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

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Revised Academic Calendar of VTU, Belagavi for ODD Semester of 2020-21 (Tentative)

	I Sem B. E. / B. Tech. / B. Arch./B.Plan	I sem M.Tech./MBA /MCA/M.Arch.	III, V B. E. /B. Tech./B.Plan/ B.Arch & VII sem BPlan /BArch & IX Sem B. Arch.	VII Sem B. E. /B. Tech	III & V Sem MCA	III Sem MBA	III Sem M. Tech.	III Sem M. Arch.
Commencement of ODD Semester	14.12.2020	Will be announced later	01.09.2020	01.09.2020	01.09.2020	01.09.2020	01.09.2020	01.09.2020
Last Working day of ODD Semester	25.03.2021		16.01.2021	16.01.2021	16.01.2021	16.01.2021	16.01.2021	16.01.2021
Practical Examinations	29.03.2021 Onwards#		21.01.2021 Onwards#	21.01.2021 Onwards#	08.02.2021 Onwards#	--	21.01.2021 Onwards#	--
Theory Examinations	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	21.01.2021 To 06.02.2021
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	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 01 Weeks.
- The classroom sessions for all the semesters would be in ONLINE mode/blended mode until further orders.
- The Institute needs to function for six days a week with additional hours (Saturday is a full working day).
- The faculty/staff shall be available to undertake any work assigned by the university.
- If any of the above dates are declared to be a holiday then the corresponding event will come into effect on the next working day.
- (#) Notification regarding the 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 the future by MHRD/UGC/AICTE/State Government.
- Revised Academic Calendar is also applicable for Autonomous Colleges.
- The MBA students are permitted to carry out project work in blended mode (ONLINE/OFFLINE). More emphasis on OFFLINE mode wherever feasible.

04-12-2020
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	14-10-2020	01-09-2020	01-09-2020	01-09-2020	01-09-2020	01-09-2020
Last Working Day	28-03-2021	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.

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.

Name of the Faculty : Kum. Supriya Xavier Lopes							
Time / Day	**8 – 9**	**9 – 10**	**10.30 – 11.30**	**11.30 – 12.30**	**2 – 3**	**3 – 4**	**4 – 5**
Mon			**20CSE12**				
Tue			**20CSE12** ***18CV56 – A***				
Wed		**20CSE12** ***18CV56 – A***					
Thu				**18CV56 – A**	**18CVL37 – B1 (SXL + RBV)**		
Fri		**17CV741 – A**	**20CEEL16 (SXL + GC)**		**20CSE12**		
Sat		**18CVL58 – B1 (SXL + MDV)**					

Time Table Coordinator **HOD** **Principal**

B. E. CIVIL ENGINEERING

Choice Based Credit System (CBCS) and Outcome Based Education (OBE)

SEMESTER - V

HIGHWAY ENGINEERING

Course Code	**18CV56**	CIE Marks	40
Teaching Hours/Week(L:T:P)	(3:0:0)	SEE Marks	60
Credits	03	Exam Hours	03

Course Learning **Objectives:** This course will enable students to;

1. Gain knowledge of different modes of transportation systems, history, development of highways and the organizations associated with research and development of the same in INDIA.
2. Understand Highway planning and development considering the essential criteria's (engineering and financial aspects, regulations and policies, socio economic impact).
3. Get insight to different aspects of geometric elements and train them to design geometric elements of a highway network.
4. Understand pavement and its components, pavement construction activities and its requirements.
5. Gain the skills of evaluating the highway economics by B/C, NPV, IRR methods and also introduce the students to highway financing concepts.

Module-1

Principles of **Transportation Engineering:** Importance of transportation, Different modes of transportation and comparison, Characteristics of road transport Jayakar committee recommendations, and implementation – Central Road Fund, Indian Roads Congress, Central Road Research Institute.

Highway **Development and Planning:** Road types and classification, road patterns, planning surveys, master plan – saturation system of road planning, phasing road development in India, problems on best alignment among alternate proposals Salient Features of 3rd and 4thtwenty year road development plans and Policies, Present scenario of road development in India (NHDP & PMGSY) and in Karnataka (KSHIP & KRDCL) Road development plan - vision 2021.

