³ N/mm²

Given $t = 20°c$ $P = ?$

$E_a = 70$ GN/m²

$= \frac{70\times10^9}{10^6}$ N/mm²

$E_a = 70\times10^3$ N/mm²

$E_s = 200$ GN/m²

$E_s = 200\times10^3$ N/mm²

$\alpha_a = 11\times10^{-6}/°c$

$\alpha_s = 12\times10^{-6}/°c$

$L_a = 1m = 1000$ mm

$L_s = 3m = 3000$ mm

W.K.T. Total Deformation $\Delta = \Delta_a + \Delta_s$

$\Delta = \alpha_a t L_a + \alpha_s t L_s$

$\Delta = (11\times10^{-6}\times(20\times1000)) + [12\times10^{-6}\times20\times3000]$

$\Delta = 0.94$ mm

If P is the support reaction then.

$\Delta = \Delta a + \Delta s$

$0.94 = \frac{P.L_a}{A_a.E_a} + \frac{P.L_s}{A_s.E_s}$

$P\left[\frac{L_a}{A_a.E_a} + \frac{L_s}{A_s.E_s}\right] = 0.94$

$P\left[\frac{1000}{600\times70\times10^3} + \frac{3000}{300\times200\times10^3}\right] = 0.94$

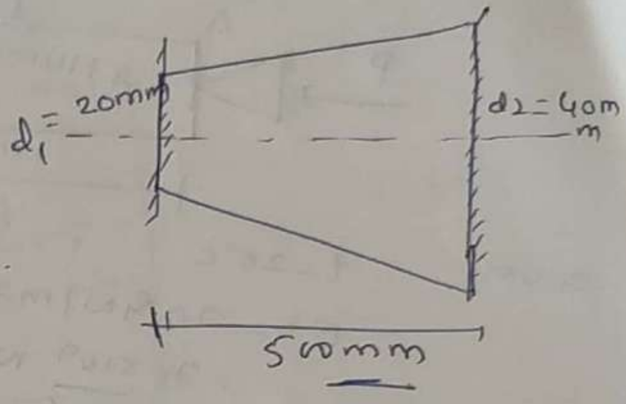
$P[2.380\times10^{-5} + 5\times10^{-5}] = 0.94$

$P = 12,737.12$ N.

$P = 12.737$ KN

Ea = 70 GN/m²
= 70×10⁹ N/m²
1m = 1000mm = 70×10⁵/1000×1000 N/mm²
= 70×10³ N/mm²
Es = 200×10³ N/mm²

A steel bar of uniform varying Diameter as shown in fig is held b/w two ~~Varying~~ unyielding supports at room temperature. What is the maximum stress induced in the bar if the temperature rises by 30°C? Take $E_s = 2\times10^5 N/mm^2$ and $\alpha_s = 12\times10^{-6}/°C$



Ans Free Expansion of the bar $\Delta = \alpha t L$

$\Delta = 12\times10^{-6} \times 30 \times 500$

$\Delta = 0.180mm$

W.K.T. for uniform varying diameter.

$\Delta = \frac{4PL}{\pi E d_1 d_2}$

$0.180 = \frac{4\times P\times 500}{\pi \times 2\times10^5 \times 20\times40}$

$\frac{0.180 \times \pi \times 2\times10^5 \times 20\times40}{4\times500} = P$

$P = 45.23 kN.$

Stress calculation.

1) for 20mm dia, W.K.T $\sigma = P/A = \frac{45.23\times10^3}{\pi\times20^2/4}$

$\sigma = 143.97 N/mm^2$

2) for 40mm dia. bar

$\sigma = P/A = \frac{45.23\times10^3}{\pi\times40^2/4}$

$\sigma = 35.96 N/mm^2$

$\therefore$ Max stress $\sigma = 144 N/mm^2$

Scanned by CamScanner

⑥ A rod is composed of 3 segments as shown in fig. The rod is held b/w rigid supports, Find the stress developed in each material when the temperature of the system is raised to 55°C under the following different conditions.

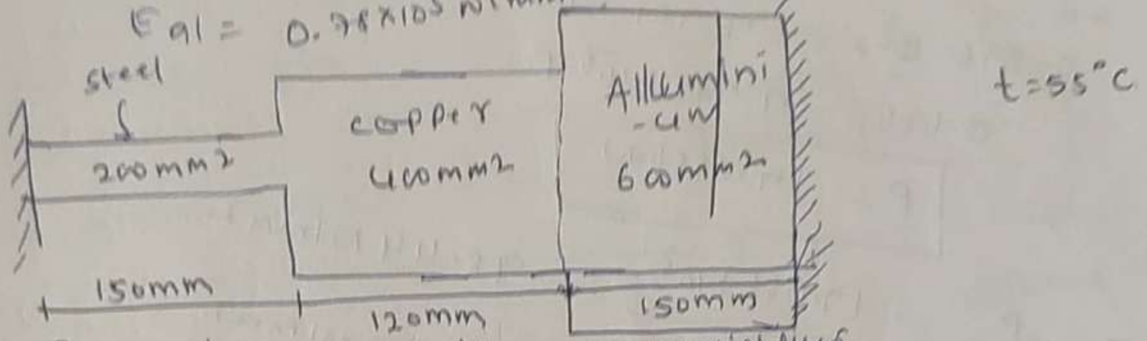
(a) when the supports are unyielding.

(b) when supports are yields by 0.2mm.

Take $E_s = 2\times10^5\ N/mm^2$, $\alpha_s = 1.2\times10^{-5}/°C$

$E_{cu} = 1\times10^5\ N/mm^2$, $\alpha_c = 1.75\times10^{-5}/°C$

$E_{al} = 0.78\times10^5\ N/mm^2$, $\alpha_{al} = 2.2\times10^{-5}/°C$



Sol case(a) when supports are unyielding.

Total Deformation $\Delta = \Delta s + \Delta cu + \Delta al$

$\Delta = \alpha_s t L_s + \alpha_{cu} t L_{cu} + \alpha_{al} t L_{al}$

$\Delta = [1.2\times10^{-5}\times55\times150] + [1.75\times10^{-5}\times55\times120] + [2.2\times10^{-5}\times55\times150]$

$\boxed{\Delta = 0.396\ mm}$

Also $\Delta = \Delta s + \Delta cu + \Delta al$

$0.396 = \left\{\frac{P\times L_s}{A_s . E_s} + \frac{P\times L_{cu}}{A_{cu}\times E_{cu}} + \frac{P . L_{al}}{A_{al}\times E_{al}}\right\}$

$0.396 = P\left[\frac{L_s}{A_s . E_s} + \frac{L_{cu}}{A_{cu}\times E_{cu}} + \frac{L_{al}}{A_{al}\times E_{al}}\right]$

$0.396 = P\left[\frac{150}{200\times2\times10^5} + \frac{120}{400\times1\times10^5} + \frac{150}{600\times0.78\times10^5}\right]$

$0.396 = P[3.75\times10^{-6} + 3\times10^{-6} + 3.205\times10^{-6}]$

$0.396 = P[9.955\times10^{-6}]$

$\boxed{P = 39.778\ kN.}$

Stress $\sigma_s = \frac{P}{A_s} = \frac{39.778\times10^3}{200} = 198.89\ N/mm^2$

$\sigma_c = \frac{P}{A_c} = \frac{39.778 \times 10^3}{400} = 99.445 \; N/mm^2.$

$\sigma_A = \frac{P}{A_A} = \frac{39.778 \times 10^3}{600} = 66.2966 \; N/mm^2$

Case (2) When supports yields by 0.2 mm

from equation (1)

$\Delta - \delta = 9.955 \times 10^{-6} P$

$0.396 - 0.2 = 9.955 \times 10^{-6} P$

$0.196 = 9.955 \times 10^{-6} P.$

$P = 19.688 \; kN.$

$\sigma_s = \frac{P}{A_s} = \frac{19.688 \times 10^3}{200} = 98.44 \; N/mm^2$

$\sigma_c = \frac{P}{A_c} = \frac{19.688 \times 10^3}{400} = 49.22 \; N/mm^2$

$\sigma_{Al} = \frac{P}{A_l} = \frac{19.688 \times 10^3}{600} = 32.81 \; N/mm^2$

~~σ_A~~

Poisson's ratio :-

It is the ratio of lateral strain to the longitudinal strain. This ratio is known as poisson's ratio. & It is denoted by 'μ'.

$$\text{Poisson's ratio, } \mu = \frac{\text{lateral strain}}{\text{longitudinal strain}}$$

$\therefore$ lateral strain = μ × longitudinal strain

As lateral strain is opposite in sign to the longitudinal strain, we can write as

$$\boxed{\text{lateral strain} = -\mu \times \text{longitudinal strain}}$$

Volumetric strain :

It the ratio of change in volume to the original volume of the body.

It is denoted by eV

$$eV = \frac{\delta V}{V}$$

δV = Change in volume

V = original volume.

Elastic constants

Elastic constants are those factors which determine the deformations produced by a given stress system acting on a material. These factors are constant within the limits for which hooks law are obeyed. various elastic constants are.

1. modulus of elasticity [E]
2. poissions ratio [μ]
3. modulus of Rigidity [G or N]
4. Bulk modulus [K].

① modulus of Elasticity [E] :

It is the ratio of Normal stress to the longitudinal strain is known as young's modulus. It is denoted by 'E' young's modulus is also known as modulus of elasticity.

$$E = \frac{\sigma}{\epsilon}$$ where σ = Stress, ϵ = strain

② poissions ratio (μ) (or $\frac{1}{m}$)

$$\mu = \frac{\text{lateral strain}}{\text{longitudinal strain}}$$

lateral strain = μ x longitudinal strain.

③ modulus of Rigidity (G or N)

It is defined as the ratio of shear stress to the corresponding shear strain within the elastic limit & is usually denoted by G or N Thus

$$G = \frac{q}{\phi}$$

where G = modulus of Rigidity
q = shearing stress
ϕ = shearing strain.

④ Bulk modulus (K) ?

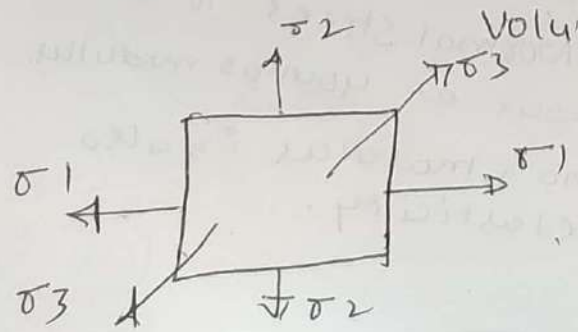
When a body is subjected to identical stress(σ) in three mutually perpendicular directions, the body undergoes uniform changes in three directions without undergoing distortion of shape. The ratio of change in volume to the original volume is defined as volumetric strain (ev). Then the bulk modulus K is defined as

As the ratio of identical stress acting in three mutually perpendicular directions to the corresponding volumetric strain. & it is denoted by K.

$$K = \frac{\sigma}{ev}$$

where σ = Identical Stress in three mutually ⊥r directions
ev = volumetric strain

Bulk modlus K = $\frac{\text{Direct stress}}{\text{Volumetric strain}}$ ev = $\frac{\delta V}{V}$ (or) $\frac{dv}{v}$



$\sigma_1 = \sigma_2 = \sigma_3 = \sigma$

Poisson's Ratio. :

$$\mu = \frac{\text{Lateral strain}}{\text{longitudinal strain}}$$

Lateral strain = $\mu \times$ longitudinal ~~re~~ strain

① Determine the change in length, Breadth and thickness of a steel bar which is 4m long, 30mm wide and 20mm thick & is subjected to a an axial pull of 30KN in the direction of its length. Take E = 2×10^5 N/mm² and Poisson's ratio = 0.3

$A = b \times t = 30 \times 20$
$= 600 mm^2$

→ L = 4m = 4000m, b = 30mm, t = 20mm.

P = 30 KN, E = 2×10^5 N/mm², $\mu = 0.3$

Now strain in the direction of load [longitudinal strain]

Stress = $\frac{\text{Load}}{\text{Area}}$

Strain = $\frac{\delta L}{L}$

$$\text{Strain} = \frac{\text{Stress}}{E}$$

$$\frac{\delta L}{L} = \frac{\text{Load}}{A \times E}$$

$$\text{longitudinal strain} = \frac{30000}{600 \times 2 \times 10^5} = 2.5 \times 10^{-4}$$

But longitudinal strain = $\frac{\delta L}{L}$

$$\frac{\delta L}{L} = 2.5 \times 10^{-4}$$

$$(\delta L) \text{ or change in length} = 2.5 \times 10^{-4} \times 4000$$

$$= 1 \text{ mm}$$

$$\text{Poisson's ratio} = \frac{\text{lateral strain}}{\text{longitudinal strain}}$$

$$0.3 = \frac{\text{lateral strain}}{2.5 \times 10^{-4}}$$

$$\text{Lateral strain} = 7.5 \times 10^{-5}$$

we know that

lateral strain $= \frac{\delta b}{b}$ (or) $\frac{\delta d}{d}$ [(or) $\frac{\delta t}{t}$]

$\delta b =$ b x lateral strain

$\delta b = 30 \times 0.000075 = 0.00225$ mm

similarly: $\delta t =$ ~~δt x t~~ t x lateral strain

$= 20 \times 0.000075$

$= 0.0015$ mm

(2) Determine the value of young's modulus and poisson's ratio of a metallic bar of length 30cm, breadth 4cm and depth 4cm when the bar is subjected to an axial compressive load of 400KN. The decrease in length is given as 0.075cm and increase in breadth is 0.003cm.

Given E = ? E = ? L = 30cm = ~~300~~ mm. B = 4cm = 40mm d = 4cm = 40mm

P = 400KN. $\delta L = 0.075$cm decr $\delta b = 0.003$cm. Increase

Area of cross $b \times d = 40 \times 40 = 1600 \, mm^2$

longitudinal strain $= \frac{\delta L}{L} = \frac{0.075}{30} = 0.0025$

lateral strain $= \frac{\delta b}{b} = \frac{0.003}{4} = 0.00075$

poisson's ratio $=$ ~~Long~~ $\frac{\text{lateral strain}}{\text{longitudinal strain}} = \frac{0.00075}{0.0025}$

$\boxed{\mu = 0.3}$

longitudinal strain $= \frac{\text{stress}}{E}$

$\frac{\delta L}{L} = \frac{P}{A \times E}$

$0.0025 = \frac{400 \times 10^3}{1600 \times E}$

$E = 100 \times 10^3 \, N/mm^2$

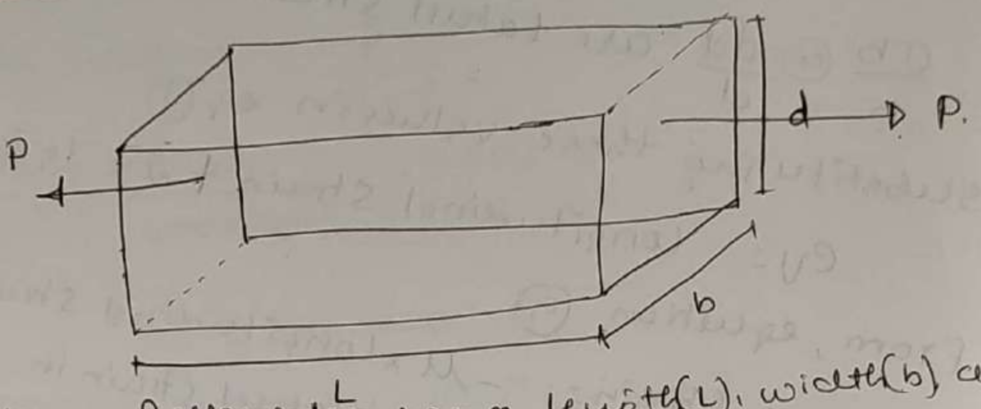
$\boxed{E = 1 \times 10^5 \, N/mm^2}$

Volumetric Strain :

The ratio of change in volume to the original volume of a body [when a body is subjected to a single force or system of forces] is called volumetric strain. It is denoted be eV

$$eV = \frac{\delta V}{V}$$ where, δV = change in volume, V = original volume.

Volumetric strain of a Rectangular Bar which is subjected to an axial load 'P' in the Direction of its length :



Consider a Rectangular bar of length (L), width (b) and depth (d), which is subjected to an axial load 'P' in the direction of its length as shown in fig.

let δL = change in length, δb = change in breadth,

δd = change in depth.

Final length of the bar = $L + \delta L$

Final breadth of the bar = $b + \delta b$

Final depth of the bar = $d + \delta d$

Now original volume of the bar $V = L \cdot b \cdot d$.

Final volume $= [L + \delta L][b + \delta b][d + \delta d]$

$= L \cdot b \cdot d + b \cdot d\, \delta L + L \cdot d \cdot \delta b + L \cdot b \cdot \delta d$

[ignoring the small quantities]

Change in volume δV = Final volume − original volume.

$$\delta V = [Lbd + b \cdot d\, \delta L + L\, b\, \delta d + Ld \cdot \delta b] - Lbd$$

$$\delta V = bd\, \delta L + L b\, \delta d + L d \cdot \delta b$$

<u>Volumetric strain</u> $e_V = \frac{\delta V}{V}$

$$e_V = \frac{b \cdot d\,\delta L + L b\,\delta d + L d\,\delta b}{L b d}$$

$$e_V = \frac{\delta L}{L} + \frac{\delta d}{d} + \frac{\delta b}{b} \longrightarrow (1)$$

But $\frac{\delta L}{L}$ = Longitudinal strain

$\frac{\delta b}{b}$ (or) $\frac{\delta d}{d}$ are lateral strain.

substituting these values in eq (1)

e_V = Longitudinal strain + 2 × Lateral strain → (a)

From, equation (9)

Lateral strain = $-\mu$ × Longitudinal strain

substituting the value of lateral strain in equation (a) we get

e_V = Longitudinal strain − 2 × μ Longitudinal strain

= Longitudinal strain $[1 - 2\mu]$

$$e_V = \frac{\delta L}{L}[1 - 2\mu]$$

Lateral strain = $-\mu$ × Longitudinal strain.

① Determine the volumetric strain and final volume of the given steel bar. which is 4m long, 30 mm wide and 20mm Thick and it subjected to an axial pull of 30kN in the direction of its length. Take $E = 2\times10^5\ N/mm^2$ and poisson's ratio = 0.3

$P = 30kN$ $E = 2\times10^5 N/mm^2$

d = 20mm.

→ $L = 4m = 4000m$ $b = 30mm$,

$\mu = 0.3$

original volume $V = L \cdot b \cdot d = 4000 \times 30 \times 20$

$= 2400000\ mm^3$

The value of longitudinal strain ie $\left[\frac{\delta L}{L}\right]$

$$\text{strain} = \frac{\text{stress}}{E} = \frac{P}{A \times E}$$

$$\frac{\delta L}{L} = \frac{30000}{600 \times 2\times10^5} = 0.00025$$

$$\frac{\delta L}{L} = 0.00025$$

volumetric strain $e_v = \frac{\delta L}{L}[1 - 2\mu]$

$$\frac{\delta V}{V} = 0.00025[1 - 2\times 0.3]$$

$$\frac{\delta V}{V} = 0.0001$$

$$\delta V = 0.0001 \times V$$

$$= 0.0001 \times 2400000$$

$$\boxed{\delta V = 240\ mm^3}$$

Final volume = original volume + δV

$= 2400000 + 240$

$= 2400240\ mm^3$

② A steel bar 300mm long, 50mm wide and 40mm Thick is subjected to a pull of 300kN in the direction of its length. Take $E = 2\times10^5\ N/mm^2$ and Determine the change in volume.

$\mu = 0.25$

→ Given $L = 300mm$ $b = 50mm$, $t = 40mm$ $P = 300kN$.

$\mu = 0.25$

$E = 2\times10^5\ N/mm^2$

Original volume = $L \times b \times t$

$= 300 \times 50 \times 40 = 600000 mm^3$

Longitudinal strain = $\frac{Stress}{E}$

$$\frac{\delta L}{L} = \frac{P}{AE}$$

$$\frac{\delta L}{L} = \frac{300 \times 10^3}{50 \times 40 \times 2 \times 10^5}$$

$$\frac{\delta L}{L} = 0.00075$$

Now volumetric strain is given by equation

$$e_V = \frac{\delta L}{L}[1 - 2\mu]$$

$$\frac{\delta V}{V} = 0.00075 [1 - 2 \times 0.25]$$

$$\frac{\delta V}{V} = 0.000375$$

Let δV = change in volume.

then $\frac{dV}{V}$ represents volumetric strain

$$\frac{\delta V}{V} = 0.000375$$

$$\delta V = 0.000375 \times V$$

$$\delta V = 0.000375 \times 600000$$

$$\delta V = 225 mm^3$$

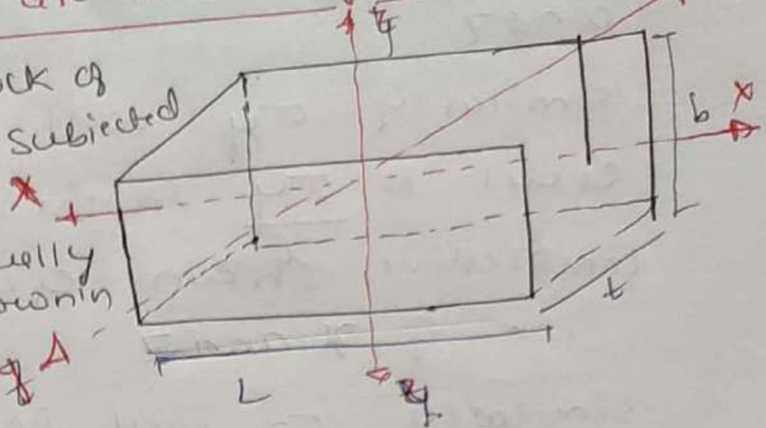
Final volume = original volume + δV

$= 600000 + 225$

Final volume $= 600225 mm^3$

Volumetric Strain of a Rectangular Bar subjected to three forces which are mutually Perpendicular

Consider a rectangular block of dimensions x, y and z subjected to three direct tensile stresses along three mutually perpendicular axis as shown in fig.



Then volume $V = xyz$

Taking log on both sides

$\log V = \log x + \log y + \log z$

Differentiating the above equation we get

$$\frac{1}{V} \cdot dV = \frac{1}{x} \cdot dx + \frac{1}{y} \cdot dy + \frac{1}{z} \cdot dz$$

or
$$\frac{dV}{V} = \frac{dx}{x} + \frac{dy}{y} + \frac{dz}{z} \quad \to (1)$$

But $\frac{dV}{V} = \frac{\text{change of volume}}{\text{original volume}}$ = volumetric strain

$\frac{dx}{x} = \frac{\text{change of dimension } x}{\text{original dimension of } x}$ = strain in x direction $= e_x$

Similarly $\frac{dy}{y}$ = strain in y direction $= e_y$

and $\frac{dz}{z}$ = strain in z-direction $= e_z$

Substituting these values in eq (1)

we get $\frac{dV}{V} = e_x + e_y + e_z$

longitudinal strain $= \frac{\sigma_t}{E}$

Now, let σ_x, σ_y & σ_z, Tensile stress in x-x, y-y & z-z direction respectively.

E = Young's modulus. μ = Poisson's ratio.

Now σ_x will produce a tensile strain equal to $\frac{\sigma_x}{E}$ in the direction of x, and a compressive strain equal to $\frac{\mu \times \sigma x}{E}$ in the direction of y and z.

Similarly, σy will produce a tensile strain equal to $\frac{\sigma y}{E}$ in the direction of y and a compressive strain equal to $\frac{\mu \times \sigma y}{E}$ in the direction of x and z.

Similarly, σz will produce a tensile strain equal to $\frac{\sigma z}{E}$ in the direction of z and a compressive strain equal to $\frac{\mu \times \sigma z}{E}$ in the direction of x and y.

Hence σy and σz will produce a compressive strain equal to $\frac{\mu \times \sigma y}{E}$ and $\frac{\mu \times \sigma z}{E}$ in the direction of x.

Now tensile strain along x-direction is given by.

$$e_x = \frac{\sigma x}{E} - \frac{\mu \times \sigma y}{E} - \frac{\mu \times \sigma z}{E}$$

$$e_y = \frac{\sigma y}{E} - \frac{\mu \sigma z}{E} - \frac{\mu \sigma x}{E}$$

$$e_x = \frac{\sigma x}{E} - \mu \left[\frac{\sigma y + \sigma z}{E} \right]$$

$$e_z = \frac{\sigma z}{E} - \frac{\mu \sigma x}{E} - \frac{\mu \sigma y}{E}$$

Similarly $e_y = \frac{\sigma y}{E} - \mu \left[\frac{\sigma z + \sigma x}{E} \right]$

$$e_z = \frac{\sigma z}{E} - \mu \left[\frac{\sigma x + \sigma y}{E} \right]$$

Adding all the strains we get

$$e_x + e_y + e_z = \frac{1}{E} [\sigma x + \sigma y + \sigma z] - \frac{2\mu}{E} (\sigma x + \sigma y + \sigma z)$$

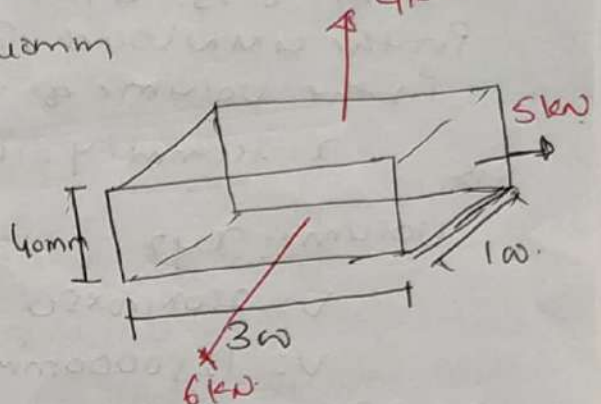
$$= \frac{1}{E} [\sigma x + \sigma y + \sigma z] [1 - 2\mu]$$

But $e_x + e_y + e_z$ = volumetric strain $= \frac{dV}{V}$

$$\boxed{\frac{dV}{V} = \frac{1}{E} [\sigma x + \sigma y + \sigma z] [1 - 2\mu]} \rightarrow (a)$$

Problems

① A metallic bar 300mm × 100mm × 40mm is subjected to a forces of 5KN (tensile) 6KN (tensile) and 4KN (tensile) along x, y and z directions respectively. Determine the change in volume of the block. Take E = 2×10⁵ N/mm2 and poisson's ratio = 0.25.



Ans $x = 300mm$, $y = 100mm$ and $z = 40mm$

volume $= xyz$

$= 300 \times 100 \times 40$

$= 1200000 mm^3$

load in the direction of x = 5KN

— " — y = 6KN

z = 4KN

$E = 2 \times 10^5 \ N/mm^2$

$\mu = 0.25$

$\sigma_x = \dfrac{\text{load in x-direction}}{y \times z}$

$\sigma_x = \dfrac{5000}{100 \times 40}$

$\boxed{\sigma_x = 1.25 \ N/mm^2}$

$\sigma_y = \dfrac{\text{load in y-direction}}{x \times z}$

$\sigma_y = \dfrac{6000}{300 \times 40} = 0.5 \ N/mm^2$

$\boxed{\sigma_y = 0.5 \ N/mm^2}$

$\sigma_z = \dfrac{\text{load in z-direction}}{x \times y} = \dfrac{4000}{300 \times 100}$

$\boxed{\sigma_z = 0.133 \ N/mm^2}$

$$\frac{dV}{V} = \frac{1}{E}(\sigma_x + \sigma_y + \sigma_z)(1 - 2\mu]$$

$$\frac{dV}{V} = \frac{1}{2 \times 10^5}\left[1.25 + 0.5 + 0.133\right]\left[1 - 2 \times 0.25\right]$$

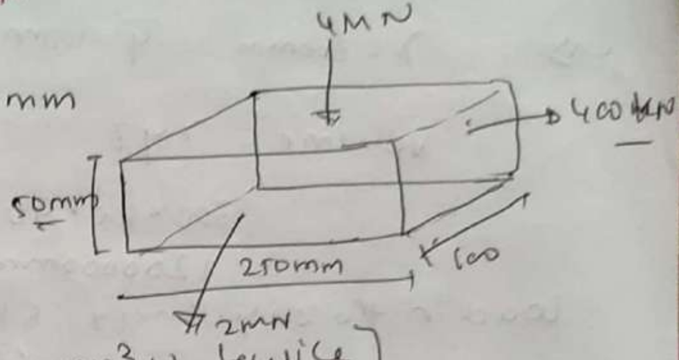
$dV = 47803.33 \times V$

$dV = 47803.33 \times 1200000 = 5.65 \ mm^3$

$dv = 5.649 mm^3$

(5) A metallic bar 250mm×100mm×50mm is loaded as shown in fig. find the change in volume. take $E = 2\times10^5 N/mm^2$ and $\mu = 0.25$. also find the change that should be made in the 4MN load. Inorder that there should be no change in the volume of the bar.

$x = 250mm \quad y = 100mm \quad z = 50mm$



us

Volume $= xyz$

$V = 250\times100\times50$

$V = 1250000 mm^3$

Load in x-direction $= 400kN = 400\times10^3 N$. tensile]

Load in y-direction $= 2MN = 2\times10^6 N$ (tensile]

Load in z-direction $= 2MN = 2\times10^6 N$ (Compression

$E = 2\times10^5 N/mm^2, \quad \mu = 0.25$

σx = Stress in x-direction

$\sigma x = \dfrac{\text{Load in x-direction}}{\text{Area of cross section}(y\times z)}$

$\sigma x = \dfrac{400\times10^3}{100\times50}$

$\sigma x = 80 N/mm^2$ (T)

$\sigma y = \dfrac{\text{Load in y-direction}}{(z\times x)}$

$\sigma y = \dfrac{2\times10^6}{50\times250}$

$\sigma y = 160 N/mm^2$ (T)

$\sigma z = \dfrac{\text{Load in z-direction}}{(x\times y)} = \dfrac{4\times10^6}{(250\times100)} =$

$\sigma z = 160 N/mm^2$ compression.

Volumetric Strain $\dfrac{dV}{V} = \dfrac{1}{E}(\sigma x + \sigma y + \sigma z)(1-2\mu)$

$\dfrac{dV}{V} = \dfrac{1}{2\times10^5}[80 + 160 - 160][1 - 2\times0.25]$

$dV = 0.0002V.$

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Change in volume

$dV = 0.0002 \times V$

$= 0.0002 \times 1250000$

$dV = 250 mm^3$

Change in the 4MN load when there is no change in volume of bar

$\frac{dV}{V} = \frac{1}{E}(\sigma_x + \sigma_y + \sigma_z)(1-2\mu]$

If there is no change in volume, then $\frac{dV}{V} = 0$.

$\frac{1}{E}(\sigma_x + \sigma_y + \sigma_z)(1-2\mu] = 0$

But for most of materials, the value of μ lies b/w 0.25 and 0.33 and hence the term $[1-2\mu]$ is never zero.

$\sigma_x + \sigma_y + \sigma_z = 0.$

The stresses σ_x and σ_y are not to be changed. only the stress corresponding to the load 4MN (i.e stress in z-direction) is to be changed.

$\sigma_z = -\sigma_x - \sigma_y = -80 - 180 = -240 N/mm^2$ (C)

$\sigma_z = \frac{load}{Area(x \cdot y)} = \frac{load}{250 \times 100}$

$240 = \frac{load}{250 \times 100}$

$load = 240 \times (250 \times 100)$

$= 6 \times 10^6 N.$

$load = 6 MN$

But already a compressive load of 4MN is acting

∴ Additional load that must be added

$= 6MN - 4MN$

$= 2MN$ (compressive).

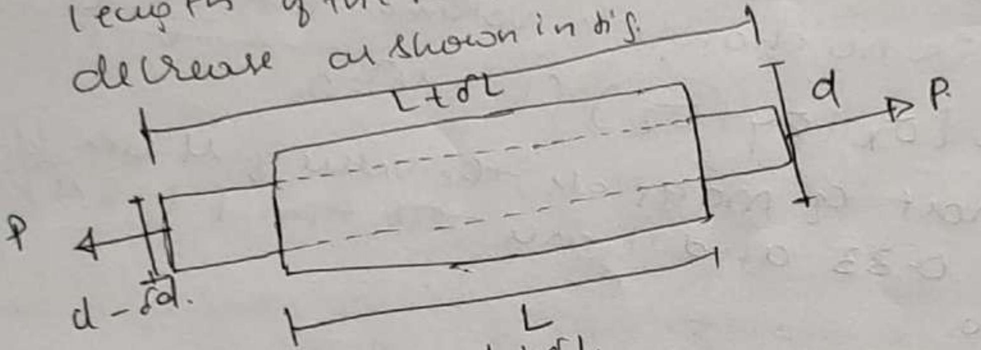
Volumetric strain of a cylindrical rod.

Consider a cylindrical rod which is subjected to an axial tensile load P.

Let d = diameter of the rod.

L = length of the rod.

Due to tensile load P there will be an increase in length of the rod, but the diameter of the rod will decrease as shown in fig.



Final length = $L+\delta L$.

Final Diameter = $d-\delta d$.

Now original volume of the rod.

$$L = \frac{\pi}{4} d^2 \times L$$

Final volume $= \frac{\pi}{4}[d-\delta d]^2 [L+\delta L]$

$$\frac{\pi}{4}[d^2+\delta d^2 - 2d \times \delta d][L+\delta L]$$

$$= \frac{\pi}{4}[d^2 + \delta d^2 - 2d \times L \times \delta d + d^2 \times dL$$

$$= \frac{\pi}{4}\Big[d^2 \times L + \delta d^2 \times L - 2d \times L \times \delta d \times \delta L\Big] + d^2 \times dL - 2d \times \delta d \times \delta L$$

$$= \frac{\pi}{4}\left(d^2 \times L + \delta d^2 L - 2dL\delta d + d^2 \delta L + \delta d^2 dL - 2d\,dL\delta d\right]$$

$$= \frac{\pi}{4}\left[d^2 L - 2dL\delta d + d^2 \times \delta L\right]$$

Neglecting the product and higher powers of two small quantities.

∴ change in volume, δV = Final volume - original volume

=

$$= \frac{\pi}{4}[d^2 \times L - 2d \times L \times \delta d + d^2 dL] - \frac{\pi}{4} d^2 L$$

$$= \frac{\pi}{4}[d^2 \times \delta L - 2dL\delta d]$$

Volumetric strain $e_v = \frac{\text{Change in volume}}{\text{original volume}} = \frac{\delta V}{V}$

$$= \frac{\frac{\pi}{4}(d^2 \times \delta L - 2dL\delta d]}{\frac{\pi}{4} d^2 \times L}$$

$$= \frac{\delta L}{L} - \frac{2\delta d}{d} \rightarrow (1)$$

Where $\frac{\delta L}{L}$ is the strain of length and $\frac{\delta d}{d}$ is strain of diameter.

∴ Volumetric strain = strain in length − Twice the strain of diameter.

(*) Problem

(1) A steel rod of 5m long and 30mm in diameter is subjected to an axial tensile load of 50kN. Determine the change in length, diameter and volume of the rod. Take $E = 2 \times 10^5$ N/mm², and Poisson's ratio = 0.25.

length $L = 5m = 5 \times 10^3$ mm, $d = 30$mm, volume $V = \frac{\pi}{4} \times d^2 \times L$

$\delta L = ?$ $E = 2 \times 10^5$ N/mm², $V = \frac{\pi}{4} \times 30^2 \times 5 \times 10^3$

$P = 50 \times 10^3$N, $V = 35.34 \times 10^5$.

$\mu = 0.25$

Let δd = Change in diameter,

δL = Change in length, δV = change in volume

Strain in length = $\frac{\text{Stress}}{E}$

$$= \frac{\text{Load}}{\text{Area}} \times \frac{1}{E}$$

$$= \frac{P}{\frac{\pi}{4} \times d^2} \times \frac{1}{E}$$

$$= \frac{50 \times 10^3}{\frac{\pi}{4} \times 30^2} \times \frac{1}{2 \times 10^5}$$

$\Delta = 0.0003536$ mm

But Strain of length = $\frac{\delta L}{L}$

$$\frac{\delta L}{L} = 0.0003536$$

Longitudinal strain $\delta L = 0.0003536 \times 5 \times 10^3$

$\delta L = 1.768$ mm

Now Poisson's ratio = $\frac{\text{lateral strain}}{\text{Longitudinal strain}}$

Lateral Strain = Poisson's ratio × Longitudinal strain

$= \mu \times \delta L$

$= 0.25 \times 0.0003536$

$= 0.0000884$

But lateral strain = $\frac{\delta d}{d}$

$$\frac{\delta d}{d} = 0.0000884$$

$\delta d = 0.0000884 \times d$

$\delta d = 0.0000884 \times 30$

$\delta d = 0.002652$ mm

Volumetric Strain $\frac{\delta V}{V} = \frac{\delta L}{L} - \frac{2\delta d}{d}$

$= 0.0003536 - 2[0.0000884]$

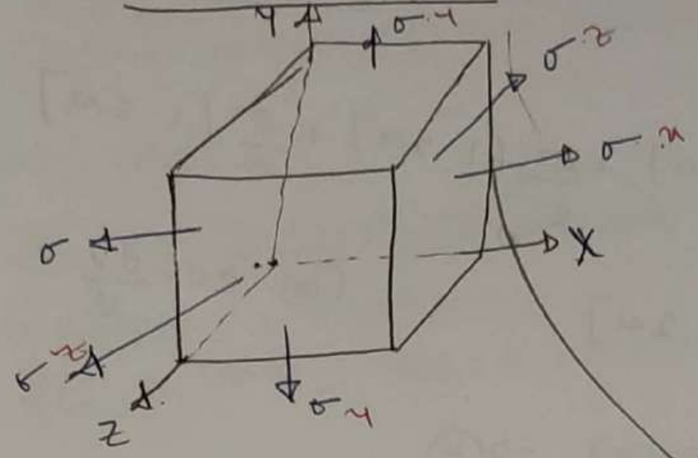
$= 0.0001768$

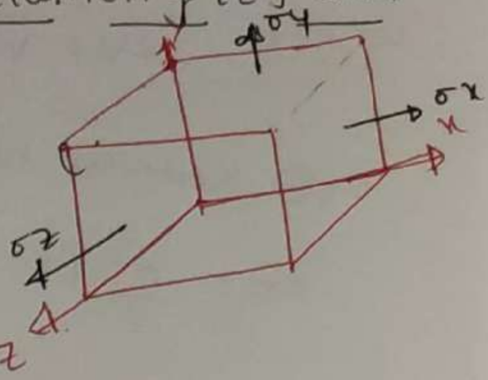
$\delta V = 0.0001768 \times V$

$= 0.0001768 \times 35.343 \times 10^5$

$\delta V = 624.86 \text{ mm}^3$

Relationship b/w modulus of elasticity [E] and Bulk modulus [K]





Consider a Rectangular/cube which is subjected to three mutually ⊥r tensile stress of "equal Intensity"

Let L = length of the cube
dL = change in length of the cube.
E = young's modulus of the material of the cube
σ = Tensile stress acting on the faces
μ = poissions ratio.

When σ_x produces a tensile strain equal to $\frac{\sigma_x}{E}$ in the direction of x on the other hand σ_y & σ_z will produces a compressive strain equal to $\mu \cdot \frac{\sigma_y}{E}$ & $\mu \cdot \frac{\sigma_z}{E}$ in the direction x.

Since in this case when the stress is subjected to mutual ⊥r tensile stress of equal Intensity.

i.e, $\sigma_x = \sigma_y = \sigma_z = \sigma$

Tensile strain along x- direction is given by

$$e_x = \frac{\sigma}{E} - \mu \cdot \frac{\sigma}{E} - \mu \cdot \frac{\sigma}{E}$$

$$e_x = \frac{\sigma}{E}[1 - 2\mu] \longrightarrow (a)$$

Illy Tensile strain along - y-direction

$$e_y = \frac{\sigma}{E}[1 - 2\mu] \longrightarrow (b)$$

Illy Tensile strain along Z- direction

$$e_z = \frac{\sigma}{E}[1 - 2\mu] \longrightarrow (c)$$

w.k.t. ~~ev~~ = volumetric strain $\boxed{e_v = e_x + e_y + e_z}$ → (1)

eq (1) reduces to.

$$e_v = \frac{\sigma}{E}[1-2\mu] + \frac{\sigma}{E}[1-2\mu] + \frac{\sigma}{E}[1-2\mu]$$

(or) $e_v = \frac{\delta V}{V}$

$$e_v = 3\left(\frac{\sigma}{E}\right)[1-2\mu]$$

$$\frac{\delta V}{V} = \frac{3\sigma}{E}[1-2\mu] \rightarrow (2)$$

But Bulk modulus $K = \frac{\text{Direct stress}}{\text{volumetric strain}} = \frac{\sigma}{e_v}$

$$\boxed{K = \frac{\sigma}{\frac{\delta V}{V}}} \rightarrow (3)$$

Substituting eq (2) in eq (3) we get

$$K = \frac{\sigma}{\frac{\delta V}{V}}$$

$$K = \frac{\sigma}{\frac{3\sigma[1-2\mu]}{E}}$$

$$K = \frac{E}{3(1-2\mu)}$$

$$\boxed{3K(1-2\mu) = E}$$

Relationship b/w E & K

① A bar of 30mm diameter is subjected to a pull of 60kN. The measured extension on gauge length of 200mm is 0.1mm and change in diameter is 0.004mm, calculate. ① Young's modulus, ② Poisson's ratio, ③ Bulk modulus.

⇝ Diam = 30mm

Area of bar = $\frac{\pi}{4}(30)^2 = 706.85\ mm^2$

$P = 60kN \quad L = 200mm,$

$\delta L = 0.1mm \quad \delta d = 0.004mm.$

① Young's modulus $E = \frac{\text{Tensile stress}}{\text{Longitudinal strain}}$

Tensile stress $\sigma = \frac{P}{A} = \frac{60\times10^3}{706.85} = 84.87\ N/mm^2$

Longitudinal strain $\epsilon = \frac{\delta L}{L} = \frac{0.1}{200} = 0.0005$

$E = \frac{\text{Tensile stress}}{\text{longitudinal strain}}$

$E = \frac{\sigma}{\epsilon} = \frac{84.87}{0.0005}$

$E = 1.69\times10^5\ N/mm^2$

② Poisson's ratio

$\mu = \frac{\text{lateral strain}}{\text{longitudinal strain}}$

$\mu = \frac{\left(\frac{\delta d}{d}\right)}{0.0005} = \frac{\left[\frac{0.004}{30}\right]}{0.0005}$

$\mu = 0.266$

③ Bulk modulus (K)

$K = \frac{E}{3(1-2\mu)} = \frac{1.69\times10^5}{3(1-2\times0.266)}$

$K = 1.209\times10^5\ N/mm^2$

Assumptions Made in the properties of Materials

① The material is homogenous having same composition Through out the body.

② The elastic properties are same at each & every Point in the body.

③ The material is isotrophic, which means that The material is equally elastic in all the directions.

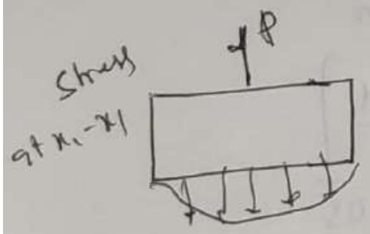
④ The material of the body has a solid structure

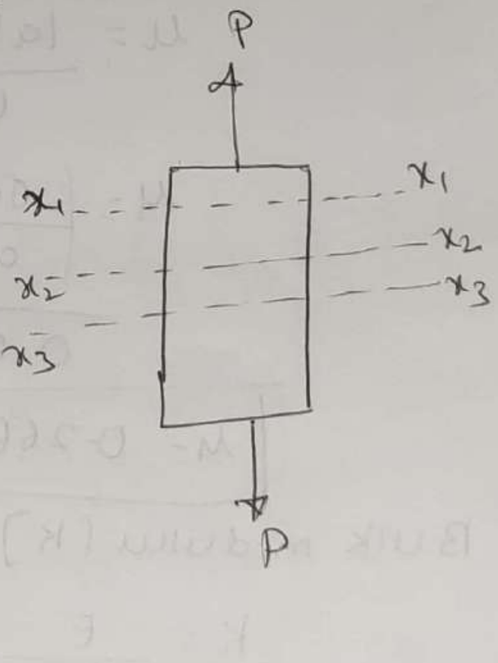
⑤ Initially there are number of internal forces in the body.

⑥ principle of superposition holds good for internal force in the body.

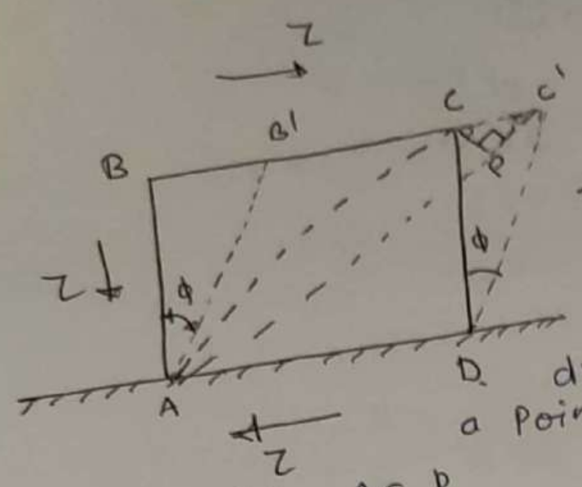
Saint Venant's Principle:

It is assumed that the distribution of stress over the cross section is uniform [$f = P/A$]. This assumption is based on saint venant's principle. The principle states that except in the region of extreme ends of a bar carrying direct loading. The stress distribution over a cross-section is uniform.





Relationship b/w modulus of elasticity (E) and Modulus of Rigidity (C & G)



Consider a body ABCD of unit thickness with its face AD is rigid and shear force is acting on the side face BC as shown in fig.

Due to the shear force the body takes a new plane AB'C'D. Draw diagonal AC' and draw ⊥r to AC' from C to meet at a point 'P'.

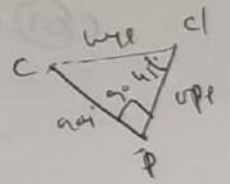
From Δle ACP

$AC = AP$ ✓

$\angle PCC' = 45°$ [since angle of deformation is very small we can assume that it is 45°]

since the deformation of the diagonal member AC is given by

$$\text{strain } \epsilon_{AC} = \frac{AC' - AP}{AP} = \frac{PC'}{AP} \rightarrow (1)$$



From Δle PCC'

$$\sin 45 = \frac{PC'}{CC'}$$

$$\frac{1}{\sqrt{2}} = \frac{PC'}{CC'}$$

$$PC' = CC' \times \frac{1}{\sqrt{2}} \rightarrow (2)$$

From Δle ACD

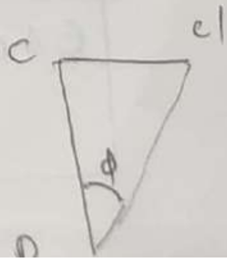
$$AC = \sqrt{AD^2 + CD^2}$$

Assume that the section is square $AD = CD$.

$$AP = AC = \sqrt{CD^2 + CD^2} = \sqrt{2CD^2} = \sqrt{2}\cdot CD \rightarrow (3)$$

Shear strain for the Δle DCC'

i.e $\tan\phi = \dfrac{CC'}{CD}$



For small angle $\tan\phi = \phi$

$\therefore \phi = \frac{CC'}{CD} \rightarrow (4)$

Substituting (2) & (3) in eq (1)

$$\epsilon_{AC} = \frac{CC' \times 1/\sqrt{2}}{\sqrt{2}.CD} = \frac{CC'}{2CD}$$

from eq (4) $\phi = \frac{CC'}{CD}$

$$\epsilon_{AC} = \frac{CC'}{CD}$$

$$\epsilon_{AC} = \frac{CC'}{2.CD}$$

$$= \frac{1}{2} \times \frac{CC'}{CD}$$

$$\boxed{\epsilon_{AC} = \frac{\phi}{2}} \rightarrow (5)$$

W.K.T. Modulus of Rigidity

$$C \text{ (or) } G = \frac{q \text{ (or) } f \text{ (or) } \tau}{\phi}$$

$$G = \frac{\tau}{2\epsilon_{AC}} \rightarrow (6)$$

$$\boxed{\epsilon_{AC} = \frac{\tau}{2G}} \rightarrow C$$

An element oriented along the diagonal AC & BD subjected to tensile stress & compressive stress in the fig

Hence the strain along the member AC is given by

$$\epsilon_{AC} = \frac{\sigma}{E} - \left(-\mu\frac{\sigma}{E}\right)$$

$$\epsilon_{AC} = \frac{\sigma}{E} + \mu\frac{\sigma}{E}$$

$$\boxed{\epsilon_{AC} = \frac{\sigma}{E}[1+\mu]} \rightarrow (7)$$

In equation (7) strain ...

$$\epsilon_{AC} = \frac{\tau}{E}(1+\mu) \rightarrow (8)$$

comparing eq (6) & (8)

$$\frac{\tau}{2G} = \frac{\tau}{E}(1+\mu)$$

$$E = 2G[1+\mu]$$

Relationship b/w modulus of elasticity (E), modulus of Rigidity (G) and Bulk modulus (K)

w.k.t = $E = 2G(1+\mu) \rightarrow (1)$

& $E = 3K[1-2\mu) \rightarrow (2)$

from eq (1) $E = 2G[1+\mu]$

$$\frac{E}{2G} = (1+\mu)$$

$$\mu = \frac{E}{2G} - 1 \rightarrow (3)$$

Substituting the value of μ in eq (2) we get

$$E = 3K\left[1 - 2\left(\frac{E}{2G} - 1\right)\right]$$

$$E = 3K\left[1 - \frac{2E}{2G} + 2\right]$$

$$E = 3K\left[1 - \frac{E}{G} + 2\right]$$

$$E = 3K\left(3 - \frac{E}{G}\right)$$

$$E = 9K - \frac{3KE}{G}$$

$$E + \frac{3KE}{G} = 9K \qquad E\left[1 + \frac{3K}{G}\right] = 9K.$$

Poisson's ratio and bulk modulus of a material, ... given for which Young's modulus is 1.2×10^5 N/mm², and modulus of rigidity is 4.8×10^4 N/mm²

→ $\mu = ?$ $K = ?$ $E = 1.2 \times 10^5$ N/mm² $G = 4.8 \times 10^4$ N/mm²

$$E = 2G[1+\mu]$$

$$1.2 \times 10^5 = 2 \times 4.8 \times 10^4 [1+\mu]$$

$$(1+\mu) = \frac{1.2 \times 10^5}{2 \times 4.8 \times 10^4}$$

$$1+\mu = 1.25$$

$$\mu = 1.25 - 1$$

$$\boxed{\mu = 0.25}$$

Bulk modulus is given by by equation

$$K = \frac{E}{3[1-2\mu]}$$

$$K = \frac{1.2 \times 10^5}{3[1 - 2 \times 0.25)}$$

$$\boxed{K = 8 \times 10^4 \text{ N/mm}^2}$$

(2) A bar of cross section 8mm×8mm is subjected to an axial pull of 7000N. The lateral ~~too~~ dimension of the bar is found to be changed to 7.9985mm × 7.9985mm. If the modulus of rigidity of the material is 0.8×10^5 N/mm², determine the Poisson's ratio and modulus of elasticity.

Given Cross-section 8mm×8mm $P = 7000N$,

lateral dimension of bar = 7.9985 mm × 7.9985 mm

Volume of G = 0.8×10^5 N/mm²

Let $\mu = ?$ $E = ?$

$$\text{Now lateral strain} = \frac{\text{change in lateral dimension } \text{~~Length~~}}{\text{Original lateral dimension}}$$

$$= \frac{8 - 7.9985}{8} = \frac{0.0015}{8}$$

$$= 0.0001875.$$

To find the value of Poisson's ratio, we must know the value of longitudinal strain. But in this problem the length of the bar and the axial tension is not given. Hence the longitudinal strain cannot be calculated. But axial stress can be calculated. Then longitudinal strain will be equal to the axial stress divided by E.

axial stress $\sigma = \frac{P}{Area} = \frac{7000}{64} = 109.375\ N/mm^2$

longitudinal strain $= \frac{\sigma}{E}$

But lateral strain $= \mu \times$ longitudinal strain $= \frac{\mu \times \sigma}{E}$

$$0.0001875 = \frac{\mu \times 109.375}{E}$$

$$\frac{E}{\mu} = \frac{109.375}{0.0001875}$$

$$\boxed{E = 583333.3\mu}$$

(a) using equation

$$G = \frac{E}{2(1+\mu)}$$

$$E = 2C(1+\mu)$$

$$= 2 \times 0.8 \times 10^5 (1+\mu)$$

$$= 2 \times 0.8 \times 10^5 (1+\mu)$$

$$583333.3\mu = 2 \times 0.8 \times 10^5 (1+\mu)$$

$$(1+\mu) = \frac{583333.3\mu}{2 \times 0.8 \times 10^5}$$

$$1+\mu = 3.6458\mu$$

$$1 = 3.6458\mu - \mu$$

$$1 = \mu[3.6458 - 1]$$

$$1 = 2.6458\mu$$

$$\mu = \frac{1}{2.6458} = 0.378$$

Modulus of elasticity (E)

$E = 583333.3 \mu$

$E = 583333.3 \times 0.378$

$E = 2.2049 \times 10^5$ N/mm2

③ calculate the modulus of rigidity and bulk modulus of a cyclindrical bar of diameter 30mm and of length 1.5m if the longitudinal strain in a bar during a tensile stress is four times the lateral strain. Find the change in volume when the bar is subjected to a hydrostatic pressure of 100 N/mm². take E = 1×10^5 N/mm².

→ Dia = 30mm.

$L = 1.5m = 1.5 \times 1000$
$= 1500 mm.$

Volume of bar $V = \frac{\pi}{4} d^2 \times L$

$= \frac{\pi}{4} (30)^2 \times 1500$

$= 1060287.52 mm^2$

longitudinal strain = 4 × lateral strain.

$P = 100$ N/mm²

$\mu = \frac{\text{lateral strain}}{\text{longitudinal strain}} = \frac{1}{4} = 0.25$

$\mu = 0.25$

C = modulus of rigidity, K = Bulk modulus, E = young's modulus $= 1 \times 10^5$ N/mm²

$E = 2C[1 + \mu]$

$1 \times 10^5 = 2 \times C[1 + 0.25]$

$C = \frac{1 \times 10^5}{2 \times 1.25}$

$G = 4 \times 10^4$ N/mm²

$E = 3K[1 - 2\mu]$

$1 \times 10^5 = 3 \times K[1 - 2 \times 0.25]$

$K = \frac{1 \times 10^5}{3 \times 0.5}$

$K = 0.667 \times 10^5$ N/mm²

$K = \frac{P}{\text{volumetric strain}} = \frac{P}{\left(\frac{dV}{V}\right)}$

$6.667 \times 10^5 = \frac{100}{\frac{dV}{V}}$

$\frac{dV}{V} = \frac{100}{0.667 \times 10^5} = 1.5 \times 10^{-3}$

$dV = 1.5 \times 10^{-3} \times V = 1590.43 mm^3$

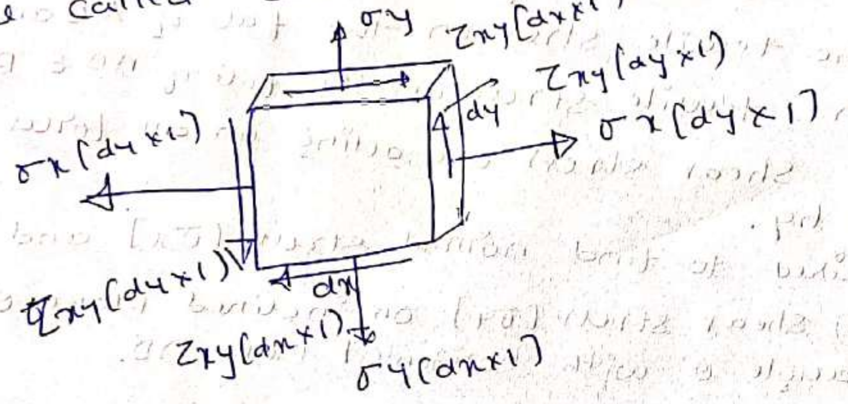
Module: 2

Compound Stresses

Introduction, state of stress at a point, General two Dimensional stress system, Principal stresses and principal planes. Mohr's circle of stresses. Theory of failures. Max. shear stress theory and max principle stress theory.

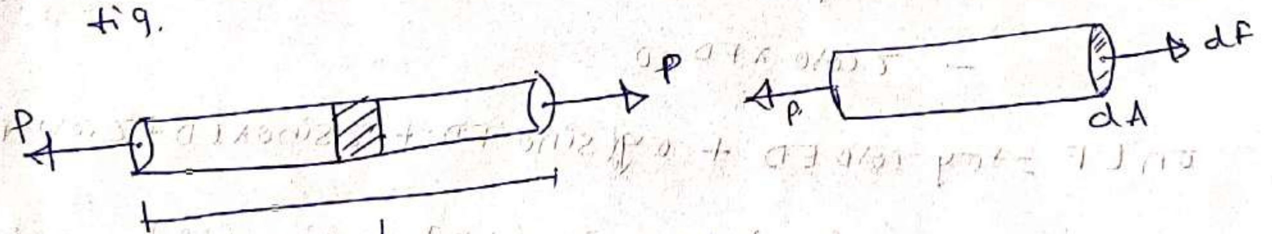
Compound Stresses:

The stress system in which both Direct stresses [σ or σ] and shearing stresses [τ] are acting simultaneously are called combined stresses or compound stresses.



Stress at a point:

Consider an elastic body subjected to the forces as shown in fig. consider an element as shown in fig.



Force on element = dF

Area of the element = dA

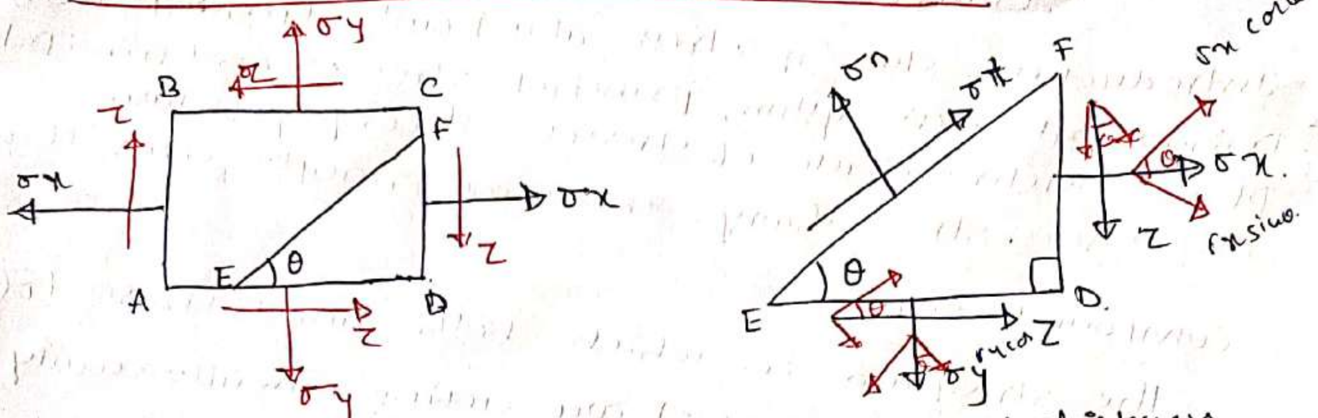
Stress at a point OR element $= \frac{dF}{dA}$

As $dA \to 0$

$$\text{Stress} = \lim_{dA \to 0} \frac{dP}{dA}$$

$$\boxed{dF = \frac{\partial P}{\partial A}}$$ - Stress at a point.

General two dimensional Stress System :-



Consider a rectangular block ABCD of unit thickness under two dimensional stress system as shown in fig.

Let σ_x be the tensile stress on the face of AB and CD

σ_y be the tensile stress on the face of AD & BC.

τ be the Shear stress are acting on all forces as shown in fig.

It is required to find normal stress $[\sigma_n]$ and Tangential (or) shear stress $[\sigma_t]$ on inclined plane θ. making an angle θ with horizontal plane AD.

Considering portion EDF

Resolving all forces along σ_n & σ_t direction

Along σ_n direction.

$$\sigma_n \times [EF\times1] - \sigma_y[\cos\theta\,[ED\times1]] - \sigma_x \sin\theta\,[FD\times1] - \tau\sin\theta\times ED - \tau\cos\theta\times FD = 0$$

$$\sigma_n EF = +\sigma_y \cos\theta\, ED + \sigma_x \sin\theta\, FD + \tau\sin\theta\times ED + \tau\cos\theta\times FD$$

$$\sigma_n = \sigma_y \cos\theta\left(\frac{ED}{EF}\right) + \sigma_x \sin\theta\left[\frac{FD}{EF}\right] + \tau\sin\theta\times\left[\frac{ED}{EF}\right] + \tau\cos\theta\times\left[\frac{FD}{EF}\right]$$

$$\frac{ED}{EF} = \cos\theta \qquad \frac{FD}{EF} = \sin\theta.$$

Substituting these values in the above eq.

$$\sigma_n = \sigma_y.\cos\theta\times\cos\theta + \sigma_x \sin\theta.\sin\theta + \tau\sin\theta\times\cos\theta + \tau\cos\theta\times\sin\theta.$$

$$\sigma_n = \sigma_x \sin^2\theta + \sigma_y \cos^2\theta + 2\tau\sin\theta.\cos\theta.$$

$$\sigma x = \sigma x\left[\frac{1-\cos 2\theta}{2}\right] + \sigma y\left[\frac{1+\cos 2\theta}{2}\right] + \tau \sin 2\theta$$

$$\sigma x = \frac{\sigma x}{2} - \frac{\sigma x \cos 2\theta}{2} + \frac{\sigma y}{2} + \frac{\sigma y \cos 2\theta}{2} + \tau \sin 2\theta.$$

$$\boxed{\sigma x = \left(\frac{\sigma x + \sigma y}{2}\right) + \cos 2\theta\left[\frac{\sigma y - \sigma x}{2}\right] + \tau \sin 2\theta} \rightarrow (1)$$

Along σ_T direction

$$\sigma_t(EF) + \sigma x \cos\theta \times DF - \sigma y \sin\theta \times ED + \tau \cos\theta \times ED - \tau \sin\theta\, FD = 0.$$

$$\sigma_t(EF) = -\sigma x \cos\theta \times DF + \sigma y \sin\theta \times ED - \tau \cos\theta\, ED + \tau \sin\theta\, FD$$

$$\sigma_t = -\sigma x \cos\theta \times \left(\frac{DF}{EF}\right) + \sigma y \sin\theta \times \left(\frac{ED}{EF}\right) - \tau \cos\theta\left[\frac{ED}{EF}\right] + \tau \sin\theta \left(\frac{FD}{EF}\right)$$

$$\frac{DF}{EF} = \sin\theta \qquad \frac{ED}{EF} = \cos\theta$$

$$\sigma_t = -\sigma x \cos\theta \times \sin\theta + \sigma y \sin\theta \cos\theta - \tau \cos\theta \cos\theta + \tau \sin\theta \times \sin\theta$$

$$= -\tau \cos^2\theta + \tau \sin^2\theta.$$

$$\sigma_t = (\sigma y - \sigma x) \sin\theta \cos\theta - \tau (\cos^2\theta - \sin^2\theta)$$

$$\sigma_t = \left[\frac{\sigma y - \sigma x}{2}\right] \sin 2\theta - \tau \cos 2\theta$$

$$\boxed{\sigma_t = \left[\frac{\sigma y - \sigma x}{2}\right] \sin 2\theta - \tau \cos 2\theta} \rightarrow (2)$$

$\cos^2\theta - \sin^2\theta$

$\frac{1+\cos 2\theta}{2} - \frac{1+\cos 2\theta}{2}$

$\cos 2\theta.$

Equation is normal stress on Inclined Plane where Eq (2) is shear or Tangential stress on Inclined Plane.

The planes on which the shear stress (Tangential stress) is zero are known as principal planes. And the stresses acting on the principal planes are known as principal stress.

$\therefore$ For principal plane

$$\sigma_t = 0$$

$$\left(\frac{\sigma y - \sigma x}{2}\right) \sin 2\theta - \tau \cos 2\theta = 0$$

$$\frac{(\sigma y - \sigma x)}{2} \sin 2\theta = \tau \cos 2\theta$$

$$(\sigma y - \sigma x) \sin 2\theta = 2\tau \cos 2\theta$$

$$\frac{\sin 2\theta}{\cos 2\theta} = \frac{2\tau}{\sigma y - \sigma x}$$

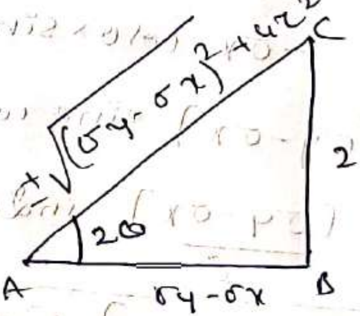
$$\boxed{\tan 2\theta = \frac{2\tau}{\sigma y - \sigma x}}$$

Principal stresses and principal planes

In case of two dimensional stress system there always exists two planes seperated by 90°, on which the shearing stresses are zero. These shear free planes are called principal planes and the corresponding values of value of normal stress (σn) acting on these planes are called principal stresses of which one is major principal stress and minor principal stress.