Highway Alignment and Surveys: Ideal Alignment, Factors affecting the alignment, Engineering surveys-Map study, Reconnaissance, Preliminary and Final location & detailed survey, Reports and drawings for new and re-aligned projects.

Module-2

Highway Geometric Design of horizontal alignment elements: Cross sectional elements–width, surface, camber, Sight distances–SSD, OSD, ISD, HSD, Radius of curve, Transition curve, Design of horizontal and vertical alignment–curves, super-elevation, widening, gradients, summit and valley curves.

Module-3

Pavement Materials: Sub grade soil - desirable properties-HRB soil classification-determination of CBR and modulus of sub grade reaction with Problems Aggregates- Desirable properties and tests, Bituminous materials- Explanation on Tar, bitumen, cutback and emulsion-tests on bituminous material Pavement Design: Pavement types, component parts of flexible and rigid pavements and their functions, ESWL and its determination (Graphical method only)-Examples.

Module-4

Pavement Construction: Design of soil aggregate mixes by Rothfuch's method. Uses and properties of bituminous mixes and cement concrete in pavement construction. Earthwork; cutting and Filling, Preparation of subgrade, Specification and construction of i) Granular Sub base, ii) WBM Base iii) WMM base,iv) Bituminous Macadam v) Dense Bituminous Macadam vi) Bituminous Concrete,vii) Dry Lean Concrete sub base and PQC viii) concrete roads.

Module-5

Highway Drainage: Significance and requirements, Surface drainage system and design-Examples, sub surface drainage system, design of filter materials, Types of cross drainage structures, their choice and location.

Highway Economics: Highway user benefits, VOC using charts only-Examples, Economic analysis - annual cost method-Benefit Cost Ratio method-NPV-IRR methods- Examples, Highway financing-BOT-BOOT concepts.

Course Outcomes: After studying this course, students will be able to:

1. Acquire the capability of proposing a new alignment or re-alignment of existing roads, conduct necessary field investigation for generation of required data.
2. Evaluate the engineering properties of the materials and suggest the suitability of the same for pavement construction.
3. Design road geometrics, structural components of pavement and drainage.
4. Evaluate the highway economics by few select methods and also will have a basic knowledge of various highway financing concepts.

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. S K Khanna and C E G Justo, "Highway Engineering", Nem Chand Bros, Roorkee.
2. L R Kadiyali, "Highway Engineering", Khanna Publishers, New Delhi.
3. R Srinivasa Kumar, "Highway Engineering", University Press.
4. K. P.Subramanium, "Transportation Engineering", SciTech Publications, Chennai.

Reference Books:

1. Relevant IRC Codes.
2. Specifications for Roads and Bridges-MoR T&H, IRC, New Delhi.
3. C. JotinKhisty, B. Kentlal, "Transportation Engineering", PHI Learning Pvt. Ltd. New Delhi.

Title & Code	Highway Engineering (18CV56)
CO	Statement
18CV56.1	**Explain** the principles of transportation including the present scenario of road development in India
18CV56.2	**Select** a new alignment and re-alignment of existing roads
18CV56.3	**Design** the geometrics of the road as per IRC recommendations
18CV56.4	**Explain** the properties of pavement materials for the design
18CV56.5	**Explain** the techniques of construction for various types of pavements
18CV56.6	**Evaluate** highway economics and also to design a suitable drainage system

Course Title		Highway Engineering										
CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
18CV56.1	1											2
18CV56.2	2	2		1		1	1					2
18CV56.3	2	2	2	1		1	1	1				2
18CV56.4	2		2	1		1		1				2
18CV56.5	2		2	1		1	1	1				2
18CV56.6	2	2	2	1		1	1	1			1	2
Average	1.83	2	2	1		1	1	1			1	2

CO	PSO1	PSO2
18CV56.1	2	2
18CV56.2	2	2
18CV56.3	2	2
18CV56.4	2	2
18CV56.5	2	2
18CV56.6	2	2
Average	2	2