We know that

$$\tan 2\theta = \frac{2\tau}{\sigma y - \sigma x}$$



$AB = \sigma y - \sigma x$

$BC = 2\tau$

Then $AC = \pm\sqrt{AB^2 + BC^2}$

$$AC = \pm\sqrt{(\sigma y - \sigma x)^2 + (2\tau)^2}$$

$$AC = +\sqrt{(\sigma y - \sigma x)^2 + 4\tau^2}$$

$$AC = -\sqrt{(\sigma y - \sigma x)^2 + 4\tau^2}$$

From fig

$$\sin 2\theta = \frac{opp}{hyp} = \frac{BC}{AC} = \frac{\pm 2\tau}{\sqrt{(\sigma y - \sigma x)^2 + 4\tau^2}}$$

$$\cos 2\theta = \frac{adj}{hyp} = \frac{AB}{AC} = \frac{\pm(\sigma y - \sigma x)}{\sqrt{(\sigma y - \sigma x)^2 + 4\tau^2}}$$

$$\sigma_{n1} \text{ or } \sigma_{n2} = \left[\frac{\sigma_x+\sigma_y}{2}\right] + \frac{\cos 2\theta}{2}\left[\frac{\sigma_y-\sigma_x}{2}\right] + \tau \sin 2\theta.$$

$$= \left[\frac{\sigma_x+\sigma_y}{2}\right] \pm \left[\frac{\sigma_y-\sigma_x}{2}\right]\frac{(\sigma_y-\sigma_x)}{\sqrt{(\sigma_y-\sigma_x)^2+4\tau^2}} \pm \frac{\tau\times 2\tau}{\sqrt{(\sigma_y-\sigma_x)^2+4\tau^2}}$$

$$\sigma_{n1} \text{ (or) } \sigma_{n2} = \left[\frac{\sigma_x+\sigma_y}{2}\right] \pm \frac{[\sigma_y-\sigma_x]^2}{2\sqrt{(\sigma_y-\sigma_x)^2+4\tau^2}} \pm \frac{2\tau^2}{\sqrt{(\sigma_y-\sigma_x)^2+4\tau^2}}$$

$$= \left[\frac{\sigma_x+\sigma_y}{2}\right] \pm \frac{[\sigma_y-\sigma_x]^2+4\tau^2}{2\sqrt{(\sigma_y-\sigma_x)^2+4\tau^2}}$$

$$= \left[\frac{\sigma_x+\sigma_y}{2}\right] \pm \frac{\sqrt{(\sigma_y-\sigma_x)^2+4\tau^2}}{2}$$

$$\boxed{\sigma_{n1} \text{ (or) } \sigma_{n2} = \left[\frac{\sigma_x+\sigma_y}{2}\right] \pm \sqrt{\left(\frac{\sigma_y-\sigma_x}{2}\right)^2+\tau^2}}$$

Major principal stress $\sigma_{n1} = \left[\frac{\sigma_x+\sigma_y}{2}\right] + \sqrt{\left(\frac{\sigma_y-\sigma_x}{2}\right)^2+\tau^2}$

Minor principal stress $\sigma_{n2} = \left[\frac{\sigma_x+\sigma_y}{2}\right] - \sqrt{\left[\frac{\sigma_y-\sigma_x}{2}\right]^2+\tau^2}$

Maximum shear stress:

$$\sigma_t = \left[\frac{\sigma_y - \sigma_x}{2}\right] \sin 2\theta - \tau \cos 2\theta = 0$$

The plane when shear is maximum

when $\frac{d}{d\theta}(\sigma_t) = 0.$

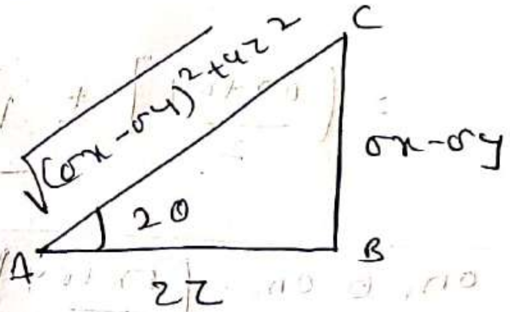
$$0 = \frac{d}{d\theta}\left[\left[\frac{\sigma_y - \sigma_x}{2}\right] \sin 2\theta - \tau \cos 2\theta\right]$$

$$0 = \left[\frac{\sigma_y - \sigma_x}{2}\right] \cos 2\theta \times 2 - \tau \sin 2\theta (-2)$$

$$0 = [\sigma_y - \sigma_x] \cos 2\theta + 2\tau \sin 2\theta$$

$$0 = -[\sigma_x - \sigma_y] \cos 2\theta + 2\tau \sin 2\theta.$$

$$\tan 2\theta = \frac{\sigma_x - \sigma_y}{2\tau}$$



$$\sin 2\theta = \frac{\pm(\sigma_x - \sigma_y)}{\sqrt{(\sigma_x - \sigma_y)^2 + 4\tau^2}}$$

$$\cos 2\theta = \pm \frac{2\tau}{\sqrt{(\sigma_x - \sigma_y)^2 + 4\tau^2}}.$$

$$\sigma_t = \left(\frac{\sigma_y - \sigma_x}{2}\right] \sin 2\theta - \tau \cos 2\theta$$

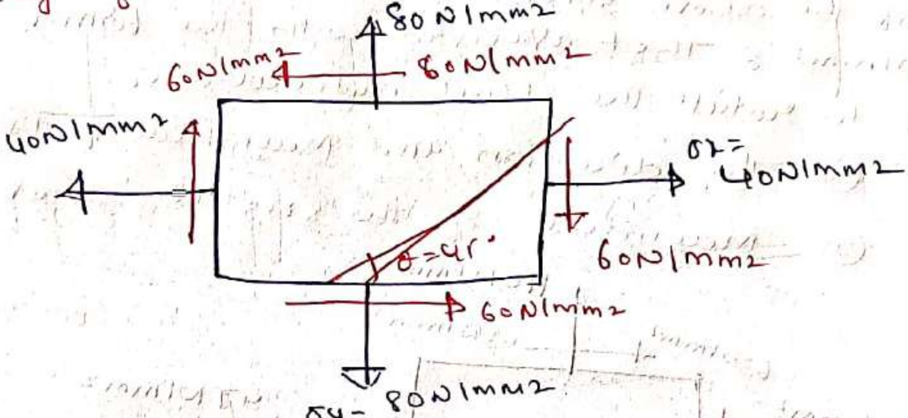
$$\sigma_t = \pm\left(\frac{\sigma_y - \sigma_x}{2}\right]\frac{(\sigma_x - \sigma_y]}{\sqrt{(\sigma_x - \sigma_y)^2 + 4\tau^2}} \mp \frac{\tau \times 2\tau}{\sqrt{(\sigma_x - \sigma_y)^2 + 4\tau^2}}$$

$$\sigma_t = \frac{\mp (\sigma_x - \sigma_y)^2 + 4\tau^2}{2\sqrt{(\sigma_x - \sigma_y)^2 + 4\tau^2}}.$$

$$\sigma_t \Big]_{max} = \pm\frac{1}{2}\sqrt{(\sigma_x-\sigma_y)^2+4\tau^2}$$

Problems

1. At a point with in a body subjected to two mutually perpendicular directions, the stresses are 80 N/mm² tensile and 40 N/mm² tensile. Each of the above stress is accompained by a shear stress of 60 N/mm². Determine normal stress, shear stress & resultant stress on an oblique plane inclined at an angle of 45° with the axis of minor tensile stress.



1 Normal stress

$$\sigma_n = \left[\frac{\sigma_x+\sigma_y}{2}\right] + \left[\frac{\sigma_y-\sigma_x}{2}\right]\cos 2\theta + \tau \sin 2\theta$$

$$\sigma_n = \left[\frac{40+80}{2}\right] + \left[\frac{80-40}{2}\right]\cos 2\times45° + 60\sin 2\times45$$

$$\sigma_n = 60 + 0 + 60$$

$$\boxed{\sigma_n = 120\ N/mm^2}$$

(2) Shear stress

$$\sigma_t = \left[\frac{\sigma_y-\sigma_x}{2}\right]\sin 2\theta - \tau\cos 2\theta$$

$$\sigma_t = \left[\frac{80-40}{2}\right]\sin 2\times45 - 60\cos 2\times45$$

$$\sigma_t = 20 - 0$$

$$\boxed{\sigma_t = 20\ N/mm^2}$$

(3) Resultant Stress

$$\sigma_R = \sqrt{\sigma_n^2 + \sigma_t^2}$$

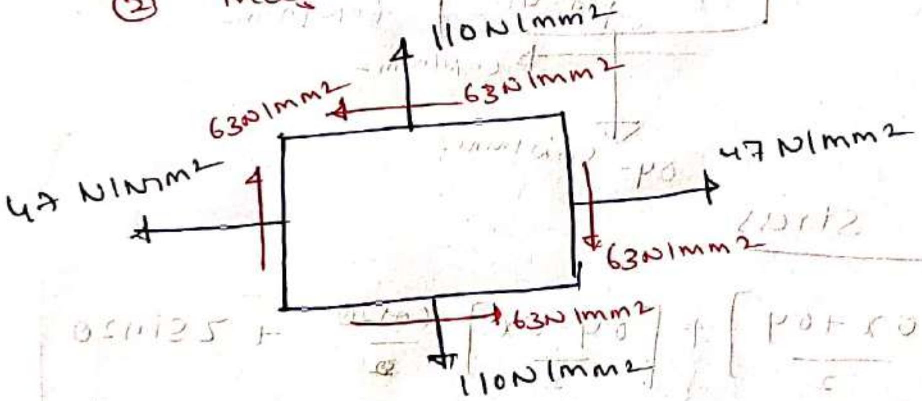
$$= \sqrt{120^2 + 20^2}$$

$$\boxed{\sigma_R = 121.65 \text{ N/mm}^2}$$

(02) A Rectangular block of material is subjected to a tensile stress of 110 N/mm² on one plane & a tensile stress of 47 N/mm² on the plane at right angles to the former. Each of the above stress is accompolised by a shear stress of 63 N/mm² & that associated with the former tensile stress tends to rotate the block anticlockwise.

Find (1) The direction and Magnitude of principal stress.

(2) Magnitude of the greatest shear stress.



(1) Major Principal stress:

$$\sigma_{n1} = \left[\frac{\sigma_x + \sigma_y}{2}\right] + \sqrt{\left[\frac{\sigma_y - \sigma_x}{2}\right]^2 + \tau^2}$$

$$\sigma_{n1} = \left[\frac{47 + 110}{2}\right] + \sqrt{\left[\frac{110 - 47}{2}\right]^2 + 63^2}$$

$$= 78.5 + \sqrt{992.25 + 3969}$$

$$= 78.5 + 70.43$$

$$\boxed{\sigma_{n1} = 148.93 \text{ N/mm}^2}$$

(6b) Minor Principal Stress:

$$\sigma n_2 = \left[\frac{\sigma x + \sigma y}{2}\right] - \sqrt{\left[\frac{\sigma y - \sigma x}{2}\right]^2 + \tau^2}$$

$$\sigma n_2 = \left[\frac{47+110}{2}\right] - \sqrt{\left[\frac{110-47}{2}\right]^2 + 63^2}$$

$$= 78.5 - 70.43$$

$$\boxed{\sigma n_2 = 8.07 \ N/mm^2}$$

(4) Direction

$$\tan 2\theta = \frac{2\tau}{\sigma y - \sigma x}$$

$$\tan 2\theta = \frac{2 \times 63}{110 - 47}$$

$$2\theta = \tan^{-1}(2)$$

$$\theta = \frac{63.43}{2}$$

$$\theta = 31.71$$

$$\boxed{\theta = 31^\circ.43'}$$

(5) Magnitude of greatest shear.

$$\sigma t]_{max} = \frac{1}{2}\sqrt{(\sigma x - \sigma y)^2 + 4\tau^2}$$

$$= \frac{1}{2}\sqrt{(47-110)^2 + 4 \times 63^2}$$

$$\frac{1}{2} \times 140.8$$

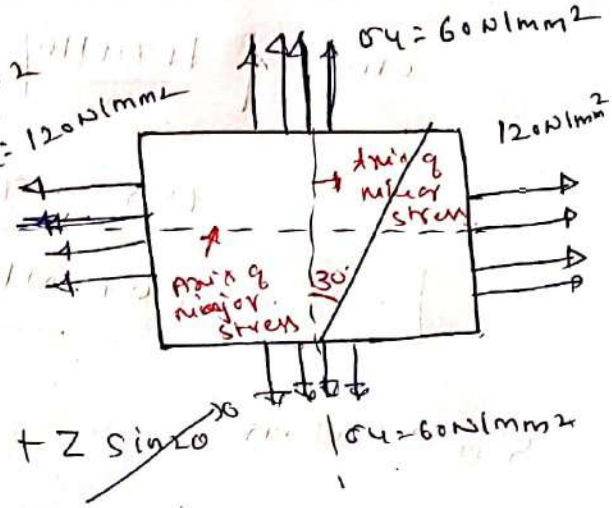
$$\boxed{\sigma t]_{max} = 70.43 \ N/mm^2}$$

(03) The Tensile Stresses at a point across two mutually Perpendicular planes are 120 N/mm² and 60 N/mm². Determine the normal, tangential and resultant stresses on a Plane Inclined at 30° to the axis of the minor stress.

As Major principal stress $\sigma_x = 120 N/mm^2$

Minor principal stress $\sigma_y = 60 N/mm^2$

Angle of oblique plane with the axis of minor plane. $\theta = 30$



1. Normal stress

$\sigma_n = \frac{\sigma_x + \sigma_y}{2} + \left(\frac{\sigma_x - \sigma_y}{2}\right) \cos 2\theta + \tau \sin 2\theta$

$\sigma_n = \frac{120+60}{2} + \left[\frac{120-60}{2}\right] \cos 2\times30$

$\sigma_n = 90 + 30 \cos 60 = 105 N/mm^2$

$\boxed{\sigma_n = 105 N/mm^2}$

2. Tangential stress:

$\sigma_t = \left[\frac{\sigma_x - \sigma_y}{2}\right] \sin 2\theta$

$= \left(\frac{120-60}{2}\right) \sin \times 2\times30$

$\boxed{\sigma_t = 25.98 N/mm^2}$

Resultant stress

$\sigma_R = \sqrt{\sigma_n^2 + \sigma_t^2}$

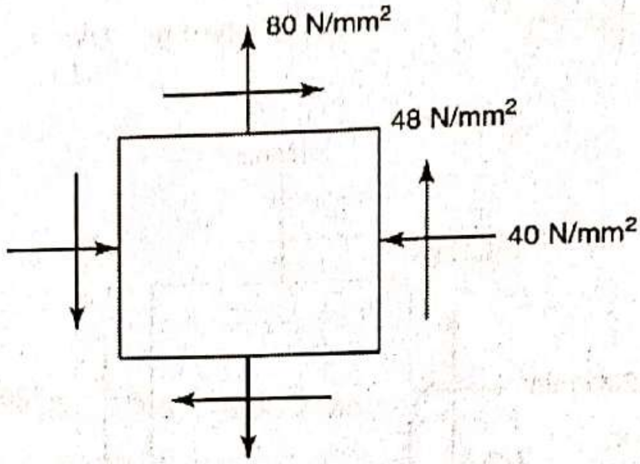
$= \sqrt{105^2 + 25.98^2}$

$\boxed{\sigma_R = 108.16 N/mm^2}$

Fig. 3.15(b).

Example 3.9 At a point in a strained material there is tensile stress of 80 N/mm^2 on a horizontal plane and a compressive stress of 40 N/mm^2 on a vertical plane. There is also a shear stress of 48 N/mm^2 on each of these planes.

Determine the planes of maximum shear stress at the point. Determine also the resultant stress on the planes of maximum shear stress.



(a)

Fig 3.16

Solution

The state of stress is as shown in Fig. 3.16(a).

Taking horizontal axis as *x* and vertical axis as *y*, we have $P_x = -40$ N/mm^2, $P_y = 80$ N/mm^2 and $q = 48$ N/mm^2.

$$q_{max} = \sqrt{\left(\frac{p_x - P_y}{2}\right)^2 + q^2} = \sqrt{\left(\frac{-40-80}{2}\right)^2 + 48^2} = 76.84 \ \text{N/mm}^2$$

Inclination of principal stress to the plane of p_x (vertical) is given by

$$\tan 2\theta = \frac{2q}{p_x - p_y}$$

$$\tan 2\theta = \frac{2 \times 48}{-40-80} = \frac{96}{-120}$$

$$2\theta = -38.66° \quad \text{and} \quad 141.34°$$

$$\text{or} \quad \theta = -19.33° \quad \text{and} \quad 70.67°$$

Inclination of maximum shear stress is $-19.33° + 45°$ and $70.67 + 45°$, *i.e.*, 25.67° and 115.67°.

The corresponding normal stress is given by

$$P_n = \frac{P_x + P_y}{2} + \frac{P_x - P_y}{2}\cos 2\theta' + q \sin 2\theta'$$

$$= \frac{-40+80}{2} + \frac{-40-80}{2}\cos 2(25.67) + 48 \sin 2(25.67)$$

$$P_n = \frac{P_x + P_y}{2} + \frac{P_x - P_y}{2}\cos 2\theta' + q\sin 2\theta'$$

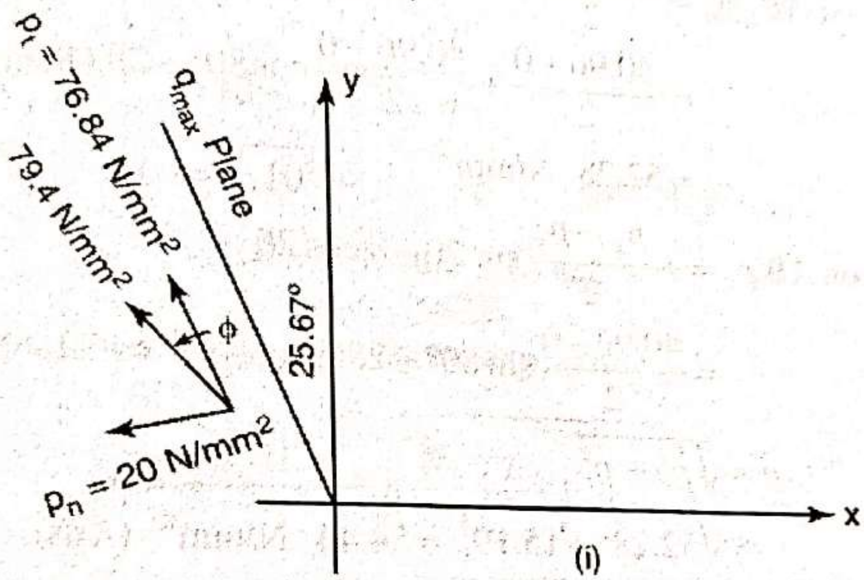
$$= \frac{-40+80}{2} + \frac{-40-80}{2}\cos 2(25.67) + 48\sin 2(25.67)$$

$$= +20 \text{ N/mm}^2$$

Resultant stress $= \sqrt{p_n^2 + p_t^2}$

$$= \sqrt{(20)^2 + 76.84^2}, \quad (\text{Since } p_t = q_{max})$$

$$= 79.4 \text{ N/mm}^2 \quad \textbf{(Ans)}$$



(b)

Fig. 3.16

Referring to Fig. 3.16(b), we get

$$\tan\varphi = \frac{20}{76.84}$$

$\varphi = 14.59°$ as shown in Fig. **(Ans)**

∴ Its inclination to the plane of p_x (*i.e.,* vertical plane) is given by

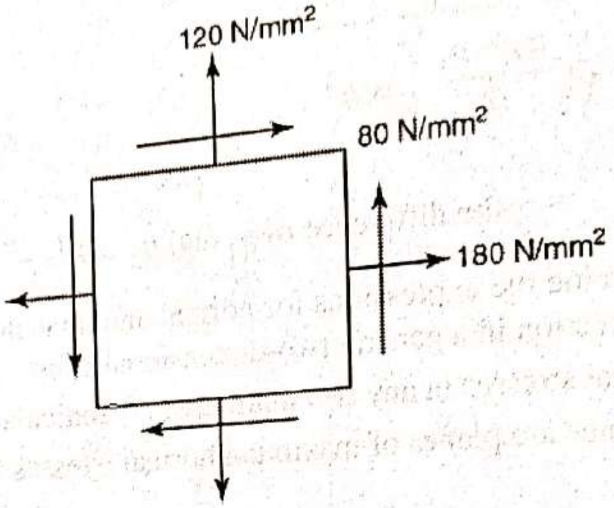
$$\alpha = 25.67 + 14.59 = 41.26°$$

Example 3.6 The state of stress at a point in a strained material is as shown in Fig. 3.13(a). Determine

(*i*) The direction of the principal planes

(*ii*) The magnitude of principal stresses, and

(*iii*) The magnitude of maximum shear stress and its direction. Indicate all the above planes by a sketch



(a)

Fig. 3.13

Solution

Let θ be the inclination of principal plane to the plane of 180 N/mm². Then

$$p_x = 180\ \text{N/mm}^2, \quad p_y = 120\ \text{N/mm}^2, \quad q = 80\ \text{N/mm}^2.$$

$$\therefore \quad \tan 2\theta = \frac{2q}{p_x - p_y} = \frac{2\times 80}{180-120} = 2.6667$$

$$\therefore \quad 2\theta = 69.444^\circ \quad \text{and} \quad 69.444 + 180^\circ$$

i.e., $\theta = 34.722^\circ$ and 124.722° **(Ans)**

$$p_1 = \frac{p_x + p_y}{2} + \sqrt{\left(\frac{p_x - p_y}{2}\right)^2 + q^2}$$

$$= \frac{180+120}{2} + \sqrt{\left(\frac{180-120}{2}\right)^2 + 80^2}$$

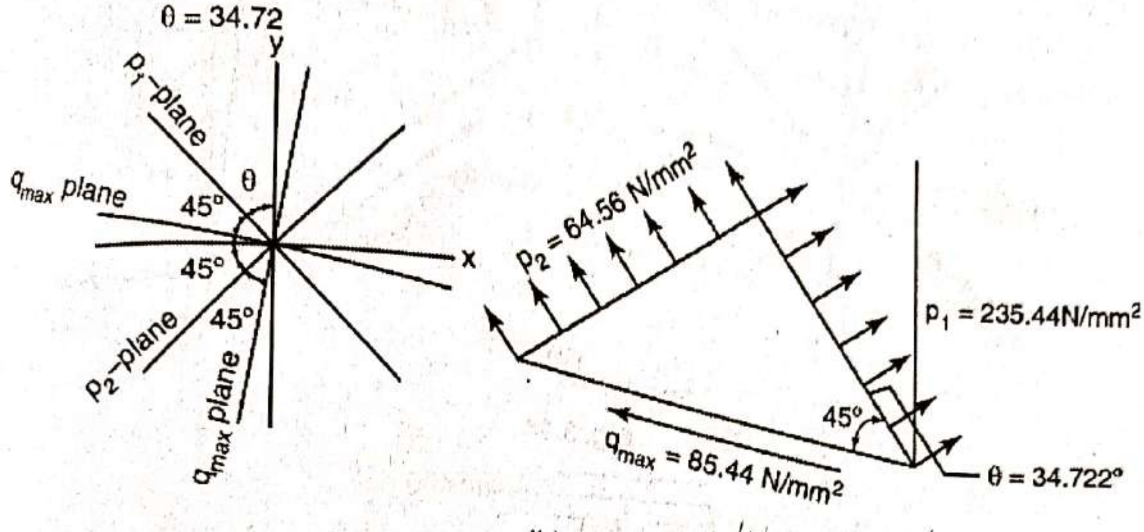
$= 150 + 85.44 = 235.44$ N/mm² (tensile) **(Ans)**

$$p_2 = \frac{p_x + p_y}{2} - \sqrt{\left(\frac{p_x - p_y}{2}\right)^2 + q^2}$$

$= 150 - 85.44 = 65.56$ N/mm² (Tensile) **(Ans)**

$$q_{\max} = \sqrt{\left(\frac{p_x - p_y}{2}\right)^2 + q^2} = 85.44\ \text{N/mm}^2$$ **(Ans)**

Planes of maximum shearing stresses are at 45° to principle planes. All these are shown in Fig.3.13(b).



(b)

Fig. 3.13

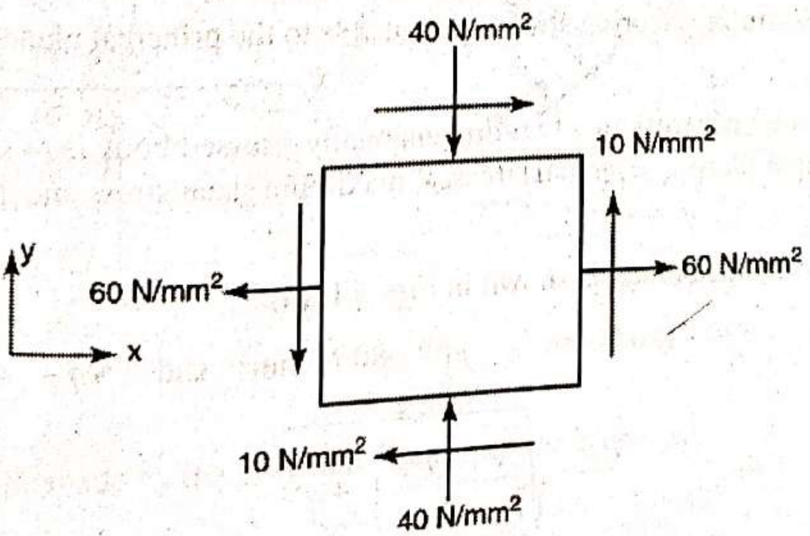
Example 3.7 A plane element is subjected to stresses as shown in Fig. 3.14(a). Determine principal stresses, maximum shear stress and their planes. Sketch the planes determined.

Solution

Taking x and y coordinates, as shown in Fig. 3.14(a), we have p_x = 60 N/mm², p_y = – 40 N/mm² and q = 10 N/mm².

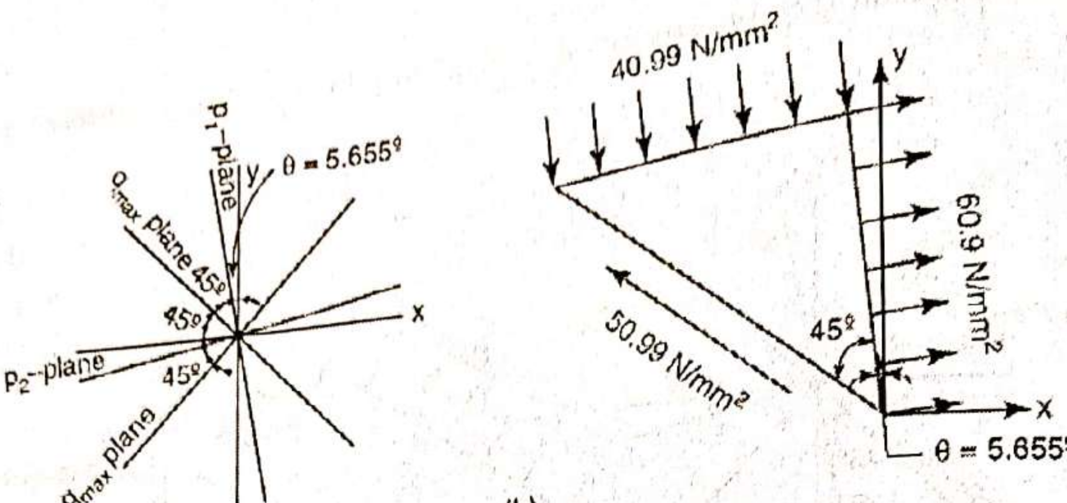
Then, $$p_1 = \frac{p_x + p_y}{2} + \sqrt{\left(\frac{p_x - p_y}{2}\right)^2 + q^2} = \frac{60-40}{2} + \sqrt{\left(\frac{60-(-40)}{2}\right)^2 + 10^2}$$

$$= 10 + 50.99 = 60.99 \text{ N/mm}^2 \text{ (Ans)}$$



(a)

Fig. 3.14



(b)

Fig. 3.14

$$P_2 = \frac{P_x + P_y}{2} - \sqrt{\left(\frac{P_x - P_y}{2}\right)^2 + q^2}$$

$$= 10 - 50.99 = -40.99 \ \text{N/mm}^2$$

$$= -40.99 \ \text{N/mm}^2 \quad \text{(Comp)} \quad \textbf{(Ans)}$$

$$q_{max} = \sqrt{\left(\frac{P_x - P_y}{2}\right)^2 + q^2} = 50.99 \ \text{N/mm}^2 \quad \textbf{(Ans)}$$

Let θ be the inclination of principal stress to the plane of 60 N/mm². Then

$$\tan 2\theta = \frac{2q}{p_x - P_y}$$

$$= \frac{2 \times 10}{60 - (-40)} = \frac{1}{5}$$

$$2\theta = 11.31° \ \text{and} \ 191.31°$$

$$\therefore \quad \theta = 5.655° \ \text{and} \ 95.655° \ \textbf{(Ans)}$$

The planes of maximum shearing stresses are at 45° to the principal planes. These are shown in Fig. 3.14(b).

Engineers have been trying to predict failure loads for various structural elements so that they can improve their designs. Most of the structural elements are in complex state of stress and it is not easy to conduct laboratory tests on models with complex loading. The procedure followed by engineers is to conduct uniaxial tests on specimens and get the failure condition for the material. From a few test results they arrive at failure criteria for structural element in a complex condition. They use these criteria for predicting failure load in any structural element. The following five theories have been put forth by researches:

1. Maximum principal stress theory
2. Maximum shear stress theory
3. Maximum principal strain theory
4. Maximum strain energy theory
5. Maximum distortions energy theory

These theories of failure are briefly explained in this chapter and suitability of these thoeries for different types of materials are mentioned.

4.1 MAXIMUM PRINCIPAL STRESS THEORY

This theory is also known as **Rankine's theory**. According to it, a material in complex state of stress fails, when the maximum principal stress in it reaches the value of stress at elastic limit in simple tension.

Thus, in a two-dimensional general stress condition, the failure criteria is

$$p_1 = \sqrt{\frac{p_x + p_y}{2}} + \sqrt{\left(\frac{p_x - p_y}{2}\right)^2 + q^2} = p_e \tag{4.1}$$

where p_e is the stress at elastic limit in uniaxial tension test.

$\approx f_y$, Yield stress.

This theory is found to be reasonably good for brittle materials.

4.2 MAXIMUM SHEAR STRESS THEORY

This theory is known as **Coulomb's theory** as it was originally proposed by CA Coulomb. But it is also associated with the names of J Guest and H Tresca. According to this theory, a material in complex state of stress fails when the maximum shearing stress in it reaches the value of shearing stress at elastic limit in uniaxial tension test. In a general two-dimensional stress system maximum shearing stress is given by

$$q_{max} = \sqrt{\left(\frac{p_x - p_y}{2}\right)^2 + q^2}$$

In uniaxial tension test, maximum shearing stress at elastic limit is

$$q_{max} = \sqrt{\left(\frac{p_e - 0}{2}\right)^2 + 0} = \frac{p_e}{2}$$

∴ According to this theory, failure criterion is

$$\sqrt{\left(\frac{p_x - p_y}{2}\right)^2 + q^2} = \frac{p_e}{2}$$

In case of three-dimensional problems, maximum shear stress at a point may be taken as $(p_1 - p_3)^2$, where p_1 is the maximum principal stress and p_3 is minimum principal stress. Hence, the failure criterion is $(p_1 - p_3)/2 = p_e/2$, or

$$(p_1 - p_3) = p_e \tag{4.2}$$

This theory gives better results for ductile materials with elastic limit same in tension and in compression.

4.3 MAXIMUM STRAIN THEORY

This theory is also known as **St. Venant's theory**. According to it, failure in a complex system occurs when the maximum strain in it reaches the value of the strain in uniaxial stress at elastic limit.

If p_1 is the maximum stress in a complex state and p_2 and p_3 are the stresses in other two mutually perpendicular directions, then

$$\text{Maximum strain } e_{max} = \frac{p_1 - \mu(p_2 + p_3)}{E}$$

$$\text{Strain in uniaxial tension at elastic limit} = \frac{p_e}{E}$$

$$\therefore \text{ The failure criterion is } \quad \frac{p_1 - \mu(p_2 + p_3)}{E} = \frac{p_e}{E}$$

or

$$p_1 - \mu(p_2 + p_3) = p_e \tag{4.3}$$

This theory is considered to be good for materials failing with brittle fractures.

4.4 MAXIMUM STRAIN ENERGY THEORY

This theory is known as **Beltrami and Haigh's theory** also. According to this theory, a material in complex stress system fails when the maximum strain energy per unit volume at a point reaches the value of strain energy per unit volume at elastic limit in simple tension test.

Consider an element of unit side in a three-dimensional stress system subjected to principal stresses p_1, p_2 and p_3 as shown in Fig. 4.1.

$$\text{Strain energy in it is } = \frac{1}{2}p_1e_1 + \frac{1}{2}p_2e_2 + \frac{1}{2}p_3e_3$$

Now,

$$e_1 = \frac{1}{E}[p_1 - \mu(p_2 + p_3)],$$

$$e_2 = \frac{1}{E}[p_2 - \mu(p_1 + p_3)] \quad \text{and} \quad e_3 = \frac{1}{E}[p_3 - \mu(p_1 + p_2)]$$

hence, this theory is used by designers for all ductile materials.

Example 4.1 A bolt is subjected to an axial pull of 12 kN together with a transverse shear force of 6 kN. Determine the required diameter of the bolt by using

(*i*) Maximum principal stress theory

(*ii*) Maximum strain theory

(*iii*) Maximum shear stress theory

Use the following data:

Elastic limit in tension = 300 N/nm², Factor of safety = 3, Poisson's ratio = 0.3

Solution

Let the diameter of the bolt be '*d*'. Then the direct stress

$$p_x = \frac{12\times10^3}{\pi/4\, d^2} = \frac{48\times10^3}{\pi d^2}$$

Shear stress at the centre of the bolt is

$$q = \frac{4}{3}\times q_{av}$$

$$= \frac{4}{3}\times\frac{6\times10^3}{\pi/4\, d^2}$$

$$= \frac{32\times10^3}{\pi d^2}$$

∴ The principal stresses are $p_1 = \frac{p_x}{2} + \sqrt{\left(\frac{p_x}{2}\right)^2 + q^2}$

$$= \frac{24\times10^3}{\pi d^2} + \sqrt{\left(\frac{24\times10^3}{\pi d^2}\right)^2 + \left(\frac{32\times10^3}{\pi d^2}\right)^2}$$

$$= \frac{24\times10^3}{\pi d^2}\left(1+\sqrt{1+\left(\frac{32}{24}\right)^2}\right)$$

$$= \frac{24\times10^3}{\pi d^2}(1+1.66667)$$

$$= \frac{20371.833}{d^2}$$

$$p_2 = \frac{p_x}{2} - \sqrt{\left(\frac{p_x}{2}\right)^2 + q^2}$$

$$= \frac{24 \times 10^3}{\pi \pi d^2}(1 - 1.66667)$$

$$= -\frac{5092.984}{d^2}$$

$$q_{max} = \sqrt{\left(\frac{p_x}{2}\right)^2 + q^2}$$

$$= \frac{24 \times 10^3}{\pi d^2} \times 1.66667$$

$$= \frac{12732.421}{d^2}$$

(*i*) **From maximum principal stress theory:**

Permissible stress in tension $= \frac{300}{3} = 100\ \text{N/mm}^2$

$\therefore \quad p_1 = 100$

i.e., $\quad \frac{20371.833}{d^2} = 100$

or, $\quad d = 14.273$ mm **(Ans)**

(*ii*) **Maximum strain theory:**

$$e_{max} = \frac{p_1}{E} - \mu \frac{p_2}{E}$$

$$= \frac{20371.833}{d^2 E} - 0.3\left(-\frac{5092.984}{d^2 E}\right)$$

$$= \frac{21899.728}{d^2 \times E}$$

According to this theory, the design condition is

$$e_{max} = \frac{p_e}{E \times \text{Factor of safety}}$$

or, $\quad \frac{21899.728}{d^2 \times E} = \frac{300}{E \times 3}$

or, $\quad d = 14.799$ mm

(*iii*) **Maximum shear stress theory:** The design condition is

$$e_{max} = \frac{\text{Shear stress at elastic limit}}{\text{Factor of safety}}$$

$$\frac{12732.421}{d^2} = \frac{300/2}{3}$$

$$d = 15.958 \text{ mm}$$

Hence, maximum shear stress theory governs the design. Use at least 15.958 mm diameter bolt. The practical size is 16 mm diameter. **(Ans)**

IMPORTANT CONCEPTS AND FORMULAE

1. Theories of failure are developed to predict failure criteria in a material under complex sta of stress in terms of test results obtained in uniaxial tests.
2. Maximum principal theory is also known as Rankine's theory. According to this theory, failure condition is

$$p_1 = \frac{p_x + p_y}{2} + \sqrt{\left(\frac{p_x + p_y}{2}\right)^2 + q^2} = p_e$$

3. Maximum shear stress theory is known as Coulomb's theory. In this the failure criterion is

$$p_1 - p_3 = p_e$$

4. Maximum strain theory is known as St.Venant's theory and in this failure criterion works out to be

$$p_1 - \mu(p_2 + p_3) = p_e$$

5. Maximum strain energy theory is also known as Beltrami and Haigh's theory. In this, failure criterion works out to be

$$p_1^2 + p_2^2 + p_3^2 - 2\mu(p_1 p_2 + p_2 p_3 + p_3 p_1) = p_e^2$$

6. Maximum distortion energy theory is known as Von-Mises criteria for failures. In this case the failure criteria works out to be

$$(p_1 - p_2)^2 + (p_2 - p_3)^2 + (p_3 - p_1)^2 = 2p_e^2$$

PROBLEMS FOR EXERCISE

1. A bolt is required to resist an axial tension of 25 kN and a transverse shear of 20 kN. Find the safe size of the bolt by

   (*i*) The maximum principal stress theory

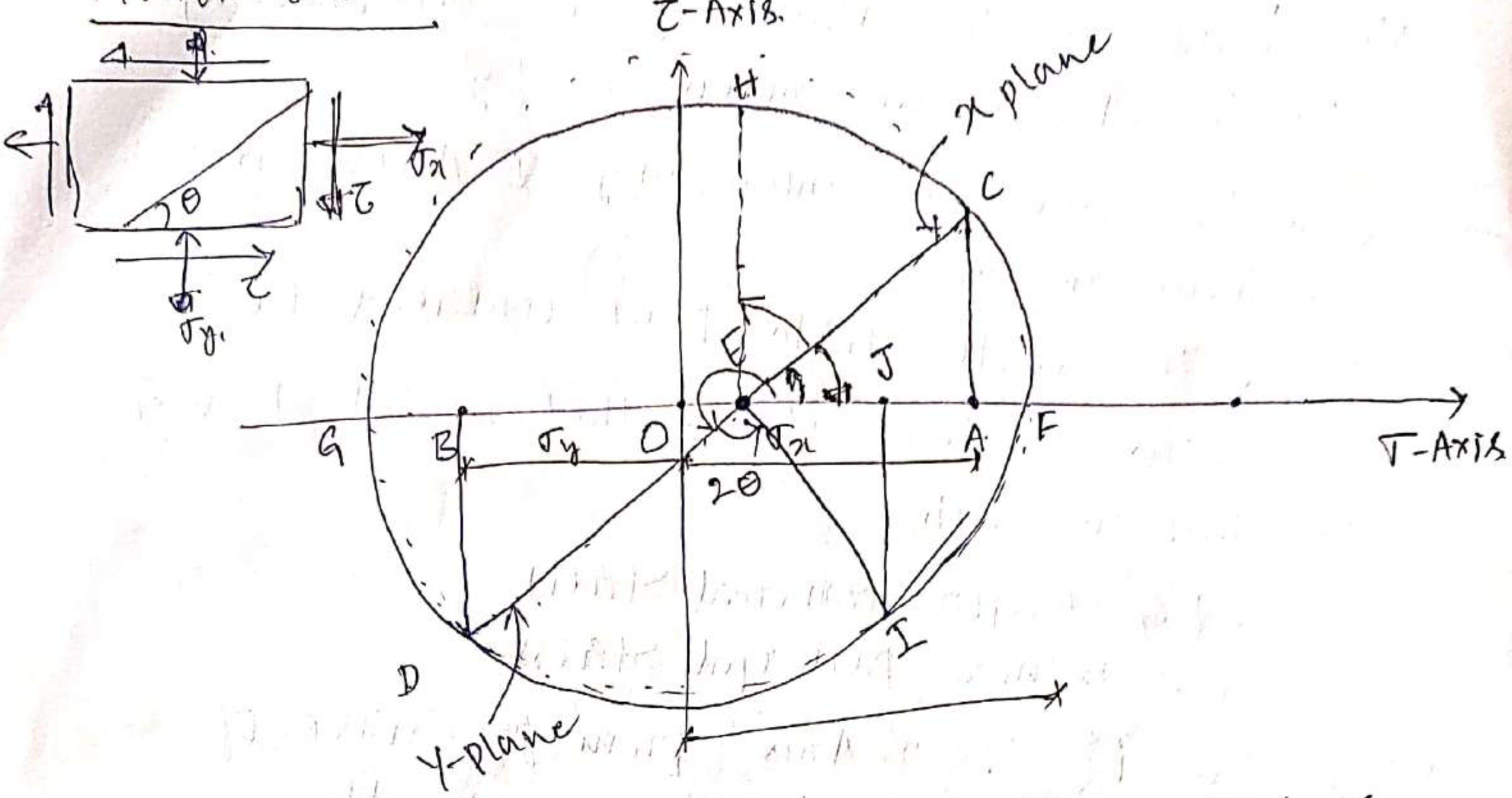
   (*ii*) The maximum shear stress theory

   (*iii*) The maximum distortion energy theory

   The elastic limit of the material is 300 N/mm². Poisson's ratio = 0.3 and factor of safety = 3.0.

   [Ans (*i*) 23.11 mm (*ii*) 27.20

Mohr's circle



1) Draw Horizontal ~~Axis~~ line indicating σ-Axis.
& Draw Vertical line τ-Axis intersecting σ-Axis at 90°.

2) Take ~~poi~~ Intersecting point of ~~of~~ σ-Axis & τ Axis as origin 'O'

3) If the Normal stress (σ_x or σ_y) is tensile. Mark a point on σ-axis as 'A' by taking proper scale. ~~If the at~~ to the right side of ~~the~~ origin, If the normal stress is negetive mark the point on σ axis to the left of origin 'B'.

4) Now see ~~whether~~ whether the ~~th~~ Shear Stress on the plane of normal stress, ~~is~~ ~~producing~~ rotating the plane clock wise or Anticlock wise. If the τ rotating the plane clock wise then Shear value is taken as '+ve & vice versa.

~~Draw ⊥r to on point A~~

Now ~~draw~~ plot the value of τ by drawing $\perp^r$ to A & B as shown in fig

5) Join the line CD intersecting σ-Axis on E as shown in fig.

6) Draw the circle with E as centre & EC as radius, so that it cut the σ axis at F & G as shown in graph.

OF = major principal stress

OG = minor principal stress.

7) Draw the $\perp^r$ to σ-Axis from the centre of circle E to meet the circle at H.,

EH = Max. shear stress.

~~8) Now observe that the inclined plane~~

8) Observe whether ~~If the plane~~ Inclined plane making an angle θ with Y-plane OR X-plane. ~~Draw the~~ with ~~either~~ clockwise OR Anticlockwise in element.

~~If the inclined~~

Now draw the line making angle '2θ' with ~~either~~ plane to meet the circle at I. as shown

9) Draw $\perp^r$ line ~~to~~ from σ-Axis to meet I.

OJ is normal stress on inclined plane

IJ is Tangential stress OR shear stress on Inclined plane.

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Module: 2

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Thin and thick cylinder

Curved structural forms like pipes, boilers, fluid storage tanks are refered as cylinders and they exhibit greater strength by virtue of shape rather than material used.

The vessels such as boilers, compressed air receivers etc. are of cylindrical and spherical forms. These vessels are generally used for storing fluids [liquid or gas] under pressure. The walls of such vessels are thin as compared to their diameters.

Thin cylinder: If the thickness of the wall of the cylindrical vessel is less than $\frac{1}{15}$ to $\frac{1}{20}$ of its internal diameter, the cylindrical vessel is known as a thin cylinder.

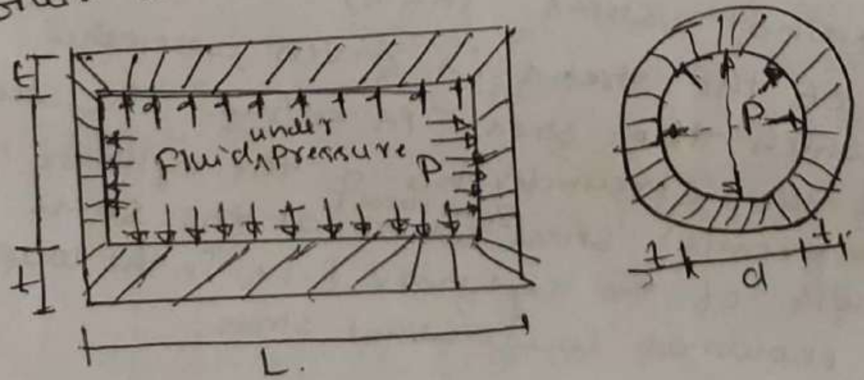
In case of thin cylinders, the stress distribution is assumed uniform over the thickness of the wall.

1. The thin cylinders are subjected to circumferential stress, sometimes they are refered as Hoop stress [σ_1]
2. Longitudinal stress [σ_2] acting longitudinally [Radial stress are neglected in case of thin cylinders]

Ex: cycle tube.

Thin cylindrical vessel subjected to internal pressure:

Fig shows a thin cylindrical vessel in which a fluid under pressure is stored.



Let d = Internal diameter of the thin cylinder
t = thickness of the wall of the cylinder
P = Internal pressure of the fluid.
L = length of the cylinder.

On the account of Internal pressure P. the cylindrical vessel may fail by splitting up in any one of the two ways as shown in fig (a) & (b).

The forces due to pressure of the fluid acting vertically upwards and downwards on the thin cylinder, tend to burst the cylinder as shown in fig (a).

The forces due to pressure of the fluid, acting at the ends of the thin cylinder, tends to burst the thin cylinder as shown in fig (b)

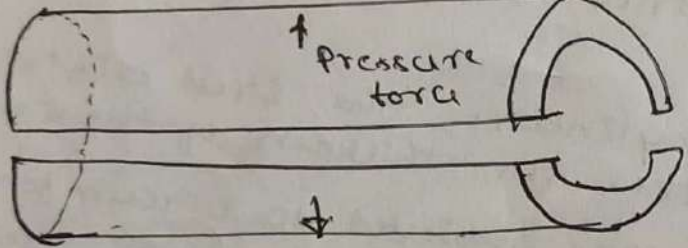


fig (a)

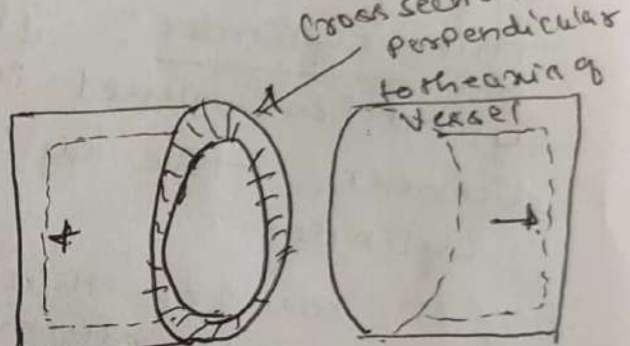


fig (b)

Stresses in a thin cylindrical vessel subjected to Internal Pressure:

When a thin cylindrical vessel is subjected to internal fluid pressure, the stresses in the wall of the cylinder on the cross section along the axis and on the cross section perpendicular to the axis are set up.

These stresses are tensile and are known as.

1. Circumferential stress [or hoop stress] and fig [a]
2. Longitudinal stress. (fig b)

The name of the stress is given according to the direction in which the stress is acting. The stress acting along the circumference of the cylinder is called circumferential [hoop stress] stress. Where as the stress acting along the length of the cylinder [i.e. in the longitudinal direction] is known as longitudinal stress.

Expression for Circumferential Stress (or) [Hoop stress] ②

Consider a thin cylindrical vessel subjected to an internal fluid pressure. The circumferential stress will be set up in the material of the cylinder. If the bursting of the cylinder takes place as shown in fig (a).

The Expression for hoop stress (or) circumferential stress (σ_1) is obtained as given below

Let p = Internal pressure of fluid.
d = Internal diameter of the cylinder
t = thickness of the wall of the cylinder.
σ_1 = circumferential (or) hoop stress in the material

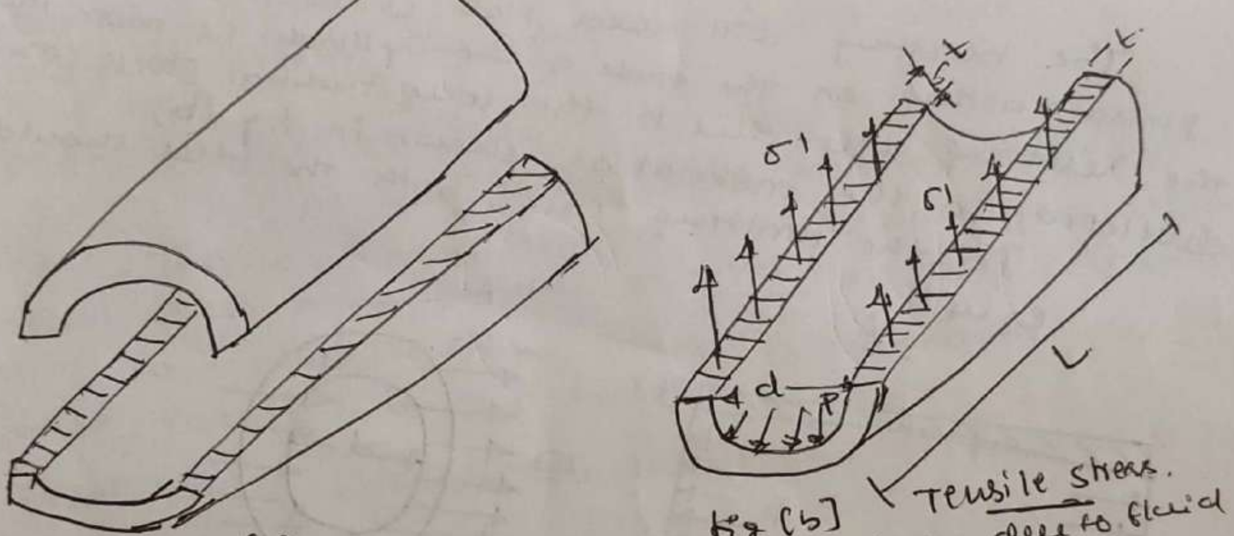


fig (a) fig (b)

The bursting will taken place if the force due to fluid pressure is more than the resisting force due to circumferential stress set up in the material. In the limiting case, the two forces should be equal

Force due to fluid pressure = p x Area on which p is acting

= p x [d x L] → ①

[∵ p is acting on projected area d x L]

∴ Force due to circumferential stress

= σ_1 x Area of which σ_1 is acting

= $\sigma_1 \times [L \times t + L \times t]$

= $\sigma_1 \times 2Lt$ = $2\sigma_1 Lt$ → ②

equating ① & ② we get

$$p \times [d \times L] = 2\sigma_1 \times Lt$$

$$\frac{pdL}{Lt} = 2\sigma_1 \Rightarrow \boxed{\sigma_1 = \frac{pd}{2t}}$$ ③

Expression for longitudinal stress:

Consider a thin cylindrical vessel subjected to internal fluid pressure. The longitudinal stress will be set up in the material of the cylinder. If the bursting of the cylinder takes place along the section AB of fig (a). The longitudinal stress σ_2 developed in the material is obtained as

let P = Internal pressure of fluid stored in thin cylinder.

d = Internal diameter of cylinder.

t = thickness of cylinder.

σ_2 = longitudinal stress in the material.

The bursting will takes place if the force due to fluid pressure acting on the ends of the cylinder is more than the resisting force due to the longitudinal stress (σ_2) developed in the material as shown in fig (b). In the limiting case, both the forces should be equal.

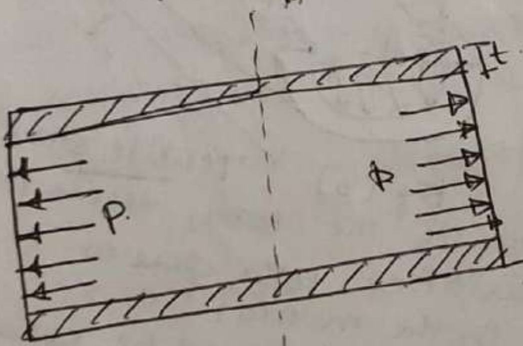


fig (a)

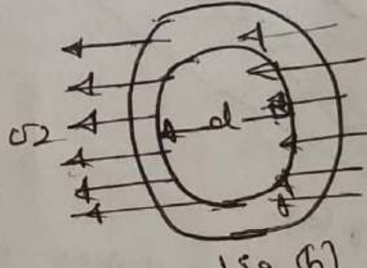


fig (b) longitudinal stress (σ_2) develop.

Force due to fluid pressure = P x Area on which P is acting

$= P \times \frac{\pi}{4} d^2.$

(Applied force) x (Area) $P \times \frac{\pi}{4} d^2$

Resisting force $= \sigma_2 \times$ Area on which σ_2 is acting

Stress x Area

$= \sigma_2 \times \pi . d \times t.$

∴ Hence in limiting case.

Force due to fluid pressure = Resisting force.

$$P \times \frac{\pi}{4} d^2 = \sigma_2 \times \pi . d \times t$$

$$\sigma_2 = \frac{P \times \frac{\pi}{4} d^2}{\pi . d . t} = \frac{Pd}{4t}.$$

The stress σ_2 is tensile.

The equation σ_2 can be written as

$$\sigma_2 = \frac{p.d.}{2.2t}$$ where $\boxed{\sigma_1 = \frac{pd}{2t}}$

$$\sigma_2 = \frac{1}{2}\sigma_1$$

longitudinal stress $= \frac{1}{2}$ of circumferential stress [Hoop stress]

This means $\boxed{\sigma_1 = 2\sigma_2}$

Hence in the materials of the cylinder the permissible stress should be less than the circumferential stress. In other words, the circumferential stress should not be greater than the permissible stress.

Maximum shear stress:

At any point in the material of the cylindrical shell, there are two principal stresses, namely a circumferential stress of magnitude $\sigma_1 = \frac{pd}{2t}$ acting circumferentially and a longitudinal stress of magnitude $\sigma_2 = \frac{pd}{4t}$ acting parallel to the axis of the shell.

These two stresses are tensile and perpendicular to each other

$\therefore$ Maximum shear stress $\tau_{max} = \frac{\sigma_1 - \sigma_2}{2}$

$$\tau_{max} = \frac{\frac{pd}{2t} - \frac{pd}{4t}}{2}$$

$$= \frac{2pd - pd}{8t} = \frac{pd}{8t}$$

$$\boxed{\tau_{max} = \frac{pd}{8t}}$$

Problems on thin cylinders

① A cylindrical pipe of diameter 1.5 m and thickness 1.5 cm is subjected to an internal fluid pressure of 1.2 N/mm². Determine ① longitudinal stress developed in the pipe ② circumferential stress developed in the pipe.

us given $d = 1.5\,m$ $t = 1.5\,cm = 1.5 \times 10^{-2}\,m$ $P = 1.2\,N/mm^2$

As the ratio $\frac{t}{d} = \frac{1.5 \times 10^{-2}}{1.5} = 0.01 = \frac{1}{0.01} = \frac{1}{100}$ which is less than $\frac{1}{20}$. hence this is a case of thin cylinder

① longitudinal stress $\sigma_2 = \frac{P \times d}{4t}$

$\sigma_2 = \frac{P d}{4t}$ ~~1 N/mm²~~ = N/mm²

$\sigma_2 = \frac{1.2 \times 1.5}{4 \times 1.5 \times 10^{-2}}$

$\sigma_2 = 30\,N/mm^2$

② circumferential stress $\sigma_1 = \frac{Pd}{2t}$

$\sigma_1 = \frac{1.2 \times 1.5}{2 \times 1.5 \times 10^{-2}}$

$\sigma_1 = 60\,N/mm^2$

② A cylinder of internal ~~Pressure~~ diameter 2.5 m & of thickness 5 cm contains a gas. If the tensile stress in the material is not exceed 80 N/mm². determine the internal pressure of the gas.

us $d = 2.5\,m$ $t = 5\,cm = 5 \times 10^{-2}\,m$.

Maximum permissible stress $\sigma_1 = 80\,N/mm^2$.

P. internal pressure = ?

$\sigma_1 = \frac{P \cdot d}{2t}$

$\frac{\sigma_1 \cdot 2t}{d} = P.$

$\frac{80 \times 2 \times 5 \times 10^{-2}}{2.5} = P$

$P = 3.2\,N/mm^2$

(3) A thin cylinder of Internal diameter 1.25 m contains a fluid at an internal pressure of 2 N/mm2. Determine the maximum thickness of the cylinder if.
(1) The longitudinal stress is not to exceed 30 N/mm2.
(2) The circumferential stress is not to exceed 45 N/mm2.

Given Data $D = 1.25 m$. $P = 2 N/mm^2$ $t = ?$

longitudinal stress $\sigma_2 = 30 N/mm^2$
circumferential stress $\sigma_1 = 45 N/mm^2$

(1)
$$\sigma_2 = \frac{P.d}{4t} = 30 = \frac{2 \times 1.25}{4 \times t}$$

$$t = \frac{2 \times 1.25}{4 \times 30}$$

$$\boxed{t = 0.020 m}$$

(2) circumferential stress σ_1

$$\sigma_1 = \frac{P.d}{2t} \qquad 45 = \frac{2 \times 1.25}{2 \times t}$$

$$t = \frac{2 \times 1.25}{45 \times 2}$$

$$\boxed{t = 0.027 m}$$

The longitudinal (or) circumferential stresses Induced in the material are inversely proportional to the thickness (t) of the cylinder.
Hence the stress Induced will be less if the value of t is more. Hence the maximum value of t is

$t = 0.027 m \simeq 2.77 cm$

Effect of Internal Pressure on the Dimensions of a thin cylindrical Shell.

When a fluid having internal pressure (P) is stored in a thin cylindrical shell, due to internal pressure of the fluid the stresses set up at any point of the material of the shell are ① Hoop (or) circumferential stress (σ_1) acting on longitudinal section.

② longitudinal stress (σ_2) is acting on the circumferential section.

These stresses are principal stresses, as they are acting on principal planes. The stress in the third principal plane is zero as the thickness (t) of the cylinder is very small. Actually the third stress in the third principal plane is radial stress which is very small for thin cylinders & can be neglected.

Let P = Internal pressure of fluid,

L = length of cylindrical shell.

d = diameter of the cylindrical shell.

t = thickness of the cylindrical shell.

E = modulus of elasticity for the material of the shell.

σ_1 = Hoop stress (or) circumferential stress in the material.

σ_2 = Longitudinal stress in the material

μ = Poisson ratio.

δd = change diameter due to the stress in the material.

δL = change in length.

δV = change in volume

The values of σ_1 & σ_2 are given

$$\sigma_1 = \frac{Pd}{2t} \quad \& \quad \sigma_2 = \frac{Pd}{4t}$$

Let e_1 & e_2 are circumferential strain & longitudinal strain

Then circumferential strain

$$e_1 = \frac{\sigma_1}{E} - \frac{\mu \sigma_2}{E}$$

Substituting the values of σ_1 & σ_2

$$e_1 = \frac{\frac{pd}{2t}}{E_1} - \frac{\frac{\mu pd}{4t}}{E_2}$$ where ~~E = E1 = E2~~

$$e_1 = \frac{pd}{2tE} - \frac{\mu pd}{4tE}$$

$$\boxed{e_1 = \frac{pd}{2tE}\left[1 - \frac{\mu}{2}\right]}$$ — circumferential strain → (a)

Longitudinal strain

$$e_2 = \frac{\sigma_2}{E} - \frac{\mu\sigma_1}{E} = \frac{\frac{pd}{4t}}{E} - \mu\frac{\frac{pd}{2t}}{E} = \left[\frac{pd}{4tE} - \frac{\mu pd}{2tE}\right]$$

$$e_2 = \frac{pd}{2tE}\left[\frac{1}{2} - \mu\right]$$

$$\boxed{e_2 = \frac{pd}{2tE}\left[\frac{1}{2} - \mu\right]}$$ → (c) → longitudinal strain

But circumferential strain is also given as

e_1 = change in circumference due to pressure / original circumference

= (final circumference − original circumference) / original circumference

$$= \frac{\pi(d + \delta d) - \pi d}{\pi d} \simeq \frac{\pi d + \pi\delta d - \pi d}{\pi d} = \frac{\pi\delta d}{\pi d}$$

$$\boxed{e_1 = \frac{\delta d}{d}} \rightarrow (b) \quad \left[\text{or} = \frac{\text{change in diameter}}{\text{original diameter}}\right]$$

equating the two values of e_1 is given by equation (a & b)

$$\frac{\delta d}{d} = \frac{pd}{2tE}\left[1 - \frac{\mu}{2}\right] \simeq \boxed{\delta d = \frac{pd^2}{2tE}\left[1 - \frac{\mu}{2}\right]} \rightarrow (1)$$

change in Diameter

Similarly longitudinal strain is also given as

$$e_2 = \frac{\text{change in length due pressure}}{\text{original length}} = \frac{\delta L}{L} \rightarrow (d)$$

equating the two values of e_2 is given by equation (c & d)

$$\frac{\delta L}{L} = \frac{pd}{2tE}\left[\frac{1}{2} - \mu\right] \simeq \boxed{\delta L = \frac{pdL}{2tE}\left[\frac{1}{2} - \mu\right]} \rightarrow (2)$$

change in length.

Change in volume of a thin cylinder:

Volumetric strain: It is defined as change in volume divided by original volume

volumetric strain = $\frac{\delta V}{V}$

But change in volume $[\delta V]$ = Final volume − original volume

original volume $[V]$ = Area of the cylindrical sheet × Length

$= \frac{\pi}{4} \times d^2 \times L$

Final volume = [Final Area of the cross section] × Final length

$= \frac{\pi}{4} (d + \delta d)^2 \times (L + \delta L)$

$= \frac{\pi}{4} [d^2 + (\delta d)^2 + 2d \cdot \delta d] \times [L + \delta L]$

$= \frac{\pi}{4} [d^2 L + (\delta d)^2 L + 2d \cdot \delta d \cdot L + \delta L\, d^2 + \delta L \cdot (\delta d)^2 + 2d \cdot \delta d \cdot \delta L]$

Neglecting the smaller quantities such as $(\delta d)^2 L$, $\delta L (\delta d)^2$ and $2d\, \delta d\, \delta L$. we get

$= \frac{\pi}{4} [d^2 L + 2d \cdot \delta d \cdot L + \delta L\, d^2]$

Final volume $= \frac{\pi}{4} [d^2 L + 2 d L\, \delta d + \delta L\, d^2]$

Change in volume (δV)

$\delta V = \frac{\pi}{4} [d^2 L + 2 dL\, \delta d + \delta L\, d^2] - \frac{\pi}{4} \times d^2 \times L$

$= \frac{\pi}{4} [2dL \cdot \delta d + \delta L \cdot d^2]$

Volumetric Strain $= \frac{\delta V}{V} = \frac{\frac{\pi}{4} [2dL \cdot \delta d + \delta L \cdot d^2]}{\frac{\pi}{4} d^2 \times L}$

$= \frac{2 \delta d}{d} + \frac{\delta L}{L}$

$= 2e_1 + e_2$

where circumferential strain

$$e_1 = \frac{\sigma_1}{E} - \frac{\mu \sigma_2}{E}$$

$$\left[\sigma_1 = \frac{pd}{2t} \quad \sigma_2 = \frac{pd}{4t} \right]$$

$$= \frac{\frac{pd}{2t}}{E} - \mu \frac{\frac{pd}{4t}}{E}$$

$$\boxed{e_1 = \frac{pd}{2tE}\left[1 - \frac{\mu}{2}\right]}$$

& longitudinal strain

$$e_2 = \frac{\sigma_2}{E} - \mu \frac{\sigma_1}{E}$$

$$= \frac{\frac{pd}{4t}}{E} - \mu \frac{\frac{pd}{2t}}{E}$$

$$= \frac{pd}{4tE} - \frac{\mu pd}{2tE}$$

$$\boxed{e_2 = \frac{pd}{2tE}\left[\frac{1}{2} - \mu\right]}$$

$$= 2e_1 + e_2$$

$$V = 2 \frac{pd}{2tE}\left[1 - \frac{\mu}{2}\right] + \frac{pd}{2tE}\left[\frac{1}{2} - \mu\right]$$

$$= \frac{pd}{2tE}\left[2 - \frac{2\mu}{2} + \frac{1}{2} - \mu\right]$$

$$= \frac{pd}{2tE}\left[2 + \frac{1}{2} - \mu - \mu\right]$$

$$= \frac{pd.}{2tE}\left[2 + \frac{1}{2} - \mu - \mu\right.$$

$$= \frac{pd}{2tE}\left[\frac{5}{2} - 2\mu\right]$$

$$\boxed{V = \frac{pd}{4tE}\left[5 - 2\mu\right]}$$

Also Change in Volume $(\delta V) = V(2e_1 + e_2)$

① A thin cylinderical shell 1m in diameter & 3m long has a metal thickness of 10mm. If it is subjected to an internal pressure of 3MPa. Determine hoop stress, longitudinal stress, change in length, change diameter and change in volume. (δL, δd, δV) if $E = 210$ GPa, $\mu = 0.3$.

$d = 1000$ mm $L = 3$ m $= 3000$ mm $t = 10$ mm, $P = 3$ N/mm²

① hoop stress $\sigma_1 = \frac{Pd}{2t}$ $\sigma_1 = \frac{3 \times 1000}{2 \times 10}$

$\sigma_1 = 150$ MPa (or) 150 N/mm²

② Longitudinal stress $\sigma_2 = \frac{Pd}{4t}$ or $\frac{\sigma_1}{2} = \frac{150}{2}$

$\sigma_2 = 75$ N/mm² (or) 75 MPa.

③ change in length is given by

$\delta L = \frac{PdL}{2tE}\left[\frac{1}{2} - \mu\right] = \frac{3 \times 1000 \times 3000}{2 \times 10 \times 210 \times 10^3}\left[\frac{1}{2} - 0.3\right)$

$\delta L = 2.1428(0.5 - 0.3)$

$\delta L = 0.428$ mm

④ change in diameter (d) is given by

$\delta d = \frac{Pd^2}{2tE}\left[1 - \frac{\mu}{2}\right] = \frac{3 \times 1000^2}{2 \times 10 \times 210 \times 10^3}\left[1 - \frac{0.3}{2}\right]$

$\delta d = 0.607$ mm

⑤ change in volume (δV) is given by equation

$\delta V = V[2e_1 + e_2]$ $\therefore [e_1 = \frac{\delta d}{d}, e_2 = \frac{\delta L}{L})$

$V = \frac{Pd}{4tE}[5 - 2\mu]$

$\delta V = V\left[2 \times \frac{\delta d}{d} + \frac{\delta L}{L}\right]$

Substituting the values of δd, δL, and L

$= \frac{3 \times 1000}{4 \times 10 \times 210}[5 - 2 \times 0.3]$

$\delta V = V\left[2 \times \frac{0.607}{1000} + \frac{0.428}{3000}\right] =$

$\delta V = 1.35 V \times 10^{-3} V.$

$V =$ original volume $= \pi/4 (d^2 L) = \frac{\pi}{4} \times 1000^2 \times 3000$

$V = 2.356 \times 10^9$ mm³

$\delta V = 1.35 \times 10^{-3} \times 2.356 \times 10^9$

$dV = 3.1806 \times 10^6$ mm³

(?) Calculate ① the change in diameter, ② change in length & ③ change in volume of a thin cylindrical shell 100cm diameter, 1cm thick and 5m long when subjected to internal pressure of 3 N/mm². Take the value of $E = 2\times10^5$ N/mm² and poisson's ratio $\mu = 0.3$.