LESSON PLAN

Subject : Highway Engineering Subject Code : 18CV56 Class : V - A

Period	Date	Topics Planned	Date	Topics Covered	Remarks
		Module-1 Principles of Transportation Engineering		Subramanya Sir has covered these topics by taking 13 classes.	
		Highway Development and Planning			
		Highway Alignment and Surveys	3/11/20	Highway Alignment and surveys	
		Module-2 Highway Geometric Design of horizontal alignment elements	4/11/20	Highway Geometric Design of horizontal alignment elements.	
		C/s sectional elements - width, surface, camber, sight distances SSD	5/11/20	C/s sectional elements - width, surface, camber	
		OSD, ISD HSD Radius of curve	10/11/20	Sight Distances SSD - Problems	
		Transition curve	11/11/20	OSD, ISD, HSD Radius of curve	
		Design of horizontal curve	12/11/20	Transition curve	
		Design of Vertical alignment curves	17/11/20	Design of horizontal curves	
		Spwr elevation	18/11/20	Design of vertical alignment curves	
		Widening	19/11/20	Super elevation - Problems	
		gradients	24/11/20	Widening of pavement	
		summit curves	25/11/20	Gradients	
		Valley curves.	26/11/20	Summit curves	
		Module - 3 Pavement material sub grade soil - desirable properties - HRB soil classification	1/12/20	Valley curves	
		Determination of CBR ~~and~~	2/12/20	Module-3 Pavement materials, sub grade soil desirable properties - HRB soil classification	
		Modulus of sub grade	3.12.20	Determination of CBR	

LESSON PLAN

Subject : Highway Engineering Subject Code : 18CV56 Class : V - A

Period	Date	Topics Planned	Date	Topics Covered	Remarks
		Aggregates - Desirable properties & tests.	8/12/20	Problems on CBR and K	
		Bituminous materials - Explanation of tar, bitumen cutback & emulsion Emulsion bituminous material.	9/12/20	Aggregates - Desirable properties and tests	
		Pavement Design Types and component parts	10/12/20	Bit. materials - tar, bitumen, cutback & emulsion & tests	
		Flexible pavement design	15/12/20	Pavement types and component parts	
		Rigid pavement design	16/12/20	Flexible pavement design	
		ESWL and its determination (Example)	17/12/20	Rigid pavement design	
		Module-4 Pavement Contd Rothfuchs method - Uses & properties of BM and CC pavement.	22/12/20	ESWL and its determination (Example)	
		Earthwork, cutting and filling, Preparation of subgrade	23/12/20	Module-4 Rothfuchs Mtd. Uses & properties of BM & CC pavement	
		specification i) Granular sub base. ii) WBM base	24/12/20	Earthwork, cutting & filling, preparation of subgrade.	
		iii) WMM base iv) Bituminous Macadam v) Dense B.M	29/12/20	specification i) GSB ii) WBM base	
		vi) Bituminous Concrete, vii) Dry lean concrete base & PQC viii) Concrete roads	30/12/20	iii) WMM base iv) Bituminous Macadam v) Dense BM	
		Module-5 : HW Drainage Significance & requirements, Surface drainage s/m	31/12/20	vi) Bit. Concrete vii) DLC base & PQC viii) Concrete roads	
		SDS design and examples	5/1/21	Module-5 : HW Drainage significance & requirements Surface Drainage s/m	
		Sub surface drainage s/m. Design of filter materials	6/1/21	SDS design and examples	
		Types of c/s drainage str's their choice and location. Highway economics - HW ~~user~~ benefits	7/1/21	Sub SDS, Design of filter materials	
		VOC using charts only - Examples, Economic analysis - annual cost Mtd	12/1/21	Types of c/s drainage str's their choice & location HW economics & benefits	
		Benifit cost ratio Mtd-NPV		VOC using charts - Ex.	

LESSON PLAN

Subject : Highway Engineering Subject Code : 18CV56 Class : V - A

Period	Date	Topics Planned	Date	Topics Covered	Remarks
			18/1/21	Benifit cost ratio, NPV & IRR MSD, HW financing BOT BOOT Concepts.	

Period	Date	Topics Planned	Date	Topics Covered	Remarks

Text Books :

1. SK Khanna & CEG Justo, "Highway Engineering"
2. LR Kadiyali, "Highway Engineering"

Reference Books :

1.
2.
3.
4.
5.