~~Subjected to Internal Pressure of 3N/mm² Take the value of~~

→ Given

Diameter of shell $d = 100cm$

Thickness of shell $t = 1cm$

length of shell $l = 5m = 5\times100 = 500cm$

Internal pressure $p = 3 N/mm^2$

$E = 2\times10^5 N/mm^2$

$\mu = 0.3$

① Change in diameter (δd) is given by equation

$$\delta d = \frac{pd^2}{2tE}\left[1 - \frac{\mu}{2}\right]$$

$$\delta d = \frac{3\times100^2}{2\times1\times2\times10^5}\left[1 - \frac{0.3}{2}\right]$$

$$\delta d = 0.075 \; (0.85)$$

~~7.5×10^{-4}~~

$$\delta d = 0.06375$$

~~6.375×10^{-4}~~

$\delta d = 0.06375\,cm$

② Change in length (δL) is given by equation

$$\delta L = \frac{pdL}{2tE}\left[\frac{1}{2} - \mu\right] =$$

$$\delta L = \frac{3\times100\times500}{2\times1\times2\times10^5}\left[\frac{1}{2} - 0.3\right]$$

$$\delta L = 0.375\,[0.2]$$

$\delta L = 0.075\,cm$

③ Change in volume (δV) is given by equation.

$$\delta V = V[2e_1 + e_2]$$

$$= V\left(2\cdot\frac{\delta d}{d} + \frac{\delta L}{L}\right)$$

Substituting the values $\frac{\delta d}{d}$, $\frac{\delta L}{L}$, etc we get

$$\delta V = V\left[2\times\frac{0.06375}{100} + \frac{0.075}{500}\right]$$

$dV = 1.425\times10^{-3}\,V$

$V =$ original volume $= \frac{\pi}{4} d^2 \times L$

$U = \frac{\pi}{4} \times 100^2 \times 500$

$V = 3.9269 \times 10^6 \ cm^3$

$\delta V = 1.425 \times 10^{-3} \times V$

$= 1.425 \times 10^{-3} \times 3.9269 \times 10^6$

$\delta V = 5595.96 \ cm^3$

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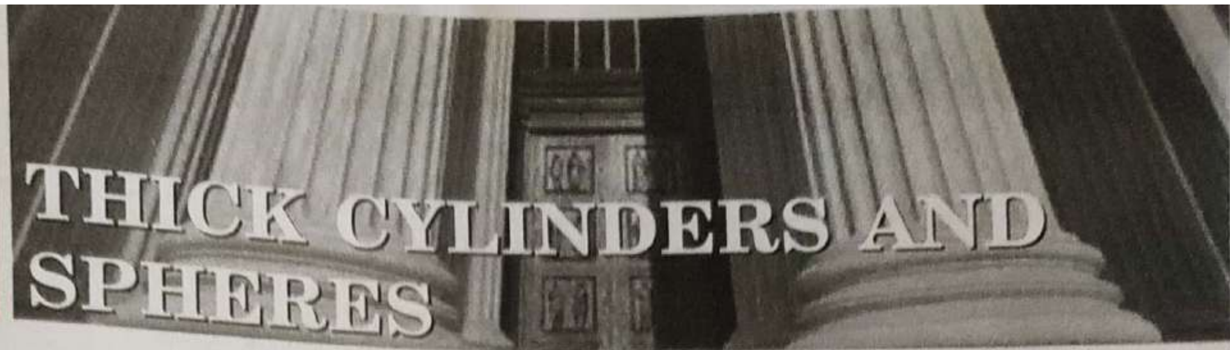
18 CHAPTER



THICK CYLINDERS AND SPHERES

18.1. INTRODUCTION

In the last chapter, we have mentioned that if the ratio of thickness to internal diameter of a cylindrical shell is less than about 1/20, the cylindrical shell is known as thin cylinders. For them it may be assumed with reasonable accuracy that the hoop and longitudinal stresses are constant over the thickness and the radial stress is small and can be neglected. If the ratio of thickness to internal diameter is more than 1/20, then cylindrical shell is known as thick cylinders.

The hoop stress in case of a thick cylinder will not be uniform across the thickness. Actually the hoop stress will vary from a maximum value at the inner circumference to a minimum value at the outer circumference.

18.2. STRESSES IN A THICK CYLINDRICAL SHELL

Fig. 18.1 (*a*) shows a thick cylinder subjected to an internal fluid pressure.

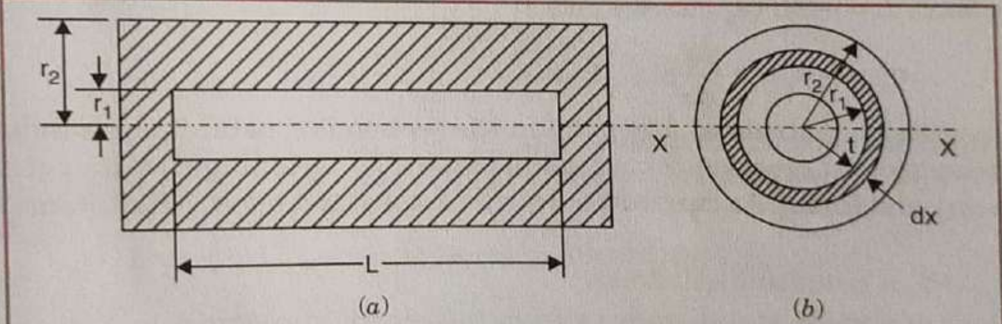


Fig. 18.1

Let r_2 = External radius of the cylinder,

r_1 = Internal radius of the cylinder, and

L = Length of cylinder.

Consider an elementary ring of the cylinder of radius x and thickness dx as shown in Figs. 18.1 (*b*) and 18.2.

Let p_x = Radial pressure on the inner surface of the ring

$p_x + dp_x$ = Radial pressure on the outer surface of the ring

σ_x = Hoop stress induced in the ring.

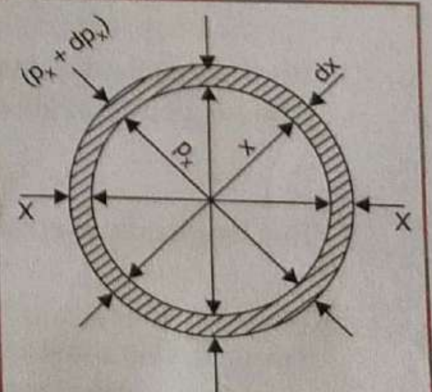


Fig. 18.2

Take a longitudinal section x-x and consider the equilibrium of half of the ring of Fig. 18.2 as shown in Fig. 18.2 (a) or in Fig. 18.2 (b).

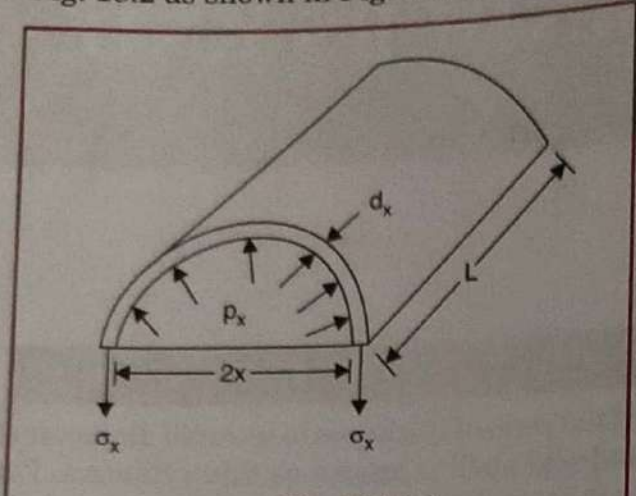


Fig. 18.2 (a)

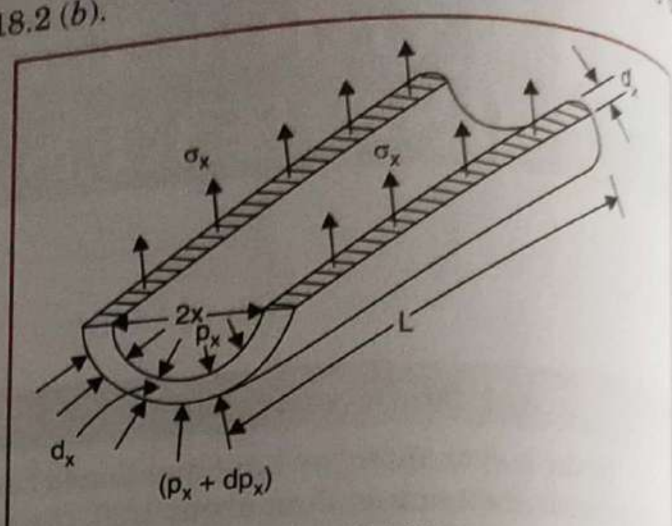


Fig. 18.2 (b)

Bursting force

$= p_x (2xL) - (p_x + dp_x) \times 2(x + dx) \,.\, L$

$= 2L\, [p_x \,.\, x - (p_x \,.\, x + p_x \,.\, dx + x.dp_x + dp_x \,.\, dx)]$

$= 2L\, [- p_x \,.\, dx - x \,.\, dp_x]$ (Neglecting $dp_x \,.\, dx$ which is a small quantity)

$= - 2L\, (p_x dx + x \,.\, dp_x)$

Resisting force = Hoop stress × Area on which it acts = $\sigma_x \times 2dx.\, L$

Equating the resisting force to the bursting force, we get

$\sigma_x \times 2dx \,.\, L = - 2L\, (p_x \,.\, dx + x \,.\, dp_x)$

or $$\sigma_x = - p_x - x\, \frac{dp_x}{dx}$$

The longitudinal strain at any point in the section is constant and is independent of the radius. This means that cross-sections remain plane after straining and this is true for sections remote from any end fixing. As longitudinal strain is constant, hence longitudinal stress will also be constant.

Let σ_2 = Longitudinal stress.

Hence at any point at a distance x from the centre, three principal stresses are acting. They are :

(i) the radial compressive stress, p_x

(ii) the hoop (or circumferential) tensile stress, σ_x

(iii) the longitudinal tensile stress σ_2.

The longitudinal strain (e_2) at this point is given by,

$$e_2 = \frac{\sigma_2}{E} - \frac{\mu \sigma_x}{E} + \frac{\mu p_x}{E}$$

But longitudinal strain is constant.

$$\therefore \quad \frac{\sigma_2}{E} - \frac{\mu \sigma_x}{E} + \frac{\mu p_x}{E} = \text{constant}$$

But σ_2 is also constant, and for the material of the cylinder E and μ are constant.

$\therefore \quad \sigma_x - p_x$ = constant

= $2a$ where a is constant

$\therefore$
$$\sigma_x = p_x + 2a \quad ...(iv)$$

Equating the two values of σ_x given by equations (*iii*) and (*iv*), we get

$$p_x + 2a = -p_x - x\frac{dp_x}{dx}$$

or
$$x \cdot \frac{dp_x}{dx} = -p_x - p_x - 2a = -2p_x - 2a$$

or
$$\frac{dp_x}{dx} = -\frac{2p_x}{x} - \frac{2a}{x} = \frac{-2(p_x + a)}{x}$$

or
$$\frac{dp_x}{(p_x + a)} = -\frac{2dx}{x}$$

Integrating the above equation, we get

$$\log_e (p_x + a) = -2\log_e x + \log_e b$$

where $\log_e b$ is a constant of integration.

The above equation can also be written as

$$\log_e (p_x + a) = -\log_e x^2 + \log_e b$$
$$= \log_e \frac{b}{x^2}$$

$\therefore$
$$p_x + a = \frac{b}{x^2}$$

or
$$p_x = \frac{b}{x^2} - a \quad ...(18.1)$$

Substituting the values of p_x in equation (*iv*), we get

$$\sigma_x = \frac{b}{x^2} - a + 2a = \frac{b}{x^2} + a \quad ...(18.2)$$

Equation (18.1) gives the radial pressure p_x and equation (18.2) gives the hoop stress at any radius x. These two equations are called *Lame's equations*. The constants 'a' and 'b' are obtained from boundary conditions, which are :

(*i*) at $x = r_1$, $p_x = p_0$ or the pressure of fluid inside the cylinder, and

(*ii*) at $x = r_2$, $p_x = 0$ or atmosphere pressure.

After knowing the values of 'a' and 'b', the hoop stress can be calculated at any radius.

Thick cylinders problems

(1) Determine the maximum and minimum hoop stress across the section of a pipe of 400mm internal diameter and 100mm thick, when the pipe contains a fluid at a pressure of 8 N/mm2. Also sketch the radial pressure distribution and hoop stress distribution across the section.

us Internal dia = d_i = 400mm t = 100mm,

Internal radius $r_1 = \frac{400}{2} = 200$ mm

External dia = d_e = 400 + 100 + 100 = 600mm

External radius = $r_2 = \frac{600}{2}$ = 300mm

Fluid pressure P_o = 8 N/mm2.

at $x = r_1$, $P_x = P_o$ = 8 N/mm2.

The radial pressure (P_x) is given by

$$P_x = \frac{b}{x^2} - a. \longrightarrow (1).$$

Now apply the boundary conditions to the above equation

The boundary conditions are.

(1) At $x = r_1$ = 200 mm, P_x = 8 N/mm2

(2) At $x = r_2$ = 300 mm , P_x = 0.

Substituting these boundary conditions in equation (1)

we get

(1) $$8 = \frac{b}{200^2} - a. = \frac{b}{40000} - a \longrightarrow (2)$$

(2) $$0 = \frac{b}{300^2} - a = \frac{b}{90000} - a \longrightarrow (iii)$$

and subtracting equation (iii) from equation (2) we get

$$8 = \frac{b}{40000} - \frac{b}{90000} = \frac{9b - 4b}{360000} = \frac{5b}{360000}$$

$$b = \frac{360000 \times 8}{5} = 576000.$$

Substituting this value in equation (iii) we get

$$0 = \frac{576000}{90000} - a$$

$a = 6.4$

The value of a and b are substituted in the hoop stress.

Now hoop stress at any radius x is given by equation.

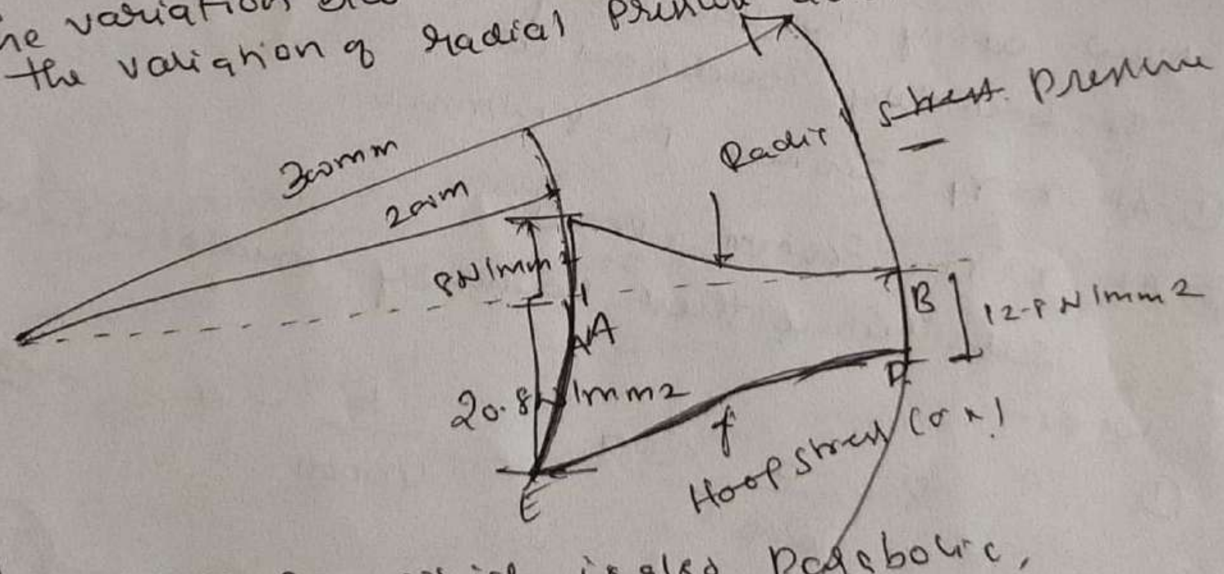
$$\sigma_x = \frac{b}{x^2} + a.$$

$$\sigma_x = \frac{576000}{x^2} + 6.4$$

At $x = 200$ mm, $\sigma_{200} = \frac{576000}{200^2} + 6.4 = 14.4 + 6.4 = 20.8\ N/mm^2$

At $x = 300$ mm, $\sigma_{300} = \frac{576000}{300^2} + 6.4 = 6.4 + 6.4 = 12.8\ N/mm^2$

The radial pressure distribution and hoop stress distribution across the section. AB is taken a horizontal line. $AC = 8\ N/mm^2$. The curve BC is parabolic. The curve BC shows the variation b/w B and C is the variation of radial pressure across AB.

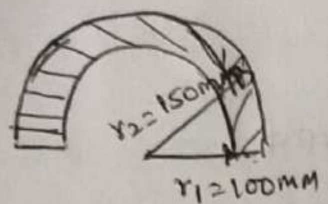


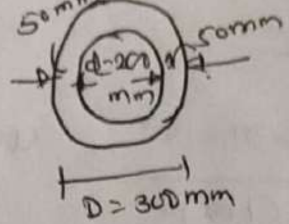
The curve DE which is also parabolic,

$BD = 12.8\ N/mm^2$, $AE = 20.8\ N/mm^2$.

the radial pressure is compressive whereas the hoop stress is tensile.

A thick pipe of outer dia 300mm where thickness of metal has 50mm is subjected to an internal fluid pressure of 40MPa and an external pressure of 2.5MPa fluid. Find maximum & minimum circumferential & radial stress in pipe thickness and plot stress variation.





$$p_x = \frac{b}{x^2} - a$$

$$\sigma_x = \frac{b}{x^2} + a$$

$d_E = 300mm$

$r_E = 150mm$

$t = 50mm$

$d_i = 200mm$

$r_i = 100mm$

Case ① $p_x = 40$ MPa at $r_i = 100mm$

② $p_x = 2.5$ MPa at $x_E = 150mm$.

case ① $p_x = -a + \frac{b}{x^2}$.

$$40 = -a + \frac{b}{(100)^2}$$

$$40 = -a + \frac{b}{10000}$$

$$400000 = -10000a + b \quad \text{eq ①}$$

$$-10000a + b - 400000 \rightarrow ①$$

case ② $2.5 = -a + \frac{b}{150^2}$.

$$2.5 = -a + \frac{b}{22500}$$

$$56250 = -22500a + b \quad \text{eq ②}$$

$$-22500a + b - 56250 = 0 \rightarrow ②$$

solving eq ① & ②

we get $a = 27.5$ $b = 6.75 \times 10^5$

To find Hoop stresses

$$\sigma_x\big]_{x=100} = a + \frac{b}{x^2} = 27.5 + \frac{6.75\times10^5}{100^2} = 95\ \text{MPa}$$

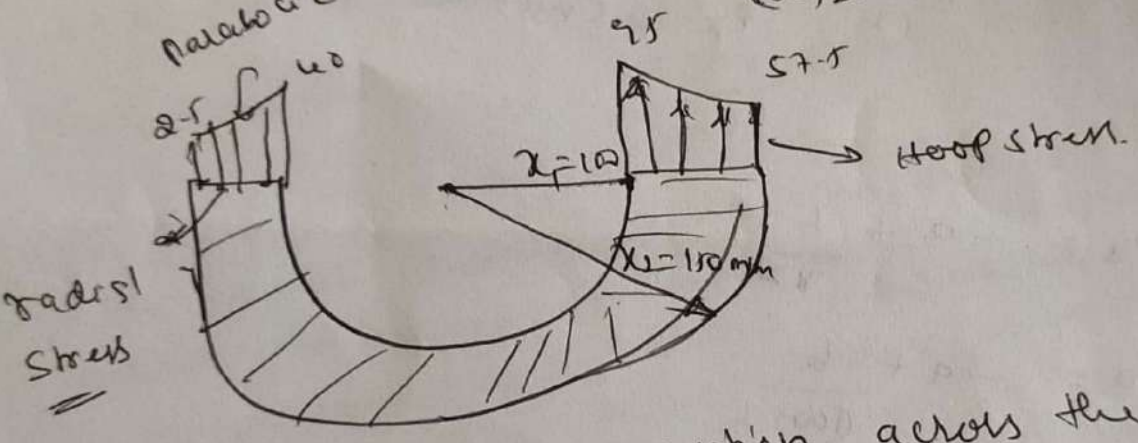
$$\sigma_x\big]_{x=150} = a + b/x^2 = 27.5 + \frac{6.75\times10^5}{(150)^2} = 57.5\ \text{MPa}$$

Radial stress

$$p_x = -a + b/x^2$$

$$p_x\big]_{x=100} = -27.5 + \frac{6.75\times10^5}{(100)^2} = 40\ \text{MPa}$$

$$p_x\big]_{x=150} = -27.5 + \frac{6.75\times10^5}{(150)^2} = 2.5\ \text{MPa}$$

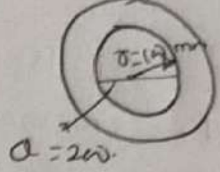


Stress variation across the thickness

Note: For design of thick cylinders, always hoop stress (σ_x) at inner surface is considered. As the maximum stress is absorbed at the inner surface & it also equated to allowable stress in tension.

A thick cylinder of internal dia 200mm. is subjected to an internal fluid pressure of 40MPa. if the allowable stress in tension for the material is 120MPa. find the thickness required.

→ $d_i = 200\,mm$ $r_i = 100\,mm$



$P_x = 40\,MPa$ at $x = 100$.

$\sigma_x = 120\,MPa$ at $x = 100$.

$\sigma_x = a + \frac{b}{x^2}$ $P_x = -a + \frac{b}{x^2}$

$120 = a + \frac{b}{100^2}$ $40 = -a + \frac{b}{100^2}$

$120 = a + \frac{b}{10000}$ $40 = -a + \frac{b}{100^2}$

$120 \times 10^4 = 10000a + b$ → ① $40 \times 10^4 = -10000a + b$ → ②

$10000a + b = 120 \times 10^4$ → ①

$-10000a + b = 40 \times 10^4$ → ②

$b = 8 \times 10^5$

$a = 40$

let t be the thickness of cylinder.

at $[x = [100 + t]]$

given. $P_x = 0 = -a + \frac{b}{x^2}$

$0 = -40 + \frac{8 \times 10^5}{(100 + t)^2}$.

$0 = -(40)(100 + t)^2 + 8 \times 10^5$

$-40t^2 - 8 \times 10^3 t + 8 \times 10^5 = 0$

$-4 \times 10^5 - 40t^2 - 8 \times 10^3 t = 0$

$4 \times 10^5 = 40t^2 - 8 \times 10^3 t$

$\boxed{t = 41.42\,mm}$

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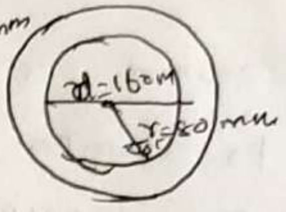
(4) Find the thickness of metal necessary for a cylinderical shell of internal dia 160mm to withstand a pressure of 8 N/mm2. The maximum hoop stress in the section is not to exceed 35MPa. (5)

$\Rightarrow$ t = ? d_i = 160mm (or) x r_i = 80mm $r_i = \frac{160}{2} = 80mm$



P_x = 8 N/mm2 (P_x = 80mm.

σ_x = 35MPa. [hoop stress]

$\Rightarrow$ Case 1 P_x = 8 N/mm2 at x = 80mm

Case σ_x = 35 N/mm2 at x = 80mm

case 1

$$P_x = -a + \frac{b}{x^2}$$

$$8 = -a + \frac{b}{80^2}$$

$$5120 = -6400a + b$$

$$-6400a + b = 5120 \rightarrow (2)$$

Case 2

$$\sigma_x = a + \frac{b}{x^2}$$

$$35 = a + \frac{b}{80^2}$$

$$224000 = 6400a + b$$

$$6400a + b = 224000 \rightarrow (1)$$

The maximum hoop stress is at the Inner radius of the Sheel

Let r_2 = External radius.

The radial pressure and hoop stress at any radius x are given by equation $\rightarrow (1)$ $\sigma_x = \frac{b}{x^2} + a \rightarrow (2)$

$P_x = \frac{b}{x^2} - a$

Let us now apply the boundary conditions. The boundary conditions are at x = 80mm, P_x = 8 N/mm2,

& σ_x = 35 N/mm2 x = 80mm, P_x = 8 N/mm2 in eq (1)

substituting the values $8 = -a + \frac{b}{80^2}$

$P_x = -a + \frac{b}{x^2} \rightarrow (11)$.

$-6400a + b = 5120$ eq (2)

x = 80mm σ_x = 35 N/mm2

$35 = \frac{b}{80^2} + a = 6400a + b = 224000 \rightarrow (4)$

$\sigma_x = \frac{b}{x^2} + a$

solving eq (3) & (4) we get $27 = 2a$

$$\boxed{a = 13.5}.$$

Substituting the value of a in equation (11) we get

$$8 = \frac{b}{6400} - 13.5$$

$$b = (8 + 13.5) \times 6400$$

$$b = 21.5 \times 6400$$

$$\boxed{b = 137600}$$

Substituting the value of a & b in eq (1)

$$p_x = \frac{21.5 \times 6400}{x^2} - 13.5$$

But at the outer surface, the pressure is zero.

Hence at $x = r_2$, $p_x = 0$, substituting these values in the above equation we get

$$0 = \frac{21.5 \times 6400}{r_2^2} - 13.5$$

$$r_2^2 = \frac{21.5 \times 6400}{13.5}$$

$$r_2 = \sqrt{\frac{21.5 \times 6400}{13.5}} = 100.96\,mm$$

Thickness of the shell $t = r_2 - r_1$

$= 100.96 - 80$

$= 20.96\,mm$

Module: 3.

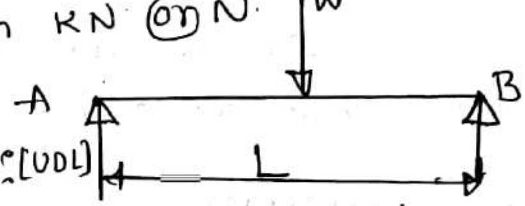
Shear Force and Bending moment in Beams.

Introduction types of loading, supports, and types of beams.

Loadings are classified based on the portion and type of which it is being applied on the body.

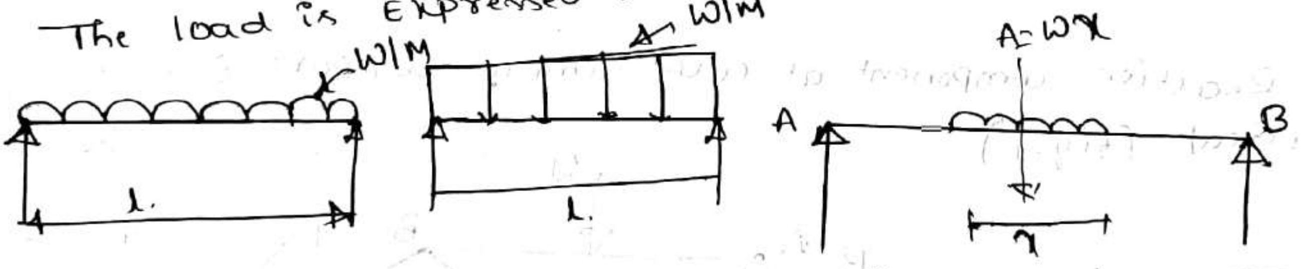
a) Point load (or) Concentrated Load :

In This type, The total load is assumed to be concentrated at a point i.e, it is not covering any distance (or) area of the body on which it is being applied. The load is in KN (or) N.



(b) Uniformly Distributed load: [UDL]

It is the one which is spread over a beam in such a manner that rate of loading w is uniform along the length [i.e each unit length is loaded to the same rate] The load is Expressed in In terms of N/m (or) KN/m.



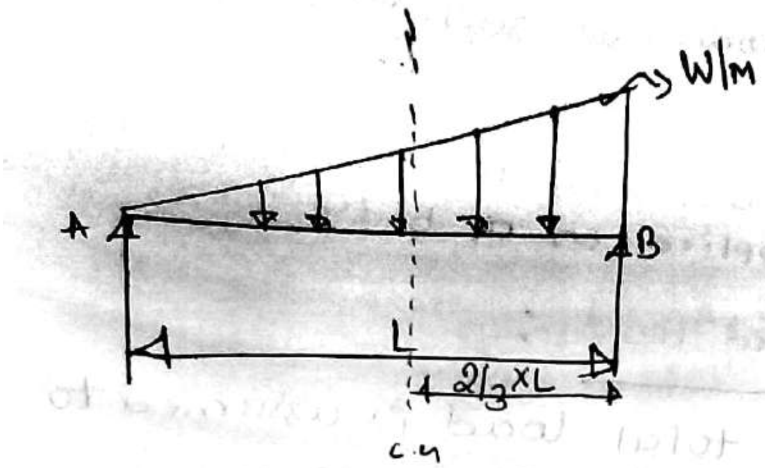
For calculation purpose it is treated has equivalent concentrated load [ECL] acting at mid point of the portion (or) at its centroid with its area has magnitude.

(c) uniformly varying load [UVL]

It is the one which is spread over a beam in such a manner that rate of loading varies from point to point along the beam. as show in fig. In which the load is zero at one end and increases uniformly to the other end. Such load is known as triangular load. (UVL)

For solving the problems the total load is equal to the area of the triangle and the total load is assumed to be acting at the c.g of the triangle i.e at a distance of

2/3 of the total length of the beam from the left end.



* Supports

Supports are classified based on number of ~~reacti~~ reactions that are going to develop at the contact ~~Start~~ points

① **Simply supports**:
The ends of the beam rest simply on a rigid body without any fixing is called simply support.

one Reaction component at each simple support & is acting vertical (fig.1)

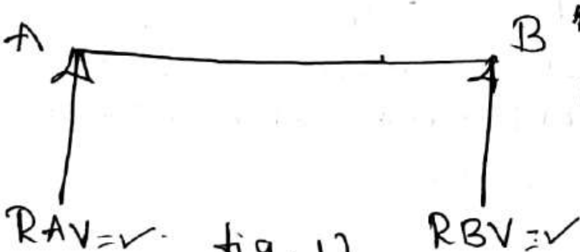


fig. 1)

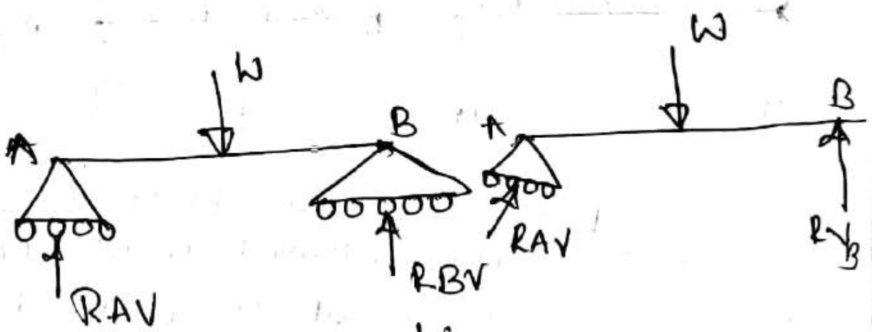
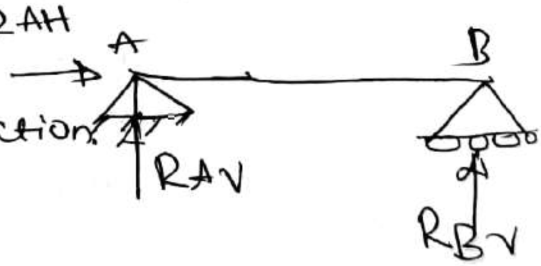


fig: 2.

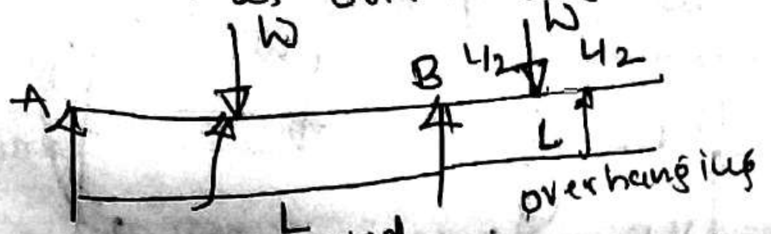
② **Roller Support**. Vertical Reaction component always acting perpendicular to the line of rollers (fig 2)

③ Hinged support (or) Pinned support two unknown in x & y direction.

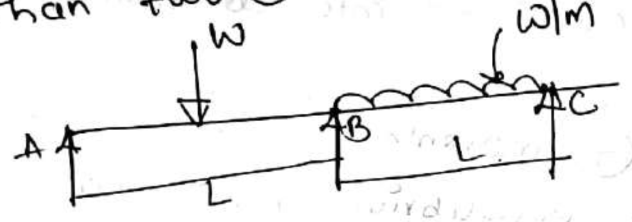
fig: 3



③ <u>Overhanging Beam</u> : If the end portion of the beam is extended beyond the support such beam is known as overhanging beam.



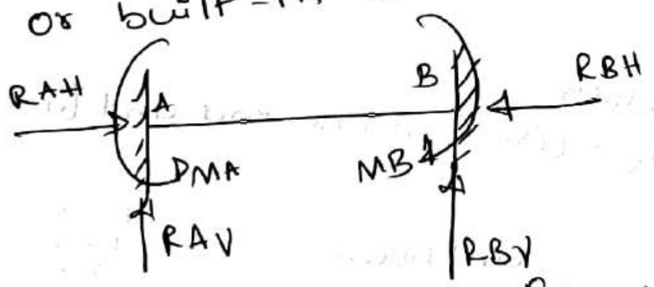
④ <u>Continous Beams</u> : A Beam which is provided more than two ~~(or) more~~ supports



⑤ Indeterminate beams all the unknowns such as reaction (or) force (or) moments cannot be evaluated by using the equilibrium conditions

Examples

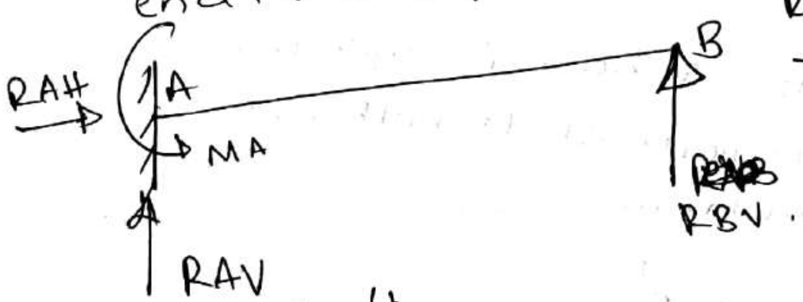
⑤ <u>Fixed Beams</u> ; A beam whose both ends are fixed or built-in walls is known as fixed beam.



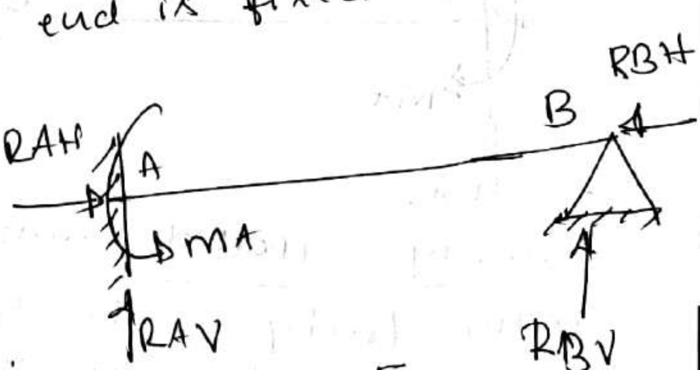
Unknowns = 6
Equilibrium conditions = 3
Indeterminate = 3rd degree.

⑥ <u>Propped Cantiler Beams</u> :

It is beam whose one end is fixed and other end is simply supported.



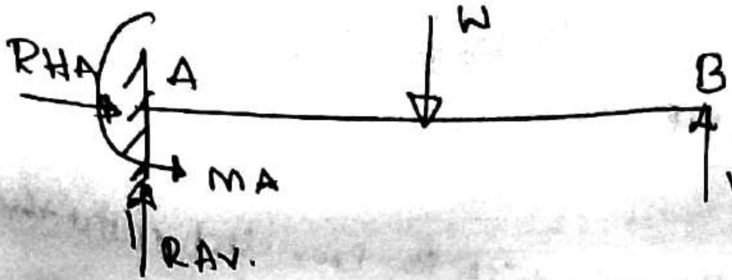
Unknowns 4
Equilibrium conditions 3
1st degree.

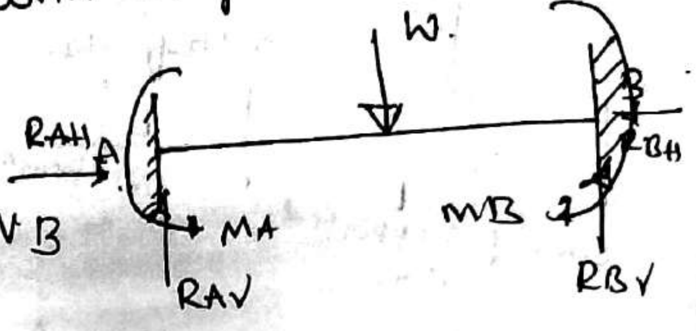


Unknowns 5
Equilibrium conditions 3
Indeterminate 2nd degree

(4) **fixed (or) built in support :**

Three unknowns with x, y and a moment.





Beams : Beam is a horizontal member.

Beams are broadly classified into determinate and Indeterminate beams.

1. In case of Determinate beams all the unknowns, such as reaction (or) forces (or) moments can be evaluated by using the three static equilibrium conditions. i.e. $\overset{+ve}{\rightarrow}\Sigma H=0$, $\overset{+ve}{\uparrow}\Sigma V=0$, $\overset{+ve}{\curvearrowleft}\Sigma M=0$

Types of Beams :

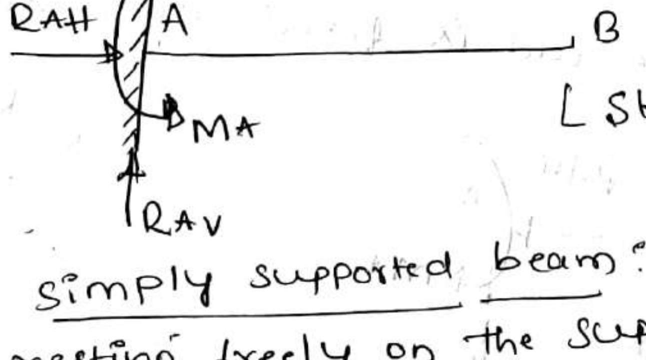
The following are the important types of beams

1. cantilever beam,
2. simply supported beam
3. overhanging beam
4. fixed beam and
5. continous beam.

1. **cantilever beam :** A Beam which is fixed at one end and free at the other end.

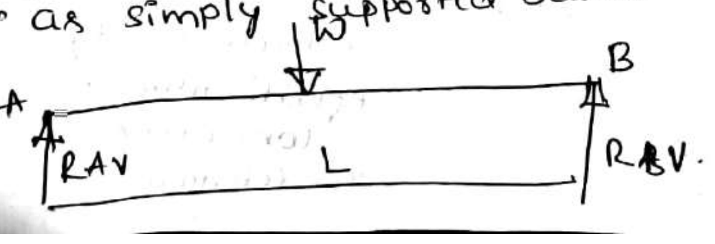
Unknowns = 3 (RAH, RAV, MA)
equilibrium conditions 3
―――
0

[Statically Determinate] Beam



(2) **simply supported beam :** A beam is supported (or) is resting freely on the supports at its both ends, is known as simply supported beam.

unknowns = 2 (RAV, RBV)
equilibrium conditions 3

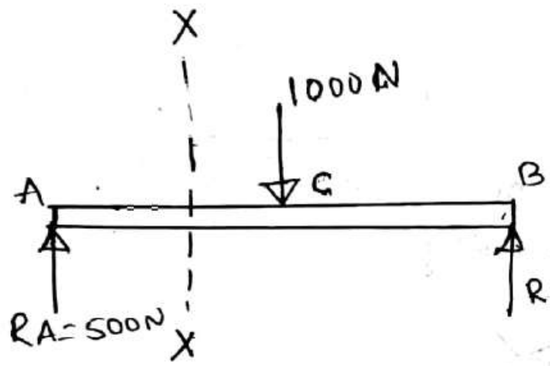


Shear Force [S.F]

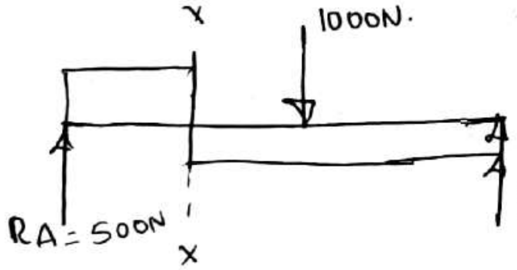
The algebraic sum of the vertical force at any section of a beam to the right or left of the section is known as shear force.

Sign convention

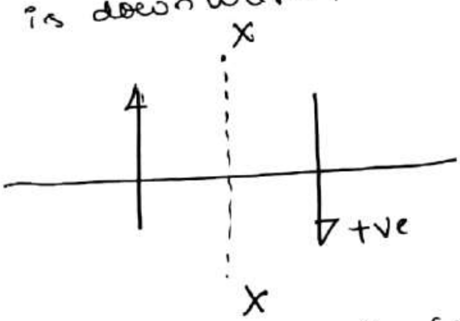
A simply supported beam AB carrying a load of 1000N at its middle point. The reactions at the supports will be equal to 500N, Hence RA = RB = 500N



The beam is divided into two portions by the section X-X. The resultant of the load and reaction to the left of X-X is 500N vertically upwards. (There is no load to the left of [X-X]. And the resultant of the load and reaction to the right of X-X is [1000↓ - 500↑ = 500↓N] 500N downwards.



The resultant force acting on any one of the parts normal to the axis of the beam is called the shear force at the section X-X. Here the shear force at the section is upwards and 500N. The shear force at a section will be considered as positive when the resultant of the forces to the left of the section including reaction is upward (or) to the right of the section is downward.



Shear force diagram: A shear force diagram is the plot which shows the variation of shear force along the length of beam.

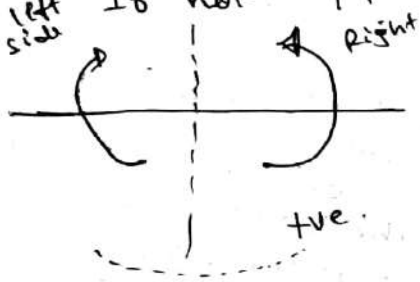
Bending moment

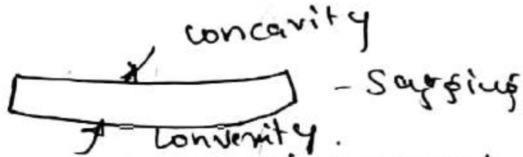
The algebraic sum of the moments of all the forces acting to the left (or) right of the section is known as Bending moment.

Bending moment at a section is constant and varies (or changes) as the distance varies,

Sign Convention

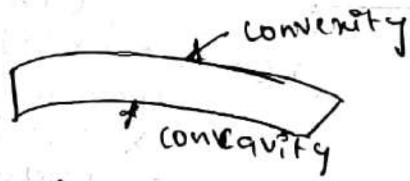
If the algebraic sum of moments to the left of the section is clockwise (or) right of the section is anticlockwise Then it is positive bend moment i.e Sagging of the member, If not it is negative bending moment i.e. is hogging





(a) Positive Bending moment

(b)



negative Bending moment.

Bending moment Diagram (BMD)

A BMD is the plot which shows the variation of bending moment along the length of the beam.

Note:

Bending moment at free end, simple support, roller support, hinged support end is zero.

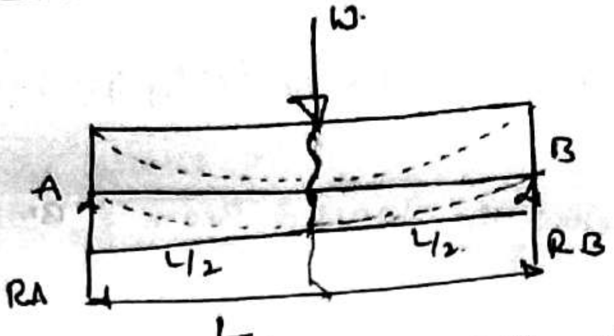
The Bending moment develops only in case of fixed supports and over hanging portion.

2hrs

Shear force and Bending moment

addition of forces to the left (or) Right of the section

Bending
(+)
shear force



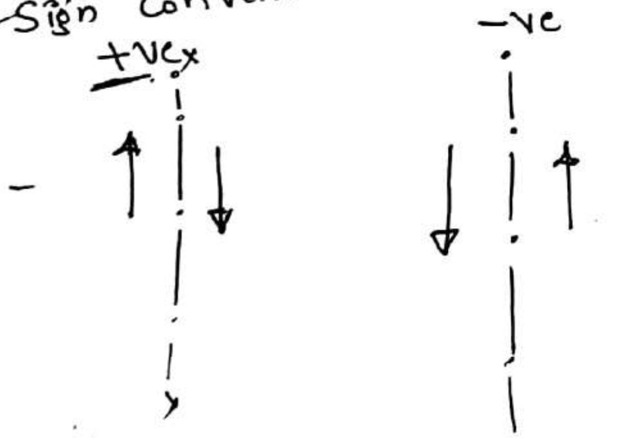
Shear Force:- It is defined as the algebraic sum of forces acting either on left hand side or right hand side of the section.

It is unit will be N (or) KN.

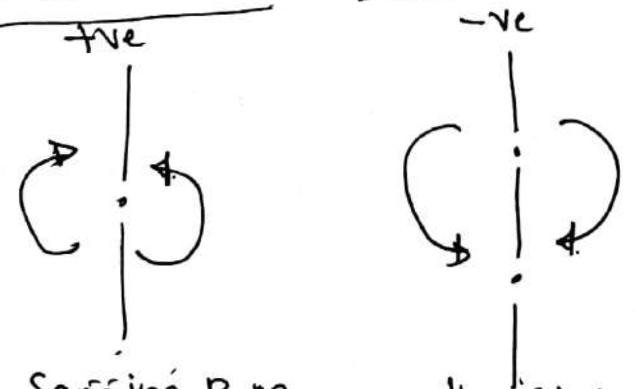
Bending moment: It is defined as the algebraic sum of moment of forces acting on the left side (or) Right side of the section.

It is unit will be N-mm (or) KN-mm.

Imp Sign convention for shear force



Sign convention for bending moment



Important points to be noted while drawing Shear force Bending Moment

1. Length of SFD & BMD must be equal to the span of the beam.

2. SFD is drawn below the loaded Beam & BMD is drawn below SFD.

3. For simply supported beam, B.m is zero at the supports.

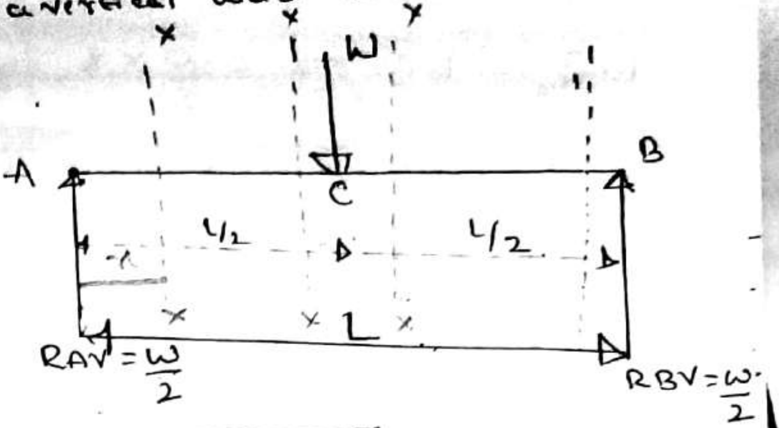
4. For cantilever beam, B.m is zero at the free end.

5. Calculate the SF & B.m at all critical points.

6. If no load is present b/w the two points then SF will be constant.

…ply supported Beam point load at the centre

…der the beam shown in fig. which is simply supported a… A and B and carries a vertical load W at the distance $\frac{L}{2}$ from the support.



Reactions $\Sigma Fx = 0$

$\Sigma Fy = 0$

$+RAV - W + RBV = 0$

$$RAV + RBV = W$$

$\Sigma MA = 0$

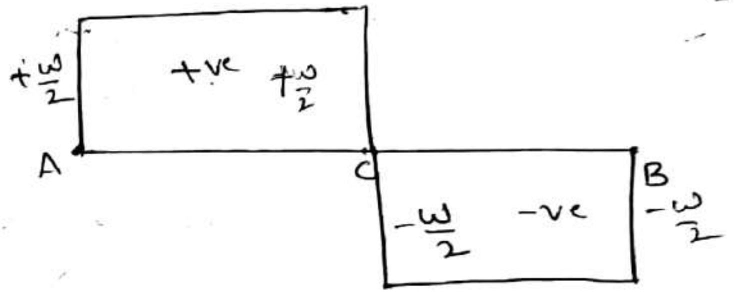
$RAV \times 0 + W \times \frac{L}{2} - RBV \times L = 0$

$$RBV = \frac{W}{2}$$

$\Sigma MB = 0$

$+RBV \times 0 - W \times \frac{L}{2} + RAV \times L = 0$

$$RAV = \frac{W}{2}$$



Shear Force Diagram

To plot the shear force Diagram.

$SF]_A = +RAV = +\frac{W}{2}$

$SF]_{C\ left} = +RAV = +\frac{W}{2}$

$SF]_{C\ Right} = +RAV - W$

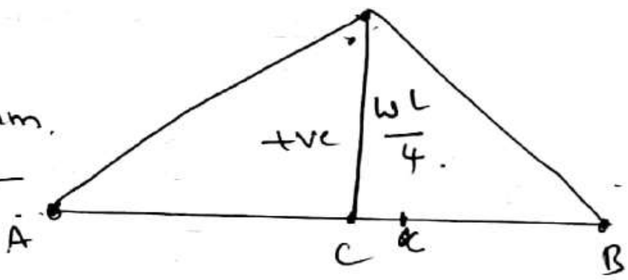
$= +\frac{W}{2} - W$

$SF]_C = -\frac{W}{2}$

$SF]_B = +RAV - W$

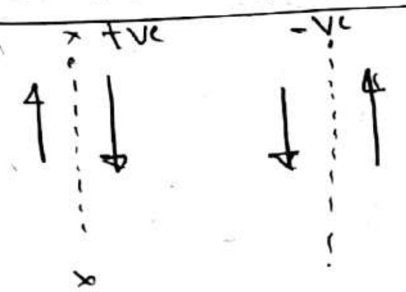
$= +\frac{W}{2} - W$

$$SF]_B = -\frac{W}{2}.$$



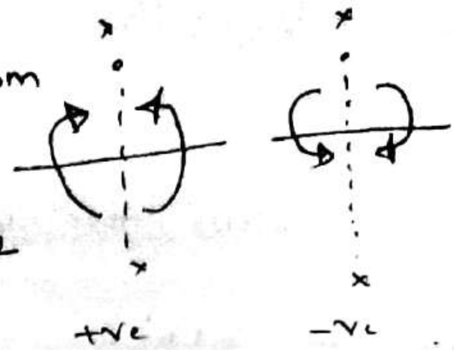
Bending moment Diagram.

Shear force sign conventions



(b) To plot the Bending moment Diagram

(a) Consider a section a distance x from the support A



$BM]_x = R_A \times x = \frac{W}{2} \times x \quad 0 < x < L/2$

$BM]_A = \frac{W}{2} \times x = \frac{W}{2} \times 0 = 0$
$x = 0$

$BM]_C = \frac{W}{2} \times x = \frac{W}{2} \times \frac{L}{2} = + \frac{WL}{4}$
$x = \frac{L}{2}$

Hence Bending varies linearly from zero at support A to a maximum value below the point load.

(b) The bending moment at any section b/w C & B at distance x from the end A is given by.

$BM]_x = R_A x - W \times (x - \frac{L}{2})$

$= \frac{W}{2} \cdot x - Wx + \frac{WL}{2}$

$BM]_x = \frac{WL}{2} - \frac{Wx}{2}$

At $BM]_C$ $x = \frac{L}{2}$ $= \frac{WL}{2} - \frac{Wx}{2} = \frac{WL}{2} - \frac{W}{2} \times \frac{L}{2} = \frac{WL}{4}$

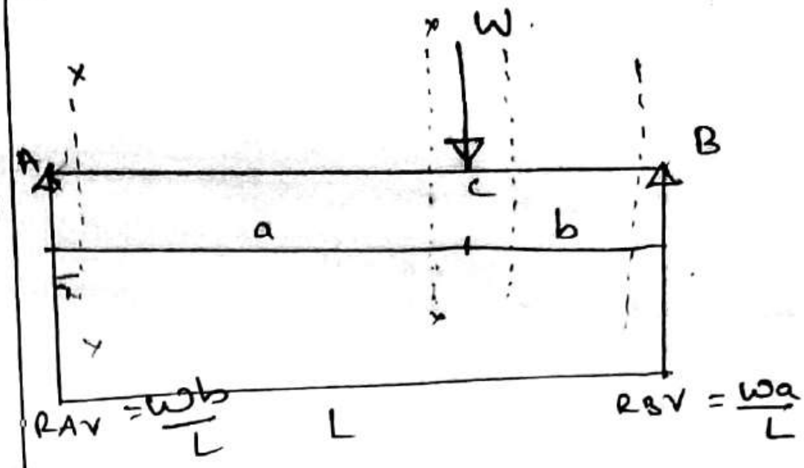
$BM]_C = + \frac{WL}{4}$
$x = L/2$

At $BM]_B$ $x = L$ $= \frac{WL}{2} - \frac{Wx}{2} = \frac{WL}{2} - \frac{W}{2} \times L = 0$

$BM]_B = 0$

Simply supported Beam subjected to eccentric loading

Consider the simply supported beam at A and B carrying a vertical load W at a distance a from the Left end



Reactions

$\Sigma F_y = 0$

$+R_{AV} - W + R_{BV} = 0$

$$R_{AV} + R_{BV} = W$$

$\Sigma M_A = 0$

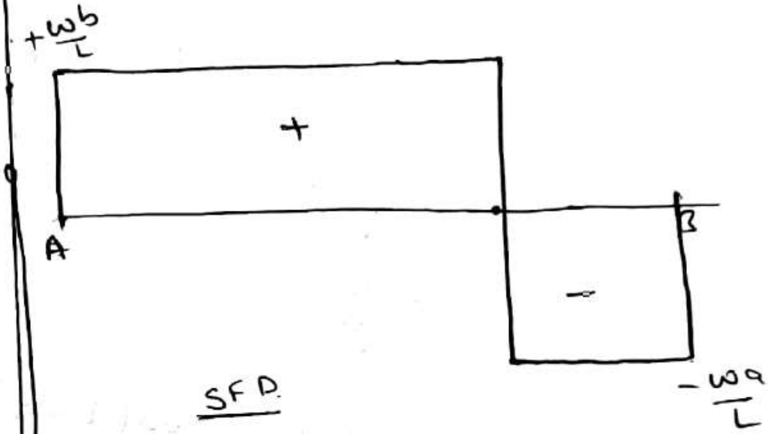
$+R_{AV} \times 0 + W \times a - R_{BV} \times L = 0$

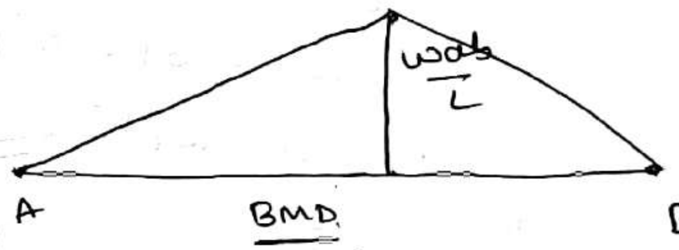
$$R_{BV} = \frac{Wa}{L}$$

$\Sigma M_B = 0$

$+R_{AV} \times L - W \times b + R_{BV} \times 0 = 0$

$$R_{AV} = \frac{Wb}{L}$$





Calculation of the SF

$SF]_A = + R_{AV} = + \frac{Wb}{L}$

$SF]_{C \text{ left}} = +R_{AV} = +\frac{Wb}{L}$

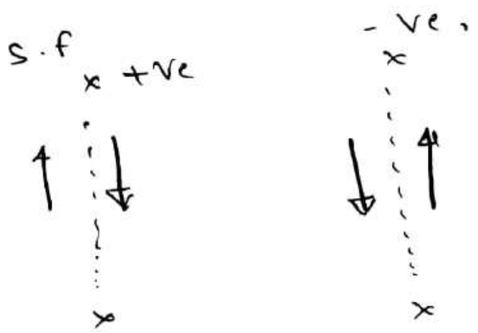
$SF]_{C \text{ Right}} = + \frac{Wb}{L} - W = W\left[\frac{b}{L} - 1\right]$

$= -W\left[\frac{L-b}{L}\right]$

where $L - b = a$

$SF]_{C \text{ Right}} = -\frac{Wa}{L}$

$SF]_B = -\frac{Wa}{L}$



BMD calculations:

$BM]_x =$

$Mx] = RAV \times x$

$Mx] = +\frac{wb}{L} \times x$

when $x = 0$

$BM]_A = \frac{wb}{L} \times 0 = 0$
$x=0$

$BM]_C$ left $= \frac{wb}{L} \times a = +\frac{wab}{L}$
$x = a$

$BM]_C$ Right $= RAV \times x - w(x - a]$

$x=a$ $= \frac{wb}{L} \times a - w(a - a]$

$BM]_C$ Right $= \frac{wab}{L}$

$BM]_B = \frac{wb}{L} \times L - w[L - a]$

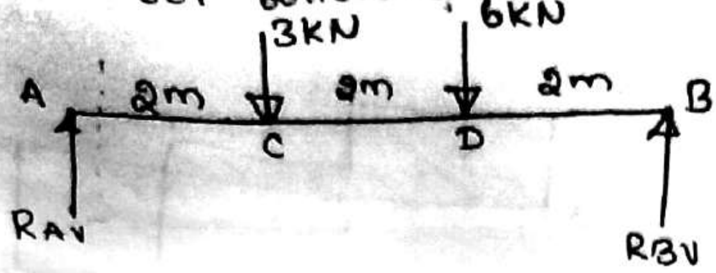
$= +wb - w[L-a]$

$= +wb - w[b]$

$BM]_B = 0$

Problems

1. Draw shear force diagram and Bending moment diagram for following beam.



It is a simply supported beam. Let RAV and RBV are be the support reactions as shown in fig.

W.K.T Applying equilibrium conditions

$\uparrow^{+ve} \Sigma Fy = 0$

$+RAV - 3 - 6 + RBV = 0$

$\boxed{RAV + RBV = 9\,KN}$

+ve $\Sigma MA = 0$

$-RBV \times 6 + 6 \times 4 + 3 \times 2 = 0$

$+RBV \times 6 = +30$

$RBV = \frac{30}{6}$

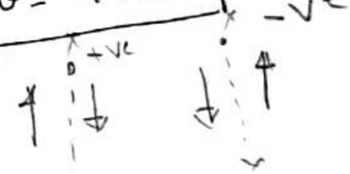
$\boxed{RBV = 5KN}$

+ve $\Sigma MB = 0$

$+RAV \times 6 - 3 \times 4 - 6 \times 2 = 0$

$RAV \times 6 = 24$

$\boxed{RAV = 4KN}$



Shear force calculations

$SF]_A = \pm 4KN = +VA$.

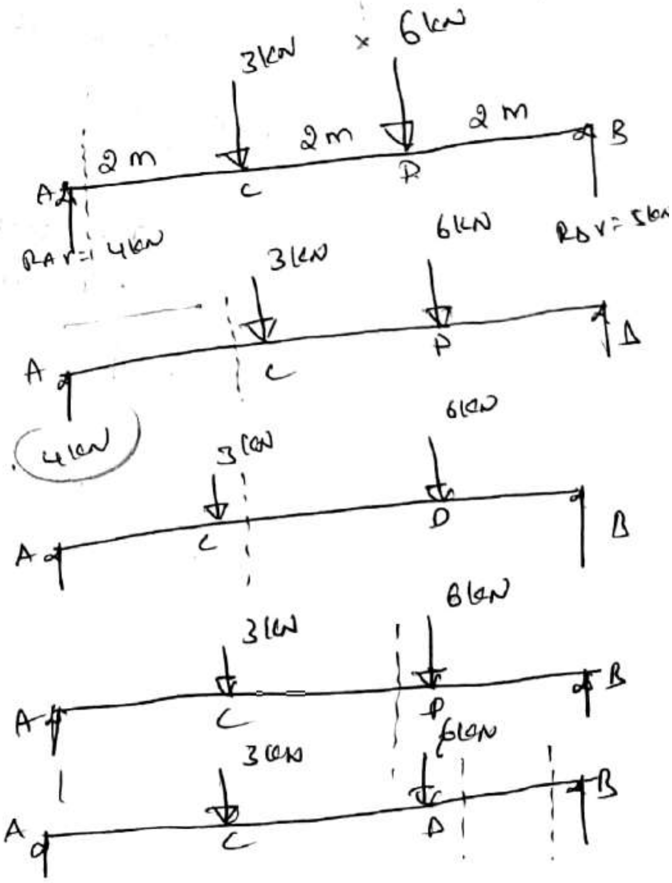
$SF]_{C\,L.C} = +4KN$

$SF]_{C\,R.C} = +4KN - 3KN = 1KN$

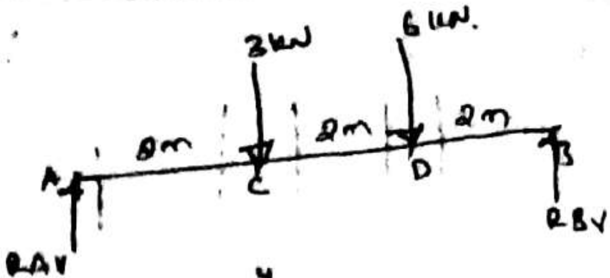
$SF]_{D\,L.C} = 4KN - 3 = 1KN.$

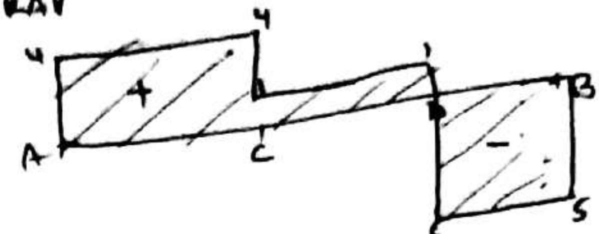
$SF]_{D\,R.C} = 4 - 3 - 6 = -5KN$

$SF]_B = 4 - 3 - 6 = -5KN.$



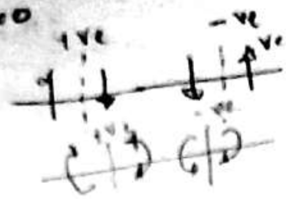
Calculation of Bending moment :





SFD

As the supports A & B are simply supported the bending moments at these points are zero.



$\therefore$ BM]$_A$ = 0

BM]$_B$ = 0

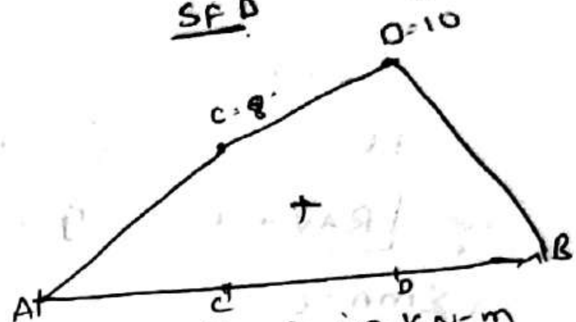
BM]$_C$ = +RAV×2 = 4×2 = 8 kN-m

Left support

BM]$_C$ Right support = ~~+RAV×4 + 3×2~~ =
~~4×4+12~~ - 16 -

RBV×4 - 6×2 = 0
5
5×4 - 12 = 8 kN-m

BM]$_C$ Right support = 8 kN-m



BMD in kN-m

BM]$_C$ = +RAV×2 - 3×

BM]$_D$ left = (RAV× 4) - 3×2
= 4×4 - 6 = 16 - 6 = 10 kN-m.

BM]$_D$ Right = +5×2 = 10 kN-m

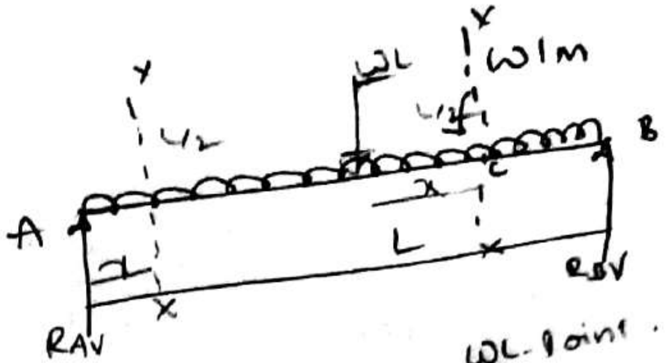
$\therefore$ In case of BMD for point source the lines will be combination of vertical and horizontal lines i.e. inclined lines].

BM]$_C$ Right = +RAV×2 - 3×0
= +4×2 = 8 kN-m

BM]$_D$ Right = RAV×4 - 3×2 - 6×0
= 4×4 - 6
= 16 - 6
= 10 kN-m

BM]$_B$ = ~~0~~ +RAV×6 - 3×4 - 6×2
= 4×6 - 12 - 12
= 24 - 12 - 12
= 0

Draw the shear force and Bending moment Diagram for the simply supported beam with uniformly Distributed load.



$\Sigma V = 0$

$RAV + RBV - WL = 0$

$RAV + RBV = WL$

$\Sigma MA = 0$

$-RBV \times L + WL \times \frac{L}{2} = 0$

$+RBV \times L = +\frac{WL^2}{2}$

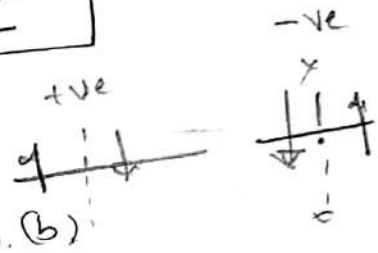
$$+RBV = \frac{WL}{2}$$

$\Sigma MB = 0$

$+RAV \times L - \frac{WL \times L}{2} = 0$

$RAV \times L = \frac{WL^2}{2}$

$$RAV = \frac{WL}{2}$$



Shear force calculation

$SF]_A = \frac{WL}{2} = +\frac{WL}{2} = +VA$ ($x = 0$)

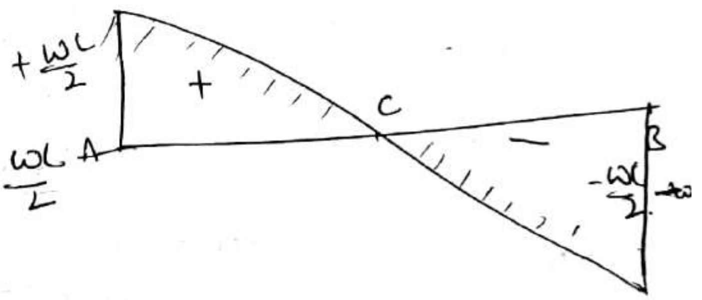
$SF]_B = -\frac{WL}{2} = -\frac{WL}{2} = -VB$ ($x = L$)

$SF]_C = +VA - wx$

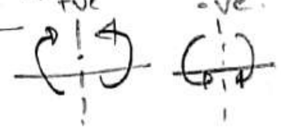
$x = L/2$ Right $= +\frac{WL}{2} - w \times L/2 = +\frac{WL}{2} - \frac{WL}{2}$

$SF]_C = 0$

SFD (b)



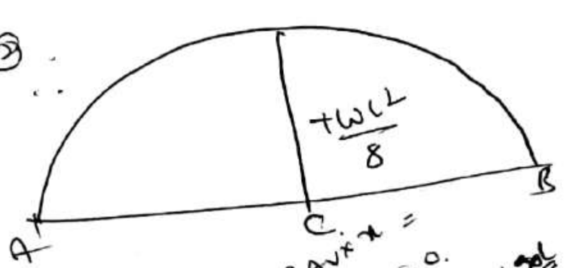
Bending Moment calculations at the section x at a distance x from left end A is given by.



BMD Diagram

$M_x = +RAV \cdot x - w \cdot x \cdot \frac{x}{2}$

$= \frac{WL}{2} \times x - \frac{w \cdot x^2}{2}$ $\therefore RA = \left(\frac{WL}{2}\right) \rightarrow (2)$



From eq (2) it is clear that BM. varies according to parabolic law.

The values of B.M at different points

BM at A $x = 0$ hence $MA = \frac{WL}{2} \times 0 - \frac{w \cdot 0^2}{2} = 0$

BM at B. $x = L$ hence $MB = \frac{WL}{2} \cdot L - \frac{w \cdot L^2}{2}$

$= \frac{WL^2}{2} - \frac{WL^2}{2} = 0$.

$BM)_A = RAV \times x = RAV \times 0 = 0$. ($x = 0$)

$BM)_C = RAV \times \frac{L}{2} - w \times \frac{L}{2} \times \frac{L}{4}$

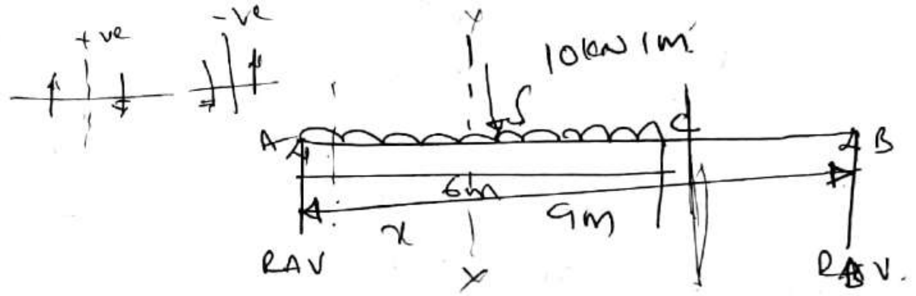
Right $x = L/2$ $= +\frac{WL}{2} \times \frac{L}{2} - \frac{WL^2}{8}$

At C, $x = L/2$ hence $M_C = \frac{w \cdot L}{2} \cdot \frac{L}{2} - \frac{w}{2}\left(\frac{L}{2}\right)^2$

$$= \frac{wL^2}{4} - \frac{wL^2}{8} = +\frac{wL^2}{8}$$

Thus, the B.M increases according to parabolic law from zero at A to $+\frac{wL^2}{8}$ at middle point of the beam and from this value the B.M. decreases to zero at B according to the parabolic law.

① Draw the shear force and bending moment diagram for a simply supported beam of length 9m and carrying a UDL of 10KN/m for a distance of 6m from the left end. Also calculate the maximum B.M on the section.



$\Sigma V = 0$

$RAV + RBV - 60 = 0$

$RAV + RBV = 60KN.$

$\Sigma M_B = 0$

$+RAV \times 9 - 60 \times 6 = 0$

$RAV = \frac{360}{9}$

$RAV = 40KN$

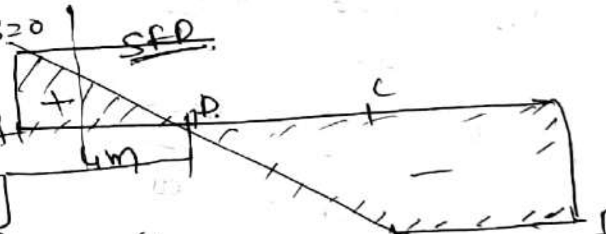
$\Sigma M_A = 0$

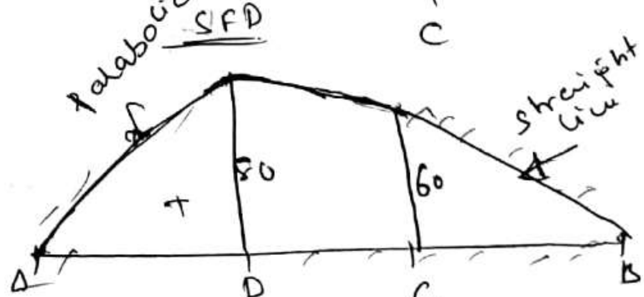
$-RBV \times 9 + 60 \times 3 = 0$

$RBV \times 9 = 180$

$RBV = \frac{180}{9}$

$RBV = 20KN$





Shear force calculations:

Consider any section at a distance x from A b/w A to C. The shear force at the section is given by

$Fx = +RAV - 10 \times x$

$= 40 - 10 \times x.$

Eq ① shows the SF varies by a straight line b/w A to C.

at $SF]_{A}: x = 0 = 40 - 10 \times 0 = 40KN.$

$SF]_B = 40 - \frac{BMD}{10 \times 6} = -20KN$

$\cdot SF]_{C}: x = 6 = 40 - 10 \times 6 = -20KN.$

The shear force at A is 40KN and at C is $-20KN$. Also shear force b/w A to C varies by a straight line. This means that somewhere b/w A to C, the shear force is zero. Let the S.F. is at x meters from A. Then substituting the value of $Fx = 0$

$F_x = 40 - 10x$

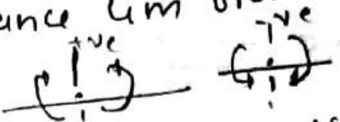
$0 = 40 - 10x$ $\qquad SF)_B = -20\,kN.$

$10x = 40$

$x = \frac{40}{10}$

$\boxed{x = 4m}$

Hence shear force is zero at a distance 4m from A.



Bending Moment Diagram.

The B.M at any section b/w A and C at a distance x from A is given by.

$M_x = +R_{AV} \times x - 10 \cdot x \cdot \frac{x}{2} = 40 \times x - \frac{10x^2}{2}$

$= 40x - 5x^2 \rightarrow (ii)$

eq (2) shows that B.M. varies according to parabolic law b/w A to C

$BM)_A$ $x = 0$. hence $M_A = 40 \times x - 5x^2 = 40 \times 0 - 5 \times 0 = 0.$

$BM]_C$ $x = 6$ $\quad M_C = 40 \times x - 5x^2 = 40 \times 6 - 5 \times 6^2 = +60\,kN\text{-}m$

$BM)_D$ $x = 4m$ $\quad M_C = 40 \times x - 5x^2 = 40 \times 4 - 5 \times 4^2 = +80\,kN\text{-}m$

$BM]_B$ $x = 8m$ $\quad M_B = 40 \times 8 - 5 \times 8^2 = 0\,kN\text{-}m.$

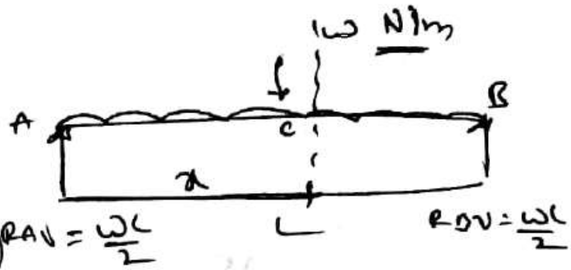
The Bending Moment b/w C and B varies according to linear law. B.M at B is zero whereas at C is 60kN-m.

Maximum Bending moment :-

The B.M is Maximum at a point where the shear force sign changes. This means that the point where shear force become zero from Positive to negative value (or) vice-versa. The B.M at that point will be maximum. From the shear force diagram, we know that at point D, the S.F is zero after changing the sign. The B.M is maximum at D

$BM)_D = +80\,kN\text{-}m$

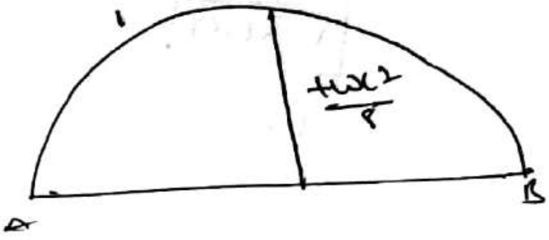
Bending moment calculations for UDL over the span



BMD] $M_x = +R_{AV} \times x - w \times x \cdot \frac{x}{2}$

$= \frac{wL}{2} \times x - \frac{w \cdot x^2}{2}$

$BMD]_x = \frac{wL}{2} \times x - \frac{w \cdot x^2}{2}$ (Parabolic variation) $R_{AV} = \frac{wL}{2}$



$BM]_A$ ($x=0$) $= \frac{wL}{2} \times 0 - \frac{w \cdot 0^2}{2}$

$BM]_A = \underline{0}$

$BM]_C$ ($x = L/2$) $= \frac{wL}{2} \times x - \frac{w \cdot x^2}{2}$

$= \frac{wL}{2} \times (L/2) - \frac{w}{2} \times [L/2]^2$

$= \frac{wL^2}{4} - \frac{wL^2}{8}$

$BM]_C = +\frac{wL^2}{8}$

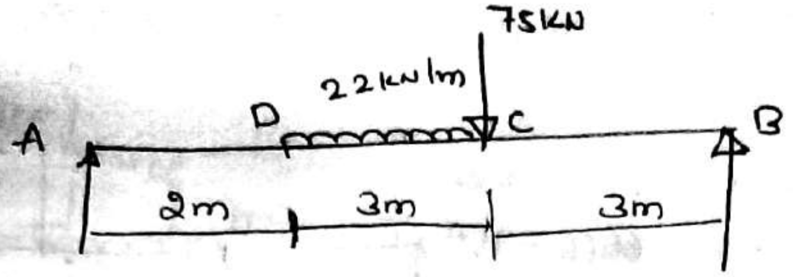
$BM]_B$ ($x=L$) $= \frac{wL}{2} \times x - \frac{w \cdot x^2}{2}$

$= \frac{wL \times L}{2} - \frac{w \cdot L^2}{2}$

$= \frac{wL^2}{2} - \frac{wL^2}{2}$

$BM]_B = \underline{\underline{0}}$

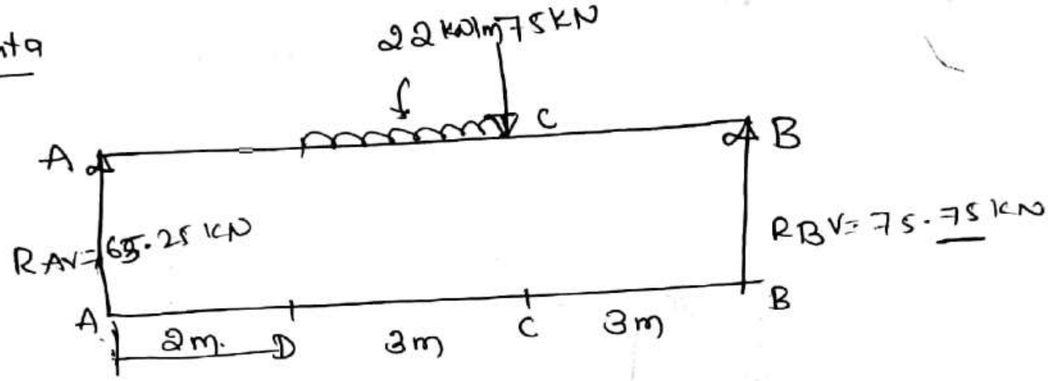
1 For the beam loaded as shown in fig.



Draw SFD and BMD.

→ Given Data

SFD = ?
BMD = ?



Soln ① Step No 1: Calculation of support reaction.

$\Sigma Fy = 0$ ↑ +ve   ↓ -ve

∴ $RA + RB - 75 - [22 \times 3] = 0$

$$\boxed{RA + RB = 141 \text{ KN}} \rightarrow ①$$

② $\Sigma M_A = 0$ ↻ +ve   ↺ -ve

$-RB \times 8 + 75 \times 5 + 66 \times 3.5 = 0$

$$\boxed{RB = 75.75 \text{ KN}}$$

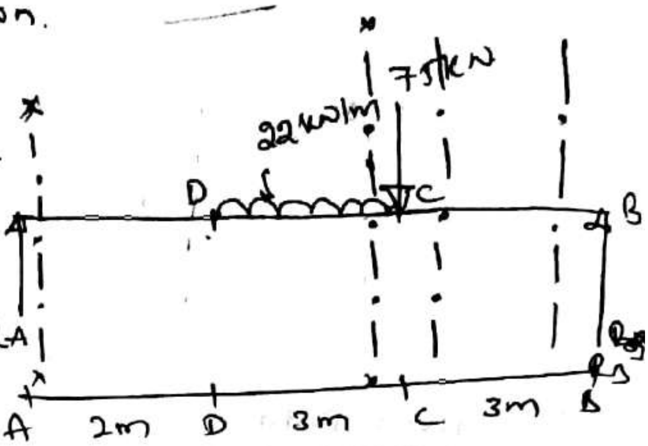
RB value in eq ① we get.

$RA + 75.75 = 141$

$$\boxed{RA = 65.25 \text{ KN}}$$

UDL = Point
22×3 = 66

Step No 2 — Shear Force calculation.

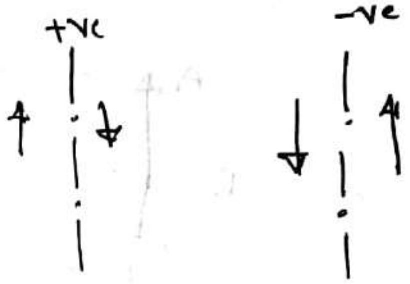


① S.F at Point A = +65.25 KN.
S.F at point D = 65.25 kN

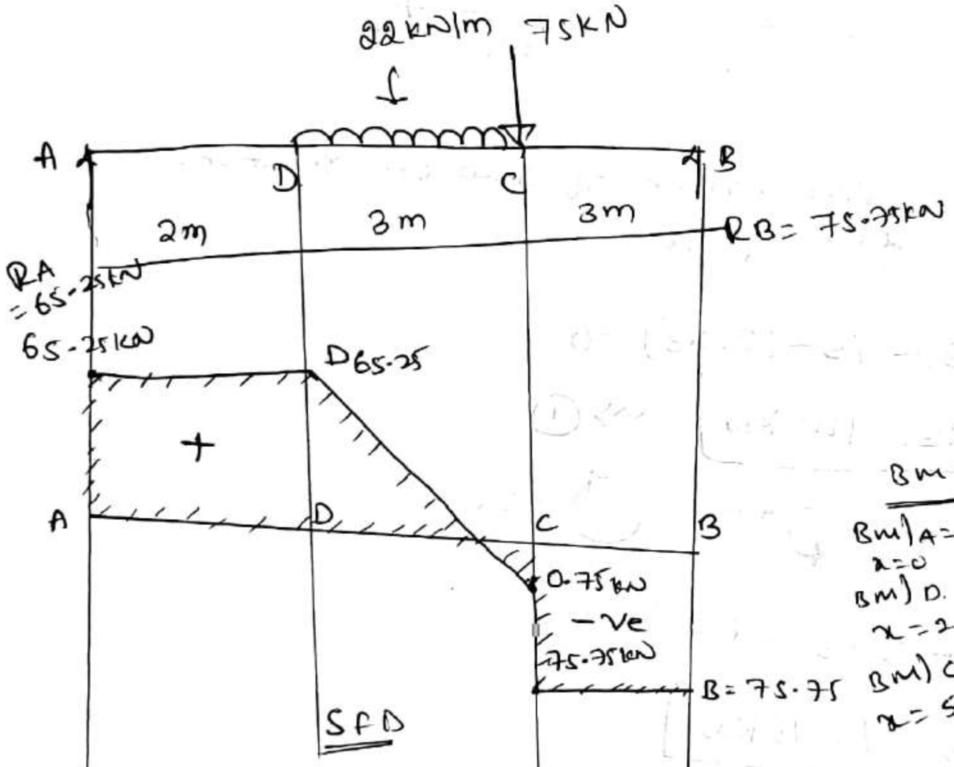
② S.F at Point C (left) = +65.25 − 66 = −0.75 KN.

③ S.F at Point C (right) = 65.25 − 66 − 75 = −75.75 KN.

④ S.F at Point B = −75.75 KN.



Shear force sign convention



UDL = Inclined
constant = straight line.

BMD calculations

$BM)_A = RAV \times 0 = 0$
$x = 0$

$BM)_D = RAV \times 2 = 65.25 \times 2 = 130.5$ kN·m
$x = 2$

$BM)_C = RAV \times 5 - 22 \times 3 \times \frac{3}{2} - 75 \times 0$
$x = 5$
$= 65.25 \times 5 - 99 = 0$
$= 326.25 - 99$
$= 227.25$

$BM)_B = 0$
$x = 0$

Step No: 3 — Bending moment calculations

MA = 0 & MB = 0 [Simply Supported beam

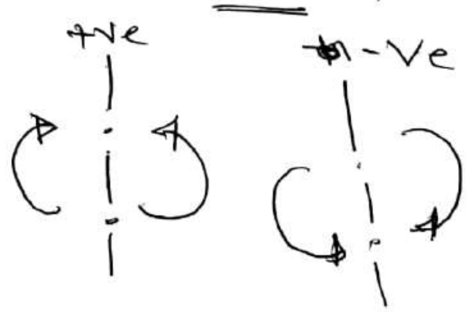
$Mc = +75.75 \times 3 = 227.25$ kN·m
$= RAV \times 5 - 22 \times 3 \times \frac{3}{2} = 65.25 \times 5 - 22 \times 3 \times \frac{3}{2}$

$MD = 65.25 \times 2 = 130.5$ KN·m
$= +RAV \times 2 = 65.25 \times 2 = 130.5$ kN·m

$BM)_A = +RAV \times 0 = 0$
$x = 0.$

$BM)_B = +RAV \times 8 - 66\times$

Sign convention



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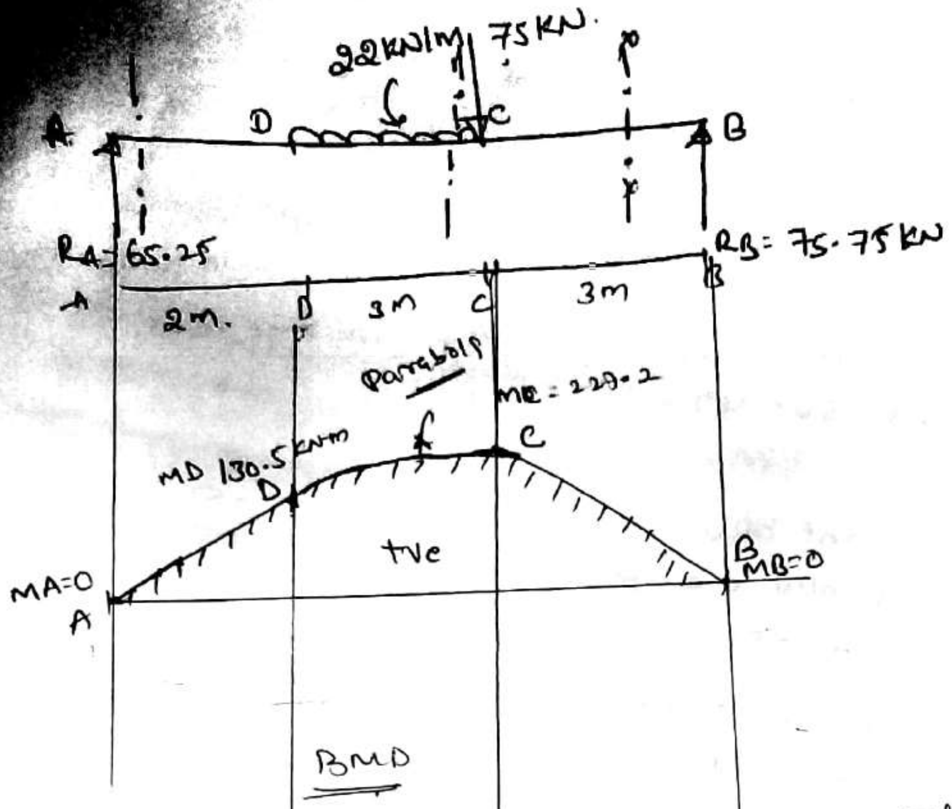
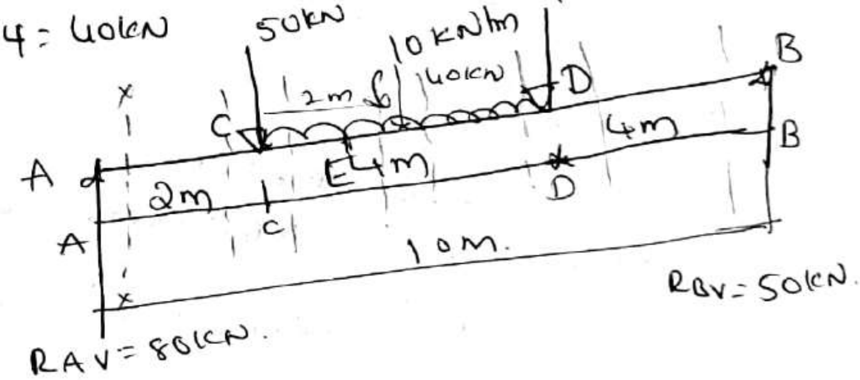


Where the SF is zero BM is maximum

where the S.F is constant BM is straight -

(2) A simply supported beam of length 10M, carries the uniformly distributed load and two point loads as shown in fig. Draw a S.F. and B.M. diagram for the beam Also calculate the ~~BM~~ Maximum Bending moment.

UDL = ~~4~~ 10×4 = 40kN



$\Sigma V = 0$

$RAV - 50 - 40 - 40 + RBV = 0$

$RAV + RBV = 130\,kN$

$\Sigma MA = 0$

$+50\times2 + 40\times4 + 40\times6 - RBV\times10 = 0$

$RBV\times10 = 500$

$RBV = \frac{500}{10}$

$RBV = 50\,kN.$

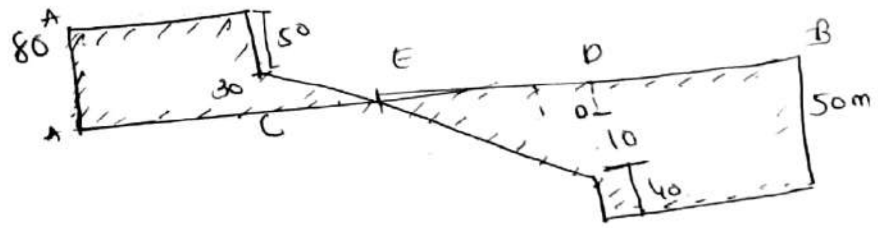
$\Sigma MB = 0$

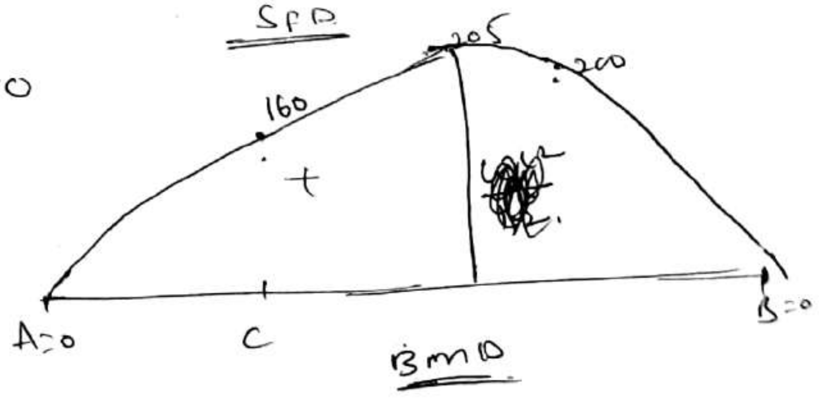
$-40\times4 - 40\times6 - 50\times8 + RAV\times10 = 0$

$-800 = -RAV\times10$

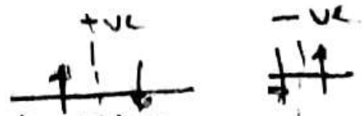
$\frac{800}{10} = RAV$

$RAV = 80\,kN$





* S.F. Diagram.



SF]A = +RAV = +80KN.

SF]C will remain constant from A to C & equal to 80KN.

Left SF]C Just on R.H.S of C = RAV − 50 = 80 − 50 = 30KN

SF]D Just on L.H.S of D = RA − 50 − 10×4 = 80 − 50 − 40 = −10 KN.

The S.F. b/w C and D varies according to straight line law.

SF)D Just on R.H.S of D = RA − 50 − 40 − 40 = −50KN.

SF]at B = −50KN

The S.F. remains constant b/w D and B & equal to −50KN

The S.F is zero at point E b/w C and D.

Now shear force at E = RA − 50 − 10×(x−2)

= 80 − 50 − 10x + 20

= 50 − 10x.

But Shear force E = 0.

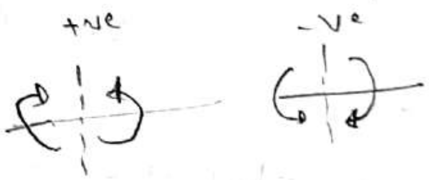
50 − 10x = 0

50 = 10x

$\frac{50}{10} = x$.

x = 5m

B.M. Diagram :



B.M at A is zero MA] = RAV×0 = 0

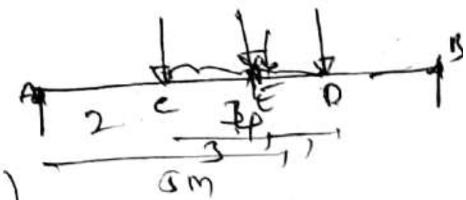
B.M at B is zero MB] = RBV×0 = 0

B.M at C, M.C = +RA×2 = 80×2 = 160KN-m

B.M at D MD = RA×6 − 50×4 − 40×$\frac{4}{2}$

= 80×6 − 50×4 − 40×2.

= 200KN-m.



At E, x = 5m, hence B.M at E.

ME = +RA×5 − 50[5−2] −10×[5−2]×($\frac{5-2}{2}$)

= 80×5 − 50×3 − 10×3×$\frac{3}{2}$

= 400 − 150 − 45

= 205 KNm

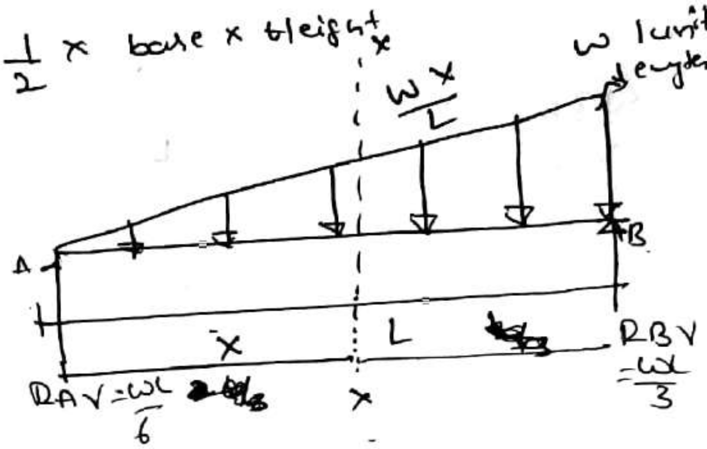
The maximum B.M is at E, where S.F. becomes zero after changing its sign.

Max BM = 205KNm

Simply supported Beam subjected to uniformly varying load.

Let the load from zero at support A to w/unit length at support B. Linearly as shown in fig.

Total load on the beam is $= \frac{1}{2} \times$ base $\times$ height



$= \frac{1}{2} \times L \times w$

$= \frac{wL}{2}$

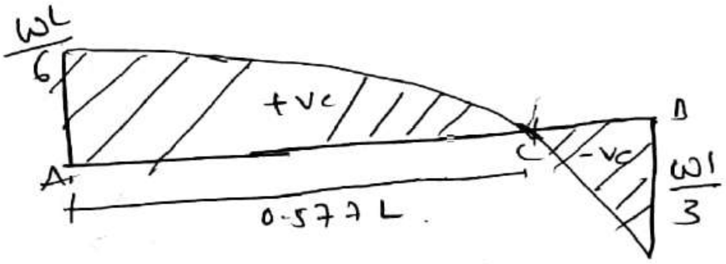
Its centroid from B is at $L/3$

$\Sigma MB = 0$

$RAV \times L - \frac{wL}{2} \times \frac{L}{3} = 0$

$RAV \times L = \frac{wL^2}{6}$

$$\boxed{RAV = \frac{wL}{6}}$$



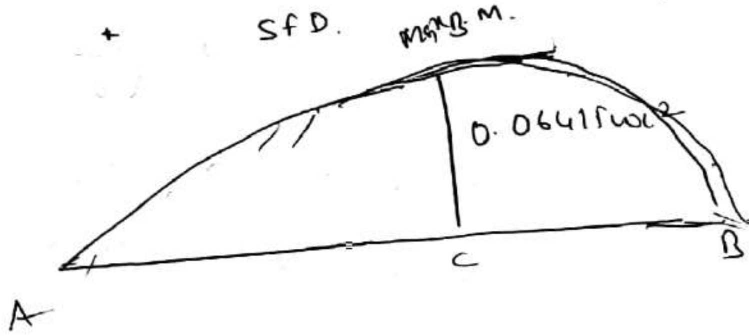
SFD.

$\Sigma MA = 0$

$-RBV \times L + \frac{wL}{2} \times \frac{2L}{3} = 0$

$-RBV \times L = -\frac{wL^2}{3}$

$$\boxed{RBV = \frac{wL}{3}}$$



BMD

Load Intensity at section x - x distance x from A is $\frac{wx}{L}$

Total load on left hand portion of the section

$= \frac{1}{2} x \cdot \frac{wx}{L} = \frac{wx^2}{2L}$

Its centroid from the section x - x is at $\frac{x}{3}$

F = RA - load on the left portion

$= \frac{wL}{6} - \frac{wx^2}{2L}$ (parabolic variation)

$SF]_A$ $_{x=0}$ $= \frac{wL}{6}$

$SF]_B$ $_{x=L}$ $= \frac{wL}{6} - \frac{wL^2}{2L}$

$= \frac{wL}{6} - \frac{wL^2}{2L} = \frac{2wL - 6wL}{12} = -\frac{4wL}{12} = \frac{-wL}{3}$

$SF]_B$ $_{x=L}$ $= -\frac{wL}{3}$

Shear force is zero at x, where x is given by

$$0 = \frac{wL}{6} - \frac{wx^2}{2L}$$

$$\frac{wx^2}{2L} = \frac{wL}{6}$$

$$x^2 = \frac{wL^2 \times 2}{6 \cdot 3}$$

$$x^2 = \frac{L^2}{3}$$

$$x = \frac{L}{\sqrt{3}} = \underline{0.577L}$$

$$x^2 = \frac{L^2}{3}$$

$$\boxed{x = \frac{L}{\sqrt{3}}}$$

BMD at section $x - x$ is given by

$M = R_A x$ - moment of load on left hand portion

$= \frac{wL}{6} \times x - \frac{wx^2}{2L} \cdot \frac{x}{3}$ (cubic variation)

$BM]_A$ $_{x=0}$ $= 0$

$BM]_B$ $_{x=L}$ $= \frac{wL \times L}{6} - \frac{wL^2}{2L} \cdot \frac{L}{3}$

$= \frac{wL^2}{6} - \frac{wL^2}{6}$

$BM]_B$ $_{x=L}$ $= 0$

Maximum moment occurs at the point where shear force is zero. Since $M = \frac{dF}{dx}$.

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Maximum moment is at $x = \frac{L}{\sqrt{3}}$

$$M_{max} = \frac{wL}{6}\frac{L}{\sqrt{3}} - \frac{w}{6L}\left[\frac{L}{\sqrt{3}}\right]^2$$

$$= \frac{wL^2}{6\sqrt{3}}\left[1 - \frac{1}{3}\right]$$

$$= 0.06415\ wL^2$$

Simply supported Beam subjected to External moment

Consider the beam AB of span L subjected to an external clockwise moment at a point, distance 'a' from support A as shown in fig.

Taking moment about B, & [downward reaction at A as positive.

$\Sigma M_B = 0$

$-R_A \times L + M_0 = 0$

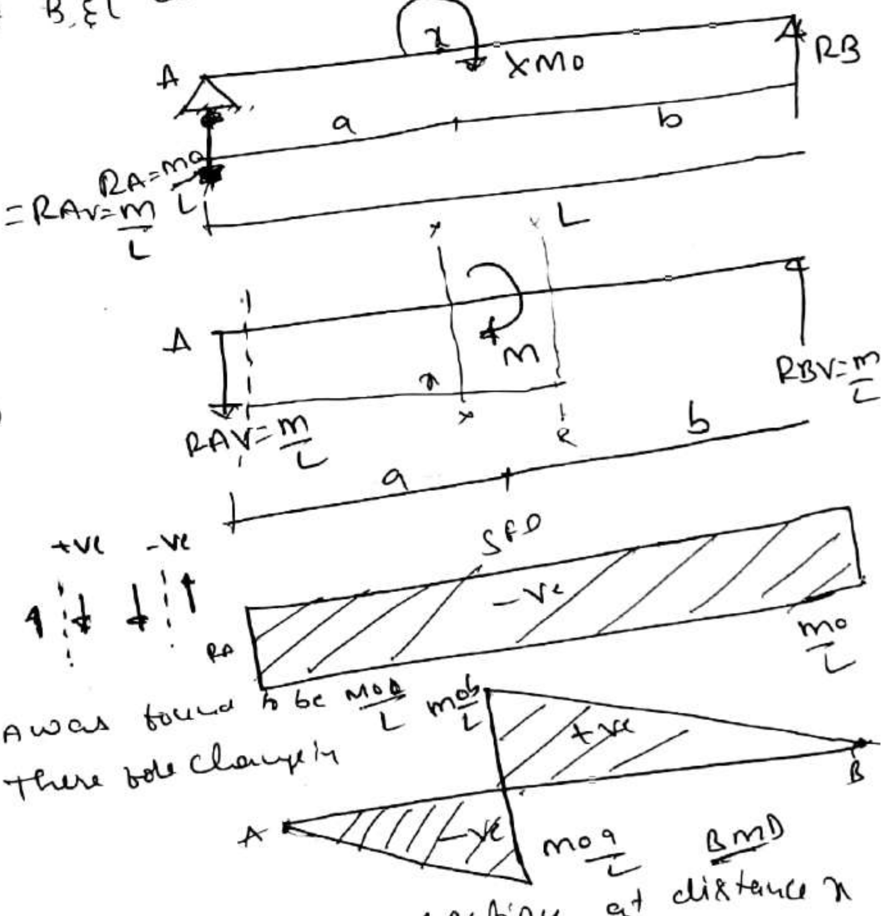
$R_{AV} = \frac{M_0}{L}$

$\Sigma M_A = 0$

$-R_{BV} \times L + M_0 = 0$

$R_{BV} = \frac{M_0}{L}$

$R_{BV} = \frac{m}{L}$



Assumed direction of RA was found to be $\frac{M_0}{L}$ wrong (Since RAV -ve) there bole changely the direction.

Shear force calculations

Now at any section at distance x from A.

~~$SF]_A = R_{AV} =$~~ -

$$SF]_x = -R_A = -\frac{M_0}{L} \quad \text{(constant.)}$$

BMD

At section x – x, in portion left of the section

$$M = -R_A x = -\frac{M_0}{L} \cdot x \quad \text{[Linear variation]}$$

At x = 0 $\quad M = 0$

At x = a. $\quad M = \frac{-M_0 a}{L}$

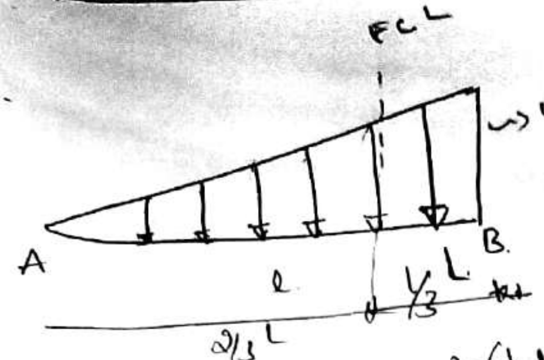
To the right of the section x - x.

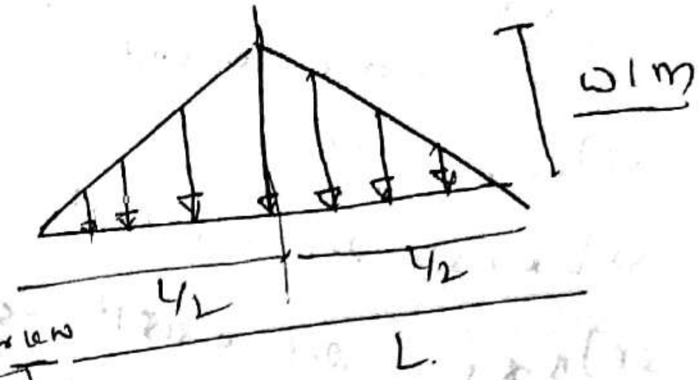
$$M = -\frac{M_0}{L}x + M_0 = M_0\left[1 - \frac{x}{L}\right] \quad \text{(Linear variation)}$$

At x = a, $\quad M_0\left[1 - \frac{a}{L}\right] = \frac{M_0 b}{L}$

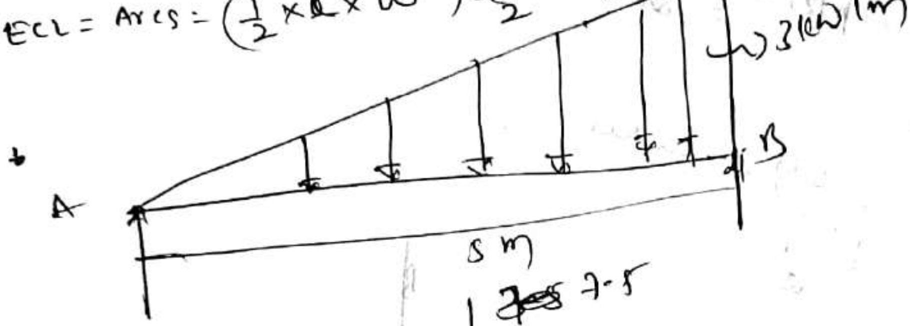
At x = L $\quad M_0\left[1 - \frac{L}{L}\right] = 0$

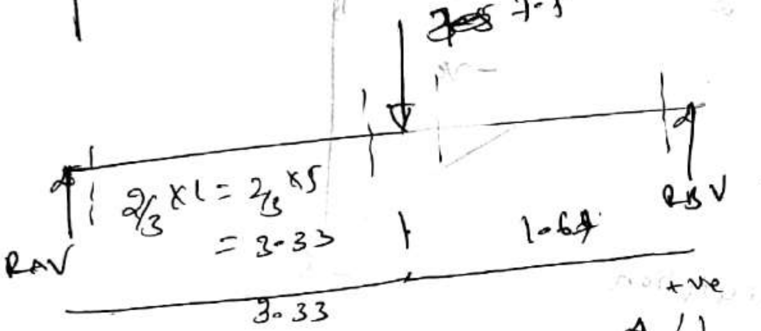
Beams subjected to uniformly varying load.

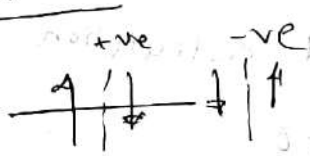




$ECL = Area = \left(\frac{1}{2} \times l \times w\right) = \left(\frac{1}{2} l w\right)$ N or kN







$\Sigma F_y = 0$

$RAV + RBV - 7.5 = 0$

$RAV + RBV = 7.5 kN$

$\Sigma M_A = 0$

$+ 7.5 \times 3.33 - RBV \times 5 = 0$

$7.5 \times 3.33 = RBV \times 5$

$RBV = 4.995 kN$

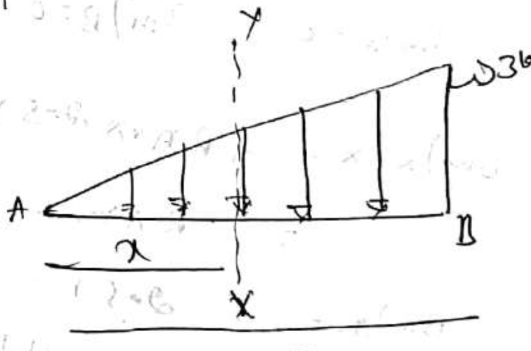
$RAV = 2.505 kN$

$SF]_A = + RAV = 2.505 kN.$

$SF]_{LC} = + RAV = + 2.505 kN.$

$SF]_{RC} = RAV - 7.5 = 2.505 - 7.5 = -4.995$

$SF]_B = - RBV = - 4.995 kN.$



By applying similar ales

5m - 3

x = y

$y = \frac{3x}{5}$

$ECL = \frac{1}{2} l w$

$= \frac{1}{2} x x \left[\frac{3x}{5}\right]$

$= 0.3 x^2$

Scanned by CamScanner

$SF)_{x-x} = +VA - [\frac{1}{2} x (\frac{3x}{5})]$

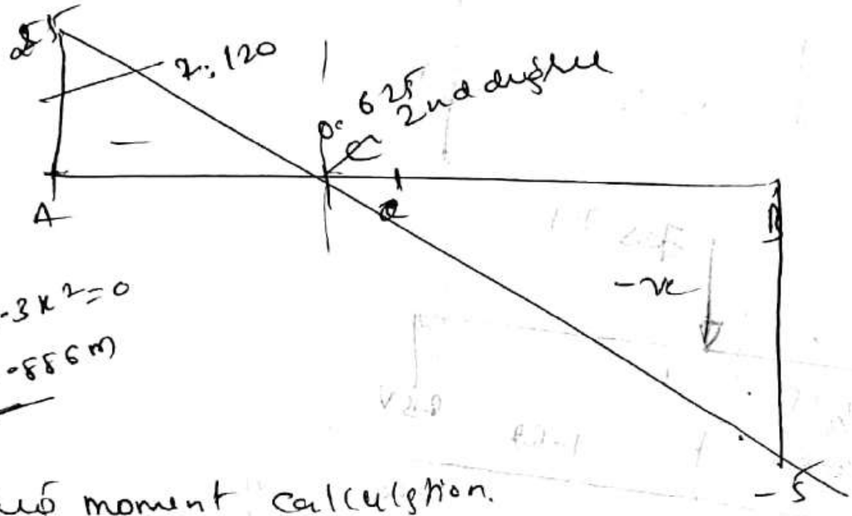
$= 2.5 - 0.3x^2$

$SF)_A \; x=0 = 2.5$

$SF)_C \; x=2.5 = 2.5 - 0.3(2.5)^2 = 0.625 kN$

$SF)_B \; x=5 = 2.5 - 0.3(5)^2 = -5 kN.$

$SF)_{1.125} = 2.5 - 0.3(1.125)^2 = 2.120 kN.$



$SF = 2.5 - 0.3x^2 = 0$

$x = 2.886 m$

Bending moment calculation.

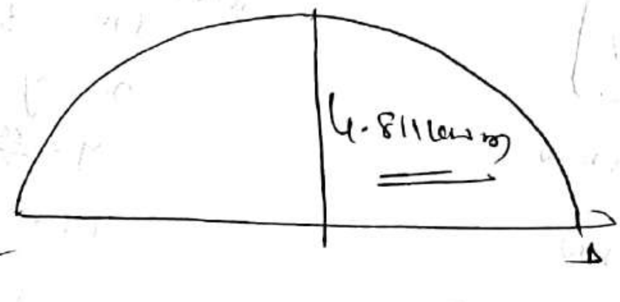
$BM)_A = 0 \quad BM)_B = 0$

$BM)_{x-x} = +RA \times x - [\frac{1}{2} x (\frac{3x}{5})] \times [\frac{1}{3} x]$

$= RA x - 0.1x^3$

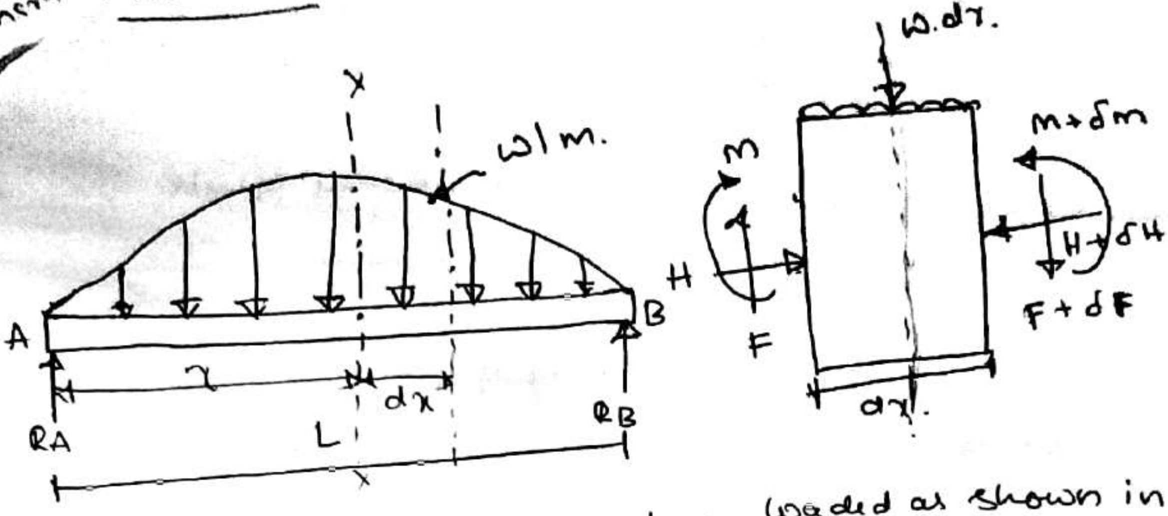
$BM)_{2.886} = 2.5x - 0.1x^3$

$= 4.811 kNm$



Derive the

Relationship between Intensity of load (W), Shear force and bending moment (M).



Consider a simply supported beam loaded as shown in fig.

Let consider an elemental strip of length dx of the beam at a distance 'x' from the left hand support A. As the length of strip 'dx' is very small the load intensity can be considered to be uniform over this length.

When the section dx of the beam is seperated the internal stresses will appear on both ends of the system. There internal stresses the resultants are M, H and F on the left hand side section and m+δm, H+δH & F+δF at the right hand side section. δm, δH & δF shows only the increment (or) decrement in the values from those at the left.

we have equations of equilibrium conditions for this free body.

$\Sigma V = 0$, $\Sigma H = 0$, and $\Sigma M = 0$

$\Sigma V = 0$ ↑ve

$$F - (w \times dx) - (F + \delta F) = 0$$ (cancelled)

$$-w \times dx - \delta F = 0$$

$$\boxed{\frac{\delta F}{dx} = -w}$$

By taking moment on the elemental strip at the right side $\Sigma M = 0$ ↻+ve same point.

$$+F \times dx + M - (M + \delta M) - w \times dx \times \frac{dx}{2} = 0$$

Neglecting the small quantity of higher order

We get

$$F\,dx + M - M - dm = 0$$

$$F\,dx = \delta m$$

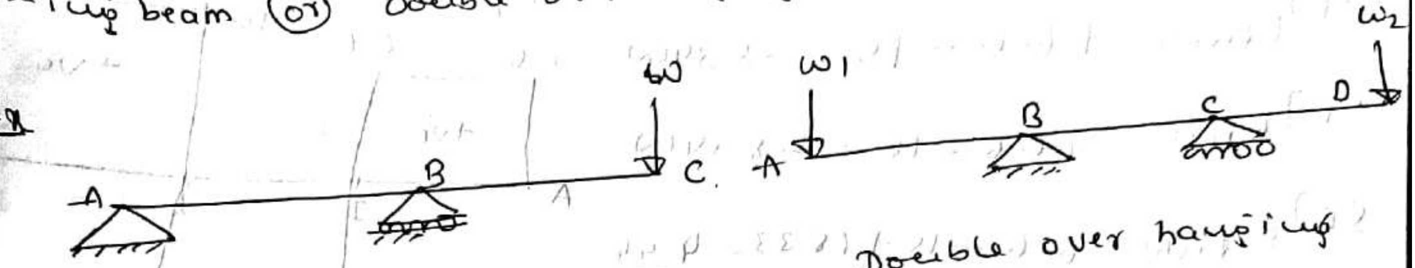
$$\boxed{F = \frac{\delta m}{dx}}$$

Hence rate of change of moment is always equals to shear force.

Overhanging Beam:

When a beam is extended beyond a support. it is reffered as overhanging beam & it may be single overhang -ing beam (or) Double over hanging beam.

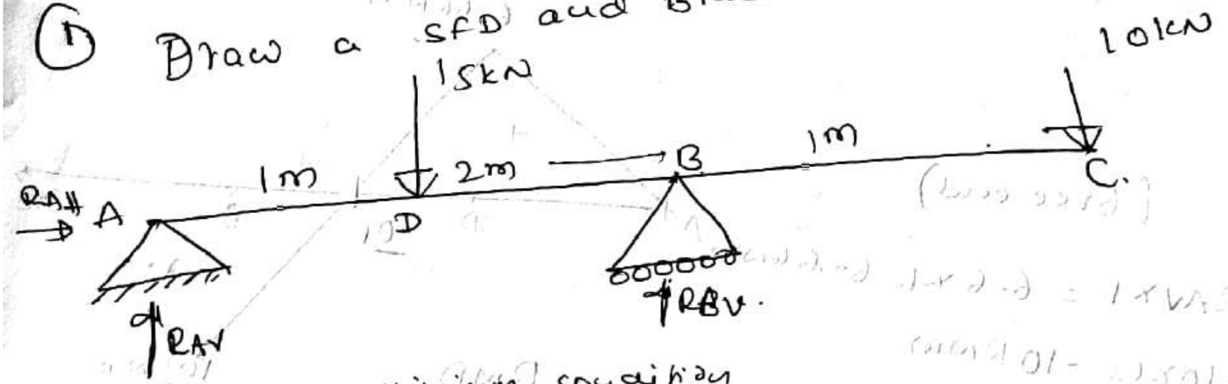
Eg



Single over hanging beam.   Double over hanging beam.

If any load is acting on the over hanging porsion. the moment at the support will not be zero.

(1) Draw a SFD and BMD for the overhanging beam



Apply the equilibrium condition

$\Sigma F_x = 0$ · $R_{AH} = 0$

$\Sigma F_y = 0$ $+R_{AV} - 15 + R_{BV} - 10 = 0$

$R_{AV} + R_{BV} = 25\,kN$ → (1)

$\Sigma M_A = 0$

$+15 \times 1 - R_{BV} \times 3 + 10 \times 4 = 0$

$15 + 40 = R_{BV} \times 3$

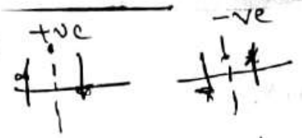
$55 = R_{BV} \times 3$

$R_{BV} = 18.33\,kN$

$R_{AV} + 18.33 = 25$

$R_{AV} = 6.66\,kN$

Shear force calculations



$SF]_A = +R_{AV} = 6.6\,kN$

$SF)_{D\,Left} = +6.6\,kN$

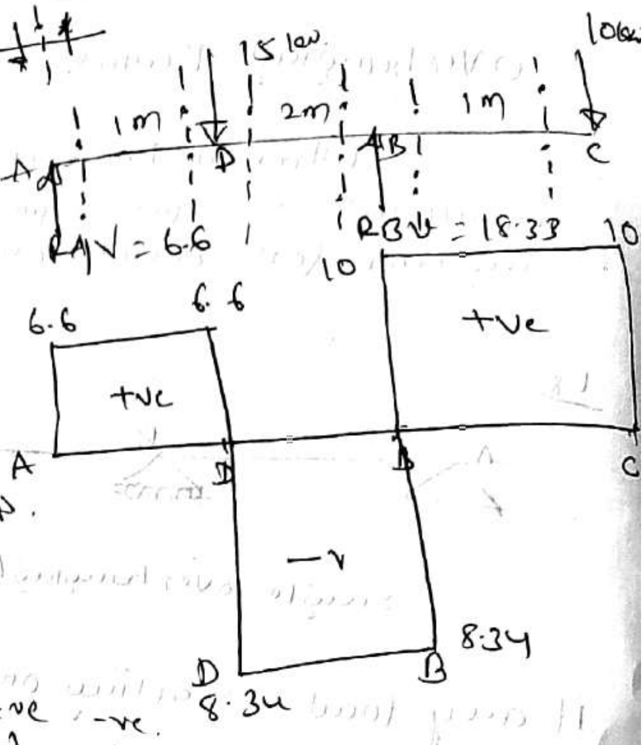
$SF)_{D\,Right} = +6.6 - 15 = -8.34\,kN$

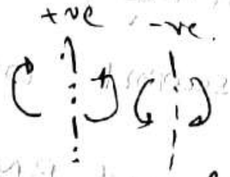
$SF]_{B\,Left} = +6.6 - 15 = -8.34\,kN$

$SF)_{B\,Right} = 6.6 - 15 + 18.33 = 9.94\,kN$

$SF)_{B\,Right}$ (or) $= 10\,kN$

$SF]_C = 10\,kN$





SFD

Bending moment calculations

$BM)_A = 0$

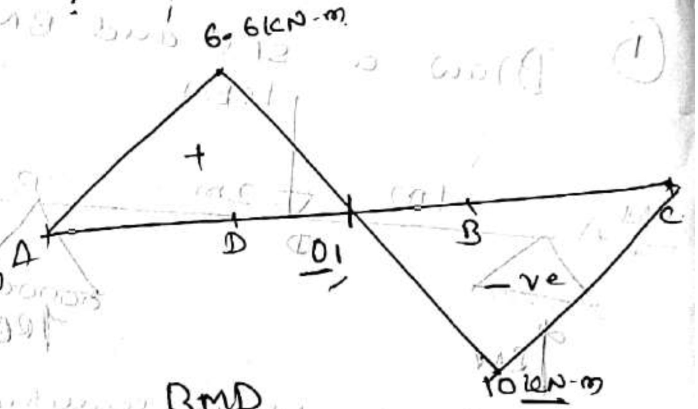
$BM]_C = 0$ (free end)

$BM]_D = +R_{AV} \times 1 = 6.6 \times 1 = 6.6\,kNm$

$BM)_B = -10 \times 1 = -10\,kNm$

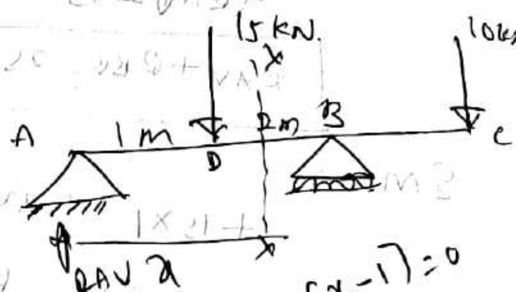
(or) $R_{AV} \times 3 - 15 \times 2 = 0$

$6.6 \times 3 - 30 = -10\,kNm$



BMD

[Note: O_1 is the point of zero bending moment which can be located with the conditions



$BM]_{O_1}$ (or) $BM]_x = 0$

$R_{AV} \times x - 15 \times [x-1] = 0$

$6.6x - 15x - 15 = 0$

$15x - 15 = 6.6x$

$8.4x = 15$

$x = 1.8m$ $= 1.785m$

$R_{AV} \times x - 15[x-1] = 0$

$R_{AV} \times x - 15x - 15$

$R_{AV} \times x - 15x - 15 = 0$

$6.6x - 15x = 15$

$15x - 6.6x = 15$

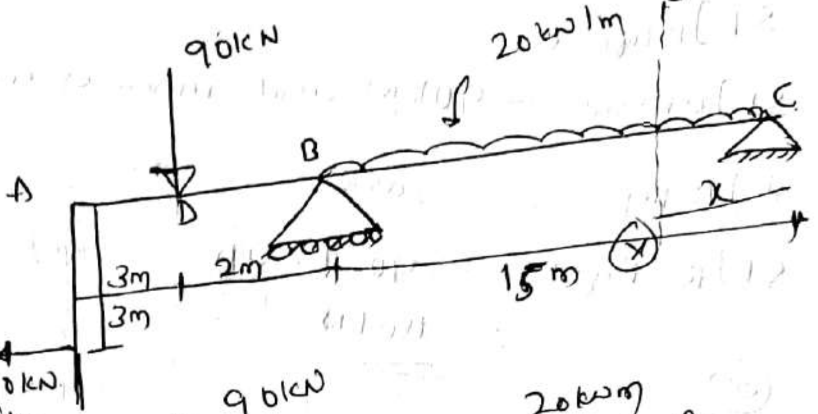
$8.4x = 15$

$x = 15/8.4$

$x = 1.785m$

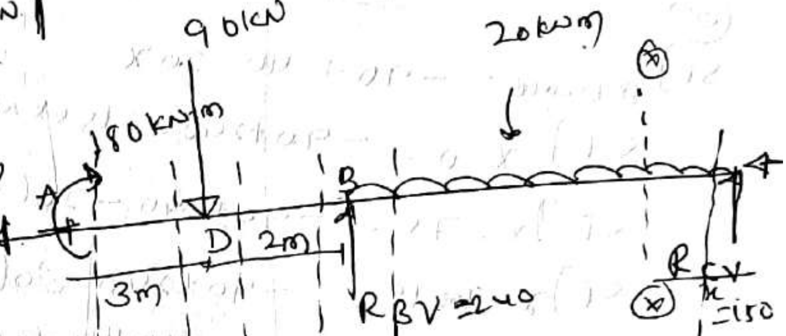
$x = ?$

(2) Draw the bending moment & shearing force diagram for the over hanging beam. as shown in fig.



Sol

A horizontal force of 60kN acting horizontally 3m below A is replaced by a clockwise moment of magnitude [60×3] = 180kNm together with a horizontal force of 60kN at A as shown in fig



$\Sigma F_x = 0$

$-60 + - R_{AH} = 0$

$R_{AH} = -60kN$

$\Sigma F_y = 0$

$-90 + R_{BV} + R_{CV} - 300 = 0$

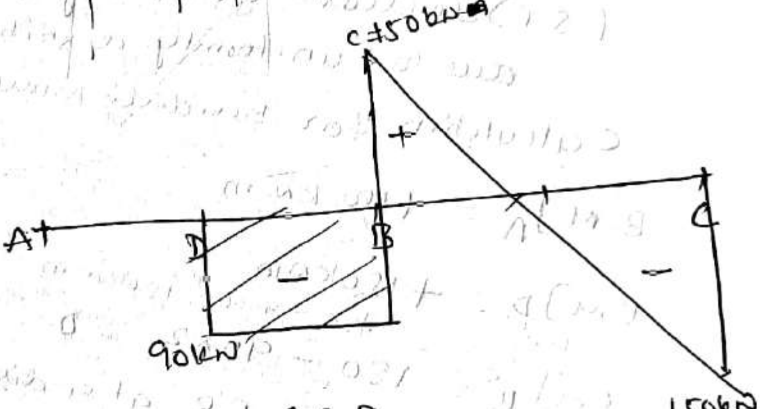
$R_{BV} + R_{CV} = 390kN$ → (1)

$\Sigma M_c = 0$

$+180 - 90 \times 17 + R_{BV} \times 15 - 20 \times 15 \times 7.5 = 0$

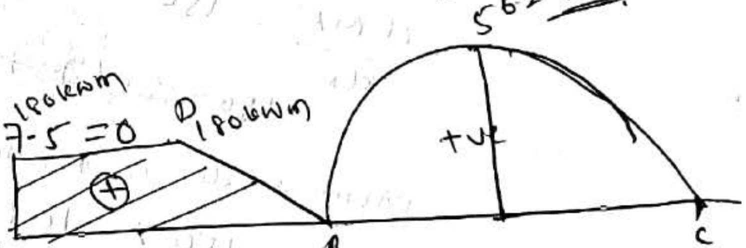
$R_{BV} = 240kN$

$R_{CV} = 150kN$



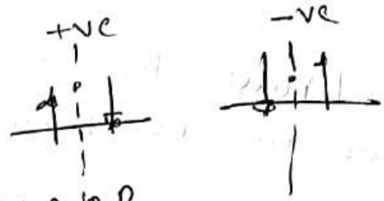
S.F.D

$\frac{\omega l^2}{8} = \frac{20 \times 15^2}{8}$ ... 562.5kN·m



BMD

Calculation for SFD



$SF]_A = 0$

$SF]_{D\ left} = 0$

$SF]_{D\ Right} = -90kN$ and remains constant up to B

$SF]_{B\ Left} = -90kN$

$SF]_{B\ Right} = -90 + 240$

$= 150 kN$

(08)

$SF]_{x\ from\ B} = -90 + 240 - 20x$

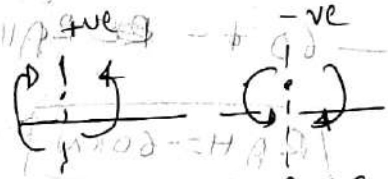
$S.F]_{x=0} = -90 + 240 = 150kN$

$S.F.]_{x=7.5} = -90 + 240 - 20(7.5) = 0$ → for SFD

$SF]_{x=15} = -90 + 240 - 20[15] = -150kN$

[S.F) decreases gradually from +150kN at B to -150kN [?] due to uniformly distributed load].

Calculation for Bending moment.



$B.M]_A = +180\ kN\text{-}m$

$BM]_D = +180kNm$

$BM]_{D\ left} = 180 - 90\times0 = 180kN\text{-}m$

$BM]_{D\ Right} = 180 - 90\times2 = 0.$

$BM]_B$ at a distance x from the right end C

In the portion CB

$B.M]_x = +150\times x - \frac{20x^2}{2} = 150x - 10x^2.$

$\frac{dMx}{dx} = 150 - 20x = 0$ when $x = 7.5m$

~~150 - 20(7.5) = 0~~

Magnitude of Maximum Bending moment

$= 150x - 10x^2$

$= 150\times7.5 - 10\times7.5^2$

$BM]_x = 562.5kNm$

$BM]_x = +150\times x - 20x\cdot\frac{x}{2}$

$= 150x - \frac{20x^2}{2}$

$= 150x - 10x^2$

$BM]_x =$

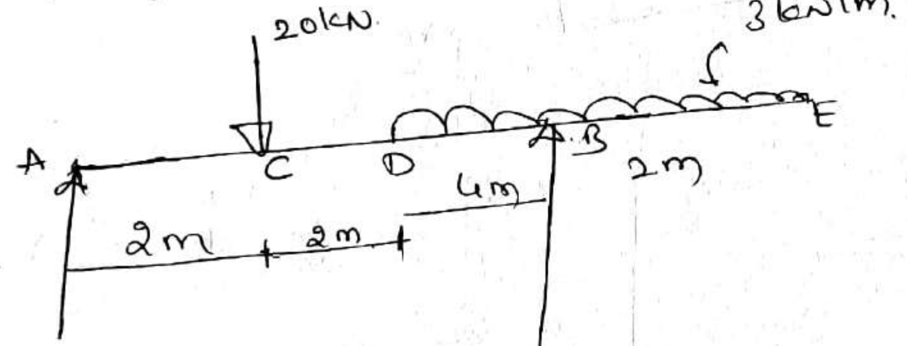
Point of contraflexure [Inflexion]

It's a point for a bending moment diagram where the bending moment changes its sign (i.e. [negative to positive] or [positive to negative]). It is also reffered as the point of inflexion. The bending moment at this point will be zero.

ie The bending moment changes from sagging to hogging (or) vice versa.

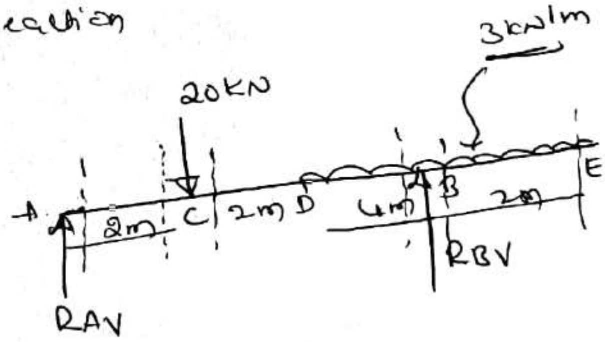
Point of contraflexure may be depending on type of loading, support and the type of beam.

(1).



point
3 × 6 = 18kN

Let RAV and RBV are the support reaction



Apply equilibrium condition

$\Sigma Fy = 0$

$+RAV - 20 + RBV - 18 = 0$

$\boxed{RAV + RBV = 38 \text{ kN}} \rightarrow (1)$

Taking moment about A.

$+20 \times 2 - RBV \times 8 + 18 \times 7 = 0$

$\boxed{RBV = 20.75 \text{kN}}$

RBV in eq (1) we get

$RAV + 20.75 = 38$

$\boxed{RAV = 17.25 \text{ kN.}}$

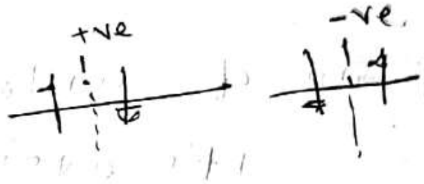
S. F calculations

$SF]_A = 17.25 kN.$

$SF]_{C\ left} = 17.25 kN$ constant from A to C

$SF]_{C\ Right} = 17.25 - 20 = - 2.75 kN.$

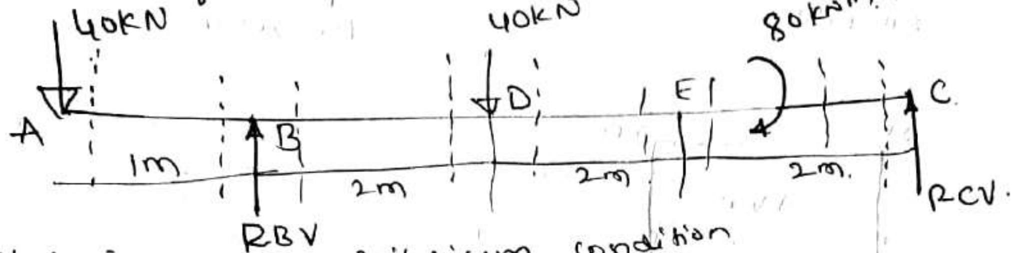
$SF]_{D\ left} = 17.25 - 20$



Scanned by CamScanner

A Beam is ... shown in fig. ...

(2) Draw the B.M & S.F. diagrams for the beam as shown in fig. indicating the salient values on them. Locate the point of inflexion if any.



Applying the equilibrium condition

$\Sigma F_y = 0$

$-40 + R_{BV} - 40 + R_{CV} = 0$

$R_{BV} + R_{CV} = 80KN$ — eq (1)

$\Sigma M_C = 0$

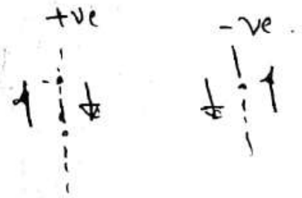
$+80 - 40\times7 + R_{BV}\times6 - 40\times4 = 0$

$R_{BV}\times6 = 440 - 80$

$R_{BV} = 60KN$

$60 + R_{CV} = 80$

$R_{CV} = 20KN$



Shear force calculations.