Date	Topics Discussed	Remarks

Test	Date	Class Strength	No. of Students Appeared	No. of Students Scored < 15	Signature of the HOD
T1	1/12/2020	72	70	–	
T2	24/12/2020	72	70	–	
T3	18/1/2021	72	70	–	

LESSON PLAN

Subject : Subject Code : Class :

Period	Date	Topics Planned	Date	Topics Covered	Remarks

Class : V - A Sec^n | Subject Code : 18CV56 | Subject : Highway Engineering | Total No. of Classes : 33

Sl No.	USN 4BD	NAME	DATE	3/11/20	4/11/20	5/11/20	10/11/20	11/11/20	12/11/20	17/11/20	18/11/20	19/11/20	24/11/20	25/11/20
1	16CV079	Ramya H Naik		1	2	3	4	5	6	7	8	9	10	11
2	17CV027	Eramma V		1	2	3	4	5	6	7	8	9	10	11
3	055	Nandeesh BK		1	2	A	3	4	A	5	6	7	8	9
4	083	Sahana N K		1	2	3	4	A	5	6	7	8	A	9
5	091	Sharath G U		1	2	3	4	A	5	6	7	8	9	A
6	105	Thippeswamy N.R		1	2	3	4	5	A	6	7	8	9	10
7	107	Varsha S Manchi		1	2	3	4	5	6	7	8	A	9	10
8	113	Vijeth K.S		1	2	3	4	5	6	7	8	9	10	11
9	18CV001	Afreen M Y		1	2	3	4	5	6	7	8	9	10	11
10	003	Ambika Ningappa		1	2	3	4	5	6	7	8	9	10	11
11	007	Arfaat Ahmed H		1	2	3	4	5	6	A	7	8	A	9
12	009	Ashwini Ningappa		1	2	3	4	5	A	6	7	8	9	10
13	011	Basavaraj V		1	2	3	4	5	6	7	8	9	10	11
14	013	Bhagyashree H N		1	2	3	4	5	6	7	8	9	10	11
15	015	Chandana P R		1	2	3	4	5	6	7	8	9	10	A
16	021	Dikshitha R P		1	2	3	4	5	6	7	A	8	9	10
17	023	Divakar Naik G C		1	2	A	3	4	A	5	6	A	7	8
18	025	Geetha R G		1	2	3	4	5	6	7	8	9	10	11
19	029	Hrithik K		1	2	3	4	5	6	7	8	9	10	11
20	031	J S Anjan		1	2	A	3	A	4	A	5	6	7	8
21	033	Kiran Gowda N M		1	2	3	4	A	5	A	6	A	7	8
22	035	Kushal P		1	2	A	3	4	A	5	A	6	7	8
23	037	M Harish Kumar		1	2	3	4	5	6	7	A	8	A	9
24	039	Mallikarjun G		1	2	3	4	5	6	7	A	A	8	9
25	041	Manoj H M		1	2	3	4	5	6	7	8	9	A	A
26	043	Megha M M		1	2	3	4	5	A	A	6	7	8	A
27	045	Mohamed Akram		1	2	3	4	5	6	7	8	9	10	A
28	049	Monika M		1	2	3	4	5	6	7	A	8	A	9
29	051	Nanditha N Angadi		1	2	3	4	5	6	7	8	9	10	11
30	053	Naveen M Patil		1	2	3	4	5	6	7	8	9	A	10
			Initials of Teacher											
			Initials of H.O.D.											

26/11/20	1/12/20	2/12/20	3/12/20	8/12/20	9/12/20	10/12/20	15/12/20	16/12/20	17/12/20	22/12/20	23/12/20	24/12/20	29/12/20	30/12/20	31/12/20	No of days	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
12	13	14	15	16	17	18	18	19	20	21	22	23	24	25	26	31	94	27	27	28	28	10	38
A	13	14	15	16	17	18	19	20	21	22	23	24	25	A	26	32	97	28	29	29	30	10	40
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	30	91	28	27	27	28	10	38
A	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	30	91	28	28	27	28	10	38
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	31	94	27	28	27	28	10	38
A	11	12	13	14	A	15	16	17	18	19	20	21	22	23	24	30	91	27	28	27	28	10	38
11	12	A	13	14	15	16	17	18	A	19	20	21	22	23	24	30	91	28	29	27	28	10	38
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	32	97	27	28	27	28	10	38
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	33	100	29	29	30	30	10	40
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	33	100	29	29	30	30	10	40
10	A	11	12	13	14	15	16	17	18	19	20	21	22	23	24	30	91	28	29	27	28	10	38
A	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	33	100	29	29	30	30	10	40
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	32	97	29	29	30	30	10	40
12	A	13	14	15	16	17	18	19	20	21	22	23	24	25	26	32	97	29	29	29	29	10	39
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	32	97	28	29	28	29	10	39
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	30	91	28	29	29	29	10	39
9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	32	100	28	29	27	28	10	38
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	32	100	28	28	27	28	10	38
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	30	91	29	29	29	29	10	39
9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	30	91	28	27	27	28	10	38
9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	30	91	27	28	27	28	10	38
9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	30	91	27	27	27	27	10	37
10	11	A	12	13	14	15	16	17	18	19	20	21	22	23	24	31	94	27	28	27	28	10	38
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	31	94	28	29	28	29	10	39
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	30	91	27	28	28	28	10	38
9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	31	94	28	28	27	28	10	38
11	A	12	13	14	15	16	17	18	19	20	21	22	23	24	25	31	94	29	29	28	29	10	39
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	32	97	28	29	28	29	10	39
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	32	97	28	29	28	29	10	39
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	32	97	28	29	28	29	10	39