$SF]_A = -40KN$

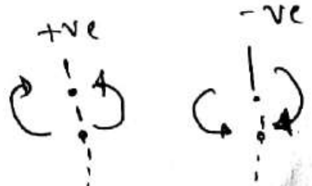
$SF)_{B\,Left} = -40KN$

$SF)_{B\,Right} = -40 + R_{BV} = -40 + 60 = 20KN.$

$SF]_{D\,Left} = 20KN$

$SF]_{D\,Right} = -40 + 60 - 40 = -20KN.$

$SF]_C = -20KN.$



~~Bendi~~ Bending Moment calculations

$BM)_A = 0$

$BM]_B = -40\times1 = -40KNm.$

$BM]_D = -40\times3 + R_{BV}\times2m = -120 + 60\times2 = 0.$

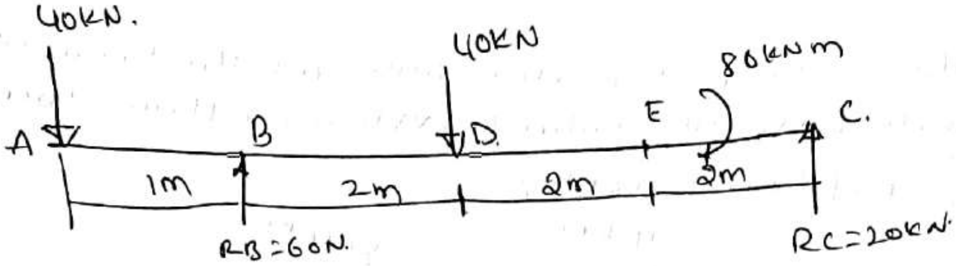
$BM)_E$ towards left $= -40\times5 + 60\times4 - 40\times2$

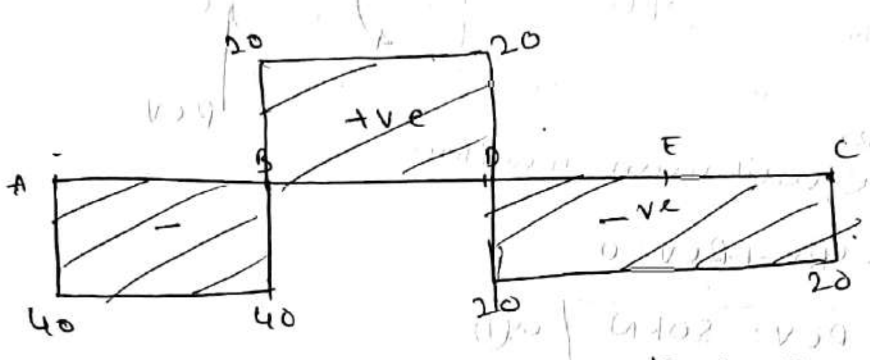
$= -40KNm$

$BM)_E$ toward Right $= +60\times4 - 40\times5 + 40\times2 + 80$

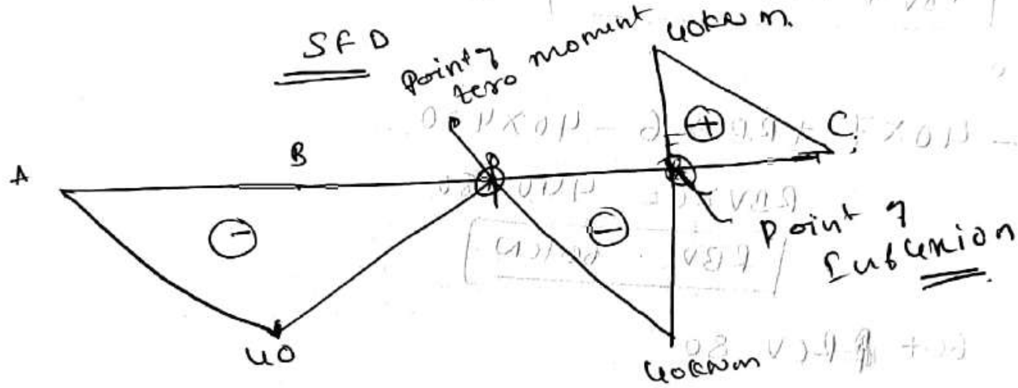
$= +40KNm$

$BM)_C = 0$


40KN.
40KN
80kNm
A
B
D.
E
C.
1m
2m
2m
2m
RB=60N.
RC=20KN.

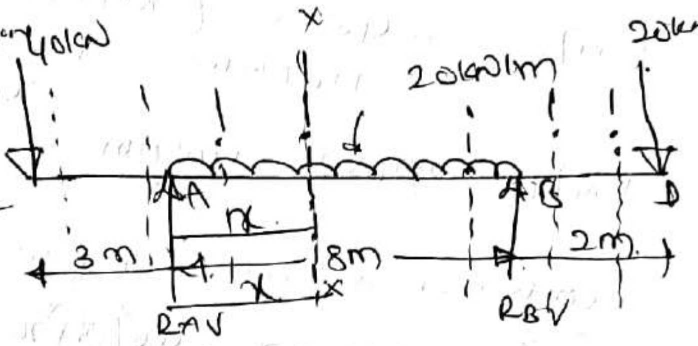

20
20
+ve
A
B
D
E
C
-
-ve
40
40
20
20

SFD


Point of zero moment
40kN m.
A
B
C.
Point of Inflexion
40
40kNm

BMD

* Draw the bending moment & shearing force diagrams for the beam shown in fig. Determine the positions of maximum shearing force and maximum bending moment and the position of the point of contraflexure.



* Apply the equilibrium condition

$\Sigma F_y = 0$

$-40 + RAV + RBV - 160 - 20 = 0$

RAV + RBV = 220 kN

ΣM_B

$-40 \times 11 + RAV \times 8 - 160 \times 4 + 20 \times 2 = 0$

RAV = 130 kN

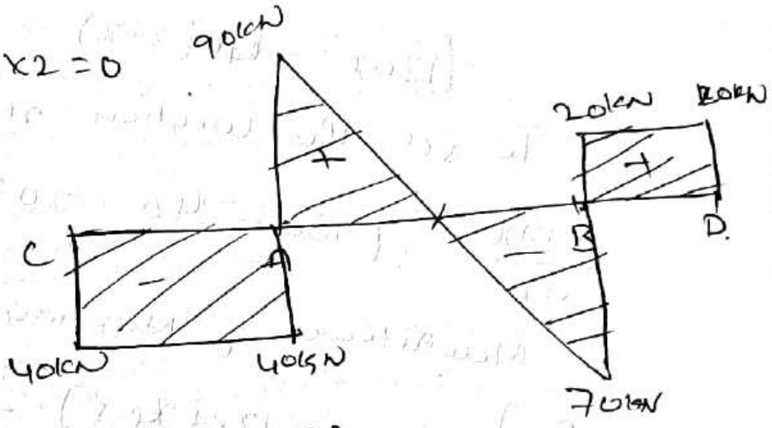
Substituting RAV value in eq (1) we get

$130 + RBV = 220$

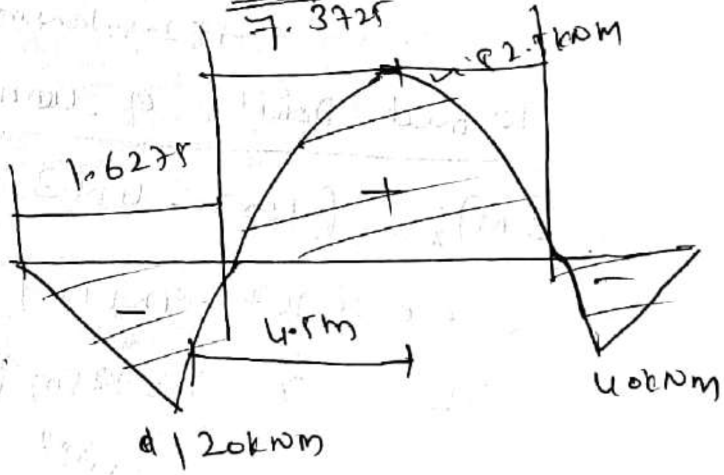
+ve −ve

$RBV = 220 - 130$

RBV = 90 kN.



SFD



BMD

Shear force calculations

SF)$_C$ = −40 kN / = −40kN

SF)$_{A\ left}$ = −40kN.

SP)$_{A\ Right}$ = −40 + 130 = 90kN.

~~SF)$_{B\ left}$ = 90 + 20 = 70 kN~~

~~SE)$_{B\ Right}$ = 70~~ 20

= −70kN.

SP)$_{B\ left}$ = +20 − 90 = −70kN.

SF)$_{B\ Right}$ −40 + 130 −160 + 90 = 20kN

SF)$_{D\ left}$ = 20kN

SF)$_{B\ left}$ = −40 + 130 − 160 = −70kN.

SF)$_{B\ Right}$ = −40 + 130 − 160 + 90 = 20kN

SF)$_{D\ left}$ = −40 + 130 − 160 + 90 = 20kN

Bending moment calculations:

$BM]_C = BM]_D = 0$ [Since C and D are free ends]

$B.M]_A = -40 \times 3$ [Negative since to the left of the section, the moment acting is anticlockwise direction].
$= -120$ kNm

$BM]_B = +20 \times 2 = 40$ kNm +

Consider a section xx at a distance x from support A,

$B.M]_x = +130 \times x - 40[3+x] - 20(x)\left(\frac{x}{2}\right)$ $3 < x < 8$

$= [130x - 40[3+x) - 10x^2]$

To get the location at which bending moment is maximum

$\frac{dMx}{dx} = [130 - 40 - 20x] = 0$ i.e $x = 4.5$ m

Magnitude of Maximum bending moment.

$BM)_{x=4.5m} = 130(4.5) - 40(3+4.5) - 40(4.5)^2)$

$= +82.5$ kNm

To find point of contraflexure.

$B.M)_x = [130x - 40(3+x] - 10x^2] = 0 = x^2 + 9x - 12$

i.e $=(x^2 - 9x + 12] = 0$

Sol $x_1 = 7.3725$ m (or) $x_2 = 1.6278$ m

$130x - 40(3+x) - 10x^2 = 0$

$130x - 40(3+x) - 10x^2 = 0$

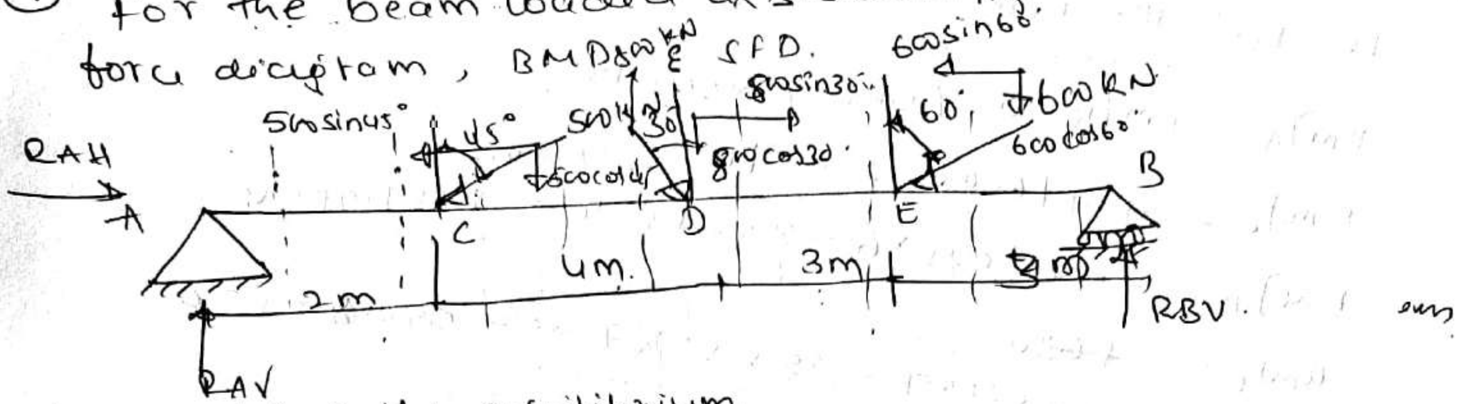
$130x - 120 - 40x - 10x^2 = 0.$

$-10x^2 - 90x - 120 = 0.$

Bending moment at free end is zero

Inclined loading on Beams

① For the beam loaded as shown in fig. draw the axial force diagram, BMD & SFD.



Applying the equilibrium.

$\Sigma F_y = 0$

RAV + RBV − 500cos45 − 800cos30 − 600cos60 = 0

RAV+RBV = 1346.37 kN → ①

$\Sigma M_A = 0$

500cos45×2 + 800cos30×6 + 600×cos60×9 − RBV×12 = 0

500cos45×2 + 800cos30×6 + (300×9) = RBV×12

(353.55×2) + (692.82×6) + (300×9) = RBV×12

RBV = 630.325 kN

$\Sigma F_x = 0$

RAH = 500sin45 + 800sin30 − 600sin60 = 0

RAH = 473.16 kN.

Substituting RBV in eq ①

RAV + 630.325 = 1346.37

RAV = 716.025 kN

Calculations for S.F.D.

SF]$_A$ = +RAV = +716.025 kN. SF)c left = 716.025 kN

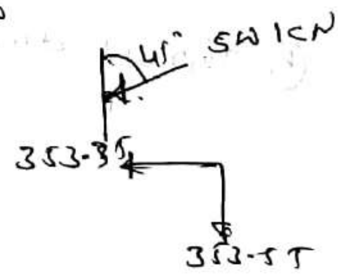
SF]$_{C\,Right}$ = +RAV − 353.55 (500cos45) = +362.475 kN.

SF)D left = 362.475 kN

SF)D Right = +362.475 − 692.82 (800cos30) = −330.325

SF) E Right = −330.325 − 300 (600cos60) = −630.325 kN.

SF)E Right = −330.325 − 300 = −630.325 kN.



To plot the thrust diagram.

(Thrust at support B) = 0 (B is the roller support)

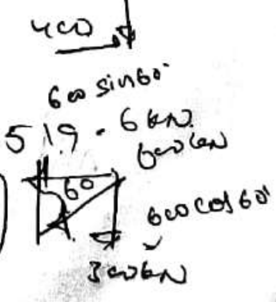
(Thrust)$_E$ = 519.6 kN & is constant upto E

600 sin60 = 519.6 kN

Thrust]$_D$ = +519.6 − 400 = +119.6 kN. (constant upto C)

Thrust]$_C$ = +119.6 kN + 353.55 = 473.15 kN

constant upto hinged support A



Thrust]$_A$ = 473.16 kN.

TO Polt the BMD.

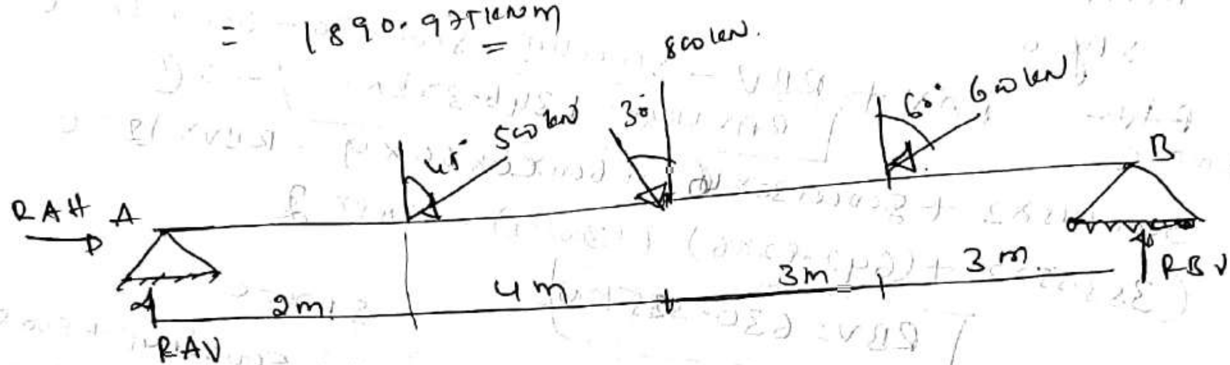
BM]$_A$ = BM]$_B$ = 0 [simply supported.

BM]$_C$ = +716.025×2 = 1432.05 kNm

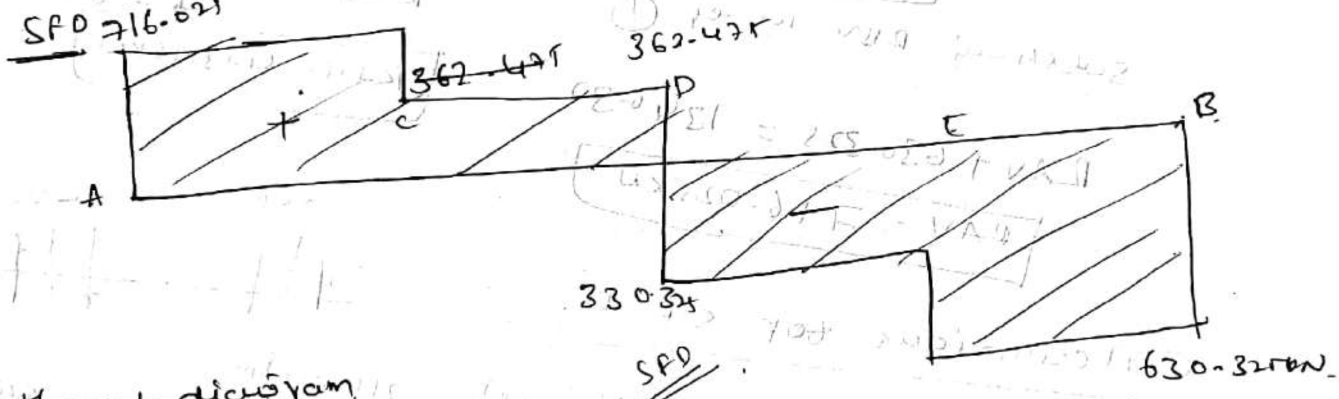
BM]$_D$ = +716.025×6 − 353.55×4 = 2881.95 kN.

BM]$_E$ = ~~+630~~ 716.025×9 − 353.55×7 − 692.8×3 = 0

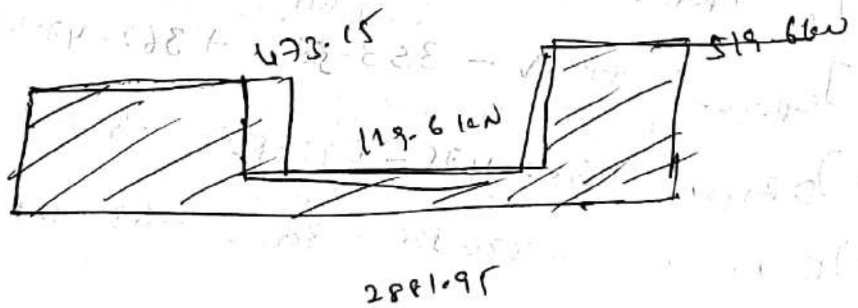
= 1890.975 kNm



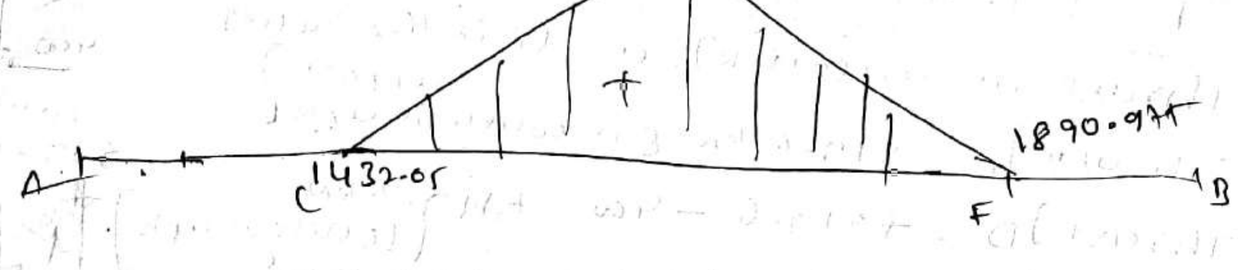
(a) SFD



(b) thrust diagram

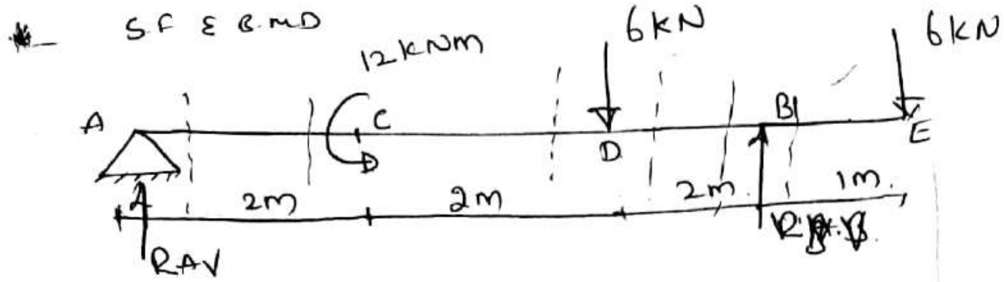


(c) BMD



Scanned by CamScanner

* SF & BMD

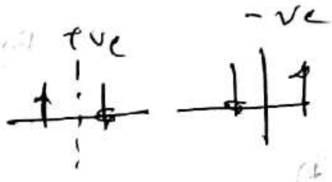


$\Sigma F_y = 0$

$+RAV + RBV - 6 - 6 = 0$

$RAV + RBV = 12 \text{ kN}$

$\Sigma M_A = 0$



$-12 + (6\times4) - RBV\times6 + (6\times7) = 0$

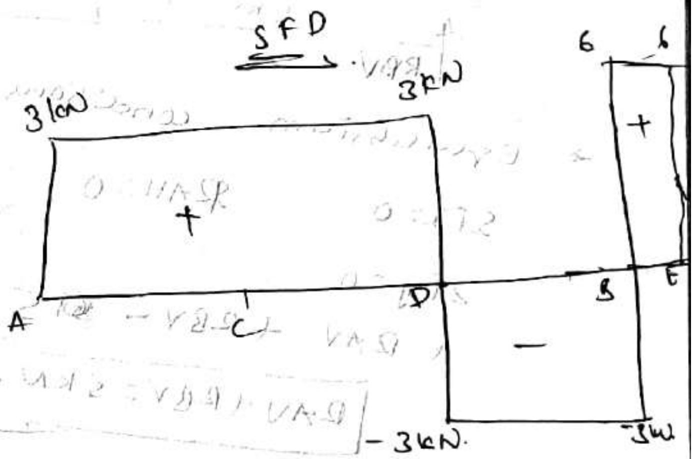
$-12 + 24 + 42 = RBV\times6 = 0$

$RBV = 9 \text{ kN}$

$RAV + 9 = 12$

$RAV = 3 \text{ kN}$

SFD



SF calculations

$SF)_A = +3 \text{ kN}$

$SF)_{LD} = +3 \text{ kN}$

$SF)_{RD} = +3 - 6 = -3 \text{ kN}$

$SF)_{LB} = -3 \text{ kN}$

$SF)_{RB} = +3 - 6 + 9 = +6 \text{ kN}$

$SF)_{LB} = +6 - 9 = -3 \text{ kN}$

$SF)_B = 6 \text{ kN}$

BM calculations

$BM)_A = 0 \quad BM)_E = 0$

$BM)_C = +RAV\times2 = 3\times2 = 6 \text{ kNm}$

$BM)_{RC} = 6 - 12 = -6 \text{ kNm}$

$BM)_D = +RAV\times4 - 12 = 0$

$= 3\times4 - 12 = 12 - 12 = 0$

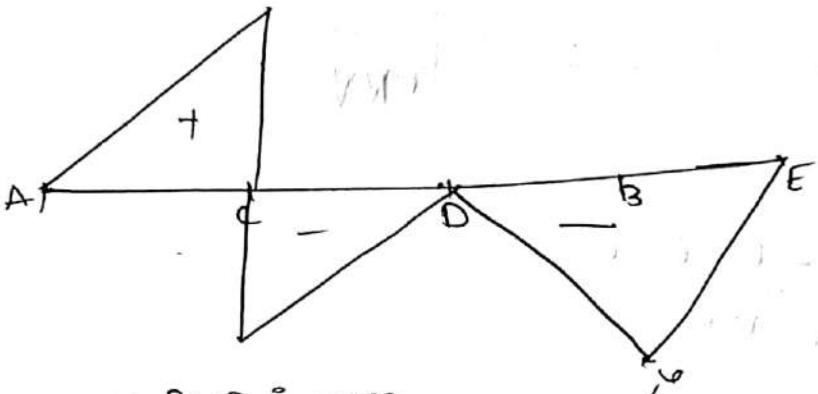
$BM)_{RD} = RAV\times4 - 12 - 6\times0 = 0$

$BM)_B = RAV\times6 - 12 - 6\times2$

$= 3\times6 - 12 - 12$

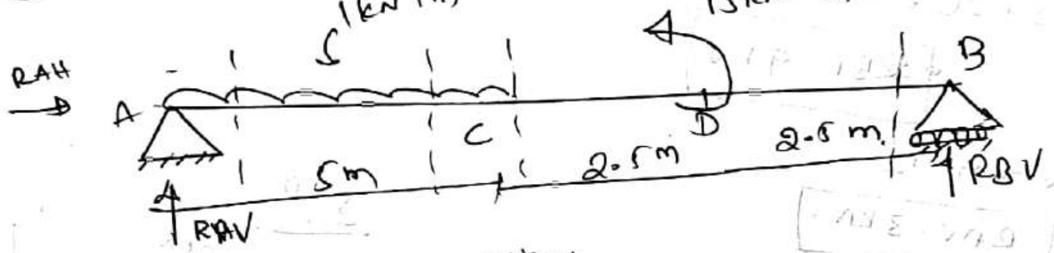
$= 18 - 12 - 12$

$BM)_B = -6 \text{ kNm}$



BMD in kNm

(1)



→ Equilibrium conditions

$\Sigma F_x = 0$ $RAH = 0$

$\Sigma F_y = 0$

$+ RAV + RBV - 5 = 0$

$RAV + RBV = 5kN$

$\Sigma M_A = 0$

$5 \times 2.5 - 15 - RBV \times 10 = 0$

$RBV = -0.25\ kN$

$RAV = 5.25\ kN$

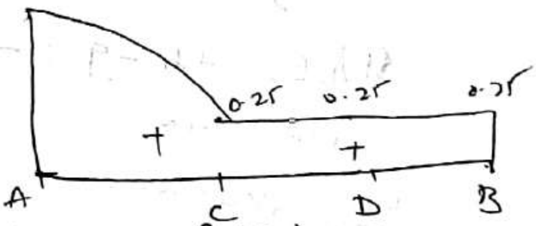
SF calculation

$SF)_A = + RAV = +5.25kN$

$SF)_C = +RAV - 5 = 5.25 - 5 = 0.25kN$

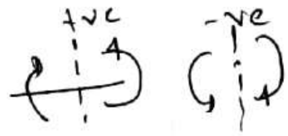
$SF)_D = +0.25kN.$

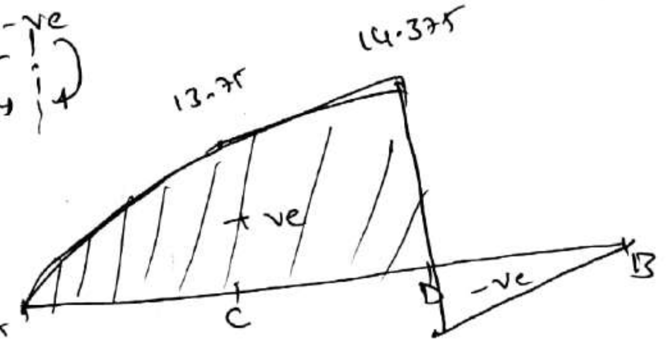
$SF)_B =$ ~~+0.25 − RBV = +0.25~~ $- (-0.25kN) = 0.25kN$



SFD in kN

BMD calculations





BM)A = 0

BM)B = 0

$BM]_C = +RAV \times 5 - 5 \times 2.5$

$= 5.25 \times 5 - 5 \times 2.5 =$

$BM)_C = 13.75$ kNm

$BM)_{LD} = RAV \times 7.5 - 5 \times 5 = 14.375$ kNm

BMD

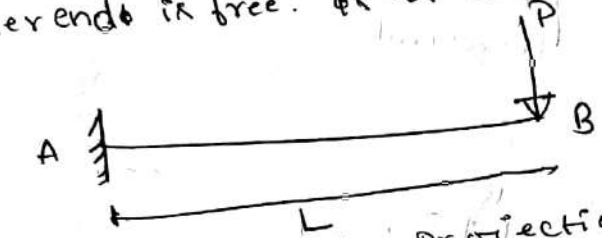
$BM)_{RD} = BM)_{LD} - 15$

$= 14.375 - 15$

$BM)_{RD} = -0.625$ KNm

Cantilever beam :

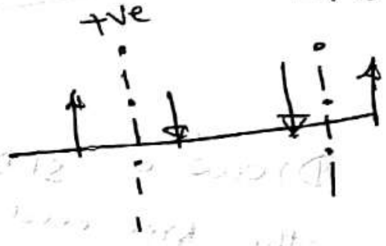
It is a type of Beam in which one end is fixed & other end is free. as shown in fig

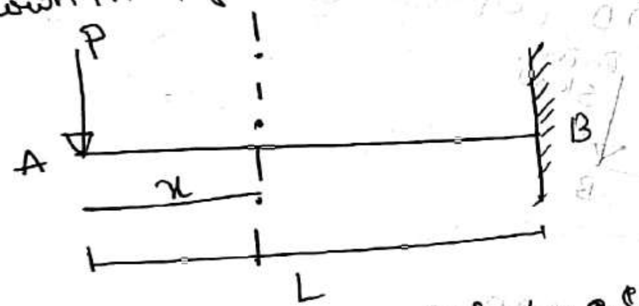


Example : ① Chejja projection above the window, flag hosting pole, cycle stand, & Transmission Tower.

Cantilever beam subjected to concentrated load at the free end

Consider a cantilever of beam AB, fixed at B and subjected to a concentrated load at free end A, as shown in fig.





Shear force at any section a distance x from A

$SF]_A = -P$

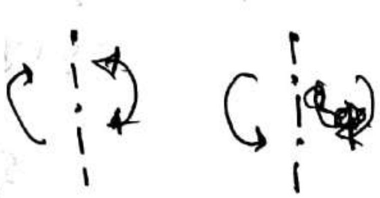
Hence S.F.D will be rectangle of height P as shown in fig. (a) [S.F at support is zero $SF]_B = 0$].

Bending moment at x. i.e

$B.M] = -P[x]$

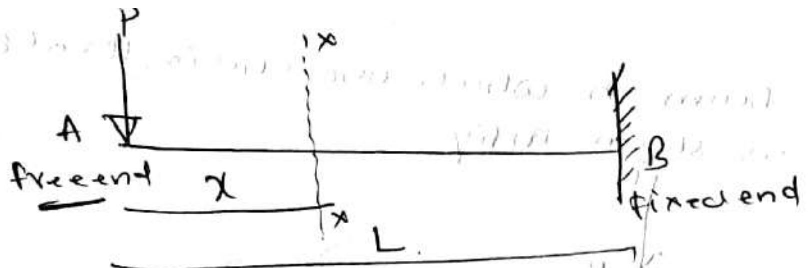
$B.M]_{x=0} = 0$ (A)

$B.M]_{B, x=L} = -PL$



Hence BM varies linearly from zero at the free end to PL at the fixed end.

hence fig (b) shows the B.M



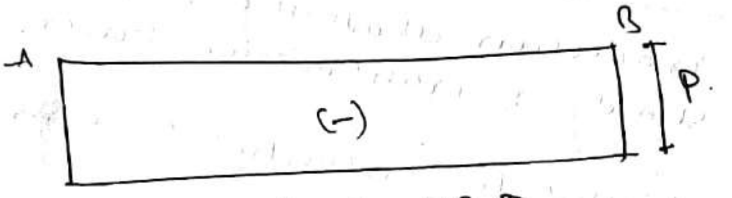


fig a SF.D

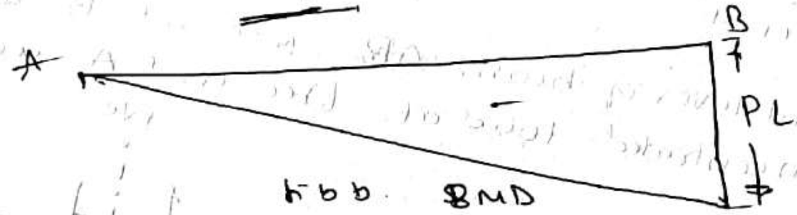
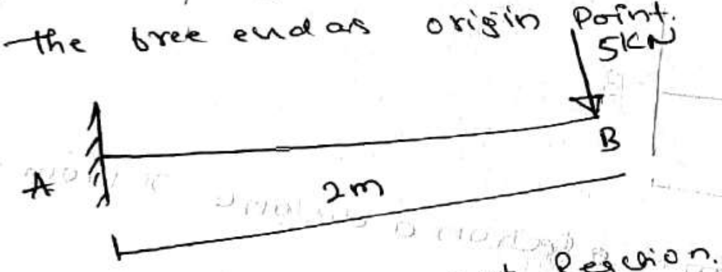
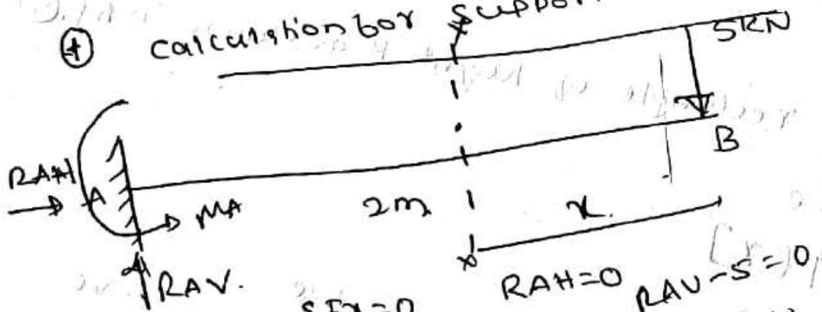


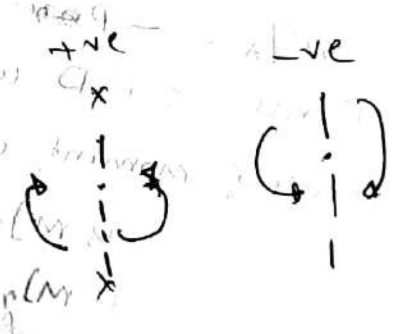
fig b BMD

(1) Draw a SFD and BMD for the cantilever beam, selecting the free end as origin point.



(+) calculation for support Reaction.





$\Sigma F_x = 0$ RAH=0

$\Sigma F_y = 0$ RAV - 5 = 0

+RAV = +5KN

RAV = +5KN

$\Sigma M_A = 0$

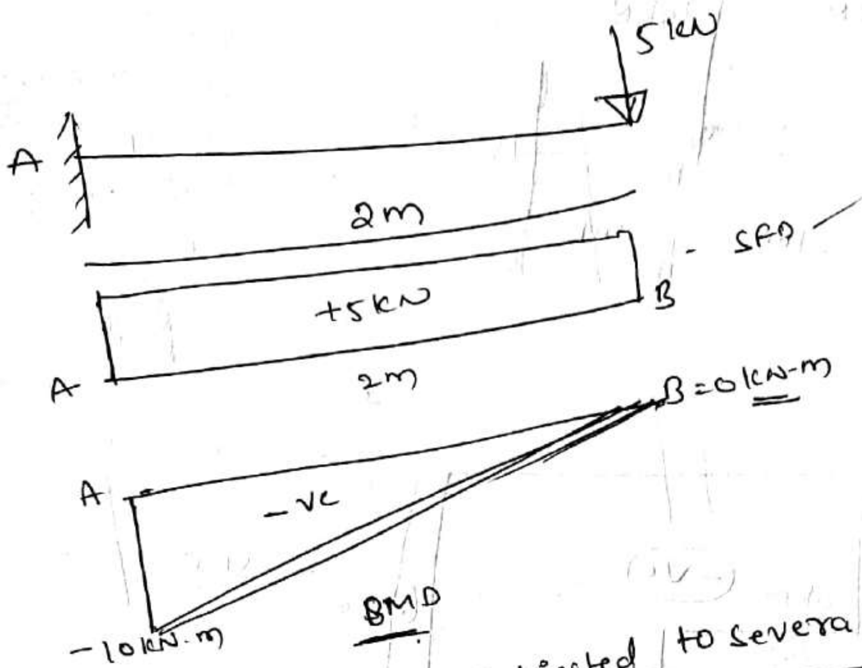
+5×2=0 = 10KN m

selecting free end as origin the shear force is uniform through out the length with +5KN as magnitude

Bending moment at any section is [-5×x] from the free end BM)x-x = -5×x.

x=0 BM]B = 0

x=2 BM]A = -5(2] = -10KN-m

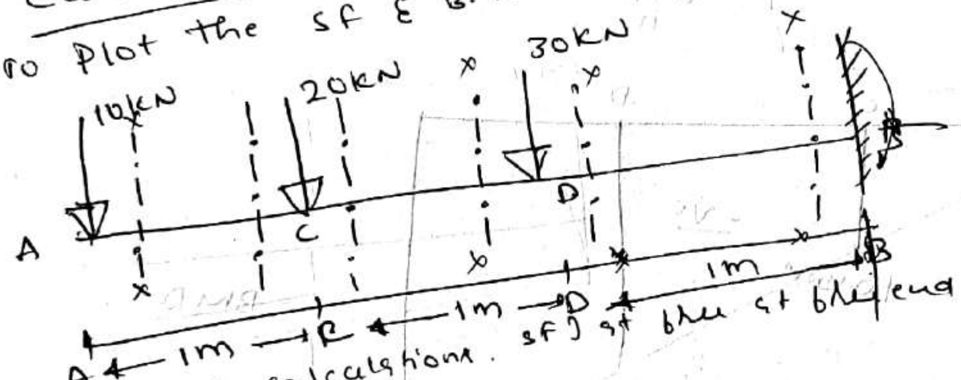


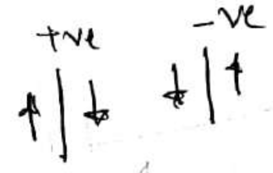
SF]A = +5kN.

SF]B left = 5kN.

② Cantilever beam subjected to several concentrated loads.

To plot the SF & B.M. Diagram





SF] at the at the end

ΣFx = 0. ΣBH = 0

ΣFy = 0

-10 - 20 - 30 + RBV = 0

RBV = 60kN

Shear force calculations.

SF]A = -10 kN

SF]A right = -10kN.

SF]C left = -10kN.

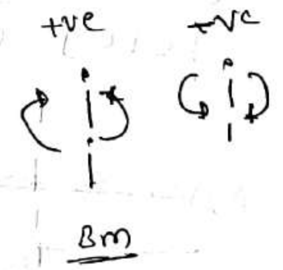
SF]C right = -10 - 20 = -30kN.

SF]D left = -10 - 20 = -30 kN.

SF]D right = -10 - 20 - 30 = -60kN.

SF]B left = -60 kN.

fig 9



To plot the bending diagram.

B.M]A = 0 [It is free end]

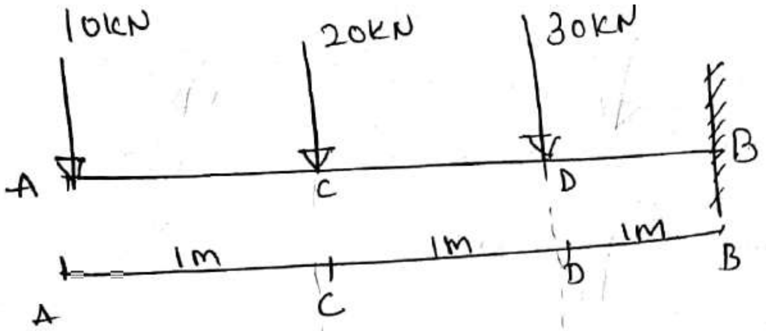
BM]C = -10×1 = -10 kN-m

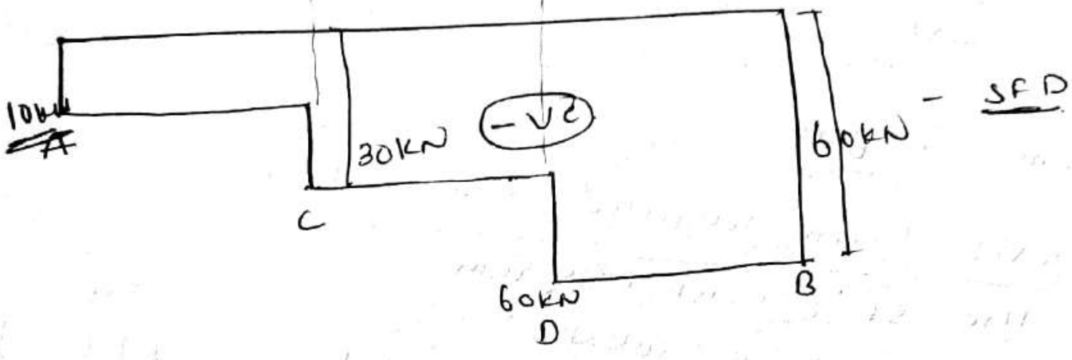
BM]D = -10×2 - 20×1 = -20 - 20 = -40kN-m

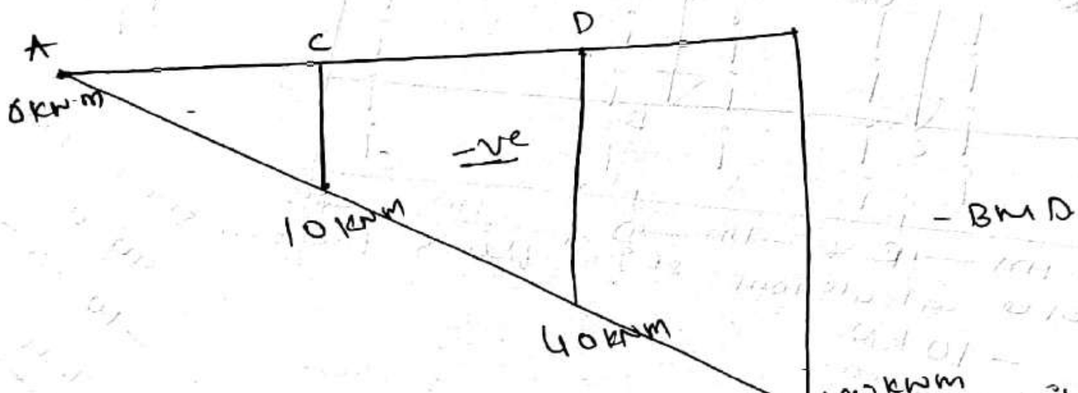
BM]D = -10×3 - 20×2 - 30×1

BM]D = -30 - 40 - 30 = ~~-100 kN-m~~

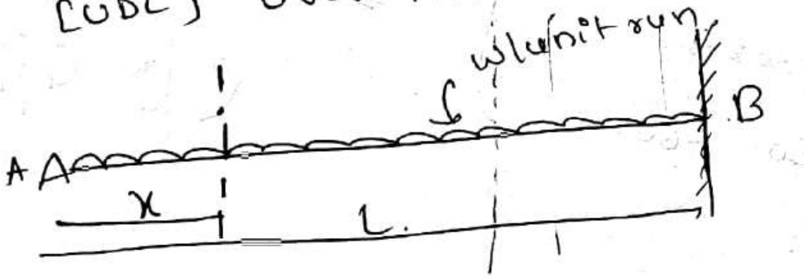
= -100kN·m







- Cantilever beam subjected to a uniformly distributed load [UDL] over the whole span.



S.F at any section from A.

$SF]_{A, x=0} = 0$

$SF]_x = -w \cdot x$

$SF]_{x=L} = -W \cdot L$

S.F. varies linearly from zero at free end to WL at fixed end.

Bending moment at any section x from A.

$B.M)_x = -(w \cdot x) \, x/2$

$B.M)_{x=0} = 0$

$B.M)_{x=L} = -\frac{WL^2}{2}$

[Variation of Bending moment is Parabolic]

② Shear force calculations

$SF]_A = 0$

$SF]_{C\,left} = 0$

$SF)_{C\,Right} = 0$

$SF]_D = -3\,KN.$

$SF]_E = -7KN$

$SF]_B = -7KN$

[There is no loading from A to C. There will not be any shear force & hence the shear force originating from A to C is zero.

[In B/w D & E, shear force is constant 3 KN, & In B/w E & B, shear force is 3+4 = 7KN is constant magnitude.]

+ve −ve

③ Bending moment calculations.

$B.M]_A = 0$

$BM]_C = 0$

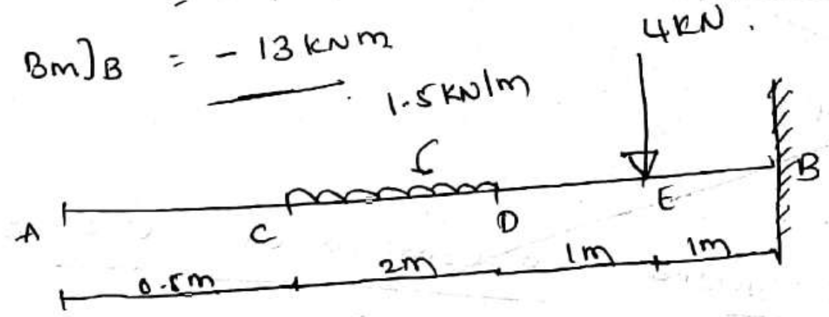
$BM]_D = \left[-1.5\times 2\times \frac{2}{2}\right] = -3KNm.$

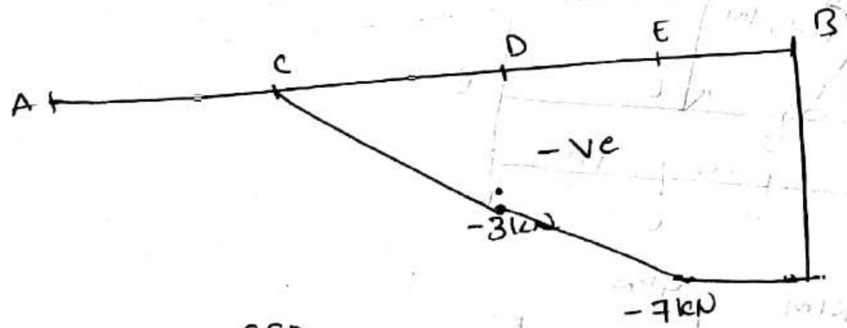
$BM]_E = -[1.5\times 2][1+1] = -6KNm$

$Bm]_B = -[1.5\times 2][1+1+1] - 4\times 1$

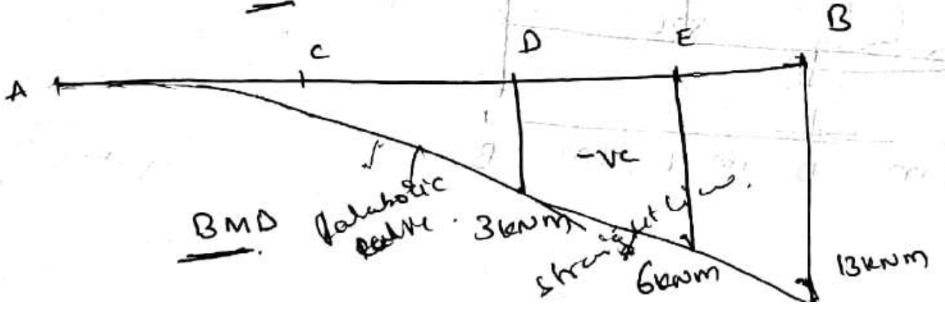
$= -9-4$

$Bm]_B = -13\,KNm$



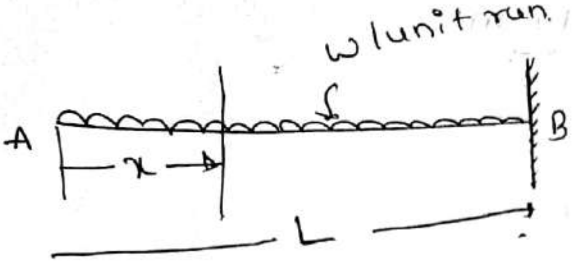


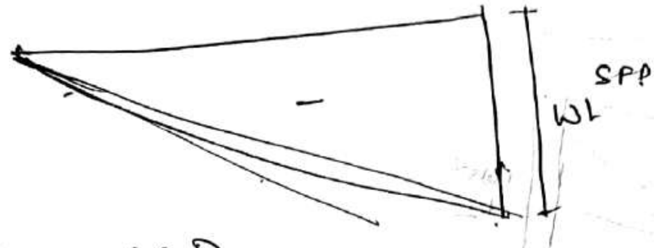
SFD



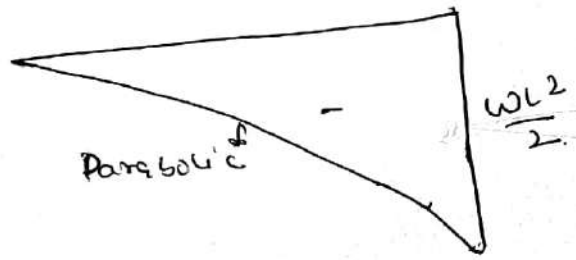
BMD

10kN 20kN 120kN



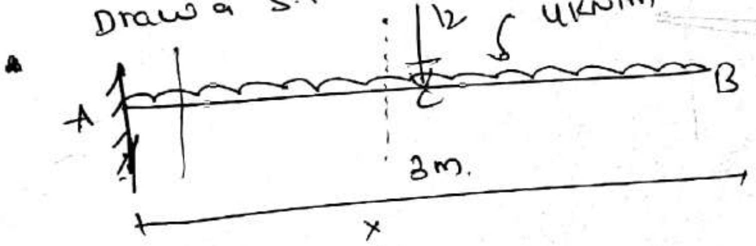


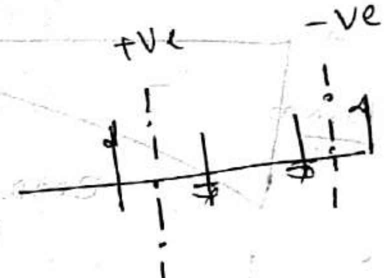
(a) S.F.D.

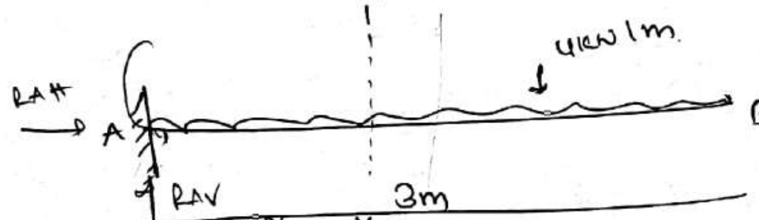


(b) B.M.D

Draw a S.F.D and B.M.D for the given cantilever beam with udl.







Reaction calculations

$\Sigma F_x = 0$

$R_{AH} = 0$

$\Sigma F_y = 0$

$+R_{AV} - 12 = 0$

$R_{AV} = 12\,kN$

$S.F]_{x-x} = 4(x)$

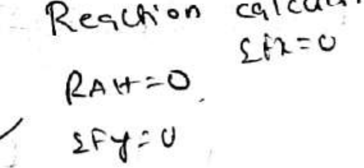
$SF]_A = +R_{AV} = 12\,kN$

$SF]_B = R_{AV} - 12 = +12 - 12 = 0$

$SF]_B$ $x=0$ $= 4 \times 0 = 0$

$SF]_C$ left $= +R_{AV}$

$SF]_A$ $x=3$ $= +4 \times 3 = 12\,kN$

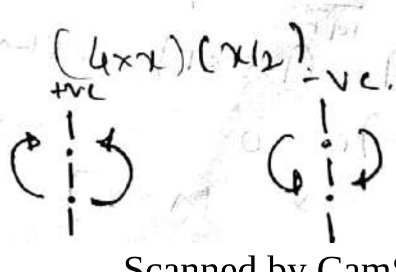


SF calculations.

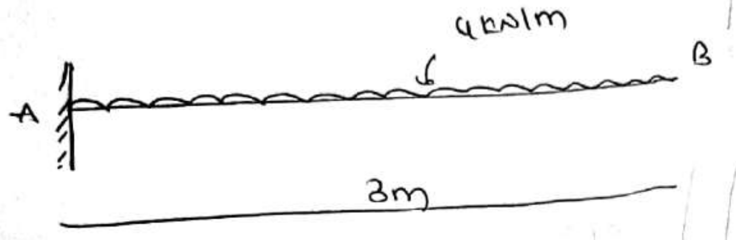
$(4 \times x)(x/2)$

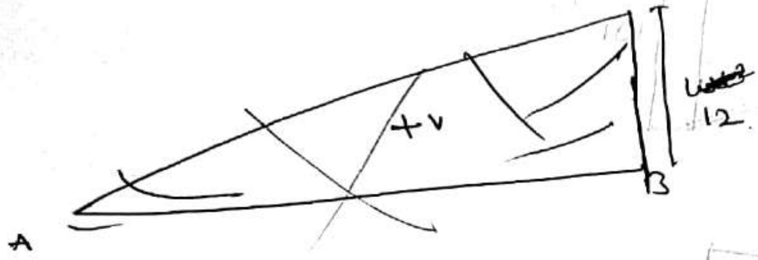
$BM]_{x-x} = -4(x)(x/2) = -2x^2$

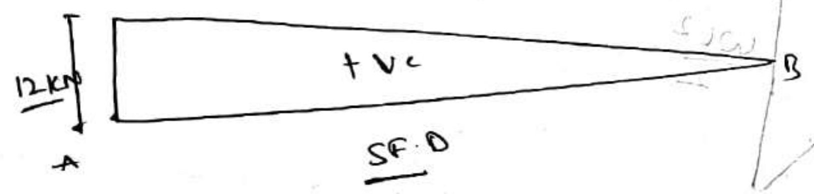
$x=0$ $BM]_B = 0$

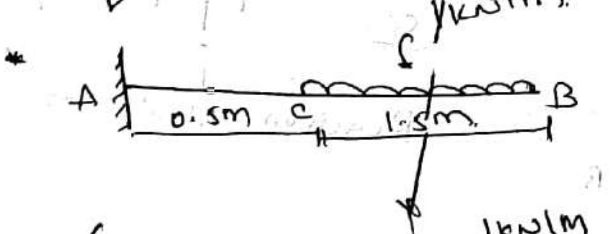


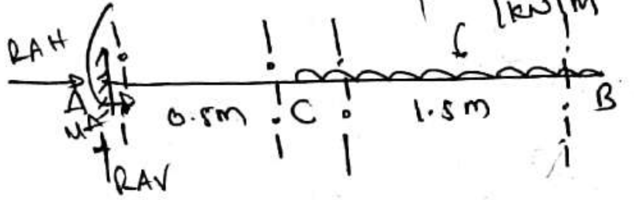
$x = 3 \quad BM]_A = -2(3)^2 = -18\ kN\ m$











$\Sigma F_x = 0 \qquad \Sigma F_y = 0$

$RAH = 0 \qquad RAV - 1.5 = 0$

RAV = 1.5kN

$SF]_A = 1.5kN. \qquad SF)_A = +RAV = +1.5kN$

$SF]_C = 1.5kN$ (Right)

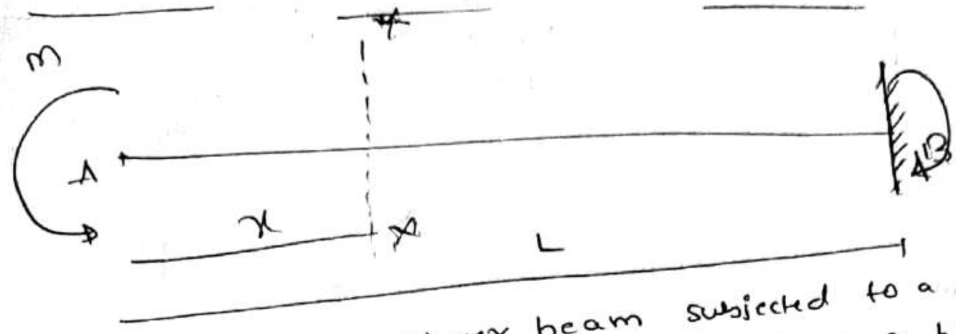
As there is no UDL load b/w A & C SFD remains constant

$SF]_C$ (left) $= (1.5 \times 1) = 1.5kN.$

$SF]_B = 0 \cdot +RAV - 1.5 = +1.5 - 1.5 = 0$

$SF]_{x-x} = [1 \times x]$

* Cantilever beam with a couple acting at the free end.

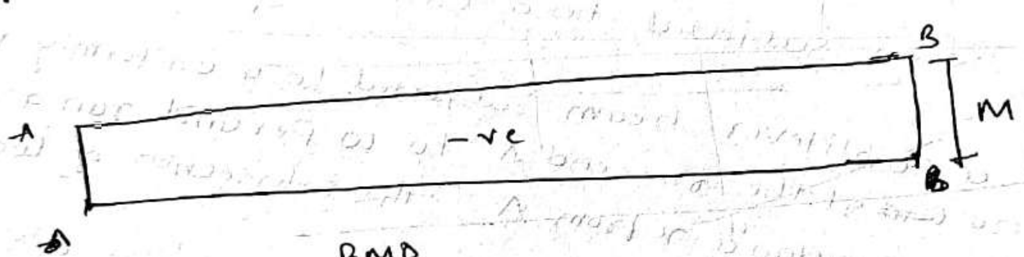


$SF]_x = 0$
$SF)_A = 0$
$SF)_B = 0$

Figure shows a cantilever beam subjected to a couple M at the free end A. Consider a section at a distance x from the free end A. Since their is no lateral force acting on the beam, the shearing force is zero throughout the length of the beam.

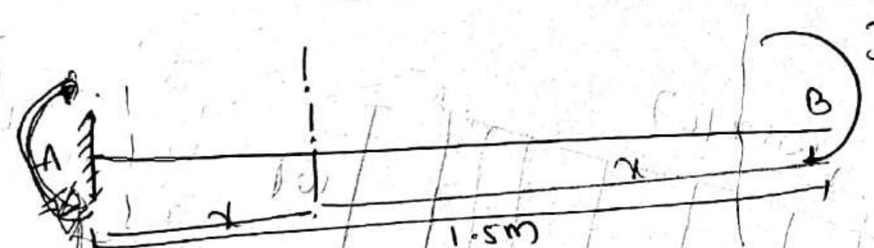
Bending moment $]_x$ = − M (−ve)

Hence Bending moment is constant Magnitude M for the entire length of the beam.



BMD

1)



As there are no vertical loads on the cantilever beam the shear force at each & every section is zero.

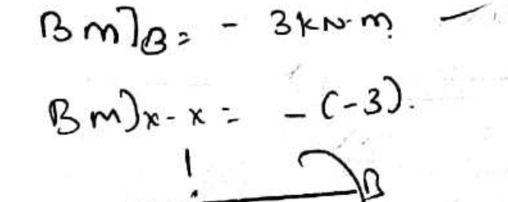
$SF]_A = 0$, $SF]_B = 0$

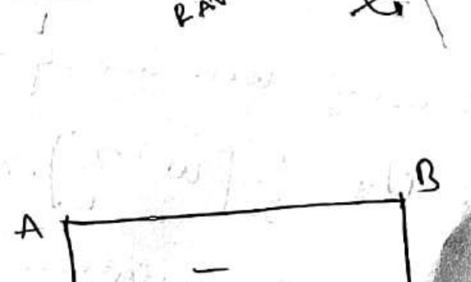
Bending moment calculations:

$BM]_A = -3KN\text{-}m$

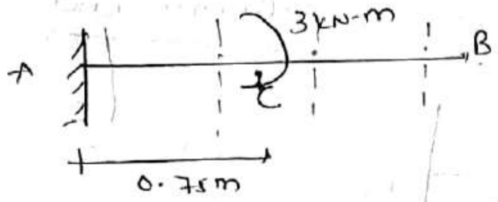
$BM]_B = -3KN\text{-}m$

$BM)_{x-x} = -(-3)$.



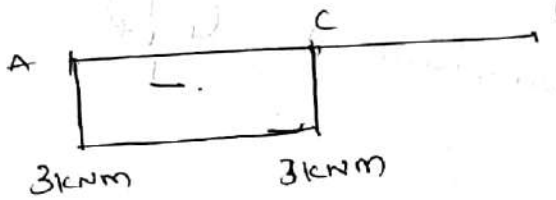


BMD



S.F$]_A = 0$.
S.F$)_B = 0$
S.F$]_C = 0$

$BM]_B = 0$ kN-m
$BM)_C = -3$ kN-m
$BM)_A = -3$ kN-m.

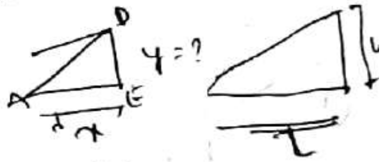


BMD

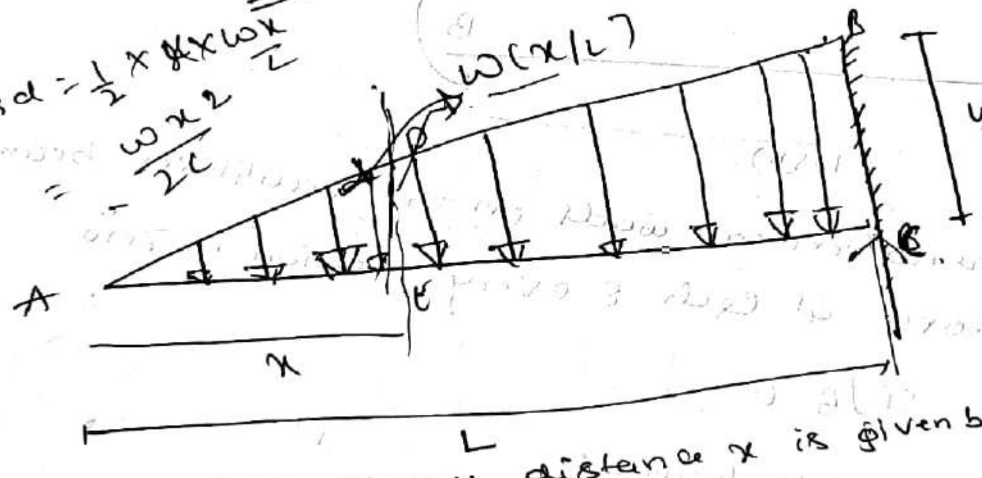
Cantilever beam subjected to a uniformly varying load.

Consider a cantilever beam subjected to a uniformly varying load from zero at the free end A to w per unit run at B as shown in fig. At a distance x from A, the intersection of loading is given by $w\left[\frac{x}{L}\right]$

similar as



total load $= \frac{1}{2} \times x \times \frac{wx}{L}$
$= \frac{wx^2}{2L}$



$\frac{y}{x} = \frac{w}{L}$
$y = \frac{wx}{L}$

Shearing force at any distance x is given by.

$S.F]_x = \frac{1}{2}\left[w \cdot \frac{x}{L}\right] \cdot x = \frac{wx^2}{2L}$

Hence the variation is parabolic.

$S.F]_{x=0} = 0$

$S.F]_{x=L} = \frac{w \cdot L^2}{2L} = \frac{wL}{2}$

To plot the BMD.

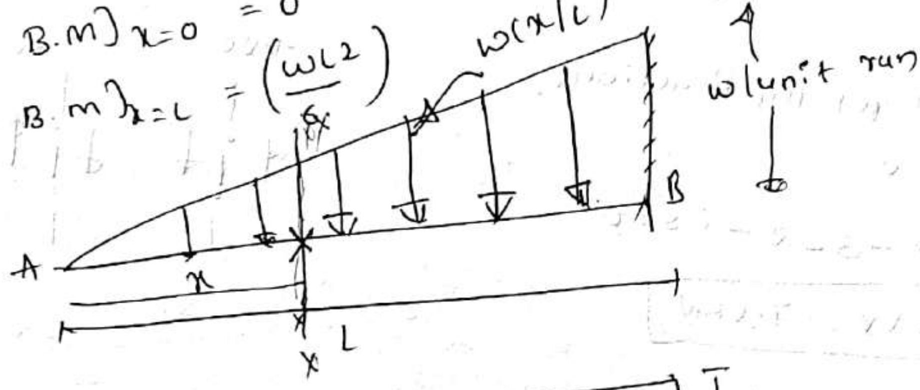
$B.m]_x = \left\{ \frac{1}{2} \left[\omega \cdot \frac{x}{L} \right] \cdot x \right\} \left\{ \frac{1}{3} x \right\} = \frac{\omega x^3}{6L}$ $= \frac{\omega \cdot x^2}{2L} \cdot \frac{x}{3} = \frac{\omega x^3}{6L} \propto x^3$

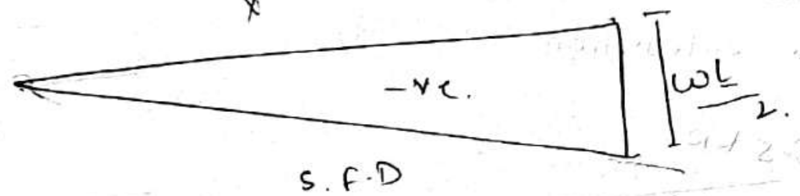
Hence, the variation is cubic

$B.M]_{x=0} = 0$

$B.m]_{x=L} = \left(\frac{\omega L^2}{6} \right)$

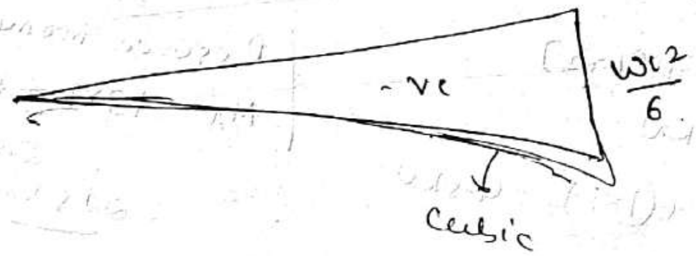
1, 2, 3,





S.F.D

$\frac{\omega x^2}{2L} \times \frac{1}{3} x.$

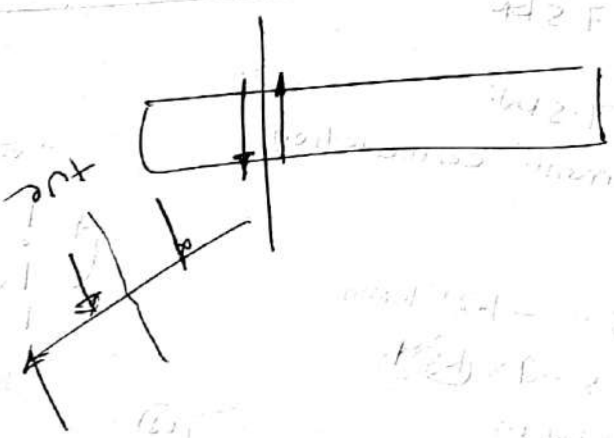


$= \frac{\omega x^3}{6L}$

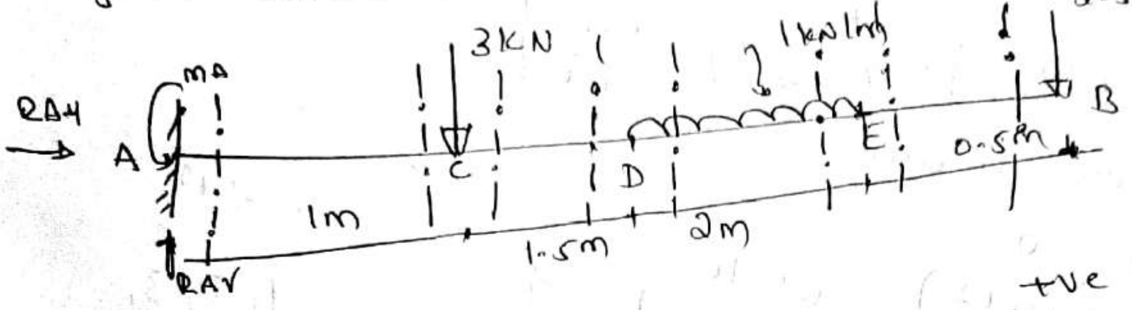
where $x = L$

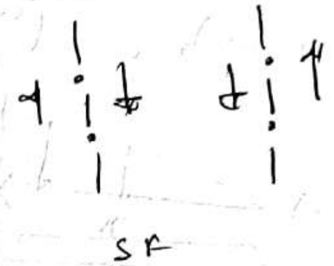
$= \frac{\omega L^3}{6L}$

$= \frac{\omega L^2}{6}$



1. Draw the SFD and Bending moment Diagram for the given cantilever beam.





Step: 1 Calculation for the Reactions.

$\Sigma F_y = 0$

$R_{AV} - 3 - 2 - 2.5 = 0$

$R_{AV} = 7.5 KN$

Reactive moment about
$M_A = +3\times1 + 2\times3.5 + 2.5\times5$
$= 22.5 kN\text{-}m$ Cauti - clockwise

Step: 2 Shear force calculation

$SF]_B = +2.5 kN$

$SF]_E = +2.5 kN$

$SF]_D = +2.5 + (1\times2)$

$SF]_D = 4.5 kN$

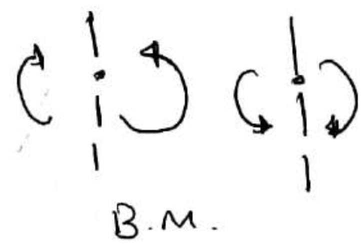
Right $SF_R]_C = +2.5 + (1\times2) = 4.5 kN$

$SF]_{LC} = +2.5 + [1\times2) + 3$

$SF.]_{LC} = 7.5 KN$

$SF]_A = +7.5 kN.$

Step: 3 Bending moment calculation



$BM]_B = 0$

$BM]_E = -2.5\times0.5 = -1.25 kNm$

$BM)_D = -2.5\times2.5 - 2\times 1$

$= -8.28 kN\cdot m$

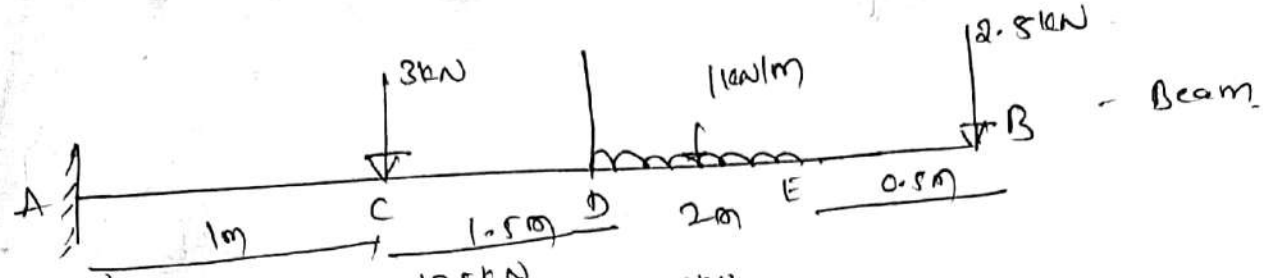
(or)

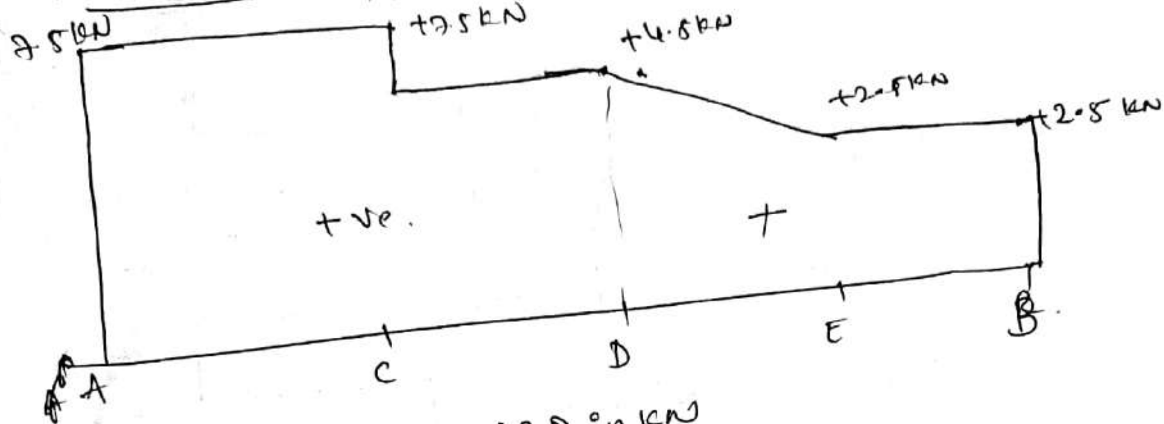
alternatevelly

$BM]_D = -22.5 + 7.5\times2.5 - 3\times1.5 = -8.25 kNm$

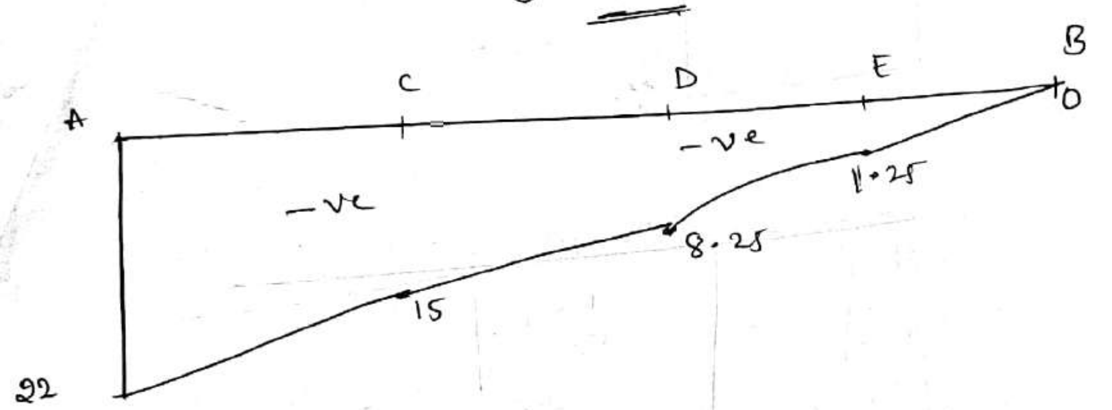
$BM]_C = ~~+7.5\times1 - 7.5 kNm~~ - 2.5\times4 - 2\times2.5 = -15 kNm$

$BM]_A = -2.5\times5 - 2\times3.5 - 3\times1 = -22.5 kN\text{-}m$



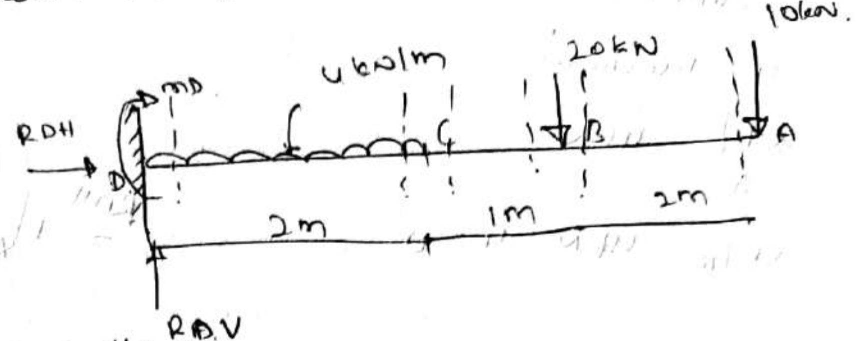


SFD. in kN



BMD in kNm.

+ Draw the shear force and bending moment diagrams for the cantilever beam shown in fig



→ $\Sigma F_x = 0$

$RDH = 0$

$\Sigma F_y = 0$

$RDV - 8 - 20 - 10 = 0$

$RDV = 38\ kN$

considering the forces from right of the section

SF calculations

$SF]_D = +RDV = +38\ kN$

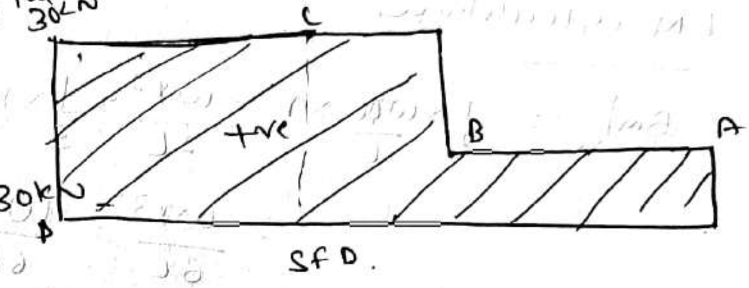
$SF]_{C\ left} = +RDV - 8 = +38 - 8 = 30\ kN$

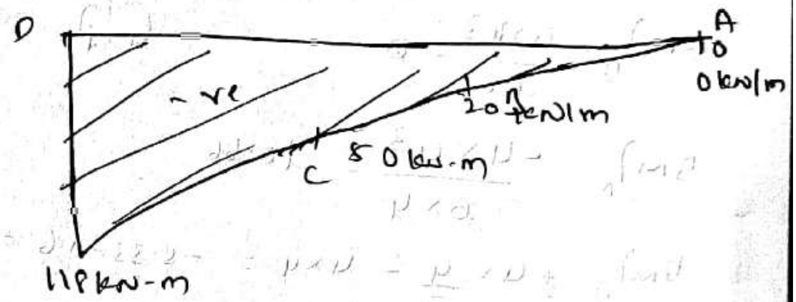
$SF]_{C\ Right} = +RDV - 8 = 30\ kN$

$SF]_{B\ left} = 30\ kN$

$SF]_{B\ Right} = 30 - 20 = 10\ kN$

$SF]_{A\ left} = 10\ kN$





BM calculations

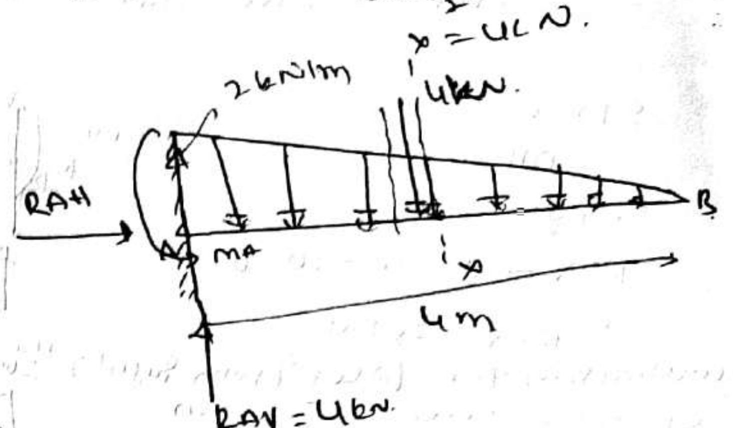
$BM]_A = 0$

$BM]_B = +10 \times 2 = 20\ kN\text{-}m$

$BM]_C = 10 \times 3 + 20 \times 1 = 50\ kN\text{-}m$

$BM]_D = 10 \times 5 + 20 \times 3 + 8 \times 1 = 118\ kN\text{-}m$

* Draw the Shear force and Bending moment Diagrams for the Cantilever beam as shown in fig.



SF calculations

$SF]_A = 4kN$

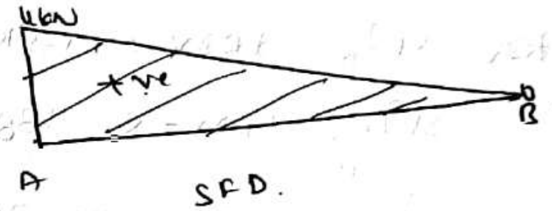
$SF]_B = 4kN - 4 = 0$

BM calculations

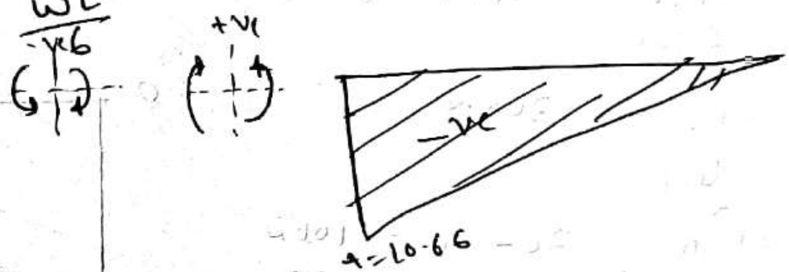
$BM]_{xx} = \frac{1}{2} \times \frac{wx}{L} \times x = \frac{wx^2}{2L} \times \frac{1}{3} \times x$

$= \frac{wx^3}{6L} = \frac{wx^3}{6L}$

$= \frac{wL^2}{6}$



SFD.

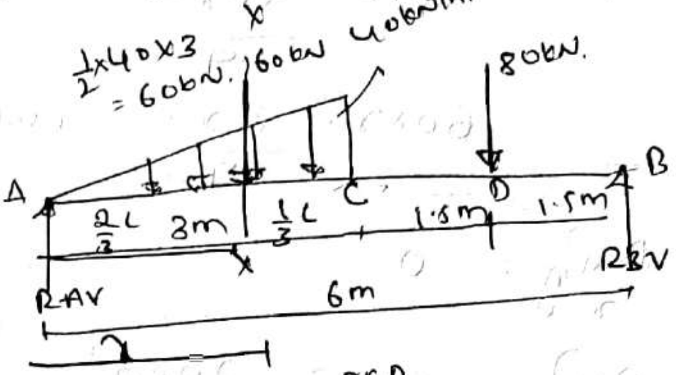


$BM]_B = \frac{wx^3}{6L} = 0$

$BM]_A = \frac{-4 \times 4^3}{6 \times 4} = 10.66$

$BM]_A = 4 \times \frac{4}{3} - 4 \times 4 = -5.33 - 16 = -10.66$

* Simply Supported beam shown in fig. Draw ... Bending moment Diagram.



$\Sigma fx = 0$

$\Sigma Fy = 0$

$+RAV + RBV - 60 - 80 = 0$

RAV + RBV = 140KN

$\Sigma MA = 0$

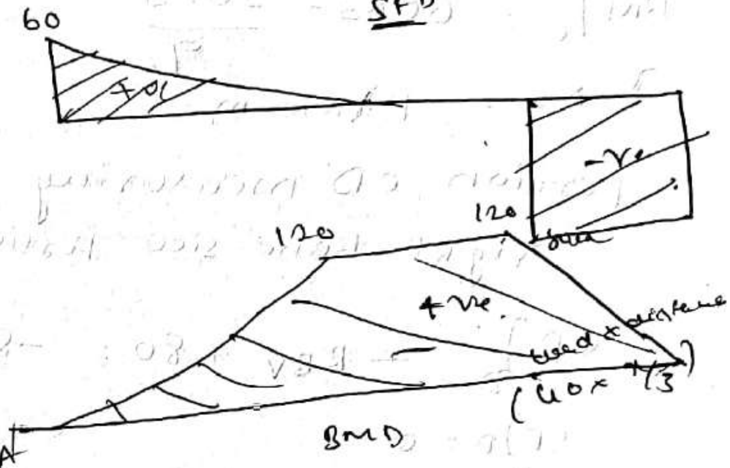
$+60\times\frac{2}{3}\times 3 + 80\times 4.5 - RBV\times 6 = 0$

RBV = 80KN

$RAV + RBV = 140$

$RAV = 140 - 80$

RAV = 60KN



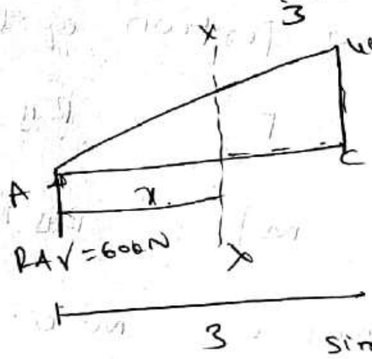
Shear force calculation

portion AC : Measuring x from A. the load Intensity is $\frac{40x}{3}$

SF$]_x$

load is $\frac{1}{2}\times x\times \frac{40x}{3} = \frac{20x^2}{3}$

$\frac{60x}{\frac{2}{3}L} = \frac{40}{L}$



similar concept

$\frac{40}{3} = \frac{9}{x}$

$9 = \frac{40x}{3}$

$F = RAV - \frac{20x^2}{3}$

At $x=0$

$SF]_A = +RAV = 60kN.$

$x=0$

$SF]_C = +RAV - \frac{20x^2}{3}$

$x=3 \quad = +60 - \frac{20\times 3^2}{3}$

$SF]_C = 0$

Moment Bending moment calculation

$M = RAx - \frac{1}{2}x\cdot\frac{40x}{3}\cdot\frac{x}{3}$

$= RA\cdot x - \frac{20x^3}{9}$

Head of C.E.D

$M = R_A x - \frac{20x^3}{9}$

$= 60 \times x - \frac{20x^3}{9}$ (cubic variation)

$BM)_{A, x=0} = 0$

$BM)_{C, x=3} = 60 \times 3 - \frac{20 \times 3^3}{9}$

$= 120\,kN\text{-}m$

Portion CD: measuring x from B and considering right hand side portion of beam

$SF)_D = -R_{BV} + 80 = -80 + 80 = 0$ (constant)

$SF)_D = 0$

$M = R_B x - 80(x - 1.5)$

$= 80 \times x - 80(x - 1.5) = 120\,kN\text{-}m$ Constant]

Portion DB: measuring x from B considering right hand portion of the beam.

$SF) = -R_B = -80\,kN$ (constant)

$M] = R_B x = 80x$. (Linear variation)

At $x = 0$ $M = 0$.

At $x = 1.5$ $M = 80 \times 1.5 = 120\,kN\text{-}m$

* Draw the SFD and BMD for the overhanging beam shown in fig. Indicate the all significant values including the point of contraflexure.

$\Sigma F_y = 0$

$+R_{AV} + R_{BV} - 60 - 20 = 0.$

$R_{AV} + R_{BV} = 80kN$

$\Sigma M_A = 0$

$+60 \times \left[1 + \frac{4}{3}\right] - R_{BV} \times 4 + 20 \times 5 = 0$

$R_{BV} \times 4 = 240$

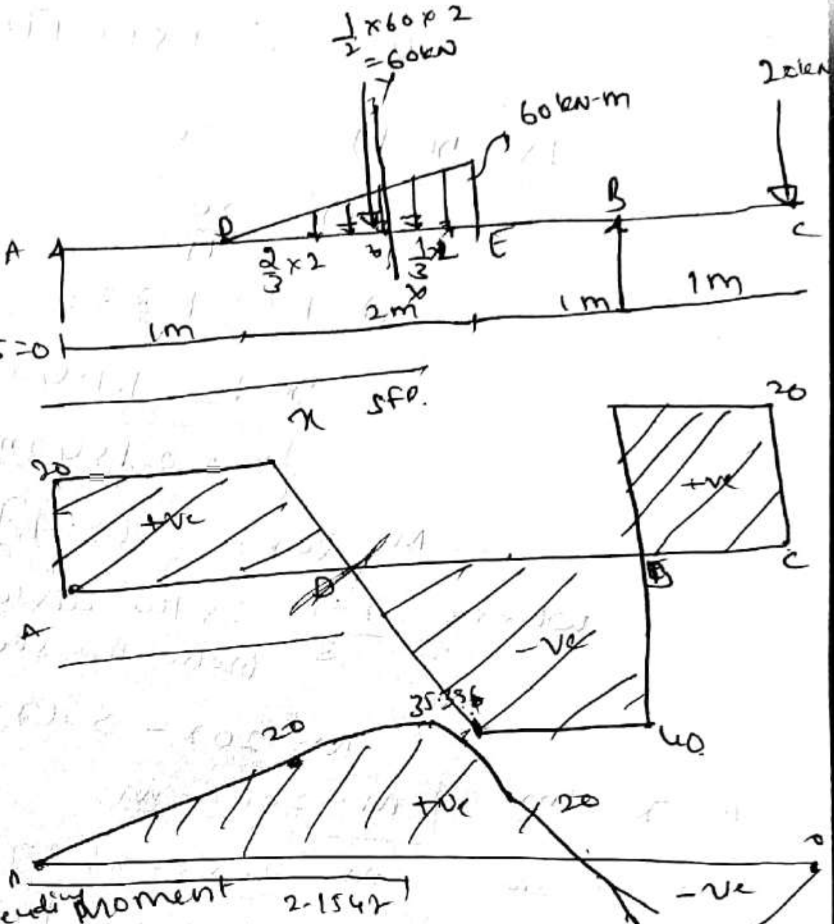
$R_{BV} = \frac{240}{4}$

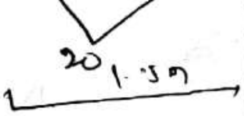
$R_{BV} = 60kN$

$R_{AV} + 60 = 80$

$R_{AV} = 80 - 60$

$R_{AV} = 20kN$





At $x = 0$ $M = 0$

At $x = 1$ $M = 20kN\text{-}m$

BMD

SF calculations

$SF]_A = +R_{AV} = +20kN.$

$SF]_D = +R_{AV} = +20kN.$

$SF]_E$:

Measuring x from A & considering the forces on left hand of the section.

Load intensity at $x = \frac{x-1}{2} \times 60 = 30(x-1)$

$(\frac{1}{2} \times B \times h)$

$F = 20 - \frac{1}{2}[x-1]\,30\,(x-1)$

$= 20 - 15(x-1)^2$ [Parabolic variation.

At $x = 1m$ $F = 20 - 15(1-1)^2$

$F = 20kN.$

At $x = 3m$ = $F = 20 - 15(3-1)^2$

$F = 20 - 15(2)^2$

$F = 20 - 60$

$F = -40kN$

Scanned by CamScanner

SF is zero at x where x is given by

$$F = 20 - 15(x-1)^2$$

$$0 = 20 - 15(x-1)^2$$

$$15(x-1)^2 = 20$$

$$(x-1)^2 = \frac{20}{15}$$

$$(x-1)^2 = 1.333$$

$$x - 1 = 1.1547$$

$$\boxed{x = 2.1547\,m}$$

$$M = 20x - \frac{1}{2}(x-1)\,30(x-1)\left(\frac{x-1}{3}\right)$$

where $\frac{x-1}{3}$ is the distance of c.g. of triangular load from the section.

$$M = 20x - 5(x-1)^3 \quad \text{(cubic variation)}$$

At $x = 1m$ $\boxed{M = 20\,kN\text{-}m}$

At $x = 3m$ $M = 20\times3 - 5[3-1]^3$

$$\boxed{M = 20\,kN\text{-}m}$$

Moment is maximum at $x = 2.1547$ m where SF = 0.

$$M_{max} = 20\times2.1547 - 5[1.1547]^3$$

$$\boxed{M_{max} = 35.396\,kN\text{-}m}$$

Portion EB: Measuring x from free end and considering the right hand side portion

$$F = 20 - R_B = 20 - 60 = -40\,kN. \text{ (constant)}$$

$$M = -20x + R_B(x-1)$$

$$= -20x + 60(x-1)$$

$$M = +40x - 60 \quad \text{(Linear variation)}$$

At $x = 1m$ $M = 40 - 60 = -20\,kN\text{-}m$

At $x = 2m$ $M = 4\times2 - 60 = 20\,kN\text{-}m.$

Point of contraflexure is in this portion E is obtained by $0 = 40x - 60$. i.e. at $x = 1.5m$ from free end

Portion BC. Measuring x from free end & considering
The right hand side force

$F = 20kN$ (Constant)

$M = -20x$ (Linear variation)

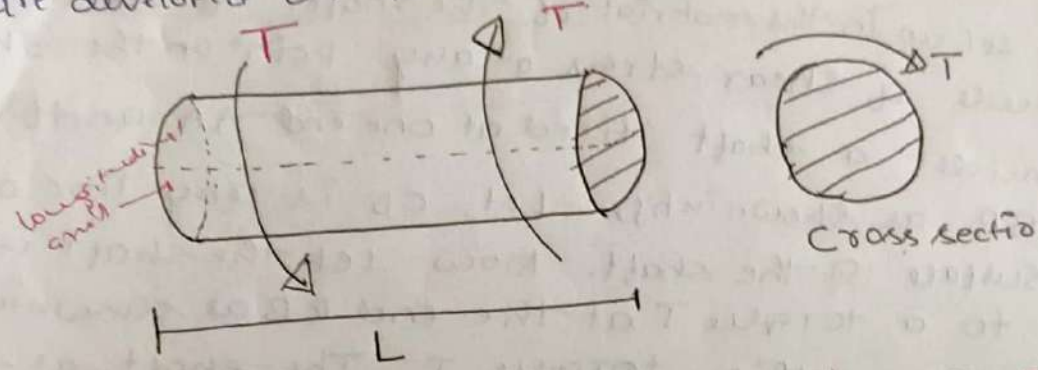
At $x = 0$ $M = 0$

At $x = 1m$ $M = -20$ kN-m.

Module: 4

Torsion in circular shafts:

A shaft is said to be in "Pure torsion", when it is subjected to equal and opposite moments which are acting parallel (or) tangential to the cross section. Hence shear stresses are developed on the cross section which is under pure shear.



Assumption made in pure torsion | torsion theory.

1. Material is Homogenous and Isotropic.
2. All the stresses are within the elastic limit.
3. Shaft is subjected to pure torsion only. [No shear force & Bending moment]
4. Shaft is uniform cross section.
5. The applied torque is uniform through out the length
6. A radial line remains straight even after twisting.
7. A plane normal sections remain plane even after twisting. [no warping (or) bending) (or) distortions are seen]

Note:

We know that young's modulus (or) modulus of elasticity.

$$E = \frac{\text{Linear Stress}}{\text{Linear strain}} = \frac{f}{e} \quad N/mm^2.$$

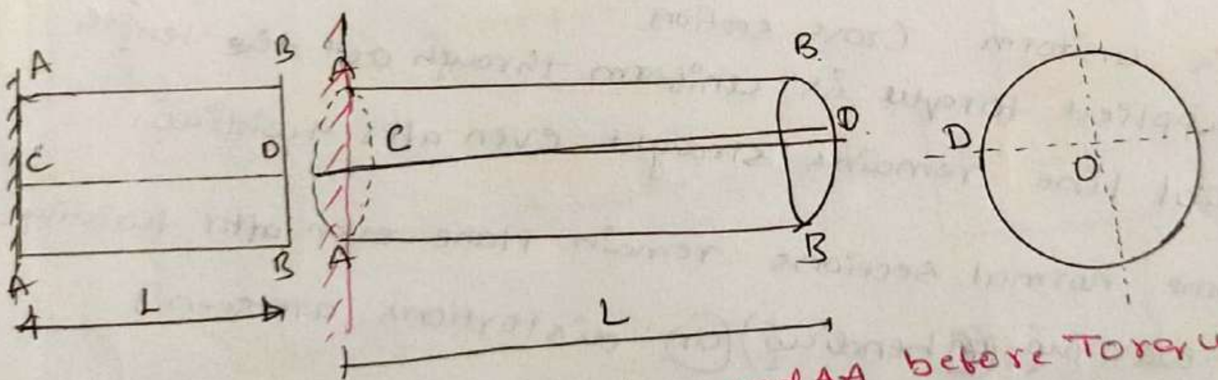
Ily Shear modulus (or) Rigidity modulus is

$$C \text{ (or) } G = \frac{\text{Shear Stress}}{\text{Shear strain}} = \frac{fs}{\phi} = \frac{\tau}{\phi} \quad N/mm^2$$

Derivation of Shear stress produced in a circular Shaft subjected to torsion (or) Derive the torsion equation with usual notations.

When a circular shaft is subjected to torsion, shear stresses are set up in the material of the shaft. To determine the magnitude of shear stress at any point on the shaft.

Consider a shaft fixed at one end AA and free at the end BB as shown in fig. Let CD is any line on the outer surface of the shaft. Now let the shaft is subjected to a torque T at the end BB as shown in fig. As a result of this torque T, the shaft at the end BB will rotate clockwise & every cross-section of the shaft will be subjected to shear stresses. The point D will shift to D' & hence line CD will be deflected to CD' as shown in fig. The line OD will be shifted to OD'.



before Torque T is applied.

fig shaft fixed at one end AA

Let R = Radius of shaft, L = Length of shaft,
T = Torque applied at the end BB.
τ = Shear stress induced at the surface of the shaft due to torque T. G = modulus of rigidity of the materials of the shaft. φ = ∠DCD' also equal to shear strain.
θ = ∠DOD' & is also called angle of twist.

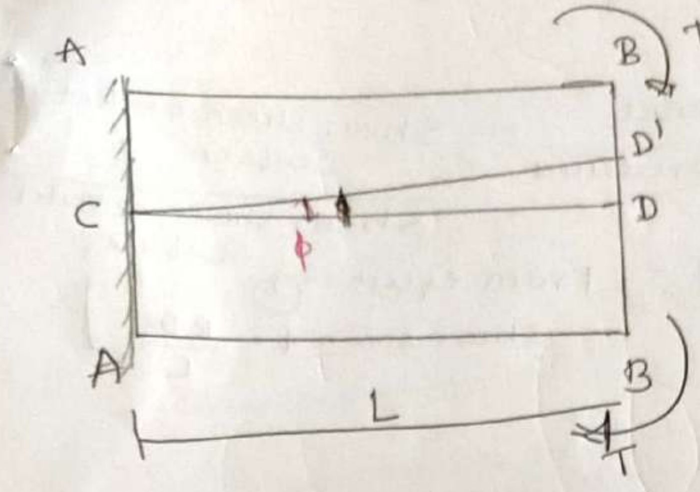


fig (a)

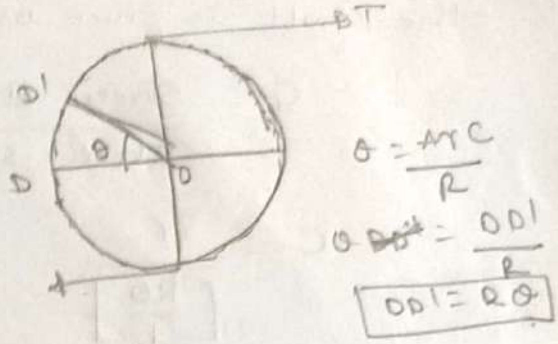


fig (b)

fig Shaft fixed at AA and subjected to torque T at BB

fig 9
$\tan\phi = \frac{opp}{adj}$
$\tan\phi = \frac{DD'}{AD}$
$\tan\phi \approx \phi = \frac{DD'}{AD}$
$\phi =$

From fig a

Now
Shear strain at outer surface = Distortion per unit length

$$\tan\phi = \frac{DD'}{L}$$

where [$\tan\phi$ is very small ($\tan\phi = \phi$)]

$$\phi = \frac{DD'}{L}$$

Shear strain at outer surface $\boxed{\phi = \frac{DD'}{L}}$ eq (1)

From fig (b)

$$\theta = \frac{Arc}{Radius}$$ where OD = Radius of circle.

$\boxed{OD = R}$

$$\theta = \frac{DD'}{OD}$$

$\boxed{DD' = R\theta}$ eq (2)

Substituting the value of DD' in eq (1) we get
Shear strain at the outer surface $\phi = \frac{DD'}{L}$

$$\boxed{\phi = \frac{R\theta}{L}} \quad \text{--- (3)}$$

Now the modulus of Rigidity (C) of the material of the shaft is given as

$$C = \frac{\text{Shear stress induced}}{\text{shear strain produced}} = \frac{\text{Shear stress at the outer surface}}{\text{Shear strain at outer surface}}$$

$$C = \frac{\tau}{\left[\frac{R\theta}{L}\right]}$$

[∴ From equation (3) shear strain $\phi = \frac{R\theta}{L}$]

$$C = \frac{\tau L}{R\theta}$$

$$\boxed{\frac{C\theta}{L} = \frac{\tau}{R}} \rightarrow (a)$$

$$\tau = \frac{C\theta R}{L} \quad \text{(or)} \quad \tau = \frac{R \times C \times \theta}{L}$$

Now for a given shaft subjected to a given torque (T) The values of C, θ, and L are constant, Hence shear stress produced is proportional to the radius R

$$\tau \propto R \quad \text{(or)} \quad \frac{\tau}{R} = \text{constant} \rightarrow (4)$$

If q is the shear stress induced at a radius r from the centre of the shaft then

$$\frac{\tau}{R} = \frac{q}{r} \rightarrow (5)$$

But

$$\frac{\tau}{R} = \frac{C\theta}{L} \text{ from equation (a).}$$

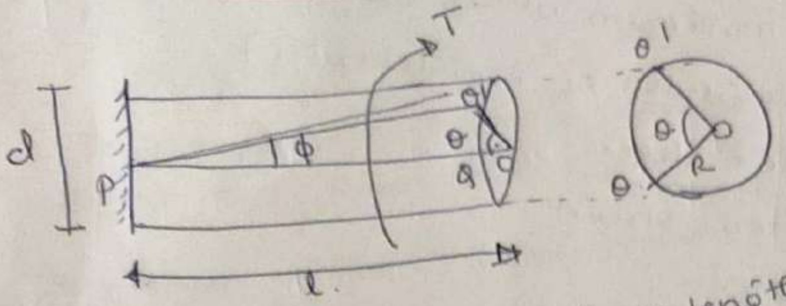
$$\frac{\tau}{R} = \frac{C\theta}{L} = \frac{q}{r} \quad \text{— (6)}$$

$$\frac{T}{J} = \frac{fs}{R} = \frac{C\theta}{L}$$

From equation (4), it is clear that shear stress at any point in the shaft is proportional to the distance of the Point from the axis of the shaft.

Hence the shear stress is maximum at the outer Surface & shear stress is zero at the axis of the shaft.

(a) Shear stress Produced in a circular shaft subjected to torsion

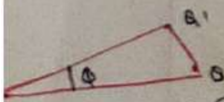


Consider a shaft of length 'l' diameter 'd' fixed at one end & free at the other end as shown in fig. take any line 'PQ' on the outer surface of the shaft. The line PQ is parallel to the longitudinal axis of the shaft. Now if torque "T" is applied to the shaft at the free end, The line PQ is shifted to the new Positions "PQ'". The angle b/w PQ and PQ'. The angle b/w ie QPQ' is φ which is the shear strain. The angle of twist "θ" is the angle QOQ' in the end view ie OQ & OQ'

Let l = length of the shaft in mm
R = Radius of shaft in mm
θ = Angle of twist - radians
ϕ = shear strain.
G or C = modulus of Rigidity N/mm^2
T = Torque applied at the end Q. (N-mm) [Torsional moment (or) Twisting moment]
(b) τ = Shear stress induced at the outer most surface.
J (or) I_P = Polar moment of Inertia in mm^4

from fig Shear strain $\tan\phi = \frac{QQ'}{PQ}$ $\left(\frac{opp}{adj}\right)$

$[\tan\phi = \phi$ [ϕ is very small] $\phi \approx 0$



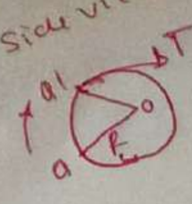
$\therefore \tan\phi = \frac{QQ'}{l}$

Shear strain at the outer surface $\phi = \frac{QQ'}{l}$

$$\boxed{QQ' = l\phi} \rightarrow (a)$$

Also from the end view Arc $QQ' = OQ \cdot \theta$

$$\boxed{QQ' = R \cdot \theta} \rightarrow (b)$$



$\theta = \frac{Arc}{Radius}$

$QQ' = \theta \cdot R \rightarrow (2)$

From eq a & b

$QQ' = QQ'$

$l\phi = R \cdot \theta$

$$\boxed{\phi = \frac{R \cdot \theta}{l}} \rightarrow (1)$$

For a given torque 'T' & length of shaft, θ is constant & therefore shear strain is directly proportional to its radial distance from the centre of the section. Hence shear strain is zero at the centre & maximum at the outer surface.

From Hook's law. Modulus of Rigidity (G)

i.e $G = \dfrac{\text{Shear stress}}{\text{Shear strain}}$

$$G = \frac{Z(fs)}{\phi}$$

Substituting the value of φ in above equation, we get

$$G = \frac{Z(fs)}{\frac{R\theta}{l}}$$

$\frac{fs}{R} = \frac{G\theta}{L}$

$\frac{fs}{R} = \frac{C\theta}{L}$

$$\boxed{\frac{Z(fs)}{R} = \frac{G\theta}{l}} \rightarrow (2)$$

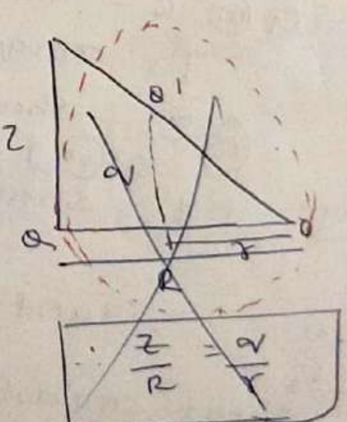
where 'θ' is in radians

For a shaft subjected to a given torque 'T' the value of G, θ & l are constants. Hence shear stress induced is directly proportional to its radius 'R', i.e radial distance from the centre of the section.

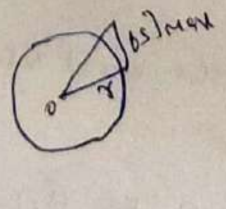
Hence shear stress is zero at the centre & maximum at the outer surface, If 'q' is the shear stress at the radius 'r' from the centre of the shaft

The.

$$\boxed{\frac{Z}{R} = \frac{G\theta}{l} = \frac{q}{r}} \rightarrow (3)$$



$\frac{T}{J} = \frac{C\theta}{L} = \frac{fs}{R}$



$\frac{fs}{R} = \frac{C\theta}{L}$

$fs = \left(\frac{C\theta}{L}\right) R$

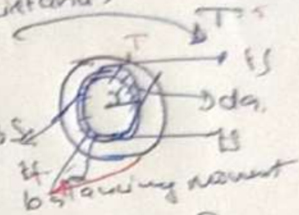
$\frac{C\theta}{L}$ = constant

$fs \propto r$

For equilibrium of the shaft the applied torque is being balanced T by resisting torque developed on the cross section by shear stress

Applied torque = Resisting torque

Consider an elementary area 'da' at a distance 'r' on which the shear stresses are acting as shown



Resisting torque = {(shear stress) (Area)} (distance)

$= \{(\frac{N}{m^2})(m^2)\} (m)$

$= N\text{-}m$

Resisting torque $= \{(f_s)(da)\}(r)$

$= \{(\frac{C\theta}{L})(r)(da)\} r$

$dT = [\frac{C\theta}{L}](da)(r^2] \quad (N\text{-}mm^4]$

$f = \frac{P}{A}$

$P = f.A$

$P = (f_s \cdot da)(r)$

In the above equation (da) (r²) = Polar moment of inertia & is denoted by J or Ip.

Hence total resisting torque on cross section should be equal to applied torque (T)

for equilibrium

$$T = \left[\frac{C\theta}{L}\right] \int_0^R da \cdot r^2$$

$$T = \frac{C\theta}{L} (J]$$

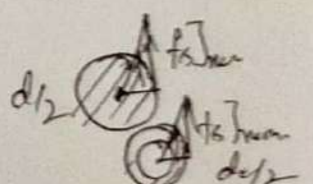
$$\boxed{\frac{T}{J} = \frac{C\theta}{L}} \rightarrow (2)$$

$\frac{T}{J} = \frac{f_s}{R}$

$f_s = (R)(\frac{T}{J})$

$f_s]_{max} = (d/2)(T/J)$

$= (d_e/2)(T/J)$



$$\boxed{\frac{T}{J} = \frac{C\theta}{L} = \frac{f_s}{R}}$$

The above equation is the Expression for pure torsion.

T = torque

J = Polar moment of inertia

G or C = modulus of shear stress

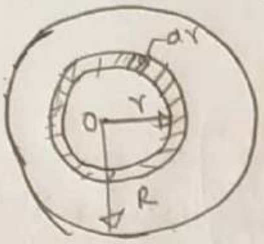
R or fs = shear stress

L = length of the shaft

R = Radius of the circular shaft

θ = shear strain

2) Relationship b/w torque & shear stress in a solid circular shaft.



Consider an elementary strip at 'r' from the centre of the section 'O'. The thickness of the strip is dr as shown in fig.

let R = Radius of the shaft

T = Torque applied

q = Shear stress induced at radius 'r' from the centre.

Z = Maximum shear stress induced at the outer surface.

Area of the elementary circular ring/shaft $\delta a = 2\pi r \cdot dr$.

From eq (3) ie Torsion equation

$$\frac{Z}{R} = \frac{G\theta}{l} = \frac{q}{r}$$

$$\frac{T}{J} = \frac{G\theta}{L} = \frac{fs}{R}$$

$$\frac{Z}{R} = \frac{q}{r}$$

Shear stress at radius 'r'

$$\boxed{q = \frac{Z}{R} \cdot r}$$

Shear force on the elementary circular ring

= Shear stress in ring × Area of the ring

$$\delta F = \text{Shear stress in ring} \times [2\pi r \cdot dr]$$

$$= \left[\frac{Z}{R} r\right] \times [2\pi r \cdot dr]$$

$$dF = \frac{Z}{R} 2\pi r^2 \cdot dr$$

∴ Torque on the elementary circular ring

= δF × Distance of the ring from the centre.

$$\delta T = \delta F \times \text{Distance}$$

$$\delta T = \left[\frac{Z}{R} \cdot 2\pi r^2 \cdot dr\right] \times r$$

$$\boxed{\delta T = \frac{Z}{R} 2\pi r^3 \cdot dr}$$

∴ Total torque (or) Total resisting torsional moment.

$$T = \int_0^R \frac{Z}{R} 2\pi r^3 \cdot dr$$

$$= \frac{Z}{R} \cdot 2\pi \int_0^R r^3 \cdot dr$$

$$= \frac{Z}{R} \cdot 2\pi \left[\frac{R^4}{4}\right]_0^R$$

$$= \frac{Z}{R} \cdot 2\pi \left(\frac{R^4}{4}\right) = \frac{Z\pi R^3}{2}$$

$$T = \frac{\tau}{R}\left[\frac{\pi R^4}{2}\right] \quad [R = d/2]$$

$$T = \frac{\tau}{R}\left[\frac{\pi d^4}{32}\right]$$

$$\boxed{T = \frac{\tau}{R} \cdot J_P}$$

where $J_P = \frac{\pi d^4}{32}$ = Polar M.I of Solid circular shaft

$$\boxed{\frac{T}{J_P} = \frac{\tau}{R}} \rightarrow (4)$$

from eq (2) & (4)

$$\boxed{\frac{T}{J_P} = \frac{\tau}{R} = \frac{G\theta}{l}} \rightarrow (5)$$

The above equation (5) is known as torsional equation.

~~where~~.

Polar modulus (or) section modulus:

It is defined as the ratio of polar moment of ~~for the~~ Inertia to the radius of the shaft is known as polar modulus. It is denoted by Z (or) ZP.

W.K.T.

$$\frac{T}{J} = \frac{\tau}{R}$$

$$\frac{T}{J} = \frac{f_s}{R}$$

$$T = \left(\frac{J}{R}\right) \cdot f_s$$

$$T = Z_P \cdot f_s$$

$$T = \left(\frac{J}{R}\right) \cdot \tau$$

$$\boxed{T = Z \cdot \tau}$$ where $Z_P = \frac{J}{R}$ = polar modulus.

$Z_P = m^3$

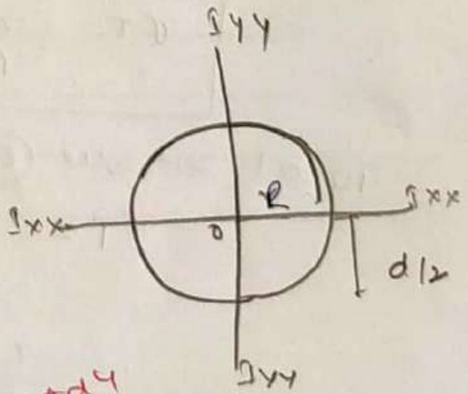
Z (or) ZP for solid shaft

$Z = J/R$ where = $I_{xx} + I_{yy}$

$$I_p = \frac{\pi d^4}{64} + \frac{\pi d^4}{64}$$

$$J = \frac{\pi d^4}{32}$$

solid shaft $I_P = J = \frac{\pi d^4}{32}$



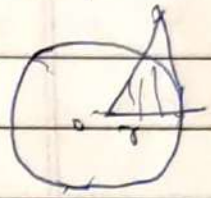
$$Z = \frac{\left(\frac{\pi d^4}{32}\right)}{(d/2)}$$

$$\boxed{Z = \frac{\pi d^3}{16}}$$

Polar modulus:

- Let T be the torsional moment of resistance of the section of a shaft of radius R and Ip [Jp] the polar moment of inertia of the shaft section.

The shear stress intensity q at any point on the section distant r from the axis of the shaft is given by



$$q_r = \frac{T}{I_p} \cdot r$$

$$\left[\frac{T}{J} = \frac{f_s}{R}\right]$$

$$f_s = \left(\frac{T}{J}\right) \cdot R$$

The maximum shear stress fs occurs at the greatest radius R.

$$f_s = \left(\frac{T}{J}\right) R.$$

$$T = f_s \cdot Z_P.$$

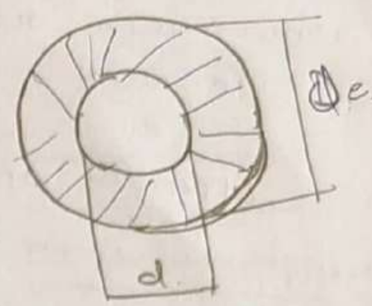
$$Z_P = \frac{I_P}{R}$$

$$f_s = \frac{J_P}{R} \text{ (or) } \frac{I_P}{R}$$

$$Z_P = \frac{\text{Polar moment of Inertia of the shaft}}{\text{Maximum radius}}$$

Z or Zp for Hollow shaft

$J = \frac{\pi}{32}[d_e^4 - d_i^4]$ & $R = D/2$



$Z = \frac{J}{R} = \frac{\pi/32\,(D^4 - d^4)}{D/2}$

$$Z = \frac{\pi}{16}\left[\frac{D^4 - d^4}{D}\right]$$

Torsional Rigidity

It is defined as the ratio of torque to the angle of twist is called torsional Rigidity. It is denoted by G or C or N.

Torsional Rigidity = Torque/angle of twist

$\frac{T}{J} = \frac{C\theta}{L}$

$Q = \frac{\tau}{\theta}$

$$G = \frac{T}{\theta}$$ or $\frac{T}{J_P} = \frac{G\theta}{l}$. $$\theta = \frac{T.l}{J_P.G}$$

Torsional flexibility

It is defined as the ratio of angle of twist to the torque is called torsional flexibility. In another word, it is the reciprocal of Torsional rigidity is called torsional flexibility.

Torsional flexibility $= \frac{\theta}{T} = \frac{l}{G}$

Torsional strength or efficiency of a shaft.

It is defined as the ratio of the torque or twisting moment to the shear stress is called torsional strength

Torsional strength: $\frac{\text{Torque}}{\text{Shear stress}}$

$= \frac{T}{\tau}$

Power transmitted by solid or & hallow circular Shaft.

Consider a shaft subjected to torque T & rotating at N revolutions per minute.

Angle through which the torque moves is $\frac{2\pi N}{60}$

Power is defined as the ratio of work done & it is denoted by

$P = \frac{2\pi N}{60} \times T$

$$P = \frac{2\pi NT}{60}$$ in watt

$P = \frac{2\pi NT}{60 \times 1000}$ in k.w

$P = \frac{2\pi NT}{60}$

5.

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Note: When power P is (substituted) in watts, n is in rpm, then the torque T obtained will be always in N-m.

Strength and Stiffness conditions

Strength condition: $\frac{T}{J} = \frac{\tau}{R}$

The above condition shows, that the shaft should be strong enough to resist shear stress.

Stiffness condition: $\frac{T}{J} = \frac{G \cdot \theta}{l}$

The above condition shows that the shaft should be stiff enough to resist twisting.

(6) Power Transmitted by Shaft:

If a shaft transmits a Torque 'T' @ 'N' rpm then work done is given by P = (Torque)(Angular displacement)

$P = (T)\left(\frac{2\pi N}{60}\right)$ ∴ $P = \frac{2\pi NT}{60}$

when P is in watts & 'N' is in rpm; then Torque obtained will be in N-m.

(1). A Shaft is subjected to a Torque 16,000 Nm. If the maximum permissible stress in the material of the shaft is $65 N/mm^2$, find. i) the diameter of the solid shaft & ii) the dimensions of a hollow circular shaft if the thickness is 10% of the internal diameter.

— Given: Torque $T = 16{,}000 N\text{-}m = 16\times10^6 N\text{-}mm$

Permissible stress $f_s = 65 N/mm^2$

i) hollow shaft $\frac{T}{J} = \frac{f_s}{R} = \frac{C\theta}{L}$

Strength Equ $\frac{T}{J} = \frac{f_s}{R}$ $J = \frac{\pi d^4}{32}$ $\frac{16\times10^6}{\left(\frac{\pi d^4}{32}\right)} = \frac{65}{(d/2)}$ $d = 107.82 mm$

$r = 53.91 mm$

ii) Solid Shaft

Let d be the inner diameter

∴ External diameter be 1.1 d.

$J = \frac{\pi}{32}(1.2d^4 - d^4) = \frac{\pi}{32}(0.2d^4)$ $\frac{16\times10^6}{\left(\frac{\pi\times0.2d^4}{32}\right)} = \frac{65}{(1.2d/2)}$

0.1d, d, 0.1d

(d+0.2d)

1.2d

$\left(\frac{1.2d}{2}\right)$

T is taken in N-m, then unit of power is N-m/sec ie watt.

One horse power = 736 watts.

1HP = 736 N-m

$1 HP = 736 \times 10^3 N\text{-}mm$

$\theta = 1° = \frac{\pi}{180}$ radian

② A solid shaft is required to transmit a max torque of 170 kN-m. If shear stress does not exceed 50 MPa & the angle of twist limited to 0.17°. Find the dia of shaft. $C = 8.4\times10^4$ MPa, length of shaft is 1m

$\frac{T}{J} = \frac{f_s}{R} = \frac{C\theta}{L}$ $J = \frac{\pi d^4}{32}$ $\theta = 0.17° \times \frac{\pi}{180} = 2.96\times10^{-3}$

case i) $\frac{T}{J} = \frac{C\theta}{L}$ $T = \frac{8.4\times10^4 \times 2.96\times10^{-3}}{1000} \times \frac{\pi \times d^4}{32} = 170\times10^6$

$d = 288.89$ mm $r = 144.44$ mm

case ii) $\frac{T}{J} = \frac{f_s}{R}$ $\frac{170\times10^6}{\frac{\pi\times d^4}{32}} = \frac{50}{d/2}$ $d = 258.71$ mm $r = 129.35$ mm

Adopt always the higher value of diameter to satisfy both strength & stiffness conditions.

③ Determine the diameter of solid shaft which transmit 440 kW at 280 rpm. The angle of twist must not exceed one degree per metre length and the maximum torsional shear stress is to be limited to 40 N/mm². Assume $C = 84$ kN/mm².

$P = 440$ kW $= 440\times10^3$ W $= 440\times10^3$ N-m/sec $= 440\times10^6$ N-mm/sec

$N = 280$ rpm $\theta = 1° = \frac{1\times\pi}{180} = 0.0174$ $L = 1$ m

$P = \frac{2\pi NT}{60}$ $T = 15.00\times10^6$ N-mm

$\frac{T}{J} = \frac{f_s}{R} = \frac{C\theta}{L}$ $\frac{T}{J} = \frac{C\theta}{L}$ $\frac{15\times10^6}{\left(\frac{\pi d^4}{32}\right)} = \frac{84\times10^3 \times 0.0174}{1000}$ $d = 101.11$ mm

$\frac{T}{J} = \frac{f_s}{R}$ $\frac{15\times10^6}{\left(\frac{\pi d^4}{32}\right)} = \frac{40}{(d/2)}$ $d = 124.087$ mm

$\therefore d_{min} = 124.087$ mm

④ Determine dia of the solid shaft which will transmit 90 kW @ 160 rpm if the shear stress in the shaft is limited to 60 MPa. Find also the length of the shaft if twist is limited to 1°. Take $C = 8\times10^4$ MPa

$P = \frac{2\pi NT}{60}$ $T = 5.371\times10^6$ N-mm $\frac{T}{J} = \frac{f_s}{R}$

$\frac{5.371\times10^6}{\left(\frac{\pi d^4}{32}\right)} = \frac{60}{d/2}$

$d = 76.96$ mm

$\frac{T}{J} = \frac{C\theta}{L}$ $\frac{5.371\times10^6}{\left(\frac{\pi\times76.96^4}{32}\right)} = \frac{8\times10^4\times0.0174}{L}$

$L = 892.57$ mm

(06) A hollow shaft of 20mm outer diameter & 2mm thick is subjected to a Torque of 40N-m. Find shear stress at Inner and outer diameter of shaft. Also find maximum shear stress.

→ $d_e = 20mm$ $d_i = 16mm$ $T = 40 N\text{-}m$

$T = 40 \times 10^3 N\text{-}mm$

$\frac{T}{J} = \frac{fs}{R}$ $R = d_e/2$

$J = \frac{\pi}{32}[20^4 - 16^4]$

$J = 9273.98 mm^4$

$\frac{40 \times 10^3}{9273.98} = \frac{fs]_e}{d_e/2} = \frac{fs]_e}{20/2}$

$fs]_e = 43.13 N/mm^2$

$\frac{40 \times 10^3}{9273.98} = \frac{fs]_i}{d_i/2} = \frac{fs]_e}{16/2}$

$fs]_i = 34.50 N/mm^2$

$fs]_{max}$ at circumference at outer diameter = $43.13 N/mm^2$

(07) A hollow shaft with outer diameter 'd' & inner diameter 'd/2' is transmitting 375 kW at 105 rpm with a working stress 40MPa Determine dimension of shaft & twist in a length equal to 10 times external diameter, $C = 8 \times 10^4 MPa$.

→ $d_e = d$ $d_i = d/2$ $P = 375 \times 10^6 N\text{-}mm$ $n = 105$ rpm

$fs = 40$.

$P = \frac{2\pi NT}{60}$ $375 \times 10^6 = \frac{2 \times \pi \times 105 \times T}{60}$

$T = 34.10 \times 10^6 N\text{-}mm$

$$\frac{T}{J} = \frac{f_s}{R}$$

$$\frac{34.10\times10^6}{\frac{\pi}{32}\left[d^4-\left(\frac{d}{2}\right)^4\right]} = \frac{40}{d/2}$$

$d_e = 166.68$ mm

$d_i = 83.84$ mm

$d_i = d/2 = \frac{166.68}{2} = 83.84$ mm

$$\frac{T}{J} = \frac{C\theta}{L}$$

$L = 10 \times d_e = 10\times166.68$

$$\frac{34.10\times10^6}{70.92\times10^6} = \frac{8\times10^4\times\theta}{10\times166.68}$$

$\theta = 0.101$ rad

$\theta = 0.57°$

) A 150mm dia solid steel shaft is transmitting 450kW power at 90 rpm. Compute the maximum shear stress. Find the change that would occur in the shearing stress. If the speed increased to 360rpm.

$d = 150$mm $\quad P = 450$ kW $\quad n = 90$rpm. $\quad f_s = ?$

case i) : $P = \frac{2\pi NT}{60}$

$450\times10^6 = \frac{2\times\pi\times90\times T}{60}$

$T = 47.74\times10^6$ N-mm

$= \frac{\pi}{32}d^4 = \frac{\pi}{32}\times[150]^4$

$= 49.7\times10^6$ mm^4

$$\frac{T}{J} = \frac{f_s}{R}$$

$$\frac{47.74\times10^6}{49.7\times10^6} = \frac{f_s}{150/2}$$

$f_s = 72.04$ N/mm^2

$f_s = 72.04$ N/mm^2

(11) A shaft is required to transmit 245 kW power ... than the

Case ii] when speed increased at 360 rpm

$$P = \frac{2\pi N T}{60}$$

$$450\times10^6 = \frac{2\times\pi\times360\times T}{60}$$

$$T = 11.936\times10^6 \text{ N-mm}$$

$$\frac{T}{J} = \frac{f_s}{R}$$

$$\frac{11.936\times10^6}{45.7\times10^6} = \frac{f_s}{150/2} =$$

$$f_s = 18.012 \text{ N/mm}^2$$

As speed of shaft increases the shear stress and Torque applied decreases.

(09) During tests on a sample of steel bar 25mm in diameter, it is found that the pull of 50kN produces an extension of 0.095mm on a length of 200mm and a torque 200 N-m produces an angular twist of 0.9 degree on a length 250mm. Find the Poisson's ratio of the steel.

us $d = 25$mm $P = 50\times10^3$ N $\delta L = 0.095$ $L = 200$mm

when under Tension test.

$$\sigma = \frac{P}{A} \qquad \epsilon = \frac{\delta L}{L} \qquad E = \frac{\sigma}{\epsilon}$$

$$\sigma = \frac{50\times10^3}{\frac{\pi}{4}(25)^2} \qquad \epsilon = \frac{0.095}{200} \qquad E = \frac{101.85}{4.75\times10^{-4}} = 214.42\times10^3 \text{ N/mm}^2$$

$$\epsilon = 4.75\times10^{-4}$$

$$\sigma = 101.85 \text{ N-mm}^2$$

Now under Torsion.

$T = 200\times10^3$ N·mm $\theta = 0.9° = 0.015$ rad.

$d = 25$mm

$L = 250$mm

$$\frac{T}{J} = \frac{G\theta}{L} = \frac{200\times10^3}{38.34\times10^3} = \frac{G\times0.015}{250}$$

$$J = \frac{\pi}{32}\times25^4 = 38.34\times10^3 \text{ mm}^4$$

$$G = 117.61\times10^3 \text{ N/mm}^2$$

...ller than the

A shaft is required to transmit 245 kW power

WKT $E = 2G(1+\mu)$

$2.14\times10^5 = 2\times1.17\times10^5 (1+\mu)$

$\mu = 0.2919$

(10) A hollow ~~pro~~ shaft of a steam ship is to transmit 3750 kW at 240 rpm. If the Internal diameter is 0.8 times the External diameter & if the maximum shear developed is to be limited to 160 N/mm², determine the size of the shaft.

$P = 3750\,kW = 3750\times10^6$ N-mm. $D_i = 0.8\,D_e$

$n = 240$ rpm

$f_s = 160\,N/mm^2$.

$$P = \frac{2\pi N T}{60}$$

$3750\times10^6\times60 = 2\times\pi\times240\times T$

$T = 1.492\times10^8$ N-mm

$$J = \frac{\pi}{32}\left[d^4 - (0.8d)^4\right]$$

$J = 0.05796\,d^4$

$$\frac{T}{J} = \frac{f_s}{R}$$

$$\frac{1.492\times10^8}{0.05796\,d^4} = \frac{160}{d/2}$$

$d = 200.37$ mm

$D_i = 0.8\,d_e$

$= 0.8\times200.37$

$D_i = 160.30$ mm

(11) A Shaft is required to transmit 245 kW power at 240 rpm. The maximum torque may be 1.5 times the mean torque. The shear stress in the shaft should not exceed 40 N/mm2 and twist 1° per meter length. Determine the diameter required if a) the shaft is solid. b) The shaft is hollow with External diameter twice the Internal diameter. q = 80 kN/mm2.

→ $P = 245\,kW = 245\times10^6$ N-mm $n = 240$ rpm. $\theta = 1°$ $L = 1m$

$T_{max} = 1.5\,T =$

$f_s = 40\,N/mm^2$

$P = \frac{2\pi NT}{60}$ $245\times10^6 = \frac{2\times\pi\times240\times T}{60}$

$T = 9.748\times10^6$ N-mm

$T_{max} = 1.5\times9.748\times10^6$

$T_{max} = 14.622\times10^6$ N-mm

$1°\times\frac{\pi}{180}$

$\theta = 0.017$

a) Solid shaft

$\frac{T}{J} = \frac{fs}{R}$

$\frac{T}{J} = \frac{C\theta}{L}$

$\frac{14.622\times10^6}{\frac{\pi}{32}\times d^4} = \frac{80\times10^3\times0.017}{1000}$

$14.622\times10^6\times1000\times32 = 80\times10^3\times0.017\times\pi\times d^4$

$d^4 = 109513580.1$

$d = 102.29\,mm$

$$\frac{T}{J} = \frac{f_s}{R}$$

$$\frac{14.622\times10^6}{\frac{\pi}{32}\times d^4} = \frac{40}{d/2}$$

~~$14.622\times10^6\times 32\times d^3 = 40\times\pi\times d^3$~~

$d = 123.02\text{ mm}$

adopt 123.02 mm of

Hollow shaft

d = outer dia $d/2$ = Inner dia.

$$J = \frac{\pi}{32}\left[d^4 - 0.5d^4\right]$$

$$= 0.0920 d^4$$

$$\frac{T}{J} = \frac{f_s}{R}$$

$$\frac{14.622\times10^6}{0.0920 d^4} = \frac{40}{d/2}$$

$d = 125.696\text{ mm}$

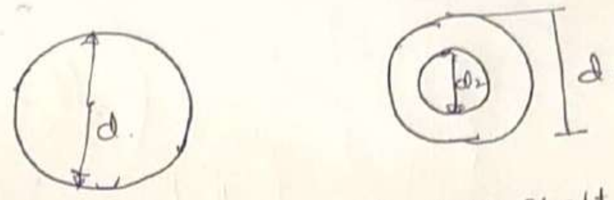
$$\frac{T}{J} = \frac{C\theta}{L}$$

$d = 103.281\text{ mm}$

Adopt $d_o = 125.696$ mm $d_i = 62.841$ mm

Dec 2024

Prove that a hollow shaft is Stronger & Stiffer than the Solid shaft of the same material, length & weight.



Solid Shaft · Hollow shaft ·

Let,

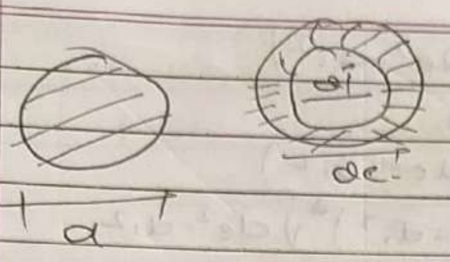
d = diameter of Solid shaft.

d_1 = outer dia of Hollow shaft.

d_2 = Inner diameter of Hollow shaft.

The two shafts have equal weight & length & are of same material. Hence equating the weight of Solid shaft to that of hollow shaft.

· weight



$\rho_s = \rho_H$

$L_s = L_H$

$W_s = W_H$

$W_s = W_H$

((Density) (Volume))$_s$ = ((Density) (Volume))$_H$

(Volume)$_s$ = (Volume)$_H$

((Area) (length))$_s$ = ((Area) (length))$_H$

(Area)$_s$ = (Area)$_H$

$$\frac{\pi d^2}{4} = \frac{\pi}{4}(d_e^2 - d_i^2)$$

$$d^2 = (d_e^2 - d_i^2)$$

$$d = \sqrt{(d_e^2 - d_i^2)}$$

Case: 1. Show hollow shaft is stronger than solid sh.

w.r.t.

$$\frac{T}{J} = \frac{f_s}{R} = \frac{C\theta}{L}$$

$$\frac{T}{J} = \frac{f_s}{R} \quad = \quad \frac{T}{f_s} = \frac{J}{R}$$

$$\frac{\left(\frac{T}{f_s}\right)_H}{\left(\frac{T}{f_s}\right)_s} = \frac{\left(\frac{J}{R}\right)_H}{\left(\frac{J}{R}\right)_s} = \frac{\left(\frac{\pi}{32}(d_e^4 - d_i^4)\right)\left(\frac{1}{d_e/2}\right)}{\frac{\pi}{32}(d^4)\left(\frac{1}{d/2}\right)}$$

$$= \frac{(d_e^4 - d_i^4)\frac{1}{d_e}}{d^4\left(\frac{1}{d}\right)} = \frac{(d_e^4 - d_i^4)}{d_e \cdot d^3}$$

$$= \frac{(de^2 + di^2)(de^2 - di^2)}{de \cdot d^2 \cdot d}$$

$$= \frac{(de^2 + di^2)(de^2 - di^2)}{de \cdot (de^2 - di^2) \sqrt{de^2 - di^2}}$$

$$\frac{\left.\frac{T}{bs}\right|_H}{\left.\frac{T}{bs}\right|_S} = \frac{(de^2 + di^2)}{de \cdot \sqrt{de^2 - di^2}} \qquad \left(de \sqrt{\left(1 - \frac{di^2}{de}\right) de^2}\right)$$

multiplying numerster & demonenter by $(1/de^2)$ we get

$$\left.\frac{T}{bs}\right|_H = \frac{\left(\frac{de^2}{de^2} + \frac{di^2}{de^2}\right)}{\frac{de^2}{de^2} \cdot \sqrt{\frac{de^2}{de^2} - \frac{di^2}{de^2}}}$$

$$\frac{\left.\frac{Ts}{bs}\right|_H}{\left.\frac{Ts}{bs}\right|_S} = \frac{\left(1 + \frac{di^2}{de^2}\right)}{\left(\sqrt{\left(1 - \frac{di^2}{de^2}\right)}\right)} > 1$$

Hence hollow shaft is stronger than solid shaft

Green book PAGE NO. DATE / /

Case: 2 Hallow shaft is stiffer.

From stiffness consider

$$\frac{T}{J} = \frac{C\theta}{L}.$$

$$\frac{T}{\theta} = \frac{C \cdot J}{L}$$

$$\frac{\frac{T}{\theta}\Big]_H}{T/\theta\Big]_S} = \frac{\frac{C \cdot J}{L}\Big]_H}{\frac{C \cdot J}{L}\Big]_S} = \frac{\frac{T}{\theta}\Big]_H}{\frac{T}{\theta}\Big]_S} = \frac{J]_H}{J]_S}$$

$$\frac{T/\theta\Big]_H}{\frac{T}{\theta}\Big]_S} = \frac{\frac{\pi}{32}(de^4 - di^4)}{\frac{\pi}{32}(d^4)} = \frac{(de^4 - di^4)}{d^4}$$

$$= \frac{(de^2 + di^2)(de^2 - di^2)}{d^2 \cdot d^2}$$

$$\frac{T/\theta\Big]_H}{\frac{T}{\theta}\Big]_S} = \frac{(de^2 + di^2)(de^2 - di^2)}{(de^2 - di^2)(de^2 - di^2)}$$

$$= \frac{de^2 + di^2}{(de^2 - di^2)} > 1$$

$$\Rightarrow$$

Hence hallow shaft is stiffer than solid shaft.

13) Compare the weight of solid shaft with that of a hollow one having the same length to transmit a given power at a given speed, if the material used for both the shaft is the same. Take the inside dia of the hollow shaft as 0.6 times the outer diameter.

- Let d be the diameter of solid shaft

Let d_1 be the outer dia of hollow shaft.

$\therefore$ Inner diameter of hollow shaft $= 0.6d_1$

Let P be the power transmitted by both shaft

N be their rpm

T be the corresponding shaft.

From Strength consideration

$\frac{T}{J} = \frac{f_s}{R}$ Solid Shaft: $J = \frac{\pi}{32} d^4$

$$T = \frac{f_s}{d/2} \frac{\pi}{32} d^4 = \frac{\pi}{16} d^3 f_s \quad \text{--- (1)}$$

Hollow Shaft $J = \frac{\pi}{32}\left[d_1^4 - (0.6d_1)^4\right] = \frac{\pi}{32} 0.8704 d_1^4$

$$T = \frac{\pi}{16} 0.8704 d_1^3 f_s \quad \text{--- (2)}$$

Equating (1) & (2)

$$d^3 = 0.8704 d_1^3$$

$$d = 0.9547 d_1$$

Area of Solid Shaft. $A_S = \frac{\pi d^2}{4} = \frac{\pi (0.9547 d_1)^2}{4} = 0.7158 d_1^2$

Hollow Shaft $A_H = \frac{\pi}{4}\left(d_1^2 - (0.6d_1)^2\right) = 0.5026 d_1^2$

$$\frac{A_S}{A_H} = 1.423$$

Area of Solid Shaft is 42% more than Hollow Shaft. ~~w~~ when Strength is Considered.