Class : V - A Sec^n Subject Code : 18CV56 Subject : Highway Engineering Total No. of Classes : 33

Sl No.	USN 4BD	NAME	DATE	3/11/20	4/11/20	5/11/20	10/11/20	11/11/20	12/11/20	17/11/20	18/11/20	19/11/20	24/11/20	25/11/20
31	18CV055	Noor Jahan NH		1	2	3	4	5	6	7	8	A	9	10
32	057	Prabhudev H D		1	2	3	4	5	6	7	8	9	10	A
33	061	Puttaveerachari B. L		1	2	3	A	4	5	6	7	8	9	10
34	063	Rahim Mirza		1	2	3	4	5	A	6	7	8	9	10
35	065	Rashmi G S		1	2	3	A	5	6	7	8	9	10	11
36	067	S V Mohammed Sohil		1	2	3	4	A	5	6	7	8	9	10
37	069	Sahana K M		1	2	3	A	4	5	6	7	8	9	10
38	071	Sanjay M S		1	2	3	4	5	6	A	7	8	9	10
39	073	Sagib Aftab Pasha H A		1	2	3	4	5	6	7	8	A	9	10
40	079	Subhash K P		1	2	3	A	4	5	6	7	8	9	10
41	081	Spandana V		1	2	3	4	5	A	6	7	8	9	10
42	083	Subhasini Angadi		1	2	3	4	5	6	7	8	9	10	11
43	085	Sumanth Rao M G		1	2	3	4	5	6	7	8	A	9	10
44	087	Supriya T		1	2	3	4	5	6	7	8	9	10	11
45	089	Tejashwini Angadi		1	2	3	4	5	6	6	7	8	9	10
46	091	Thanmai S R		1	2	A	3	4	5	A	6	7	8	9
47	093	Vachan H M		1	2	A	3	4	A	5	6	7	8	9
48	095	Vanitha B L		1	2	3	A	4	5	6	7	A	8	9
49	097	Vijay Kumar H		1	2	3	A	4	5	6	7	8	9	10
50	103	Yashaswini B S		1	2	3	4	A	5	6	7	8	A	9
51	105	Yogana Gowda B P		1	2	3	4	5	6	7	8	A	9	10
52	106	Abhishek K		1	2	3	A	A	5	6	7	8	9	10
53	107	Anusha N												
54	108	Nuthan Kumar L B												
55	19CV400	Akash BH		1	2	3	4	5	6	7	8	9	10	11
56	402	Anusha B K		1	2	3	4	5	6	7	A	8	9	10
57	403	Arshalatha H T		1	2	3	4	5	6	7	8	9	10	11
58	405	Girish N Kabbur		1	2	A	3	4	5	A	6	7	8	9
59	407	Hasrat Raj H K		1	2	3	4	5	A	6	7	8	9	10
60	410	Kiran Kumari C		1	2	3	4	5	6	A	7	8	9	10
			Initials of Teacher											
			Initials of H.O.D.											