From Stiffness consideration

$\frac{T}{J} = \frac{G\theta}{L}$ SS $J = \frac{\pi}{32} d^4$ =

HS $J = \frac{\pi}{32}\left[d_1^4 - (0.6d_1)^4\right] = \frac{\pi}{32}(0.8704\, d_1^4)$

SS $T = \frac{G\theta}{L}\,\frac{\pi}{32} d^4$

HS $T = \frac{G\theta}{L}\,\frac{\pi}{32}(0.8704 d_1^4)$

$d^4 = 0.8704 d_1^4$ =

$d^2 = 0.9329 d_1^2$

$A_S = \frac{\pi}{4} 0.9329 d_1^2$

$A_H = \pi/4 \left[d_1^2 - (0.6d_1)^2\right]$

$\frac{A_S}{A_H} = \frac{0.9329}{0.64} = 1.45$

Area of Solid shaft is 45% more than hollow shaft when Stiffness is considered.

(14) A solid shaft transmits 250 kW at 100 rpm. If the shear stress is not to exceed 75 N/mm², what should be the diameter of the shaft? If this shaft is to be replaced by a hollow one whose internal dia is equal to 0.6 times outer dia, Determine the size & the % saving in weight, the maximum shearing stress being same.

$P = 250\text{ kW} = 250 \times 10^6\text{ N-mm/sec}$

$P = \frac{2\pi N T}{60}$ $T = 23.87327 \times 10^6\text{ N-mm}$

Solid shaft: $\frac{T}{J} = \frac{f_s}{R}$ $d = 117.473\text{ mm}$

Hollow shaft: $d_i = 0.6 d_e$

$d_e = 123.036\text{ mm}$ $d_i = 73.822\text{ mm}$

$A_S = 10838.421\text{ mm}^2$ $A_H = 7609.164\text{ mm}^2$

$\%\text{ Saving in weight} = \frac{W_S - W_H}{W_S} \times 100$

$= \frac{(A_S - A_H)\rho L}{A_S \rho L} \times 100 = 29.75\%$

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A solid shaft of 60mm dia rotates at 160rpm. Find the power that the shaft can transmit if permissible shear stress is 80Mpa & max Torque likely to exceed 30% AvgT. Also find the angle of twist in degrees for a length of 8000mm if G = 80Gpa.

$T_{max} = T_{avg} \times 1.3$

$\frac{T_{max}}{J} = \frac{f_s}{R}$ $\quad T_{max} = 3.393 \times 10^3$ N-m $\quad T_{avg} = \frac{T_{max}}{1.3}$

$= 2.6099 \times 10^3$ N-m

$\frac{T_{max}}{J} = \frac{C\theta}{L} \Rightarrow \theta = 0.2669$ rad $(15°17')$.

$P = \frac{2\pi NT}{60} = 43.73$ kW.

Compare torsional strength ~~and angle~~ of 2 shafts of same material, length & weight & having same max. shear stress. One is solid & other is hollow ~~having~~ with ... ID of diameter is 0.5. Take same rigidity modulus.

$L_s = L_H$, $W_s = W_H$ $\quad f_s J_H = f_s J_s$

$d_i = 0.5 d_e$, d.

$W_H = W_s$

$\rho(Vol)_H = \rho(Vol)_s$

$d_e^2 - d_i^2 = d^2$

$\frac{T}{J} = \frac{f_s}{R}$

$$\frac{T_H}{T_s} = \frac{f_s\left[\frac{\pi/32\,(d_e^4 - d_i^4)}{(d_e/2)}\right]}{\left[f_s \frac{\pi/32\, d^4}{(d/2)}\right]}$$

$$\frac{T_H}{T_s} = \frac{\frac{(d_e^2 - d_i^2)(d_e^2 + d_i^2)}{d_e}}{d^2 d}$$

$$\frac{T_H}{T_s} = \frac{d_e^2 + d_i^2}{d_e d} = \frac{d_e^2 + 0.25 d_e^2}{d_e\sqrt{d_e^2 - 0.25 d_e^2}}$$

$$= \frac{1.25 d_e^2}{0.86 d_e^2} = 1.453$$

$$\frac{T_H}{T_s} = 1.453$$

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Module: 4

(17) What % of strength of a solid circular shaft 100mm diameter is lost by boring 50mm axial hole in it? Compare the strength & weight ratio of two cases.

$$T_S = \frac{\pi}{32} 100^2 \times \frac{f_s}{50} = 19.63 f_s$$

$$T_H = \frac{\pi}{32}(100^2 - 50^2)\frac{f_s}{100} = 14.72 f_s$$

$$\frac{T_H}{T_S} = \frac{14.72}{19.63} = 0.749$$

Loss in strength $= \frac{T_S - T_H}{T_S} \times 100$

$= \left(1 - \frac{T_H}{T_S}\right) \times 100$

$= 25\%$

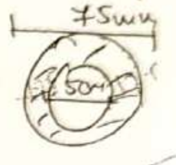
$$\text{Weight ratio} = \frac{W_H}{W_S} = \frac{\rho L \frac{\pi}{4}(100^2 - 50^2)}{\rho L \frac{\pi}{4} 100^2}$$

$$= 0.75$$

(18) P.T. Shear stress due to the pure Torsion is proportional to the radius of circular shaft.

(Refer derivation)

14. what power can be transmitted at 300 rpm by a hallow shaft of 75 mm external dia & 12.5 mm thickness when the permissable shear stress is 70 N/mm² & the maximum torque is 1.30 times the mean. compare the strength of this hallow shaft with that of a ~~hallow~~ solid shaft of the same material, weight & length.



⇒ $P = ?$

$n = 300$ rpm

$d_e = 75$ mm

$d_i = 50$ mm

$f_s = 70$ N/mm²

$T_{max} = 1.3\ T_{mean}$

$$J = \frac{\pi}{32}(75^4 - 50^4)$$

$$J = 2.492 \times 10^6 \text{ mm}^4$$

$$P = \frac{2 n \pi T_{avg}}{60} = \frac{(2)(300)(\pi) T_{avg}}{60}$$

$$P = 31.41\ T_{avg} \rightarrow (*)$$

$$R = \frac{d_e}{2} = 37.5 \text{ mm}$$

$$\frac{T_{max}}{J} = \frac{f_s}{R} \Rightarrow \frac{T_{max}}{2.492 \times 10^6} = \frac{70}{37.5}$$

$$T_{max} = 4.65 \times 10^6 \text{ N-mm}$$

$T_{max} =$ ~~Tavg~~ $+ (1.3)\ T_{avg}$.

$$T_{mean} = \frac{T_{max}}{1.3} = 3.57 \times 10^6 \text{ N-mm}$$

$T_{mean} = 3.57 \times 10^3$ N m.

$P = 31.41\ T_{mean}$.

$P = 31.41 \times 3.57 \times 10^3$

$P = 112.13 \times 10^3$ W

Consider a solid shaft of dia 'd' as shown in figure.

$l_H = l_s$
$w_H = w_s$
$\rho_H = \rho_s$.

$w_H = w_s$.

$[(\rho)(v)]_H = [(\rho)(v)]_s$

$[(A)(l)]_H = [(A)(l)]_s$

$A_H = A_s$.

$\frac{\pi}{4}[75^2 - 50^2] = \frac{\pi}{4}[d^2]$

~~2454.36~~.

$d = 55.9$ mm

WKT

Strength equation $\frac{T}{J} = \frac{f_s}{R}$.

$\frac{T]_H}{T]_s} = \frac{[f_s \times J/R]_H}{[f_s \times J/R]_s}$.

f_s- material same.

$= \frac{\frac{(2.49 \times 10^6)}{d_{o}/2 = 75/2}}{\frac{(958.6 \times 10^3)}{55.9/2}}$.

$J = \frac{\pi}{32}(55.9)^4$.

$J = 958.6 \times 10^3 \text{ mm}^4$

27.95.

$\frac{T]_H}{T]_s} = \frac{66400}{34296.95} = 1.93$

15. A hallow shaft of dia of ratio 3/5 is required to transmit 700 kW at 110 rpm, the max torque being 12% greater than the mean. the shear stress is not to exceed 60 MPa & twist in a length of 3m is not to exceed (1)°. calculate the cross sectional dimension. Given $G = 0.8 \times 10^5$ MPa.

=> $P = 700\ kW = 700 \times 10^3\ W$.

$n = 110$ rpm.

$T_{max} = 12\%\ T_{avg}$.

$f_s = 60\ N/mm^2$.

$l = 3000$ m.

$\theta = (1)^\circ = 0.01745$

$G = 0.8 \times 10^5\ N/mm^2$.

$\frac{d_i}{d_e} = 3/5$

$d_i = 0.6\, d_e$

$P = \frac{2 n \pi T_{avg}}{60}$.

$T_{avg} = \frac{(P)(60)}{2 n \pi}$.

$= \frac{(700 \times 10^3 \times 60)}{2 \times 110 \times \pi}$

$T_{avg} = 60.76 \times 10^3$ N m.

$T_{avg} = 60.76 \times 10^6$ N-mm

$T_{max} = T_{avg} + 0.12\, T_{avg}$

$T_{max} = (0.12)(60.76 \times 10^6) + 60.76 \times 10^6$.

$T_{max} =$ ~~7.2912×10^6~~ N-mm 68.05×10^6.

$J = \pi/32\, [d_e^4 - 0.6^4 d_e] = 0.085\, d_e^4$.

$R = d_e/2$

$\frac{T_{max}}{J} = \frac{f_s}{R}$.

$\frac{68.05 \times 10^6}{0.085\, d_e^4} = \frac{60}{d_e/2}$

$d_e = 188.25$ mm

$d_i = 112.95$ mm.

$\frac{T_{max}}{J} = \frac{C\theta}{l}$.

$\frac{68.05 \times 10^6}{0.085\, d_e^4} = \frac{(0.8 \times 10^5)(0.01745)}{3000}$.

$d_e = 203.66$

$d_i = 122.19$

16. A solid circular shaft has to transmit a power of 1000 kW at 120 rpm. Find the diameter of shaft if shear stress limited to 80 MPa. The max torque 1.25 is its mean. What % of saving in material is would be obtained if the shaft is replaced by hallow (shaft) one whose internal dia is 0.6 times external dia, the length, material & maximum shear stress being same.

=> $P = 1000 \times 10^3$ W }
$n = 120$ rpm.

=> $P = 1000 \times 10^3 W$.

$n = 120$ rpm.

$f_s = 80 \ N/mm^2$

$T_{max} = 1.25 \ T_{avg}$

$d_i = 0.6 \ d_e$

$P = \frac{2 n \pi T}{60}$

$T_{avg} = \frac{(P)(60)}{2 n \pi} = \frac{(1000 \times 10^3 \times 60)}{2 \times 120 \times \pi}$

$T_{avg} = 79.577 \times 10^6$ Nmm

$T_{max} = 1.25 \ T_{avg} = 99.47 \times 10^6$ Nmm.

$J = \frac{\pi}{32} (d^4)$ $\quad R = d/2$

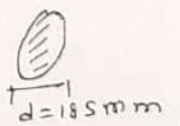
$$\frac{T_{max}}{J} = \frac{f_s}{R}$$

$$\frac{99.47 \times 10^6}{\pi/32 \, (d^4)} = \frac{80}{d/2}$$

$$(99.47 \times 10^6 \times 32) \, d = (80 \times \pi \times 2) \, d^4$$

$$d = 185 \text{ mm}$$

For given condition dia of the solid shaft is 185 mm



1. Consider a hallow shaft of

external dia $= d_e$

Internal dia $= d_i = (0.6) \, d_e$

given

$l_s = l_H$

$\rho_A = \rho_H$

$f_s]_A = f_s]_H$ = maximum.

given $f_s = f_H$

$\frac{W}{V} = \frac{W}{Al}$

$= \frac{W}{\frac{\pi}{4}(d^4)\,l}$

$f_s]_s = f_s]_H$

$\frac{W}{\frac{\pi}{4}(d^4)\,l} = \frac{W}{\frac{\pi}{4}(d^4)\,l}$

$\frac{TR}{J}\Big]_s = \frac{TR}{J}\Big]_H$

$\frac{T}{J} = \frac{f_s}{R}$

$$R = \frac{d/2}{\frac{\pi}{32}(d^4)} = \frac{d_e/2}{\frac{\pi}{32}[d_e^4 - d_i^4]}$$

$d_e = 185$ mm

$d_i = 111$ mm

$$\frac{d}{2d^4} = \frac{92.5}{[185^4 - 111^4]}$$

1019 54358

$$\frac{1}{d^3} = \frac{2 \times 92.5}{(1019 54358)}$$

193

$d^3 =$

$d_e^4 (92.5 \times 2 \times 0.8704) = (92.5)^4 d_e$

$$\frac{92.5}{(92.5)^4} = \frac{d_e/2}{(d_e^4 - 0.6 d_e^4)}$$

$= (0.8704)d_e$

$d_e = 193$ mm. $d_i = 116.29$ mm

$$\% \text{ saving in material} = \frac{W_s - W_H}{W_s} \times 100$$

$$= \frac{\{(\rho)(V)\}_s - \{(\rho)(V)\}_H}{\{(\rho)(V)\}_s} \times 100$$

$$= \frac{\{(Al)\}_s - \{(Al)\}_H}{\{(Al)\}_s} \times 100$$

$$\% = \frac{\frac{\pi d^2}{4} - \frac{\pi}{4}(d_e^2 - d_i^2)}{\frac{\pi}{4}(d^2)} \times 100$$

$$\% = \frac{d^2 - (d_e^2 - d_i^2)}{d^2} \times 100$$

$$= \frac{185^2 - (193^2 - 116.29^2)}{(185)^2} \times 100$$

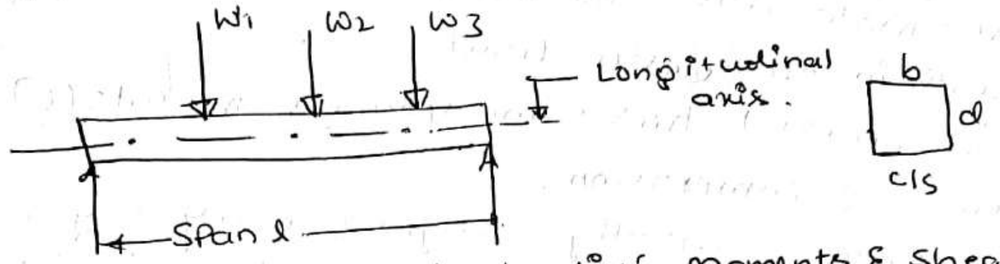
23725.62

$$\therefore \% = 29.76\,\%$$

Module - 4. Bending & Shear Stresses in Beams

①

A Beam is a structural member on which a system of external loads acts at right angles to its longitudinal axis, as shown in fig.



Due to these lateral loads, bending moments & shear forces are ~~setup~~ developed along the length of the beam & longitudinal stress is developed at any section. to bending is known as bending stress (or) flexure.

Theory of simple Bending

When a beam is bent due to the application of a constant bending moment, without any shear, it is said to be in a state of simple bending (or) pure bending.

Consider a simply supported beam AB acted upon by two equal loads as shown in fig(a)

In the simply supported beam, it is seen that in b/w c and D the bending is constant & their is no shear force,

Hence the Beam portion CD is subjected only to constant bending Moment, & free from shear force. This condition of the beam in b/w C&D is called Pure bending.

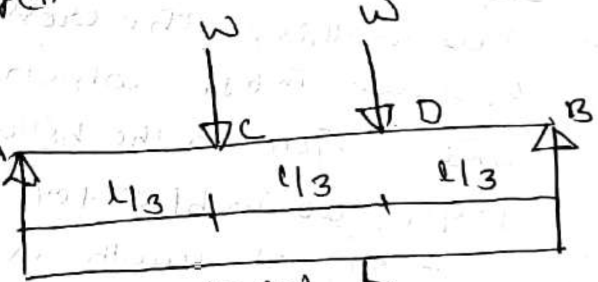
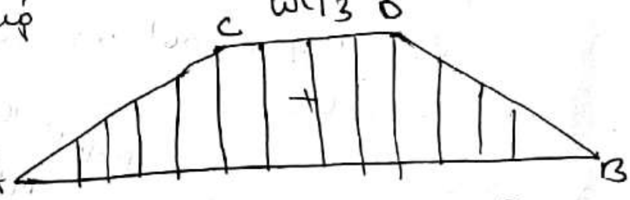


fig (a)



fig(b) Bending Moment Diagram

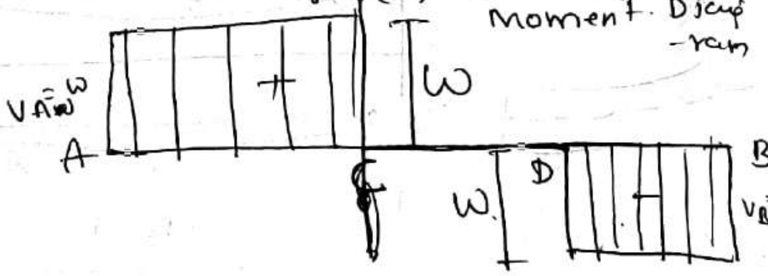


fig (c) Shear force Diagram

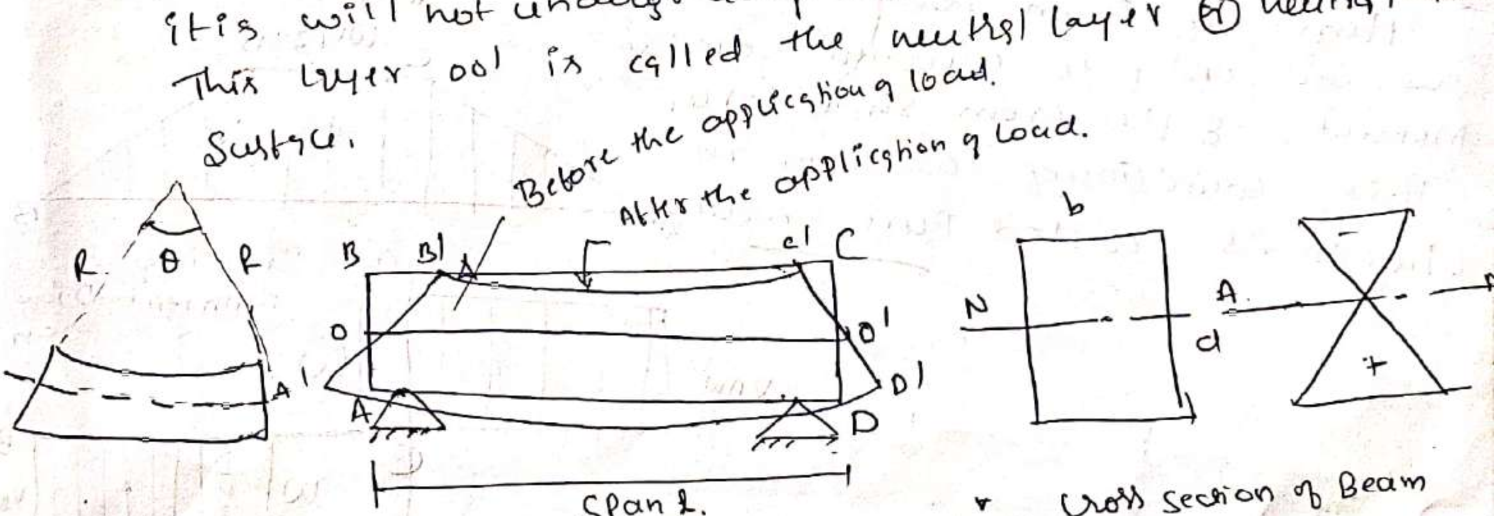
Assumptions made in Theory of Pure bending:

- The following are some of the Assumptions for theory of Pure Bending as follows.

1. The material is homogenous, Isotrophic, & obeys Hook's Laws with in the elastic limit.
2. The material has same young's moduls [E] both in tension & compression.
3. The beam is initially straight & every layer of material is free to expand (or) contract longitudinally.
4. The Stress is purely longitudinal.
5. Radius of curvature [R] of beam is very large compared to dimensions of beam.
6. The cross section of beam which is plane before bending will remain plane even after bending it, no wrapping (or) no distortion.

contin Theory of simpling Bending:

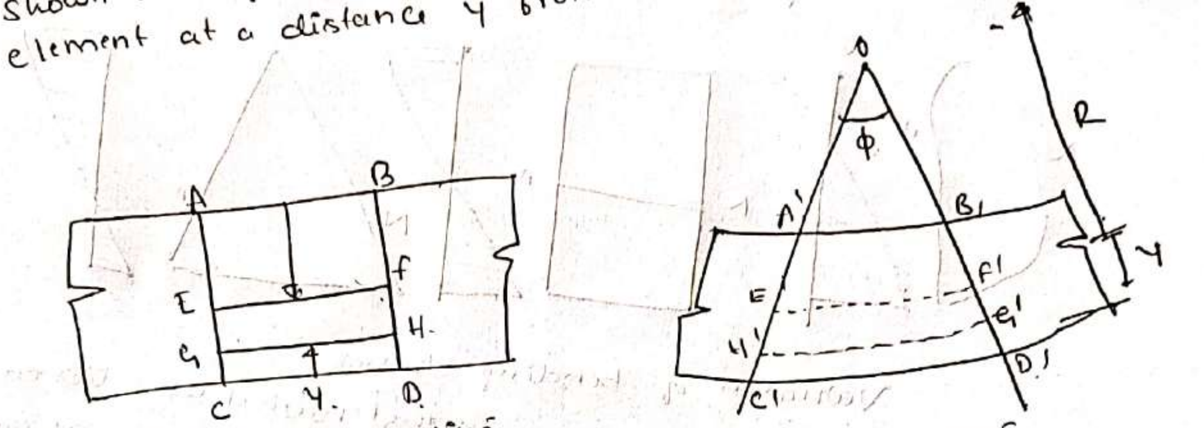
When a beam is subjected to external loads, it undergoes deformation and beam attains a curved in shape. Due to this, the cross section AB rotates through an angle θ as shown in fig. which causes compression in the top fibres and tension in the bottom fibers. However there exists a layer OO' in b/w top and bottom fibres, which will retain its original length even after deformation. it is will not undergo any change in its length. This layer OO' is called the neutral layer (or) neutral axis surface.



Neutral axis [N-A] always lies on the centroid of the cross section.

Relationship b/w Bending stresses and Radius of curvature

Consider a portion of beam b/w sections AC and BD as shown in fig(a). Let EF be the neutral axis and GH an element at a distance y from neutral axis.



(a) Before Bending. (b) After Bending.

Fig (b) shows the same portion after bending. Let R be the radius of curvature and φ be the angle subtended by C'A' and D'B' at the centre of curvature.

Since EF is the neutral axis, There is no change in its length [at neutral axis stresses are zero]

$$EF = E'F' = R\phi$$

Now Strain in the layer GH = $\frac{\text{Final length} - \text{original length}}{\text{original length}}$

$$= \frac{G'H' - GH}{GH}$$

$$GH = EF = R\phi$$

$$G'H' = (R+y)\phi$$

Strain in the layer GH = $\frac{(R+y)\phi - R\phi}{R\phi} = \frac{y}{R}$

$$\boxed{\epsilon = \frac{y}{R}}$$

We know that from hook's law.

$E = \frac{f}{\epsilon}$ Youngs modulus = $\frac{\text{stress}}{\text{strain}}$

$$E = \frac{f}{\epsilon}$$

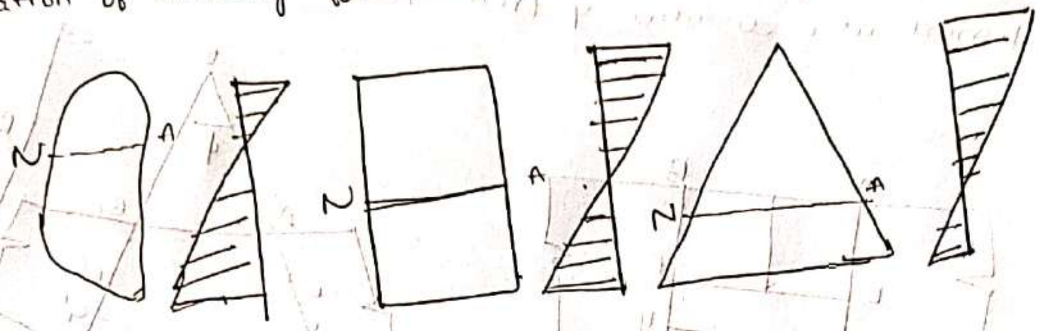
$$\epsilon = \frac{f}{E}$$

(or) $\frac{y}{R} = \frac{f}{E}$ (or) $f = \frac{y}{R} \times E$ (or) $\frac{E}{R} \times y$

$$\boxed{f = \frac{E}{R} \times y} \rightarrow (1)$$

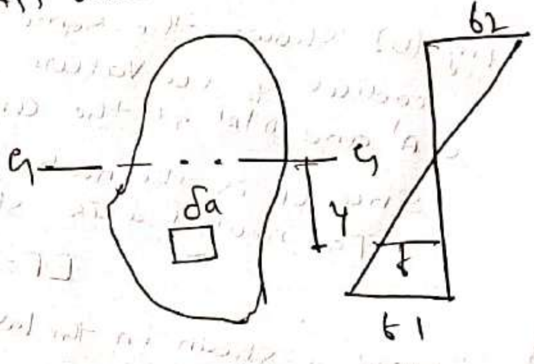
Head of C.E.D

Thus, bending stress varies linearly across the depth. The typical variation of bending for various sections are shown in fig.



Variation of bending stresses.

In all these cases it can be seen that neutral axis lies on the centroid of the section. Consider a beam with arbitrary cross-section as shown in fig. consider an elemental area δa at distance y from the neutral axis.



Let f be the stress on this area.

Force on elemental area = $f \cdot \delta a$

Total force on cross section of beam $= \Sigma f \cdot \delta a$

but from eq ① $f = \frac{E}{R} \cdot y$

Total force on cross section $= \Sigma \frac{E}{R} \cdot y \cdot \delta a = \frac{E}{R} \Sigma y \cdot \delta a$

Since there is no axial force on the beam and the above force is in axial direction, from equilibrium condition we get.

$$\frac{E}{R} \Sigma y \cdot \delta a = 0$$

$$\Sigma y \cdot \delta a = 0$$

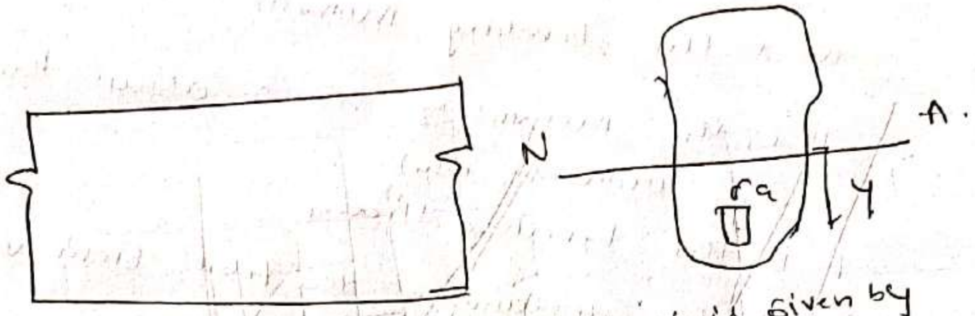
$$\frac{\Sigma y \cdot \delta a}{A} = 0$$

where A is the total area.

Since $\Sigma y \cdot \delta a$ is the first moment of area about the neutral axis, $\frac{\Sigma y \cdot \delta a}{A}$ is the distance of the centroid from the neutral axis. Thus neutral axes coincides with the centroid of the cross section.

Relationship b/w moment and Radius of curvature:

Consider an elemental area δa at a distance y from the neutral axis in the beam, the cross section of which is shown in fig



Now stress f on this element is given by

$$f = \frac{E}{R} \cdot y$$

Force on this element $= f \cdot \delta a$

$$= \frac{E}{R} \cdot y \cdot \delta a$$

Moment of this resisting force about the neutral axis

$$= \frac{E}{R} \cdot y \cdot \delta a \cdot y$$

$$= \frac{E}{R} \cdot y^2 \cdot \delta a$$

Total moment of resistance (M') of the cross sectional area

$$M' = \Sigma \frac{E}{R} \cdot y^2 \cdot \delta a$$

From definition of moment of inertia, which is second moment of area about centroid, we can write

$$I = \Sigma y^2 \delta a$$

Where I is the centroidal moment of inertia.

$$M' = \frac{E}{R} I$$

For equilibrium of the moment of resistance (M') should be equal to the applied moment M

$$M' = M$$

$$M = \frac{E}{R} \cdot I$$

$$\frac{M}{I} = \frac{E}{R} \quad \text{eq (3).}$$

From eq (1) & (3) we get

$$\frac{M}{I} = \frac{E}{R} = \frac{f}{y}$$

Head of C.E.D

$$\frac{M}{I} = \frac{f}{y} = \frac{E}{R}$$

Where = M is the bending moment

I is the moment of Interia about the centroidal axis

f is the bending stresses.

y is the distance of the fibre from neutral axis

E = youngs modulus.

R = is the radius of curvture

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Section modulus

W.K.T. $\frac{M}{I} = \frac{f}{y} = \frac{E}{R}$ Bending moment equation. $= M = \left(\frac{I}{y}\right) f = Z$

hence $\frac{M}{I} = \frac{f}{y} \Rightarrow M = \left(\frac{I}{y}\right) f = Zf$

where Z is refered as section modulus. The ratio of Moment of inertia to the distance of extreme fibre (or) layer in tension (or) compression is known as section modulus.

$$Z = \frac{I}{y_t} = \frac{I}{y_c} = \frac{I}{y_{max}} \qquad = \frac{mm^4}{mm} \quad I = mm^4 \quad y = mm$$

Denoted by Z and unit as mm^3

To Design a beam section if the value of bending moment M is known, then the equation $M = (Z)(f)$ is used to calculate the required section modulus (or) moment of Inertia.

$$M = \left(\frac{I}{y}\right)(f)$$

Flexural rigidity.

From the bending equation we have

$$\frac{M}{I} = \frac{E}{R}$$

$$M = \frac{EI}{R}$$

(or) $\frac{1}{R} = \frac{M}{EI}$

In the above equation, bending moment M, youngs modulus E and moment of Inertia I are constant. Hence R will also be constant.

Radius of curvature R at any point of the elastic curve of a beam is directly proportional to (EI) & inversly proportional to (M). The product EI is refered as flexural rigidity.

Modulus of Rupture: (sudden failure). When a beam is loaded upto failure the stresses in the beam section can not be calculated by using bending equation

$$f = M/Z$$

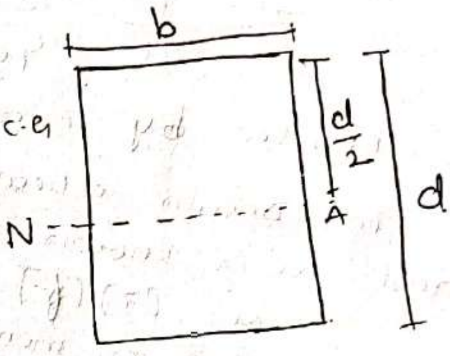
But sometimes to compare strength of beams of different materials the same bending equation is used.

The stress calculated at rupture using bending equation is known as modulus of rupture.

The term modulus of rupture is limited to cast iron, timber and rectangular section.

Section modulus for various shapes (or) Beam sections

1. Rectangular section:



Moment of inertia of a rectangular section about an axis through its c.g (or neutral axis NA) is given by

$$I = \frac{bd^3}{12}$$

Distance of outermost layer from NA is given by

$$y_{max} = \frac{d}{2}$$

(4) ∴ section modulus is given by

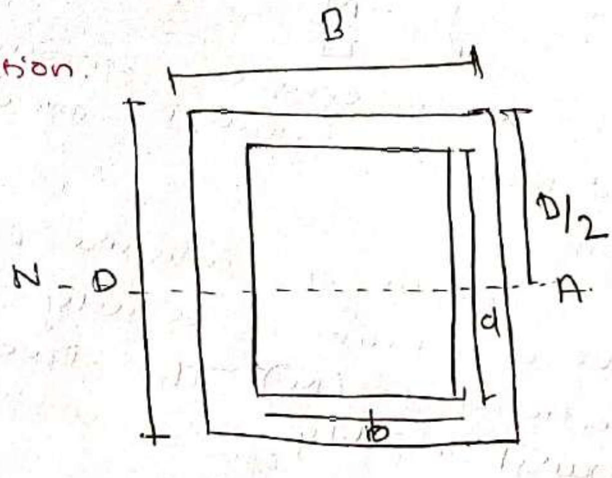
$$Z = \frac{I}{y_{max}} = \frac{bd^3}{12 \times \left[\frac{d}{2}\right]} = \frac{2bd^3}{12d} = \frac{bd^2}{6}$$

for Rectangular: $Z = \frac{bd^2}{6}$

For square $b = d$

$$Z = \frac{d^3}{6} \text{ (or) } \frac{b^3}{6}$$

(5) Hollow Rectangular section.



Here $I = \frac{BD^3}{12} - \frac{bd^3}{12}$

$$= \frac{1}{12}\left[BD^3 - bd^3\right]$$

$y_{max} = D/2$

$$Z = \frac{\frac{1}{12}\left[BD^3 - bd^3\right]}{D/2}$$

$$= \frac{1}{6D}\left[BD^3 - bd^3\right]$$

$$Z = \frac{BD^3 - bd^3}{6D}$$

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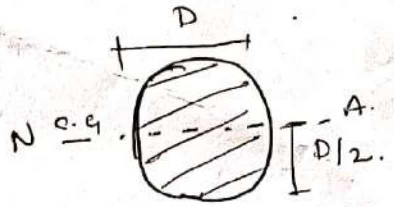
③ For circular section.



$I = \frac{\pi D^4}{64}$ $y_{max} = D/2.$

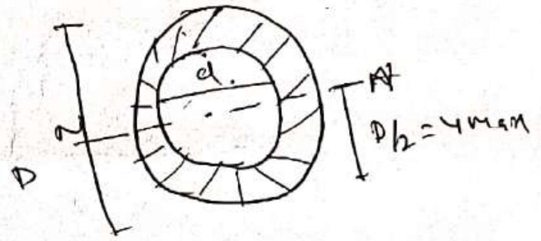
$Z = \frac{I}{y_{max}}$ $Z = \frac{\frac{\pi D^4}{64}}{D/2}$

$Z = \frac{2 \times \pi D^4}{64 \times D}$

$= \frac{\pi D^3}{32}$

$$\boxed{Z = \frac{\pi D^3}{32}}$$

④ Hallow circular section.



Here

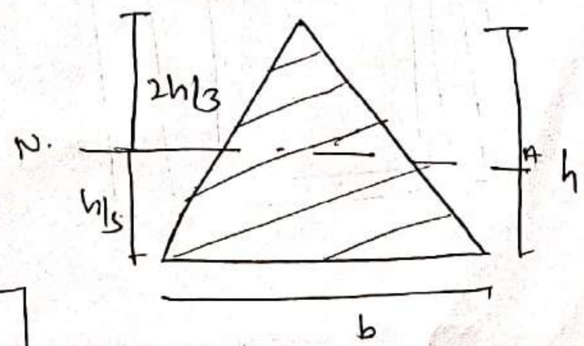
$I = \frac{\pi}{64}(D^4 - d^4)$

$y_{max} = D/2$

$Z = \frac{\frac{\pi}{64}(D^4 - d^4)}{D/2.}$

$$\boxed{Z = \frac{\pi}{32D}(D^4 - d^4)}$$

⑤ Triangular section:



$Z = \frac{I}{y_{max}}$.

$I = \frac{bh^3}{36}$ $y_{max} = 2/3\, h$

$Z = \frac{\frac{bh^3}{36}}{\frac{2}{3}h}$ $\boxed{Z = \frac{bh^2}{54}}$

Problems on Bending stress :

1. A steel Plate of width 120mm and of thickness 20mm is bent into a circular arc of radius 10m. Determine the maximum stress induced and the bending moment which will produce the maximum stress. Take E = 2×10^5 N/mm².

as width = 120mm, t = 20mm, R = 10m

f_{max} = σ_{max} = max stress induced E = 2×10^5 N/mm².

∴ moment of Inertia = $\frac{bd^3}{12} = \frac{120\times20^3}{12} = 8\times10^4\ mm^4$

using equation $\frac{\sigma_{max} \text{ (or) } f_{max}}{y_{max}} = \frac{E}{R}$ eq (1)

$y_{max} = \frac{t}{2} = \frac{20}{2} = 10\ mm.$

eq (1) can be rewritten as

$\sigma_{max} = \frac{E}{R} \cdot y_{max}$

$\sigma_{max} = \frac{2\times10^5}{10\times10^3} \times 10$

$\boxed{\sigma_{max} = 200\ N/mm^2}$

$\frac{M}{I} = \frac{E}{R}.$

$M = \frac{E}{R} \times I$

$M = \frac{2\times10^5}{10\times10^3} \times 8\times10^4$

$M = 1.6\times10^6\ N\text{-}mm$

$\boxed{M = 1.6\ KN\text{-}m}$

(2) calculate the Maximum stress Induced in a cast iron pipe of External diameter 40mm, of Internal diameter 20mm and of length 4metre when the pipe is supported at its ends and carries a point load of 80N at its centre.

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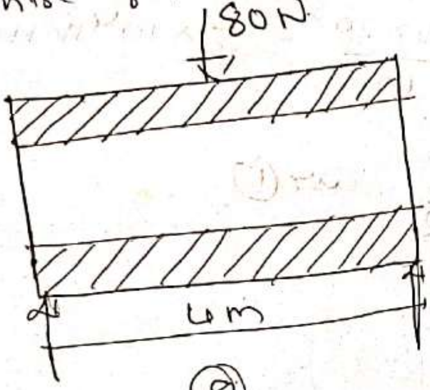
Given $D_E = 40mm$,

$d_i = 20mm$

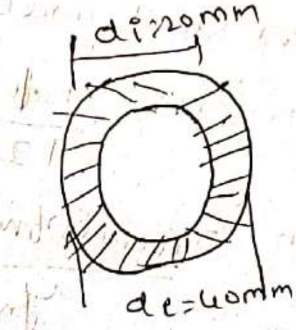
$L = 4m = 4 \times 1000 = 4000mm$.

$W = 80N$.

In case of simply supported beam carrying a point load at the centre, the maximum bending moment is at the centre of the beam.



(a)



(b) Cross section Area

(4) And maximum $B.m = \frac{W \times L}{4}$

maximum $Bm = \frac{80 \times 4000}{4} = 8 \times 10^4$ Nmm

$M = 8 \times 10^4 Nmm$

(5) The cross-section of the pipe.

Moment of Inertia of hollow pipe

$$I = \frac{\pi}{64}\left[D^4 - d^4\right]$$

$$I = \frac{\pi}{64}\left[40^4 - 20^4\right]$$

$$I = 117809.72 \ mm^4$$

When y is maximum, stress will be maximum. But y is maximum at the top layer from the N.A.

$$y_{max} = \frac{D}{2} = \frac{40}{2} = 20mm$$

Now equation $\frac{M}{I} = \frac{\sigma}{y}$ = $\sigma_{max} = \frac{M}{I} \cdot y_{max}$

$$\sigma_{max} = \frac{8 \times 10^4}{117809.72} \times 20$$

$$\sigma_{max} = 13.58 \ N/mm^2$$

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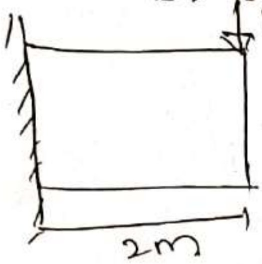
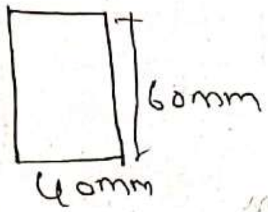
(3) A cantilever of length 2m fails when a load of 2kN is applied at the free end. If the section of the beam is 40mm x 60mm, find the stress at the failure.

→ Length $L = 2m$ $W = 2kN = 2000N$.

$L = 2 \times 10^3 mm$.

$b = 40mm$ $d = 60mm$





Section modulus of Rectangle

$Z = \frac{bd^2}{6}$

$= \frac{40 \times 60^2}{6}$

$Z = 24000 mm^3$

$I = \frac{bd^3}{12}$

$Z = \frac{\frac{bd^3}{12}}{y}$

$Z = \frac{\frac{bd^3}{12}}{d/2}$

$Z = \frac{bd^2}{6}$

Maximum bending moment for a cantilever, as shown in fig

$M = W \times L = 2000 \times 2 \times 10^3$

$= 4000 \times 10^3$ N-mm.

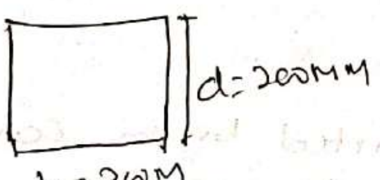
σ_{max} = stress at the failure

$M = \sigma_{max} \cdot Z$

$\sigma_{max} = \frac{M}{Z} = \frac{4 \times 10^6}{24000} = 166.66 N/mm^2$

$\sigma_{max} = 166.66 N/mm^2$

(4) A rectangular beam 200mm deep and 300mm wide is simply supported over a span of 8m. What uniformly distributed load per metre the beam may carry if the bending stress is not to exceed 120 N/mm².

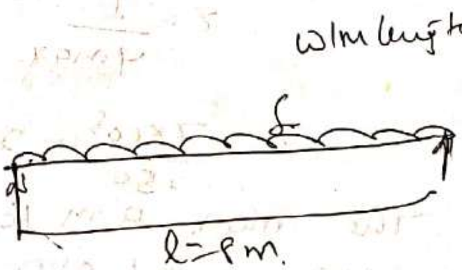


$b = 300mm$

$d = 200mm$

$L = 8m$

$\sigma_{max} = 120 N/mm^2$



w = uniformly distributed load per metre length over the beam.

Section modulus of rectangular beam

$Z = \frac{bd^2}{6} = \frac{300 \times 200^2}{6} = 2 \times 10^6 mm^3$

Max B.M for a simply supported beam carrying uniformly distributed load as shown in fig. is at the centre of the beam. It is given by

$$M = \frac{w \times l^2}{8} = \frac{w \times 8^2}{8}$$ (1m = 1000 mm)

$= 8w$ Nm

$M = 8 \times 1000$ = 8000w Nmm

using eq

$$\frac{M}{I} = \frac{\sigma}{y}$$

$M = Z \cdot \sigma_{max}$

$8000w = 120 \times 2 \times 10^6$

$$w = \frac{120 \times 2 \times 10^6}{8000} = 30000 \text{ N/mm}$$

$= 30$ kN/m

(5) A beam is simply supported and carries uniformly distributed load of 40kN/m run over the whole span. The section of the beam is rectangular having depth as 500mm. If the maximum stress in the material of the beam is 120 N/mm2 and moment of Interia of the section is 7×10^8 mm4. find the span of beam.

us UDL w = 40kN/m = 40×1000 N/m Max $\sigma_{max} = 120$ N/mm² $I = 7 \times 10^8$ mm⁴

depth d = 500mm.

L = ?

section modulus of the section is given by equation

$$Z = \frac{I}{y_{max}}$$ $y_{max} = \frac{d}{2} = \frac{500}{2} = 250$ mm

$$Z = \frac{7 \times 10^8}{250} = 28 \times 10^5 \text{ N/mm}^3$$

The max. B.M for a simply supported beam carrying a U.D.L over the whole span is at the centre of the beam & is equal to $\frac{w \cdot L^2}{8}$

$$M = \frac{40000 \times L^2}{8}$$

$M = 5000L^2$ Nm = $5000L^2 \times 1000$ = N-mm

Now equation. $M = \sigma_{max} \cdot Z$.

$M = \sigma_{max} \cdot Z$

$5000 \times 1000 \times L^2 = 120 \times 28 \times 10^6$

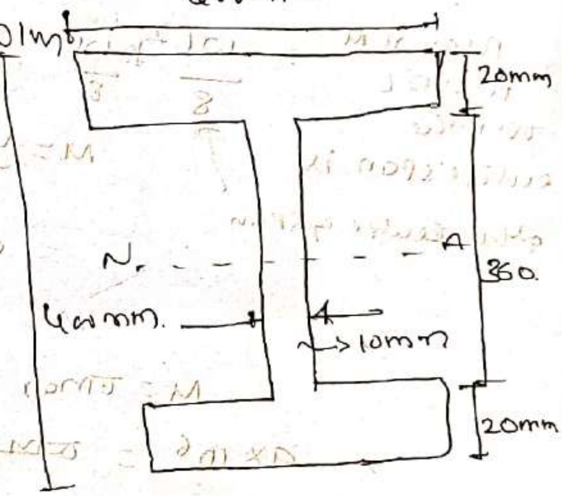
$L^2 = \dfrac{120 \times 28 \times 10^6}{5000 \times 1000}$

$L^2 = 67.2$

$L = \sqrt{67.2}$

$L = 8.19 m.$ | $L = 8.20 m$

(6) A rolled steel joist of I section has the dimensions as shown in fig. This beam of I section carries a u.d.l of 40kN/m run on a span of 10m. calculate the maximum stress produced due to bending.



As UDL, $\omega = 40 kN/m = 40 \times 1000 N/m$

Span $L = 10m$.

Moment of Inertia about the neutral axis

$I = \dfrac{200 \times 400^3}{12} - \dfrac{(200-10) \times 360^3}{12}$

$I = 1.066 \times 10^9 - 738.72 \times 10^6$

$I = 327.28 \times 10^6 mm^4$

Maximum B.M is given by

$M = \dfrac{\omega \times L^2}{8} = \dfrac{40000 \times 10^2}{8} = 500000 N m.$

$= 500000 \times 1000 N\text{-}mm$

$= 5 \times 10^8 N\text{-}mm$

using relation

$\dfrac{M}{I} = \dfrac{\sigma}{y}$

$\sigma = \dfrac{M}{I} \cdot y_{max}$

$y_{max} = \dfrac{d}{2} = \dfrac{400}{2} = 200$

$\sigma_{max} = \dfrac{5 \times 10^8}{372.28 \times 10^6} \times 200$

$\sigma_{max} = 304.92 N/mm^2$

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(7) A timber beam of rectangular section is to support a load of 20kN uniformly distributed over a span of 3.6m. when beam is simply supported. If the depth of the section is to be twice the breadth. and the stress in the timber is not to exceed 7N/mm². find the dimension of the cross section. How would you modify the cross section of the beam. if it carries a concentrated load 20kN placed at the centre with the same ratio of breadth to depth ?

Ans) $w = 20kN = 20\times1000N$. $L = 3.6m$. $d = 2b$

$\sigma_{max} = 7N/mm^2$.

section modulus of rectangular beam $Z = \frac{bd^2}{6} = \frac{b\times(2b)^2}{6}$

$Z = \frac{2b^3}{6}$

Max B.M for UDL over the entire span is at the centre of span $= \frac{wL^2}{8}$ or $\frac{wL}{8}$

$M = \frac{wL}{8} = \frac{20000\times3.6}{8} = 9000$ N-m

$= 9000\times1000$ N mm

$M = 9\times10^6$ N-mm

$M = \sigma_{max}\cdot Z$.

$9\times10^6 = 7 \times \frac{2b^3}{3}$

$b^3 = \frac{3\times9\times10^6}{7\times2}$

$b^3 = (1.9285\times10^6)$

$b = 124.47mm$

$d = 2\times b = 2\times124.47$

$d = 248.94mm$

Dimension of the section when the beam carries a point at the centre.

The B.M is maximum at the centre & it is equal to $\frac{w\times L}{4}$ when the beam carries a point load at the centre

$M = \frac{w\times L}{4} = \frac{20000\times3.6}{4} = 18000$ N-m

18000×1000 N mm

$\sigma_{max} = 7$ N/mm²

$Z = \frac{2b^3}{3}$ $\quad M = \sigma_{max} Z$

$18 \times 10^6 = 7 \times \frac{2b^3}{3}$

$b^3 = \frac{18 \times 10^6 \times 3}{7 \times 2}$

$b^3 = 3857142.85$

$\boxed{b = 156.82 \text{ mm}}$

$d = 2 \times b$

$d = 2 \times 156.82$

$\boxed{d = 313.65 \text{ mm}}$

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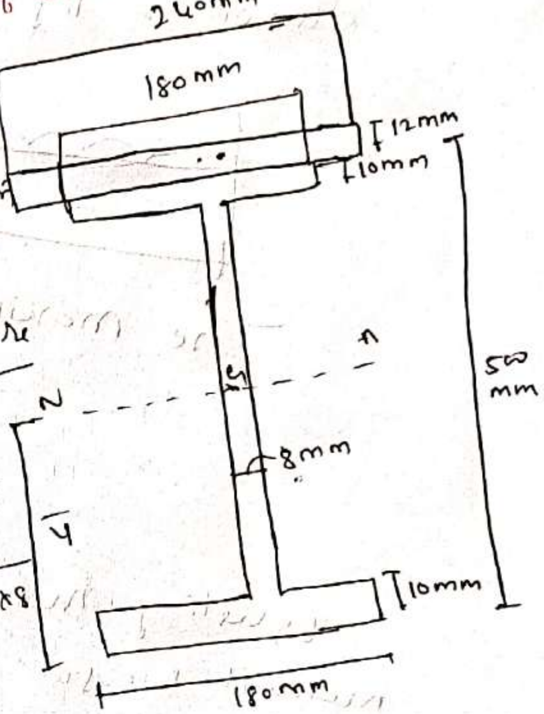
1. A symmetric I-section has flanges of size 180mm × 10 mm and its overall depth is 500mm. Thickness of the web is 8 mm. It is strengthened with a plate of size 240mm × 12mm on compression side. Find the moment of resistance of the section, if permissible stress is 150N/mm². How much uniformly distributed load it can carry if it is used as a cantilever of span 3m?



→ The section of beam is as shown in fig.

Let $\bar{y}$ be the distance of centroid from the bottom-most fibre.

$$\bar{y} = \frac{\text{moment of area about bottom fibre}}{\text{Total Area}}$$

$$\bar{y} = \frac{240\times12\times506 + 180\times10\times495 + 180\times10\times5 + 480\times8\times250}{240\times12 + 180\times10 + 180\times10 + 480\times8}$$

$$\boxed{\bar{y} = 321.442\text{mm}}$$

$$I = \frac{1}{12}\times240\times12^3 + 240\times12[506-321.442]^2 + \frac{1}{2}\times180\times10^3 + 180\times10[5-321.442]^2 + 180\times10[495-321.442]^2 + \frac{1}{12}\times180\times10^3 + 8\times480[250-321.442]^2 + \frac{1}{12}\times480^3\times8$$

$$\boxed{I = 4.2595\,2\times10^8\ \text{mm}^4}$$

$$y_{top} = 512 - 321.442 = 190.558\text{mm}$$

$$y_{max} = \bar{y} = 321.442$$

Moment of Resistance (Moment carrying capacity)

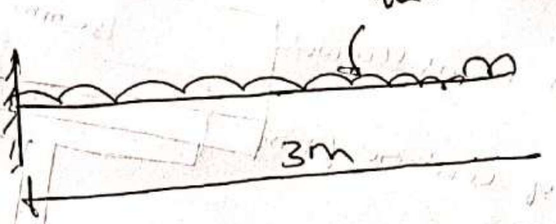
$$M = f_{per}\times Z = 150\times\frac{I}{y_{max}} = 150\times\frac{4.25952\times10^8}{321.442}$$

$$M = 1.98769\times10^8\ \text{N-mm}$$

$= 1.98769 \times 10^8$ N-mm

$M = 198.769$ kN-N

Let the load on cantilever be w/m length as shown in fig



The maximum moment produced $= \frac{wl^2}{2}$ kN-m

$= \frac{w \times 3^2}{2}$

$= 4.5\,w$ kN-m

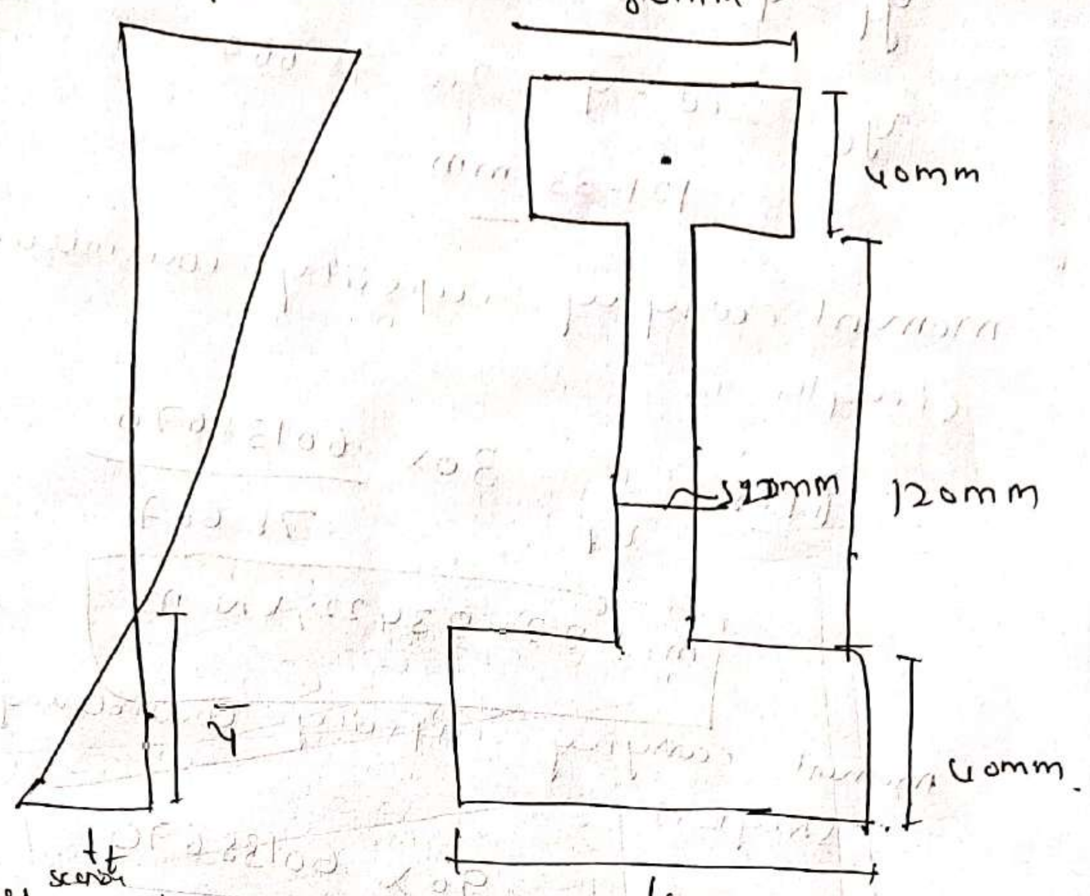
Equating moment of resistance to maximum moment we get maximum load w

$4.5w = 198.769$

$w = \frac{198.769}{4.5}$

$w = 44.171$ kN/m

(02) A cast Iron beam has a I-section with top flange 80mm x 40mm, web 120x20mm and bottom flange 160mm x 40mm, If the tensile stress is not to exceed 30 N/mm² and compressive stress 90 N/mm². What is the maximum UDL the beam can carry over a simply supported ~~beam~~ span of 6m. If the larger ~~span~~ flange is in tension?



The cross section of beam is as shown in fig.

let $\bar{y}$ be distance of centroid (hence from the neutral axis) from the bottom fibre. Then

$$\bar{y} = \frac{\Sigma ay}{A}$$

$$\bar{y} = \frac{80\times40\times180 + 120\times20\times100 + 160\times40\times20}{80\times40 + 120\times20 + 160\times40}$$

$$\boxed{\bar{y} = 78.6667\,mm}$$

$$I = \frac{1}{12}\times80\times40^3 + 80\times40\,[180-78.666]^2 + \frac{1}{12}\times20\times120^3 + 20\times120\,[100-78.667]^2 + \frac{1}{12}\times160\times40^3 + 160\times40\,[20-78.6667]^2$$

$$\boxed{I = 6013867 0\,mm^4}$$

Tension occurs at the bottom and compression at the top. Extreme fibre distances of top and bottom fibres are

$y_t = \bar{y} = 78.667\,mm$

$y_c = 200 - \bar{y} = 200 - 78.667$

$= 121.333\,mm$

moment carrying capacity considering tensile strength is

$f_{per} \times \frac{I}{y_t} = 30 \times \frac{60138670}{78.667}$

$M_T = 22.934229\,kN\text{-}m$

moment carrying capacity considering compression strength is

$f_{per} \times Z = 90 \times \frac{60138670}{121.333}$

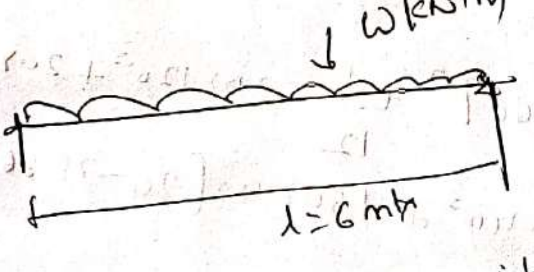
$= 44.608\,kN\text{-}m$

Actual moment carrying capacity of the section is smaller of the above two. i.e moment carrying of the section $= 22.934\,kN\text{-}m$

Max bending moment in a simply supported beam of span 6m due to the UDL of w kN/m

$= \frac{wL^2}{8} = \frac{w \times 6^2}{8}$

$= 4.5\,w.$

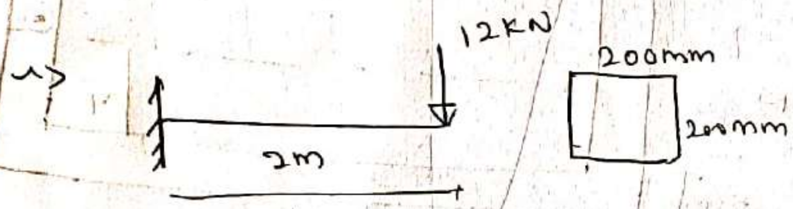


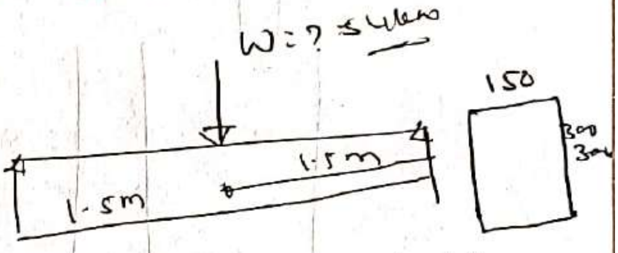
Equating it to the moment carrying capacity we get load carrying capacity w as

$4.5w = 22.934$

$w = 5.0965\,kN/m$

A cantilever of square section 200 mm x 200 mm, 2 m long, just fails in flexure when a load of 12 kN is placed at its free end. A beam of the same material and having a rectangular cross section 150 mm wide and 300 mm deep is simply supported over a span of 3 m. Calculate the minimum central concentrated load required to fail the beam.





The two beams with their loading case are as shown in fig.

In cantilever beam the moment is

$= 12 \times 2 = 24$ kN-m

$= 24 \times 10^6$ N-mm

If f is the stress at which the beam fails, then

$M = fZ = \frac{1}{6} bd^2 \times f$

$24 \times 10^6 = \frac{200 \times 200^2}{6} \times f$ $\quad$ $f = 18 \text{ N/mm}^2$

Let W kN be the central concentrated load in simply supported beam of span 3m. Then the maximum moment is

$M = \frac{WL}{4} = \frac{W \times 3}{4} = 0.75 W$ kN-m

$= 0.75 \times 10^6 W$ N-mm

The section has a moment of resistance $= fZ$

$= 18 \times \frac{1}{6} \times 150 \times 300^2$

Equating bending moment to the moment of resistance we get

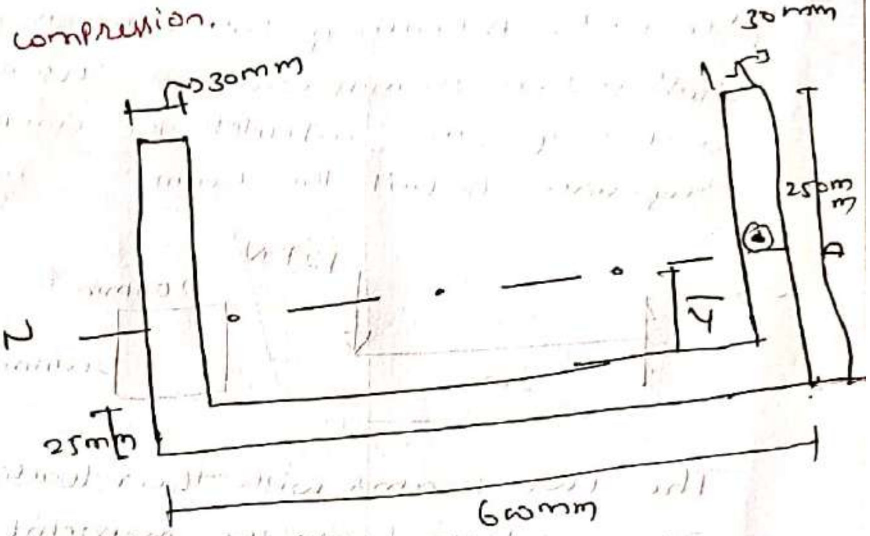
Maximum load W $\quad 0.75 \times 10^6 W = 18 \times \frac{1}{6} \times 150 \times 300^2$

Thus

$W = 54 \text{ kN}$

Head of C.E.D

A cast Iron channel section in fig. is available to be used as a simply supported beam over a span of 3m. If the permissible stress in Tension is 35 N/mm2 and in compression is 90 N/mm2. Find its uniformly distributed load carrying capacity - if web (a) In Tension and (b) In compression.



Soln

Let $\bar{y}$ be the distance of neutral axis from extreme fibre.

Then $\bar{y} = \frac{\Sigma a\bar{y}}{A}$

$$= \frac{30\times 250\times 125 \times 2 + 540\times 25\times \frac{25}{2}}{30\times 250\times 2 + 540\times 25}$$

$\boxed{\bar{y} = 71.71\ mm}$

$$I = \left[\frac{1}{12}\times 30\times 250^3 + 30\times 250\times [125 - 71.71]^2\right]\times 2 + \frac{1}{12}\times 540\times 25^3 + 540\times 25\times [12.5 - 71.71]^2$$

$\boxed{I = 1.68754\times 10^8\ mm^4}$

(a) If web is in Tension $\quad y_t = \bar{y} = 71.71mm$

$y_c = 250 - 71.71 = 178.29mm$

moment carrying capacity from consideration of Tensile stress is

$= f_t \frac{I}{y}$

$= 35\times \frac{1.68754\times 10^8}{71.71}$

$= 82.365\times 10^6$ N-mm

From consideration of compressive stress the moment carrying capacity is $= f_c \times Z$

$= f \times \frac{I}{y_c}$

$= \frac{90 \times 1.687544 \times 10^8}{178.29}$

$= 85.1863 \times 10^6$ N-mm

Moment carrying capacity = 82.365×10^6 N-mm

If w kN/m is UDL in the beam, the maximum bending moment is $= \frac{wL^2}{8}$

$= \frac{w \times 3^2}{8}$

$= 1.125\,w$ kN-m

$= 1.125\,w \times 10^6$ N-mm

Equating bending moment to the moment of resistance, we get permissible load

$1.125 \times 10^6\,w = 82.365 \times 10^6$

w = 73.213 kN/m

(b) If web in compression.

$y_t = 178.299$ mm

$y_c = 71.71$ mm.

Moment carrying capacity from the consideration of tension is $= f_t \times \frac{I}{y_t}$

$= \frac{35 \times 1.687544 \times 10^8}{178.29}$

$= 33.127994 \times 10^6$ N-mm.

This value from consideration of compression

$= f_c \times \frac{I}{y_c}$

$= \frac{90 \times 1.687544 \times 10^8}{71.71}$

$= 211.795 \times 10^6$ N-mm

Moment of resistance $= 33.1279944 \times 10^6$ N-mm

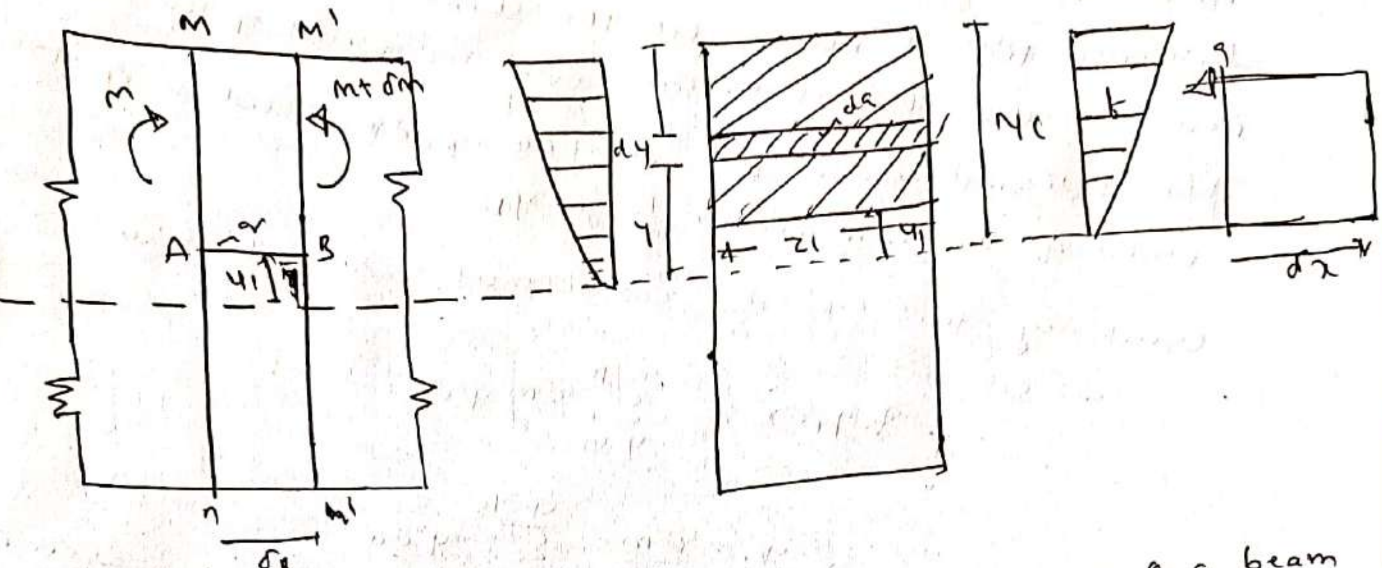
Equating it to bending moment, we get

Head of C.E.D

$1.125 \times 10^6 w = 33.127994 \times 10^6$

$$\boxed{w = 29.4471 \text{ kN/m}}$$

1. Distribution on shearing stresses



fig(a).

Let us consider two normal sections mn and m1n1 of a beam at an infinitely small distance δx. Let the bending moment at the section mn be M and that at m1n1 be [M+δM]. Let us investigate the amount of horizontal shear stress at a plane AB, distant y1 from N.A.

Due to the bending moment M at the section mn, there will be bending stresses across the section and the value of the stress will depend on the position of the layer with respect of N.A. The intensity of bending stress for any layer at a distance y from N.A., is $f = \frac{M}{I} y$. Hence the compressive thrust on the strip of δa area at this height will be equal to f δa (or) $= \frac{M}{I} y \cdot \delta a$

Similarly the elementary thrust on the strip of δa area at the height y from neutral axis at the section m1n1 will be equal to $\left[\frac{M+\delta M}{I} y \cdot \delta a\right]$

[Assuming that the section of the beam is constant from mn to m1n1]

Hence elementary unbalanced horizontal thrust, b/w mn and m1n1 $= \frac{M+\delta M}{I} y\delta a - \frac{M}{I} y\delta a = \frac{\delta M}{I} y \cdot \delta a$.

Total unbalanced horizontal thrust to the layer b/w y=y1 to y=yc will be equal to $C' = \sum_{y=y_1}^{y=y_c} \frac{\delta M}{I} \cdot \delta y a$.

Head of C.E.D

For equilibrium of the portion ABM_1M, a horizontal shear force at AB must act to counter-balance this as no other horizontal force is acting. Let the shear intensity at AB be q_1. Assuming that this is uniform over the width of the section, The horizontal shear force at $AB = q_1 \delta x \cdot z_1$ where z_1 is the width of the beam at the height y_1.

Equating this to the unbalanced horizontal thrust.

we get

$$q_1 \delta x \cdot z_1 = \sum_{y=y_1}^{y=y_c} \frac{\delta m}{I} y \cdot \delta a$$

$$q_1 = \frac{\delta m}{\delta x I z_1} \sum_{y=y_1}^{y=y_c} y \cdot \delta a$$

But $\frac{\delta m}{\delta x} = F$ and $\Sigma \delta a$ is the moment of the area above AB (i.e the shaded area) about N.A.

Hence $q = \frac{F}{I z_1} (A\bar{y})$

Or dropping the suffix, we get

$$q_1 = \frac{F}{I z} (A\bar{y})$$

$$q = \frac{F}{I z} (A\bar{y})$$

Assumptions made:

It is important to know the assumptions made. They are:

1. The material is homogeneous and Isotropic and has same value of E for Tension and compression.

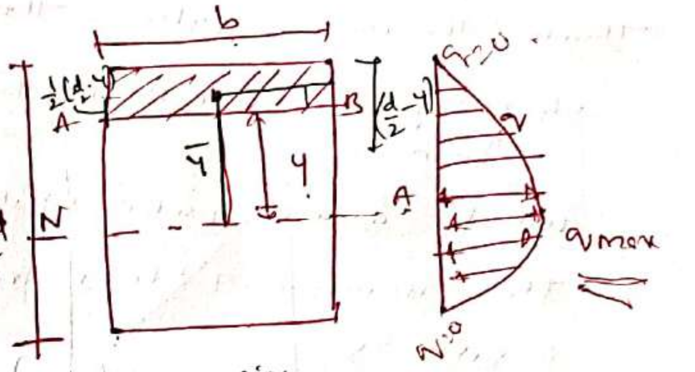
2. $F = \frac{dm}{dx}$ is derived from the assumption that the bending stress varies linearly across the section and is zero at the centroid. Actually the stress curve is not a straight line passing through the centroid of the section.

3. For all values of y, q is uniform across the width of a section of whatever shape. This is not strictly correct because the tangential value must be zero at the boundaries of the section.

Shearing stress Distribution over Rectangular Beam.

$\tau = \frac{F A\bar{y}}{Z I}$

Let us investigate the law of shearing stress distribution over the section of a beam of rectangular cross section.



only layer AB at height y from neutral axis. the Intensity of shear stress q from

$$q = \frac{F}{IZ}(A\bar{y})$$

where I = moment of Inertia of whole section.
Z = width of the section at AB = b
$A\bar{y}$ = moment of the area above.
AB = moment of the shaded area about the N.A. w.r.t.

substituting above

$$q = \frac{F}{Ib}\left[b\left[\frac{d}{2}-y\right]\right]\left[\frac{1}{2}\left[\frac{d}{2}-y\right]+y\right\}$$

$$q = \frac{F}{Ib}\left[b\left[\frac{d}{2}-y\right)\left[\frac{1}{2}\left(\frac{d}{2}+y\right)\right\}\right.$$

$\frac{d}{4}-\frac{y}{2}+y$

$\frac{d}{4}+y$

$$q = \frac{F}{Ib}\times\frac{b}{2}\left[\frac{d^2}{4}-y^2\right]$$

$$\boxed{q = \frac{F}{2I}\left(\frac{d^2}{4}-y^2\right)}$$

This is the equation of a parabola & hence the variation of q is parabolic

At $y = \pm d/2$, $q = 0$

At $y = 0$, $q = q_{max} = \frac{F}{2I}\frac{d^2}{4} = \frac{Fd^2}{8I}$ at the N.A.

$$= \frac{Fd^2}{8\times\frac{bd^3}{12}} = \frac{3}{2}\frac{F}{bd}$$

The mean shear stress on the section $= \frac{F}{area} = \frac{F}{bd}$

$$\frac{q_{max}}{q_{mean}} = \frac{\frac{3}{2}F/bd}{\frac{F}{bd}} = \frac{3}{2} = 1.5$$

Head of C.E.D

Thus the maximum shear stress at the N.A is 50% more than the mean value.

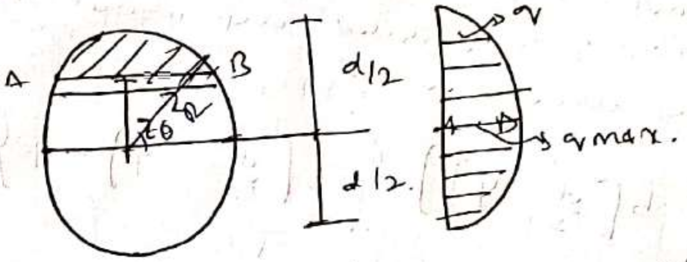
Shearing stress distribution over Beam of solid circular section

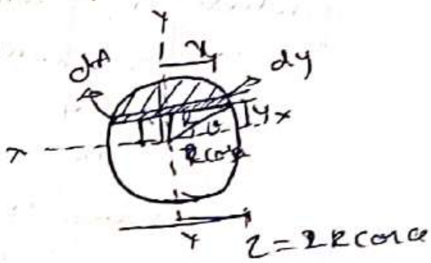
Consider a beam of solid circular-section of diameter d (radius r)

The intensity of shear stress at level AB at height y from N.A

is given by $q = \frac{F}{IZ}(A\bar{y})$

where z = width of the section at the height $y = 2(r^2-y^2)^{1/2}$





$A\bar{y}$ = moment of the shaded area, about N.A, to find the moment of the shaded area, consider a strip of thickness δy at the height y, the area of δs of the strip = $z \cdot \delta y$,

The moment of elementary area = $\delta s \cdot y = z \cdot \delta y \cdot y$.

Hence the moment of the shaded area about the N.A is

$$A\bar{y} = \int_{y=y}^{y=r} y \cdot z \cdot dy$$

$2r f(\theta)$

$z = f(\bar{y})$

$$z = 2\sqrt{r^2-y^2} \quad \text{or} \quad z^2 = 4(r^2-y^2)$$

$$2z\delta z = 4(-2y)dy = -8y \cdot dy$$

$$y\,dy = -\frac{1}{4}z\,dz.$$

when $y=r$ $z=0$ when $y=y$, $z=z$.

$$\tau = f(\theta)$$

$$\tau = f(\bar{y})$$

$$\tau = 2R\cos\theta$$

$$\tau = \frac{FA\bar{y}}{\tau I}$$

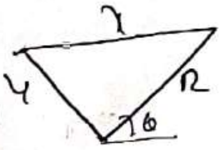
$$dA = 2x\,dy$$

$$A\bar{y} = \int (2x\,dy)\,y$$

$$I = \frac{\pi R^4}{4}$$

$$\tau = \frac{F \times \int 2x\,dy \cdot y}{(2R\cos\theta)\left(\frac{\pi}{4}R^4\right)}$$

$$\boxed{\tau = \frac{4F\int x\,dy \cdot y}{\pi R^5 \cos\theta}}$$



$$x = \sqrt{R^2 - y^2}$$

$$\tau = \frac{4F}{\pi R^5 \cos\theta}\int_{R\sin\theta}^{R} \sqrt{R^2-y^2}\cdot y\,dy$$

$$\tau = \frac{4F}{\pi R^5 \cos\theta}\left[\frac{1}{3}(R^2-y^2)^{3/2}\right]_{R\sin\theta}^{R}$$

$$\tau = \frac{4F}{\pi R^2 \cos\theta}\left[\frac{1}{3}\left[1-\sin^2\theta\right]^{3/2}\right.$$

$$\tau = \frac{4}{3}\frac{F}{R^2\pi}\cos^2\theta$$

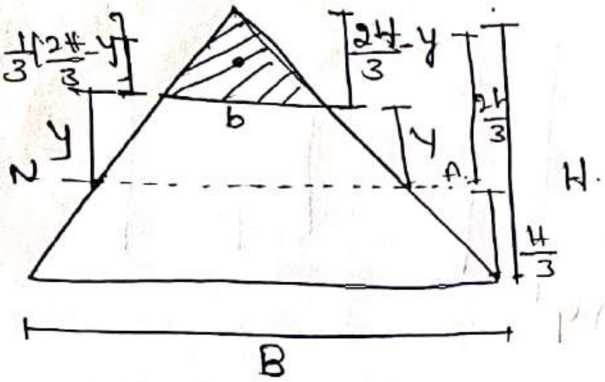
$$\tau = \frac{4}{3}\frac{F}{R^2\pi}\cos^2\theta$$

Neutral axis

$$\tau_{NA} = \frac{4}{3}\left[\frac{F}{\pi R^2}\right] - \text{Mean shear} = 1.33\,\tau_{mean}$$

$\theta = 0$

Shear stress distribution in triangular section



$$Q = \frac{1}{2} b \times \left(\frac{2H}{3} - y\right) \times \left(y + \frac{1}{3}\left(\frac{2H}{3} - y\right)\right)$$

$$= \frac{1}{2} b \left(\frac{2H}{3} - y\right)\left(\frac{2y}{3} + \frac{2H}{9}\right)$$

$$Q = \frac{1}{2} b \left[\frac{2H}{3} - y\right] \frac{2}{3}\left[y + \frac{H}{3}\right]$$

$$Q = \frac{1}{3} b \left[\frac{2H}{3} - y\right]\left[y + \frac{H}{3}\right]$$

$$Q = \frac{b}{3}\left[\frac{2H^2}{9} - y^2 + \frac{H}{3}y\right]$$

$$\tau_y = \frac{FA\bar{y}}{\tau I}$$

$$= \frac{F\left[\frac{b}{3}\left[\frac{2H^2}{9} - y^2 + \frac{H}{3}y\right]\right]}{\frac{BH^3}{36} \times b}$$

$$\tau_y = \frac{12F}{BH^3}\left[\frac{2H^2}{9} - y^2 + \frac{H}{3}y\right]$$

at $y = \frac{2H}{3}$ $\quad \tau = 0$

at $= -H/3$ $\quad \tau = 0$

$$\frac{d\tau}{dy} = 0$$

$$\frac{12F}{BH^3}\left[-2y + \frac{H}{3}\right] = 0$$

$y = \frac{H}{6}$, $\tau = \tau_{max}$

$$\tau_{max} = \frac{12F}{BH^3}\left[\frac{2H^2}{9} - \frac{H^2}{36} + \frac{H}{3} \times \frac{H}{6}\right]$$

$$= \frac{12F}{BH}\left(\frac{8 - 1 + 2}{36}\right) = \frac{3F}{BH}$$

$$\tau_{max} = \frac{3F}{BH} = \frac{3}{2}\tau_{av}$$

$$\left(\tau_{max} = \frac{3}{2}\tau_{average}\right)$$

$\tau = f(\theta)$

$\tau = f(\bar{y})$

$\tau = 2R\cos\theta$

$$\tau = \frac{FA\bar{y}}{\tau I}$$

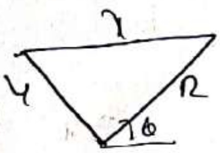
$dA = 2x\,dy$

$A\bar{y} = \int (2x\,dy)\,y$

$I = \frac{\pi R^4}{4}$

$$\tau = \frac{F \times \int 2x\,dy \cdot y}{(2R\cos\theta)\left(\frac{\pi}{4}R^4\right)}$$

$$\boxed{\tau = \frac{4F\int x\,dy \cdot y}{\pi R^5 \cos\theta}}$$



$x = \sqrt{R^2 - y^2}$

$$\tau = \frac{4F}{\pi R^5 \cos\theta} \int_{R\sin\theta}^{R} \sqrt{R^2-y^2}\cdot y\,dy$$

$$\tau = \frac{4F}{\pi R^5\cos\theta}\left[\frac{1}{3}(R^2-y^2)^{3/2}\right]_{R\sin\theta}^{R}$$

$$\tau = \frac{4F}{AR^2\cos\theta}\left[\frac{1}{3}\left[1-\sin^2\theta\right]^{3/2}\right.$$

$$\tau = \frac{4}{3}\frac{F}{R^2\pi}\cos^2\theta$$

$$\tau = \frac{4}{3}\frac{F}{R^2\pi}\cos^2\theta$$

Neutral axis

$$\tau_{NA} = \frac{4}{3}\left[\frac{F}{\pi R^2}\right] - \text{Mean shear} = 1.33\,\tau_{mean.}$$

$\theta = 0$

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Civil Department
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9741646266

Module - 5

Columns and Struts

Structural members subjected to compression, which are relatively long in comparision with cross sectional dimension and being vertical are called columns.

Ex: RCC columns, steel columns, timber columns, and composite columns. (If the member of the structure is vertical and both ends are fixed rigidly while subjected to axial compressive load, the member is known as column.)

A strut is commonly used for compression member in a roof truss. It may either be in vertical position (or) in inclined position. The principal compression member in crane is called a boom. Ex: connecting rods, piston rods etc. (If the member of the structure is not vertical & one (or) both of its ends are hinged (or) pin joined, the bar is known as strut.)

Thus a compression member is divided into three categories.

Failure of a column: (1) Direct compressive stresses (2) Buckling stresses (3) Combined direct compressive and buckling stress

(1) **Short compression members**: which fails primarily by crushing without buckling. Fig (1) [If a short length of bar (or) block is subjected to a compressive force P, uniform compressive stress $\sigma = P/A$ is induced. Such a compression member fails by crushing on increasing the value of force P]

Crushing

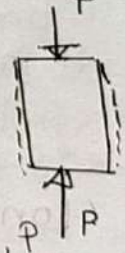
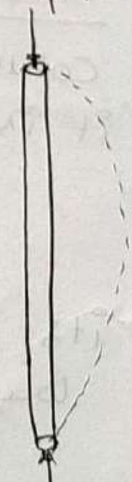


fig 1

(2) **Long columns**: which fails by buckling (or) excessive lateral bending. fig (2)



(3) **Intermediate columns**: which fails by combination of crushing and buckling.

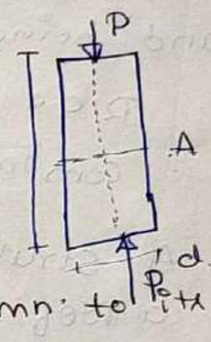
A compression member is classified by its length and least lateral dimension. Most of the practical cases of compression members fall under the second category. The critical load, which the members can carry before failure.

fig 2 Buckling

Depends upon ① member dimensions [area, shape and length] and ② end conditions

* **Short columns**: If the ratio of effective length of the column to its least lateral dimension does not exceed 15

i.e. $\frac{\text{length effective}}{\text{breadth (or) depth}} \Rightarrow \frac{l_{eff}}{b \text{ or } d} < 15$



(or)

If the ratio of effective length of the column to its least radius of gyration does not exceed 50. Then it is called short column.

$K = \sqrt{\frac{I}{A}}$

K_{min} = minimum radius of gyration.

$$\frac{l_{eff}}{K_{min}} < 50$$

A short columns fails by crushing (or) yielding

$$f_c = \left[\frac{P_c}{A}\right]$$

where f_c = crushing stress (or) ultimate stress

P_c = crushing load

A = Area

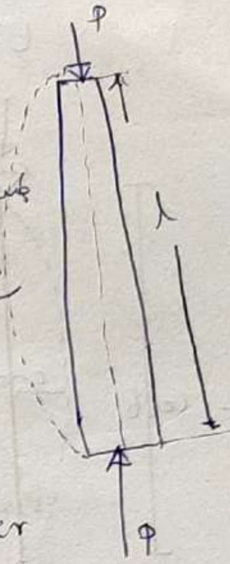
* **Long column**: If the ratio of effective length of the column to its least lateral dimension exceeds 15. then it is long column.

(or)

If the ratio of effective length of the column to its least radius of gyration exceeds 50 then it is long column.

$$\frac{l_{eff}}{b \text{ or } d} > 15 \qquad \frac{l_{eff}}{K_{min}} > 50$$

A long column fails by buckling and stresses are well below the elastic limit



③ Critical load: The maximum load which a column can support before becoming unstable is known as critical load (or) buckling load (or) crippling load.

④ Slenderness ratio: [λ]

The ratio of length of the column to its least radius of gyration.

$$K_{min} = \sqrt{\frac{I_{min}}{A}}$$

$$\lambda = \frac{l}{K_{min}}$$

where l = length of the column (mm)

K_{min} = min radius of gyration (mm)

λ = slenderness ratio (unit less)

Effective length of a column:

effective length of a column with given end conditions is the length of an equivalent column of the same material of the section with hinged ends having the value of the crippling load equal to that of the given column.

(or) It is the distance b/w points of zero moments.

Scanned by CamScanner

Examples are shown below.

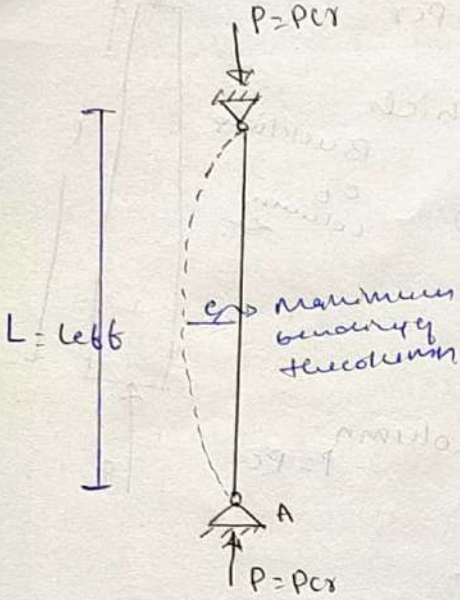


fig: 1

Both ends hinged.

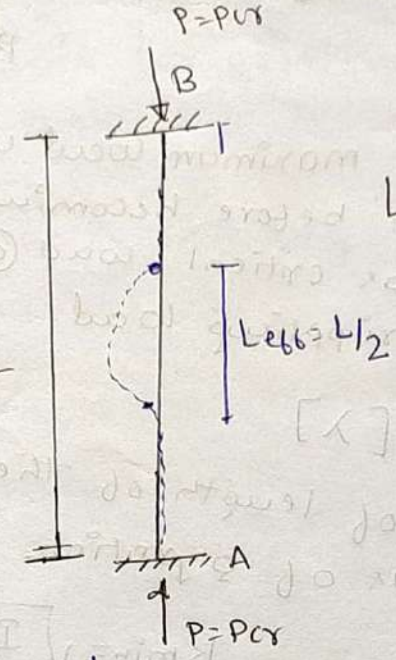


fig. 2

Both ends fixed.

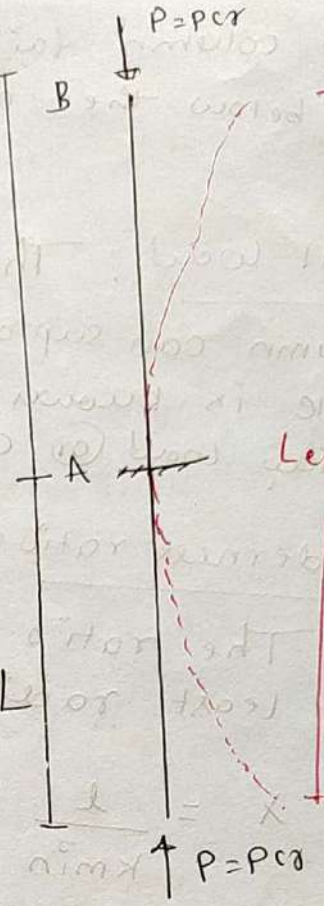


fig. 3

One End is free and Other end is fixed.

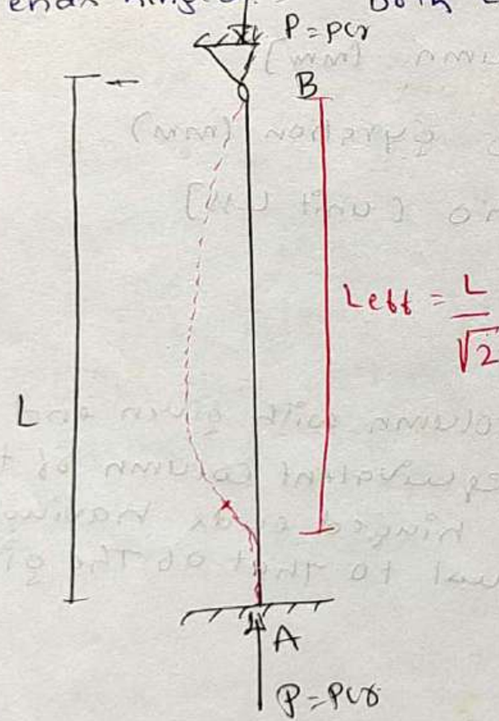


fig: 4 one end is hinged and other end fixed.

Assumptions of Euler's theory [long columns]

Euler's formula for crippling load is based on the following assumption:

1. The column is initially perfectly straight and is axially loaded.
2. The section of the column is uniform.
3. The self weight of the column is neglected.
4. The column material is perfectly elastic, homogenous & Isotrophic.
5. Stresses are within elastic limit and hence column obeys hooke's law.
6. The length is very large compared to the lateral dimensions (or) cross sectional dimension [l > b (or) d]
7. The Direct stresses are very small compared to with the bending stresses corresponding to the buckling conditions.
8. The column is fails due to buckling alone.

End conditions for long columns:

In case of long columns, the stresses due to direct load is very small in comparision with the stresses due to buckling. Hence the failure of long columns take place entirely due to buckling [or bending] The following four types of end conditions of the columns are important.

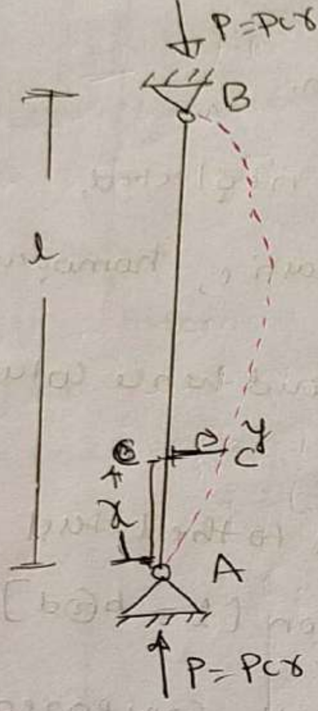
1. Both ends of the column are hinged (or) [pinned]
2. one end is fixed and other end is free.
3. Both the ends of the column are fixed.
4. one end is fixed & the other is pinned.

for a hinged end, the deflection is zero, for a fixed end the the deflection and slope is zero. for a free end the deflection is not zero.

Derive (or) Expression for Euler's theory for the Derive the Expression for crippling load when Both ends of the column are hinged.

Consider a long column of length 'l' subjected to gradually increasing load P with both ends hinged as shown in figure.

Case: 1 Both ends hinged (Pinned)



The load at which the column just buckles [or bends] is called crippling load. Consider a column AB of length l and uniform cross sectional area, hinged at both its ends A and B. Let P be the crippling load at which the column has just buckled.

Due to the crippling load the column will deflect into curved form ACB as shown fig.

Consider any section at a distance x from the end A.

Let y be the deflection (lateral displacement) at the section.

Consider a point C on the column where the deflection is y

Bending moment at the section (negative → hogging Bm)

Bm] = (−) Pcr [y] (or) $-P_{cr}\, y$

Moment curvature relationship

$$\frac{M}{EI} = \frac{d^2y}{dx^2}$$

$$M = \frac{d^2y}{dx^2} \cdot EI$$

$$\alpha^2 = \frac{P_{cr}}{EI}$$

$$\alpha = \sqrt{\frac{P_{cr}}{EI}}$$

Also WKT

$$Bm] = EI\left[\frac{d^2y}{dx^2}\right] = -P_{cr}\, y$$

$$EI\left[\frac{d^2y}{dx^2}\right] + P_{cr}(y) = 0$$

÷ by EI

$$\frac{d^2y}{dx^2} + \frac{P_{cr}\, y}{EI} = 0 \rightarrow (1)$$

$$\frac{d^2y}{dx^2} + \frac{P}{EI} \cdot y = 0$$

$$\frac{d^2y}{dx^2} + \alpha^2 y = 0$$

$$y = C_1 \cos \alpha x + C_2 \sin \alpha x$$

$$y = C_1 \cos\left[x\sqrt{\frac{P_{cr}}{EI}}\right] + C_2 \sin\left[x\sqrt{\frac{P_{cr}}{EI}}\right]$$

The moment due to crippling load at the section

$= -P \cdot y$

But moment $= E \cdot I \cdot \frac{d^2y}{dx^2}$.

Moment curvature relationship

$\frac{M}{EI} = \frac{d^2y}{dx^2}$

$M = \frac{d^2y}{dx^2} \cdot EI$

Equating the two moments, we have

$EI \cdot \frac{d^2y}{dx^2} = -P \cdot y$

$EI \cdot \frac{d^2y}{dx^2} + P \cdot y = 0$

$\div EI$

$\frac{d^2y}{dx^2} + \frac{P}{EI} \cdot y = 0$.

The equation

$\frac{d^2y}{dx^2} + \frac{P}{EI} \cdot y = 0$

can be written as

$\frac{d^2y}{dx^2} + \alpha^2 \cdot y = 0$

$\alpha^2 = \frac{P}{EI}$

$\alpha = \sqrt{\frac{P}{EI}}$

The solution of the above differential equation is

$y = c_1 \cos \alpha x + c_2 \sin \alpha x$

$y = c_1 \cos\left(\sqrt{\frac{P}{EI}} \cdot x\right) + c_2 \sin\left(\sqrt{\frac{P}{EI}} \cdot x\right) \longrightarrow (1)$

where c_1 and c_2 are the constants of integration. The values of c_1 and c_2 are as follows.

The solution of equation

$y = c_1 \cos \alpha x + c_2 \sin \alpha x$

(1) At A $x = 0$, $y = 0$, substituting these values in eq (1) we get

$y = c_1 \cos\left[\sqrt{\frac{P}{EI}} \cdot x\right] + c_2 \sin\left[\sqrt{\frac{P}{EI}} \cdot x\right]$

$0 = c_1 \cos\left[\sqrt{\frac{P}{EI}} \cdot 0\right] + c_2 \sin\left[\sqrt{\frac{P}{EI}} \cdot 0\right]$

$0 = c_1 \times 1 + c_2 \times 0$ $\quad \because \left[\begin{array}{l}\cos 0 = 1 \\ \sin 0 = 0\end{array}\right]$

$\boxed{c_1 = 0} \longrightarrow (2)$.

(2) At B $x = l$, $y = 0$ substituting these values in eq (1) we get

$0 = c_1 \cdot \cos\left[\sqrt{\frac{P}{EI}} \cdot l\right] + c_2 \sin\left[\sqrt{\frac{P}{EI}} \cdot l\right]$ $\quad (c_1 = 0.)$

$0 = 0 + c_2 \sin\left[\sqrt{\frac{P}{EI}} \cdot l\right]$

$= c_2 \sin\left[l\sqrt{\frac{P}{EI}}\right] \longrightarrow (3)$

From equation ③ it is clear that either $C_2 = 0$

$$\sin\left(l\sqrt{\frac{P}{EI}}\right) = 0$$

As $C_1 = 0$ ~~then~~ if $C_2 = 0$ is also equal to zero, then from equation ① we will get $y = 0$, this mean that the column will be zero (or) the column will not bend at all. which is not true.

$$\therefore \sin\left[l\sqrt{\frac{P}{EI}}\right] = 0$$

$$= \sin 0 \text{ (or) } \sin\pi \text{ (or) } \sin 2\pi \text{ (or) } \sin 3\pi \text{ or} \text{ ——}$$

$$l\sqrt{\frac{P}{EI}} = 0 \text{ (or) } \pi \text{ (or) } 2\pi \text{ (or) } 3\pi$$

Taking the least practical values

$$l\sqrt{\frac{P}{EI}} = \pi$$

$$\boxed{P = \frac{\pi^2 EI}{l^2}}$$

① Derive the Expression for crippling load when both the ends are fixed.

② Derive the Expression for crippling load when ~~both~~ one end ~~the~~ is free and other end fixed

③ Derive the Eulers equation ~~for~~ for buckling load ~~both~~ on an elastic column with one end is fixed and other end is ~~fi~~ hinged.

Where c_1 and c_2 are constants which are obtained by boundary condition.

at $x=0$. $y=0$, $\therefore c_1=0$

at $x=l$ $y=0$ $c_2 \neq 0$.

As c_2 can not be zero the derivation is observed at all other points hence.

$$\sin\left[l\sqrt{\frac{P_{cr}}{EI}}\right]=0$$

for minimum non-zero value of 0, we have solution has A.

$$\sin\left[l\sqrt{\frac{P_{cr}}{EI}}\right]=0, \pi, 2\pi, \ldots$$

$$l\sqrt{\frac{P_{cr}}{EI}}=\pi$$

$$\frac{l^2 P_{cr}}{EI}=\pi^2$$

$$\boxed{P_{cr}=\frac{\pi^2 EI}{l^2}}$$

As both ends are hinged (or) pinned $P_{cr}=\frac{\pi^2 EI}{(l_{eff})^2}$.

Case: 2. When both ends are fixed.

$$P_{cr}=\frac{\pi^2 EI}{(l/2)^2}=\frac{\pi^2 EI}{\frac{l^2}{4}}=\frac{4\pi^2 EI}{l^2}.$$

Case: 3 When one end is free and other end

$$P_{cr}=\frac{\pi^2 EI}{(2l)^2} \text{ (or) } \frac{\pi^2 EI}{4l^2}.$$

Case: 4 one end hinged and other end is fixed.

$k^2 = I/A$.

$$P_{cr}=\frac{\pi^2 EI}{(l/\sqrt{2})^2} \text{ (or) } \frac{\pi^2 EI}{\frac{l^2}{2}}=\frac{2\pi^2 EI}{l^2}.$$

Sign Conventions: The following sign conventions for the bending of the columns will be used.

1. A moment which will bend the column with its convexity towards its initial central line as shown in fig (a) is taken as positive.

In fig (a) AB represents the initial centre line of a column. Whether the column bends taking the shape AB' or AB'', the moment producing this type of curvature is positive.

2. A moment which will bend the column with its concavity towards its initial centre line as shown in fig (b) is taken as negative.

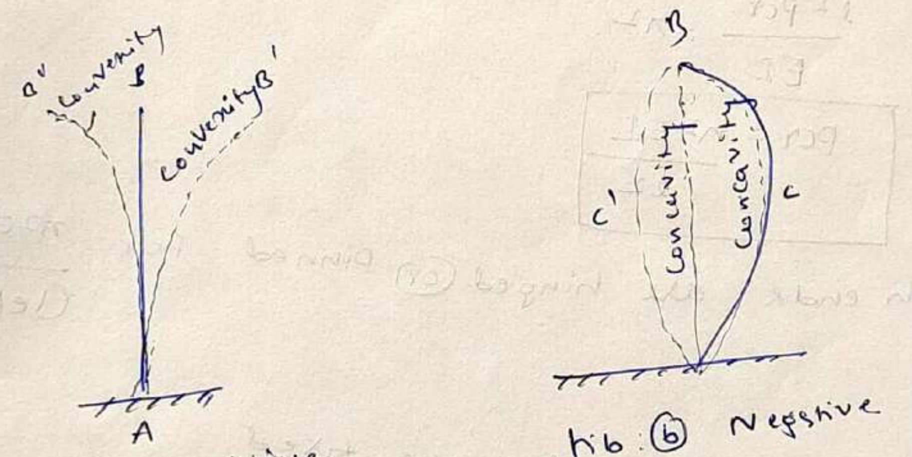


fig (a) Positive

fig (b) Negative

$$\frac{d^2y}{dx^2} + \frac{P}{EI} \cdot y = 0$$

$y = C_1 \cos(\alpha x) + C_2 \sin \alpha x$

$y = C_1 \cos\left[\sqrt{\frac{P}{EI}} \times x\right] + C_2 \sin\left[\sqrt{\frac{P}{EI}} \times x\right] \rightarrow (1)$

as $\alpha = \sqrt{\frac{P}{EI}}$ in eq (1) we get

$\frac{d^2y}{dx^2} + \frac{P}{EI} \cdot y = 0$ rewritten as

$\frac{d^2y}{dx^2} + \alpha^2 \cdot y = 0$

where $\alpha^2 = \frac{P}{EI}$

in eq (1) we get $\alpha = \sqrt{\frac{P}{EI}}$

$y = C_1 \cos(\alpha x) + C_2 \sin(\alpha x)$

(1) At A, $x = 0$, $y = 0$,

$0 = C_1 \cos 0 + C_2 \sin 0$

$= C_1 \times 1 + C_2 \times 0$

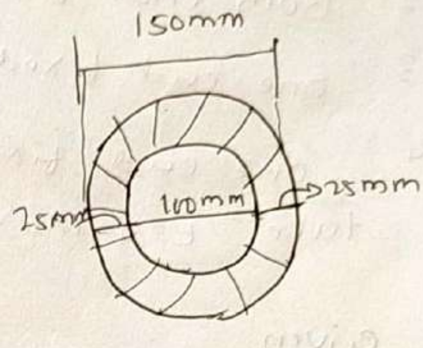
$0 = C_1$

(2) At B, $x = l$, $y = 0$,

$0 = C_1 \cos\left[\sqrt{\frac{P}{EI}} \times l\right]$

Problems on Euler's Theory

1. A hallow cast iron cylinderical column 3m long is hinged at both ends. The External diameter is 150mm & Thickness is 25mm using the factor of safety is 4. determine the same load that the column can support take $E = 89.5$ GPa.



→ $l = 3000$ mm

$d_e = 150$ mm

$d_i = 100$ mm

$l = l_e = 3000$ mm

$d_i = 150 - 25 - 25 = 100$ mm

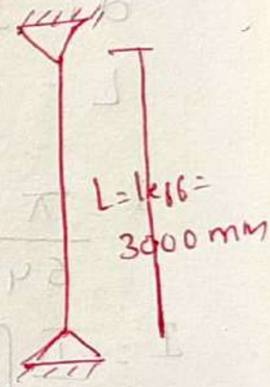
$P = ?$

$E = 89.5 \times 10^3$ MPa (or) N/mm²

FOS = 4

Both the end conditions are pinned (or) hinged.

$I = \frac{\pi}{64} d^4$



$$P_{cr} = \frac{\pi^2 E I}{(l_{eff})^2}$$

$$I = \frac{\pi}{64}\left[d_e^4 - d_i^4\right]$$

$$I = \frac{\pi}{64}\left[150^4 - 100^4\right]$$

$I = \frac{\pi d^4}{64}$

$$\boxed{I = 19.94 \times 10^6 \text{ mm}^4}$$

$$P_{cr} = \frac{\pi^2 \times 89.5 \times 10^3 \times 19.94 \times 10^6}{(3000)^2}$$

$$P_{cr} = 1.95 \times 10^6 \text{ N}$$

$$\boxed{P_{cr} = 1.95 \times 10^3 \text{ kN}}$$

$$\text{Safe load} = \frac{\text{crippling load}}{\text{FOS}} = \frac{1.95 \times 10^3}{4}$$

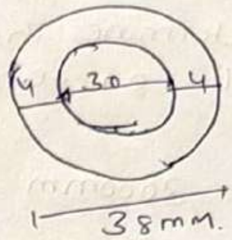
$$\boxed{\text{Safe load} = 0.4875 \times 10^3 \text{ kN}}$$

Find the shortest length

(2) A m s tube 4m long 30mm internal diameter and 4mm Thick is used as a strut. find the collapse load in

1. Both ends hinged
2. Both ends fixed
3. one end fixed & other free
4. one end fixed and other hinged.

take $E = 2.1 \times 10^5$ MPa



us Given

$d_e = 38mm$

$d_i = 30mm$

$L = 4m = 4000mm$

$I = \frac{\pi}{64}[d_e^4 - d_i^4]$

$I = \frac{\pi}{64}[38^4 - 30^4]$

$\boxed{I = 62.59 \times 10^3 mm^4}$

$\frac{N/mm^2 \times mm^4}{mm^2} = N/mm^2 \times mm^2 \simeq$

(1) Both ends Hinged

$P_{cr} = \frac{\pi^2 EI}{(L_{eff})^2}$

$P_{cr} = \frac{\pi^2 \times 2.1 \times 10^5 \times 62.59 \times 10^3}{(4000)^2}$

$\boxed{P_{cr} = 8.108 \times 10^3 N}$

(2) Both ends fixed.

$P_{cr} = \frac{\pi^2 EI}{(\frac{L}{2})^2}$

$= \frac{\pi^2 \times 2.1 \times 10^5 \times 62.59 \times 10^3}{(\frac{4000}{2})^2}$

$\boxed{P_{cr} = 32.43 \times 10^3 N}$

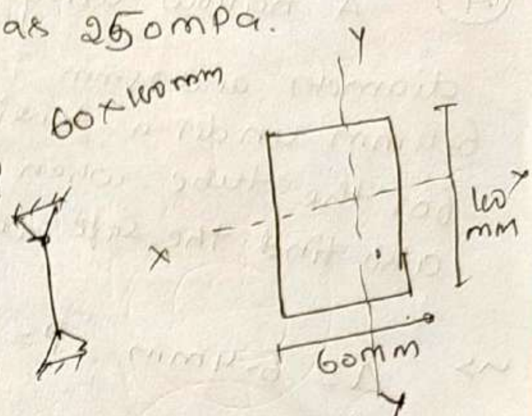
(3) one end is fixed and other free

$P_{cr} = \frac{\pi^2 EI}{(2L)^2} = \frac{\pi^2 \times 2.1 \times 10^5 \times 62.59 \times 10^3}{(2 \times 4000)^2} = \boxed{P_{cr} = 2.07 \times 10^3 N}$

(4) one end is fixed & other end hinged.

$P_{cr} = \frac{\pi^2 EI}{(\frac{L}{\sqrt{2}})^2} = \frac{\pi^2 \times 2.1 \times 10^5 \times 62.59 \times 10^3}{[\frac{4000}{\sqrt{2}}]^2} = \boxed{P_{cr} = 16.21 \times 10^3 N}$

(3) Find the shortest length 'l' for pinned ended steel column have cross section of 60mm x 100mm take $E_S = 2\times10^5\ N/mm^2$ and critical proportionality limit as 250mPa.



$\Rightarrow$ $L = ?$ $E_S = 2\times10^5\ N/mm^2$

Both ends are pinned $l_{eff} = l = ?$

$\sigma_{cr} = 250 mPa$ (or) $N/mm^2 = \left[\frac{P_{cr}}{A}\right]$

b → parallel to the reference axis x-x

d – parallel to the reference axis y-y.

$P_{cr} = \frac{\pi^2 E\,[AK^2]}{(L_e)^2}$

$\frac{P_{cr}}{A} = \frac{\pi^2 E K^2}{l_e^2} = 250$

$K = \sqrt{\frac{I}{A}}$

Determine K_{min} consider I_{min}

$I_{xx} = \frac{bd^3}{12} = \frac{60\times100^3}{12} = 5\times10^6\ mm^4$

$I_{yy} = \frac{b^3 d}{12} = \frac{100\times60^3}{12} = 1.8\times10^6\ mm^4$

$\sigma_{cr} = \frac{P_{cr}}{A}$

$K_{yy} = \sqrt{\frac{I_{yy}}{A}} = \sqrt{\frac{1.8\times10^6}{(60\times100)}}$

$K_{xx} = \sqrt{\frac{I_{xx}}{A}} = \sqrt{\frac{5\times10^6}{(60\times100)}}$

$\sigma_{cr}\times A = P_{cr}$

$\sigma_{cr}\times A = \frac{\pi^2 EI}{l_e^2}$

$K_{yy} = 17.32mm$

$K_{xx} = 28.8\ mm$

where $I = Ak^2$

$k = \sqrt{\frac{I}{A}} = k^2 A = I$

$\sigma_{cr}\times A = \frac{\pi^2 E\,(Ak^2)}{l_e^2}$

$\sigma_{cr}\ \frac{P_{cr}}{A} = \frac{\pi^2 E\,k^2}{l^2}$

$\sigma_{cr} = \frac{\pi^2 E k^2}{l_e^2}$

$250 = \frac{\pi^2\times2\times10^5\times(17.32)^2}{l_e^2}$

$250 = \frac{\pi^2 E k^2}{l_e^2}$.

$l_e = 1.539\times10^3\ mm$

$\sigma_{cr}\times A = P_{cr}$

$\sigma_{cr}\times A = \frac{\pi^2 EI}{L_e^2}$

$K = \sqrt{\frac{I}{A}}$.

$\sigma_{cr}\times A = \frac{\pi^2\times E\times k^2\times A}{l_e^2}$.

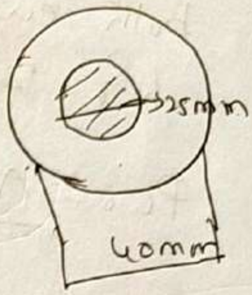
$k^2 = \frac{I}{A}$

$k^2\times A = I$

$\sigma_{cr} = \frac{\pi^2\times E\times k^2}{l_e^2}$

(4) A hallow alloy tube 5m long with 40mm External diameter and 25mm internal dia was found to extend by 6.4mm under a tensile load of 60kN. Find the buckling load for the tube when it is used as column with both ends pinned. also find the safe compressive load for the tube is FOS = 4.

$\Delta = 6.4mm \quad P = 60kN = 60\times10^3 N.$ [T]



$L_{eff} = 5m = 5000mm.$

$P_{cr} = ? \quad P_{safe} = ?$

FOS = 4

Case: 1

Youngs modlus

$$\Delta = \frac{PL}{AE} \qquad 6.4 = \frac{60\times10^3\times5000}{\frac{\pi}{4}[40^2-25^2]E} = \frac{N\,mm}{mm^2 \times N/mm^2}$$

$$E = 61.213\times10^3 \text{ mpa or } N/mm^2$$

Case: 2 To find Pcr [Pinned]

$$P_{cr} = \frac{\pi^2 EI}{L_e^2} = \frac{\pi^2(61.213\times10^3)\left(\frac{\pi}{64}[40^4-25^4]\right)}{(5000)^2}$$

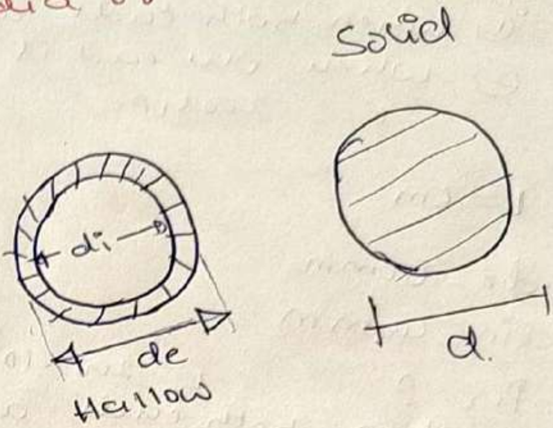
$$P_{cr} = 2.57\times10^3 N$$

$$FOS = \frac{P_{cr}}{P_{safe}}$$

$$P_{safe} = \frac{P_{cr}}{FOS} = \frac{2.57\times10^3}{4}$$

$$P_{safe} = 642.5N$$

(5) Determine ratio of buckling strength of 2 circular columns one hallow and other solid both are made of same material, same length, same cross sectional area & same end condition. The internal dia of hallow column is 1/2 external diameter.



→ Hallow

$d_i = \frac{1}{2} d_e$

$$\boxed{d_i = 0.5 d_e}$$

Solid

$E_H = E_S$

$A_H = A_S$

$L_H = L_S$

$L_{eff}]_{Hallow} = L_{eff}]_{Solid}$

$A_S = A_H$

$$\frac{\pi}{4}[d]^2 = \frac{\pi}{4}\left[d_e^2 - d_i^2\right]$$

$$\frac{\pi}{4}[d]^2 = \frac{\pi}{4}\left[d_e^2 - 0.5^2 d_e^2\right]$$

$$\frac{\pi}{4}[d]^2 = \frac{\pi}{4} d_e^2 [1 - 0.5^2]$$

$$\frac{\pi}{4}[d]^2 = \frac{\pi}{4} d_e^2 \times 0.75$$

$$d^2 = \frac{0.58 d_e^2}{0.78}$$

$$\boxed{d = 0.866 d_e}$$

$$\frac{P_{cr}]_H}{P_{cr}]_S} = ? = \frac{\frac{\pi^2 EI}{l_e^2}}{\frac{\pi^2 EI}{l_e^2}}$$

$$= \frac{I]_H}{I]_S}$$

$$\frac{P_{cr}]_H}{P_{cr}]_S} = \frac{(d_e^4 - d_i^4)}{d^4} = \frac{d_e^4 - 0.5^4 d_e^4}{(0.866 d_e)^4}$$

$$= 1.667$$

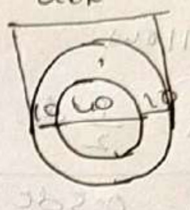
(06) A hallow tube of 6m length with external diameter 60mm & thickness 10mm is subjected to minimum crippling load. Find Euler's critical load for this column.

10M Dec-2016 Jan-2017

① when both ends are fixed.

② when one end is fixed & other end hinged. Assume E = 200GPa.

$d_{ex} = 60mm$



→ $L = 6m$

$d_e = 60mm$

$d_{in} = 40mm$

$P_{cr} = ?$

$E = 200 \times 10^3$ MPa.

① when both ends are fixed.

$$P_{cr} = \frac{4\pi^2 EI}{l^2}$$

$$I = \frac{\pi}{64}[d_e^4 - d_{in}^4] = \frac{\pi}{64}[60^4 - 40^4] = \text{~~98.17~~ } 510.50 \times 10^3 \text{ mm}^4$$

$$P_{cr} = \frac{4 \times \pi^2 \times 200 \times 10^3 \times \text{~~98.17~~ } 510.50 \times 10^3}{6000^2}$$

P_{cr} = ~~2.153~~ N.

111.967×10^3 N

② when one end is fixed & other end hinged

$$P_{cr} = \frac{2\pi^2 EI}{l^2}$$

$$P_{cr} = \frac{2 \times \pi^2 \times 200 \times 10^3 \times \text{~~98.17~~ } 510.50 \times 10^3}{6000^2}$$

P_{cr} = ~~10.76~~ N

5.598×10^6 N

S. No	Material	σc in N/mm2	a
1.	wrought	250	1/9000
2.	cast iron	550	1/1600
3.	Mild steel	320	1/7500
4.	Timber	50	1/750

type
Any column

[Rankines - Gordan's formula [Equation] (suitable for any type of column)

Euler equation for long columns

Emperical formula

Rankines - gordon has developed an emperical equation considering the failure by buckling & crushing as given below

$$\frac{1}{P_R} = \frac{1}{P_C} + \frac{1}{P_E}$$

where P_R = Rankine's load

P_C (or) P_s = load carrying capacity of short column (or) crushing load $= f_c \times A$

$f_c = \frac{P_C}{A}$

$P_C = f_c \cdot A$

P_E = Euler's load.

P_E (or) P_{cr} = Euler's critical load $\frac{\pi^2 EI}{(l_e^2)}$

l_e = effective length.

$$\frac{1}{P_R} = \frac{P_C + P_E}{P_C \times P_E}$$

Taking the reciprocal on both sides

PE sending denominator

$$P_R = \frac{P_C \times P_E}{P_C + P_E} \div P_E$$

$$P_R = \frac{P_C}{\frac{P_C}{P_E} + \frac{P_E}{P_E}}$$

radius of gyration (r)

It is the entire area which would be make it into a strip and should kept at a distance

r

$$P_R = \frac{P_C}{\frac{P_C}{P_E} + 1} \text{ (or) } \frac{P_C}{1 + \frac{P_C}{P_E}}$$

$$P_R = \frac{P_C}{1 + \frac{f_c A}{\frac{\pi^2 EI}{l_e^2}}}$$

$$r_{min} = \sqrt{\frac{I_{min}}{A}}$$

r = radius of gyration

$$P_R = \frac{P_C}{1 + \frac{f_c A l_e^2}{\pi^2 EI}}$$

$$r^2 = \frac{I}{A}$$

$$I = Ar^2$$

Problems on Rankin[e] ... external diam[eter]

1

$$P_R = \frac{P_C}{1 + \frac{\sigma_c A L^2}{\pi^2 E A r^2}}$$

$$= \frac{P_C}{1 + \frac{\sigma_c}{\pi^2 E}\left(\frac{L^2}{r^2}\right)}$$

where.

$$\lambda = \frac{L}{r}$$

λ = Slenderness ratio (or) Buckling factor.

$$\boxed{P_R = \frac{P_C}{1 + \frac{\sigma_c}{\pi^2 E}[\lambda]^2}}$$

where:

$$\boxed{\frac{\sigma_c}{\pi^2 E} = \alpha \text{ (or) } a}$$

$$\boxed{P_R = \frac{P_C}{1 + a\lambda^2}}$$

where $a = \frac{\sigma_c}{\pi^2 E}$ & is known as Rankine's constant.

~~the crushing stresses σ_c is a constant~~

For a given column material the crushing stresses σ_c is a constant for a given cross-sectional area of the column. Hence the crushing load P_C will also be constant & hence the value of P depends upon the value of P_E. In eq (1) P_C is constant. But for a given column material & given cross-sectional area, the value of P_E depends upon the effective length of the column.

(1) If the column is a short, which means the value of Le is small, then the value of P_E will be large. Hence the value of $\frac{1}{P_E}$ will be small enough & is negligible as compared to the value of $\frac{1}{P_C}$. Neglecting the value of $\frac{1}{P_E}$ in eq (1) we get

$$\frac{1}{P} \to \frac{1}{P_C} \quad \text{(or)} \quad P \to P_C.$$

Hence the crippling load by Rankine's formula for a short column is approximately equal to crushing load.

(2) If the column is a long, which the value of Le is large, then the value of P_E will be small & the value of $\frac{1}{P_E}$ will be large enough compared with $\frac{1}{P_C}$. Hence the value of $\frac{1}{P_C}$ may be neglected in eq (1).

$$\frac{1}{P} = \frac{1}{P_E} \quad \text{(or)} \quad P \to P_E$$

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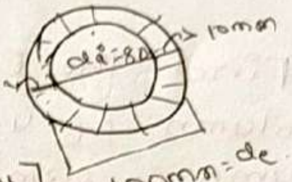
Problems on Rankine's -Gordon equation

① A cast iron column 100mm dia External diameter 10mm thick is 3m long. calculate the safe load using Rankine's formula.
i) (i) Both ends are hinged. (l)
(ii) Both ends are fixed (l/2) FOS = 3
if take fc = 600mPa. $a = \left(\frac{1}{1600}\right)$



Ans $d_e = 100mm$

$d_i = 80mm$

$l = 3000 mm$

$I = \frac{\pi}{64}\left[d_e^4 - d_i^4\right]$

$A = \pi/4 \left[d_e^2 - d_i^2\right]$

$I = \frac{\pi}{64}\left[100^4 - 80^4\right]$

$A = \pi/4 \left[100^2 - 80^2\right]$

$I = 2.898 \times 10^6 mm^4$

$A = 2.827 \times 10^3 mm^2$

radius $K = \sqrt{\frac{I}{A}}$

Rankin's equation $P_R = \frac{f_c \cdot A}{1 + a\lambda^2} = \frac{P_c}{1 + a\left(\frac{l}{r}\right)^2}$

$P_c = f_c \cdot A$

$\lambda = \frac{L}{K}$

When Both ends are hinged

Case 1. $l_{effective} = l = 3000mm$

$I = AK^2$

$P_R = \frac{600 \times [2.827 \times 10^3]}{1 + \left[\frac{1}{1600}\right]\left[\frac{3000}{32.05}\right]^2}$

$K = \sqrt{\frac{I}{A}}$

$P_R = 262.02 \times 10^3 N$

$K = \sqrt{\frac{2.898 \times 10^6}{2.827 \times 10^3}}$

When both ends are fixed l_{eff} 1/2

$K = 32.05mm$

Case: 2 $l_{effective} = \frac{l}{2} = \frac{3000}{2} = 1500 mm$

$P_R = \frac{f_c \cdot A}{1 + a\left(\frac{l}{r}\right)^2} = \frac{(600 \times 2.827 \times 10^3)}{1 + \left[\frac{1}{1600}\right]\left(\frac{1500}{32.05}\right)^2}$

$P_R = 715.1 \times 10^3 N$

Factor of safety $= \frac{P_{cr}}{P} = \frac{\text{Critical load}}{\text{Safe load}}$

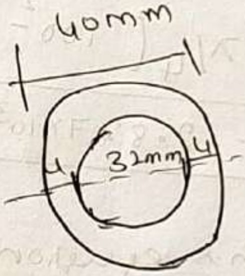
case i : $P = \frac{P_R}{FOS}$

$P_{safe} = \frac{262.02 \times 10^3}{3} = 87.34 \times 10^3\ N$

case : 2

$P_{safe} = \frac{715.1 \times 10^3}{3} = 238.36 \times 10^3\ N$

(2) Find the Euler's crippling load on a hollow steel column of 40mm External dia and 4mm thick. Length of column is 2.3m with pinned ends. Also determine crippling load by using Rankine's formula with constant as $f_c = 335$ mPa. $a = \frac{1}{750}$ $E = 205$ GPa.



Ans:

$d_e = 40mm$

$d_i = 32mm$

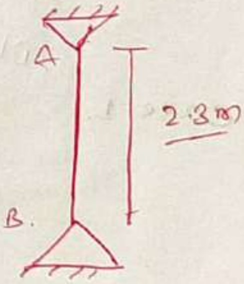
$l = 2.3m = 2300mm$

$P_{cr} = ?$

$f_c = 335$ mpa

$a = \frac{1}{7500}$

$E = 205 \times 10^3$ mpa.



$A = \frac{\pi}{4}[d_e^2 - d_i^2] = \frac{\pi}{4}[40^2 - 32^2]$

$A = 452.38\ mm^2$

$I = \frac{\pi}{64}[d_e^4 - d_i^4] = \frac{\pi}{64}[40^4 - 32^4] = 74.19 \times 10^3\ mm^4$

$I = 74.19 \times 10^3\ mm^4$

$K = \sqrt{\frac{I}{A}} = \sqrt{\frac{74.19 \times 10^3}{452.38}}$

Radius of gyration. $K = 12.80\ mm$

$$P_{cr} = \frac{\pi^2 EI}{l^2} = \frac{\pi^2 \times 205 \times 10^3 \times 74.19 \times 10^3}{(2300)^2}$$

$$\boxed{P_{cr} = 28.37 \times 10^3 N}$$

$$P_R = \frac{(f_c)(A)}{1 + a(\lambda)^2} \text{ (or) } \frac{P_c}{1 + a(\lambda)^2} \qquad \lambda = \frac{l}{K}$$

$$P_R = \frac{335 \times 452.389}{1 + \left(\frac{1}{7500}\right)\left[\frac{2300}{12.806}\right]^2}$$

$$\boxed{P_R = 28.58 \times 10^3 N}$$

Dec-2017

③ A hallow CI column whose outside diameter is 200mm as a thickness of 20mm. it is 4.5m long & fixed at both the ends

① Calculate safe load by Rankine's formula using fos=4

② Calculate the ratio of Euler's and Rankine's critical load and slenderness ratio. using Critical load in Rankine's form -ula and

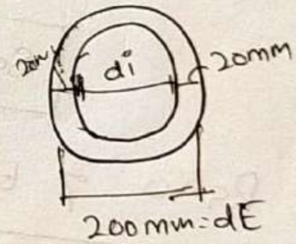
Take f_c or σ_c = 550 N/mm² $a = \frac{1}{1600}$ and $E = 9.4 \times 10^4$ N/mm²

(i)

$d_e = 200mm$

$d_i = 160mm$

$l = 4.5m$



$$A = \frac{\pi}{4}(d_e^2 - d_i^2) = \frac{\pi}{4}(200^2 - 160^2)$$

$$\boxed{A = 11.30 \times 10^3 mm^2}$$

$$I = \frac{\pi}{64}\left[d_e^4 - d_i^4\right] = \frac{\pi}{64}\left[200^4 - 160^4\right]$$

$$\boxed{I = 46.369 \times 10^6 mm^4}$$

$$k = \sqrt{\frac{I}{A}} = \sqrt{\frac{46.369 \times 10^6}{11.30 \times 10^3}}$$

$$\boxed{K = 64.05mm}$$

* End conditions are fixed

$$P_{cr} = \frac{\pi^2 E I}{Le^2}$$ ~~$= \pi^2 \times$~~

length of column = 4.5m = 4500mm

* Le = effective length

$$le = \frac{L}{2} = \frac{4500}{2} = 2250\text{ mm}$$

* factor of safety = 4 $\sigma_c = 550 N/mm^2$, $E = 9.4 \times 10^4 N/mm^2$

* Slenderness ratio $\lambda = \frac{le}{K} = \frac{4500}{64.05} = 70.25$ $\frac{2250}{64.05}$

(2) Safe load by Rankine's formula.

$$P_R = \frac{P_C}{1 + a\lambda^2} = \frac{\sigma_C \times A}{1 + a\left[\frac{le}{K}\right]^2} = \frac{550 \times 11.30 \times 10^3}{1 + \frac{1}{1600}\left[\frac{2250}{64.05}\right]^2}$$

$$P_R = 3.508 \times 10^6 N$$

P_R = crippling load

$$\text{Safe load} = \frac{\text{crippling load}}{\text{Factor of safety}} = \frac{3.508 \times 10^6}{4}$$

$$\text{Safe load} = 877.19 \times 10^3 N$$

(3) Ratio of Euler's and Rankine's critical loads

Let P_E = Euler's critical load

$$P_E = \frac{\pi^2 E I}{Le^2} = \frac{\pi^2 \times 9.4 \times 10^4 \times 46.39 \times 10^6}{2250^2}$$

$$P_E = 8.5013 \times 10^6 N$$

$$\frac{\text{Euler's critical load}}{\text{Rankine's critical load}} = \frac{P_E}{P_R} = \frac{8.5013 \times 10^6}{3.508 \times 10^6}$$

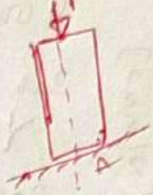
$$= 2.42$$

Limitations of Euler's Formula (Theory)

The Euler's theory is based on the following assumptions. Ideal struts.

① The axis of the strut is perfectly straight when unloaded.

② The line of thrust coincides exactly with unstrained axis of the strut.



③ The flexural rigidity EI is uniform.

④ The material is isotropic.

⑤ The buckling value of $P = P_E$ is assumed to obtained for all degrees of flexure. Buckling load = Euler crippling load.

Usually the first two assumptions are not fully realised in practice. The column may have initial curvature, distortion or crookedness. The theory refers to ideal struts & not to a real one.

It is interesting to note that no strength property of the material appears in the Euler's formulae, yet they determine the carrying capacity of a column. The only material property involved in the elastic modulus E.

The critical stress (load) p_E, which is defined as an average stress (load) over the cross section is given by.

$k = \sqrt{\frac{I}{A}}$

$$p_E = \frac{P_E}{A} = \frac{\pi^2 EI}{AL^2} = \frac{\pi^2 E A r^2}{AL^2}$$

where $Ar^2 = I$, r = radius of gyration

$$P_E = \frac{\pi^2 E r^2}{L^2}$$

$$P_E = \frac{\pi^2 E}{\frac{L^2}{r^2}} = \frac{\pi^2 E}{\left(\frac{L}{r}\right)^2}$$

$$\boxed{P_E = \frac{\pi^2 E}{(L/r)^2}}$$

In the above expression L/r is known as slenderness ratio.

The graphical interpretation of Equation is shown by the curve ACB in fig

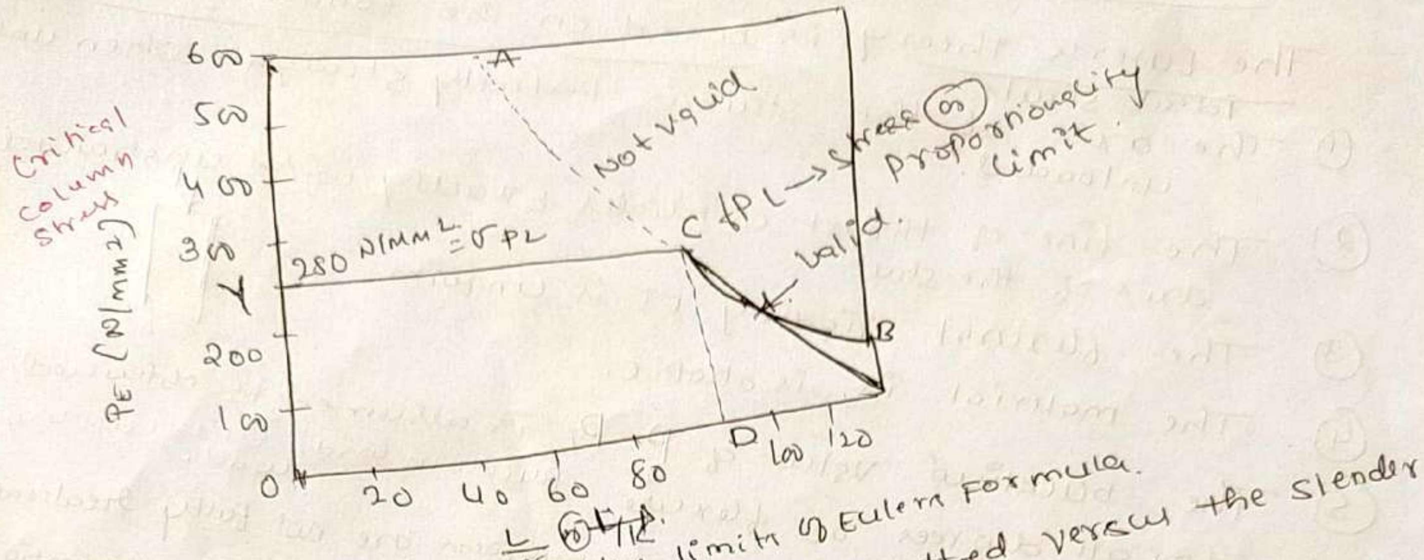


fig: validity limits of Euler's Formula.

① where the critical column stress is plotted versus the slenderness ratio for mild steel [$E = 2\times10^5$ N/mm²].

② The curve is entirely defined by the magnitude of E and is independent of its ultimate strength.

③ The long column has greater value of L/r & loses its strength at very small compressive ~~strength~~ stress.

④ This condition cannot be improved by taking a steel of higher strength, since the modulus of steel does not vary much with alloy and heat treatment, and remains practically constant.

In fig Let OY represents the proportional limit (σ_{PL}) of the material. It is clear that the Euler's formula can not possibly apply if L/r is less than OD. Since the stress is greater than OY, the material become plastic & no longer follows hooke's law.

Taking the proportional limit (σ_{PL}) is equal to ~~250~~ 250 N/mm² for mild steel.

The Euler's equation does not hold good or ceiz for any value of [L/r] less than (B) that corresponding to the value of fPl which is shown at Point B on the curve. i.e in the curve only portion BC is valid where as dotted line AC is not applicable to Euler theory.

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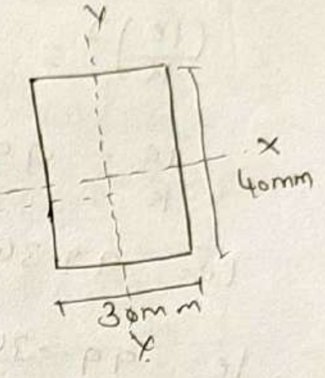
① A steel bar of rectangular section 30mm×40mm pinned at each end is subjected to axial compression. The bar is 1.75m long. determine the buckling load & corresponding axial stress using Euler's formula.

Determine the minimum length for which Euler's equation. If proportionality limit of material is 200MPa.



$I_{xx} = \frac{bd^3}{12} = \frac{30\times40^3}{12} = 160\times10^3 mm^4$

$I_{yy} = \frac{b^3d}{12} = \frac{30^3\times40}{12} = 90\times10^3 mm^4$

$k_{min} = \sqrt{\frac{I_{min}}{A}}$

$k_{min} = \sqrt{\frac{90\times10^3}{30\times40}}$

$k_{min} = 8.66mm$

$E = 2\times10^5 MPa$

$l = 1.75m \quad l_e = l = 1750mm$

Case 1 . axial stress.

$P_{cr} = \frac{\pi^2 E I_{min}}{l_e^2} = \frac{\pi^2 \times 2\times10^5 \times [90\times10^3]}{(1750)^2}$

$P_{cr} = 58.00\times10^3 N.$

Axial stress $f = \frac{Load}{Area} = \frac{P_{cr}}{A} = \frac{58\times10^3}{30\times40}$

$f = 48.33 MPa$ (or) N/mm^2.

$k = \sqrt{\frac{I}{A}}$

$k^2 \cdot A = I$

$p_{cr} = \frac{P}{A}$

$f_{cr} \cdot A = P$

Case: 2 $l_{min} = ?$

$P_{cr} = \frac{\pi^2 EI}{l_e^2} = \frac{\pi^2 E (Ak^2)}{l_e^2}$

$f_{cr} \cdot A \quad \frac{P_{cr}}{A} = \frac{\pi^2 E k^2}{l_e^2} = f_{cr} = \frac{\pi^2 E k^2}{l_e^2}$

$f_{cr} = \frac{\pi^2 E A k^2}{A \cdot l_e^2}$

$f_{cr} = \frac{\pi^2 E k^2}{l_e^2}$

$f_{cr} = \frac{\pi^2 E}{(\frac{l_e}{k})^2}$

Simply supported B...

$$b_{cr} = \frac{\pi^2 E}{\left(\frac{l_e}{k}\right)^2}$$

$$200 = \frac{\pi^2 \times 2 \times 10^5}{\left(\frac{l_e}{k}\right)^2}$$

$$\left(\frac{l_e}{k}\right)^2 = 9.86 \times 10^3$$

$$\frac{l_e}{k} = 99.34$$

$$l_e = 99.34 \times k_{min}$$

$$l_e = 99.34 \times 8.66$$

$$l_{min} = l_e = 860.33\,mm$$

$$b_{cr} = \frac{\pi^2 E}{\left(\frac{l_e}{k}\right)^2}$$

$$\left(\frac{l_e}{k}\right)^2 = \frac{\pi^2 E}{b_{cr}}$$

$$\left(\frac{l_e}{k}\right)^2 = -$$

$$l_e = -$$