26/11/20	1/12/20	2/12/20	3/12/20	8/12/20	9/12/20	10/12/20	15/12/20	16/12/20	17/12/20	22/12/20	23/12/20	24/12/20	29/12/20	30/12/20	31/12/20	No. of Days	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
11	12	A	13	14	15	16	17	18	19	20	21	22	23	24	25	31	94	28	28	29	29	10	39
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	32	97	28	29	28	29	10	39
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11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	32	97	28	27	28	28	10	38
12	A	13	14	15	16	17	18	19	20	21	22	23	24	25	26	32	97	28	28	27	28	10	38
A	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	31	94	28	28	27	28	8	39
11	A	12	13	14	15	16	17	18	19	20	21	22	23	24	25	31	94	29	28	29	29	10	39
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A	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	31	94	29	29	30	30	10	40
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	32	97	28	29	28	29	10	39
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12	13	14	15	16	17	18	A	19	20	21	22	23	24	25	26	32	97	28	29	28	29	10	39
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Class : V - A sec^n | Subject Code : 18CV56 | Subject : Highway Engineering | Total No. of Classes : 33

Sl No.	USN	NAME	DATE	3/11/20	4/11/20	5/11/20	10/11/20	11/11/20	12/11/20	17/11/20	18/11/20	19/11/20	24/11/20	25/11/20	26/11/20	1/12/20	2/12/20	3/12/20	8/12/20	9/12/20	10/12/20	15/12/20	16/12/20	17/12/20	22/12/20	23/12/20	24/12/20	29/12/20	30/12/20	31/12/20	Total	No. of Days Present	%	Test Marks I	Test Marks II	Test Marks III	Average	Remarks
	ABD																																			
61	19CV411	Mamatha B		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	26	32	97	29	29	30	30	10	40
62	412	Megharaj M M		1	2	3	A	4	5	6	7	A	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	30	91	27	28	27	28	10	38
63	413	Md. Faraan Khan		1	2	3	A	4	5	6	7	8	9	A	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	31	94	27	28	27	28	10	38
64	416	Nagaraj G M		1	2	3	4	5	A	6	7	8	9	10	11	12	A	13	14	15	16	17	18	19	20	21	22	23	24	25	31	94	28	29	28	29	10	39
65	417	Nandisha H A		1	2	3	4	5	6	7	8	9	10	11	12	13	A	14	15	16	A	17	18	19	20	21	22	23	24	25	31	94	27	28	27	28	10	38
66	420	Prasanna B Raikar		1	2	3	4	5	A	6	7	A	8	9	10	11	A	12	13	14	15	16	17	18	19	20	21	22	23	24	30	91	27	28	27	28	10	38
67	421	Rabbani A B		1	2	3	4	A	5	6	7	A	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	31	94	27	27	28	28	10	38
68	422	Rajath C		1	2	3	4	5	6	7	8	9	10	11	A	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	32	97	29	29	30	30	10	40
69	427	Sharath ES		1	2	3	A	4	5	A	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	31	94	27	28	27	28	10	38
70	430	Shubha M		1	2	3	4	5	6	A	7	8	9	A	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	31	94	27	28	27	28	10	38
71	431	Veni P		1	2	3	4	5	6	7	8	9	10	11	A	A	12	13	14	15	16	17	18	19	20	21	22	23	24	25	31	94	27	28	27	28	10	38
72	435	Zuiaulla Shareef S		1	2	3	4	5	A	6	7	8	A	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	31	94	27	27	28	28	10	38
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Highway Engineering

Module-1

Highway alignment and surveys : Ideal alignment Factors affecting the alignment, Engineering surveys- Map study, Reconnaissance, Preliminary and final location and detailed survey, Reports and drawings for new and re-aligned projects.

Highway Alignment

The position or the layout of the central line of the highway on the ground is called the alignment. Highway alignment includes both

a) Horizontal alignment – straight and curved paths, the deviations and horizontal curves.

b) Vertical alignment includes changes in level, gradients and vertical ~~paths~~ curves.

A new road should be aligned very carefully as improper alignment will lead to increase in construction, maintenance and vehicle operation cost.

Requirements of ideal alignment

a) Short : The alignment between two terminal stations should be short and be straight.

b) Easy : It should be easy for operation of vehicles. So, to the maximum extend easy gradients and curves should be provided.

c) Safe : It should be safe both from the construction and operating point of view, especially at slopes, embankments and cutting. ~~It~~

Economical : The total life cost considering the initial cost, maintenance cost and vehicle operating cost should be lowest.

Factors affecting the alignment

For an alignment to be shortest, it should be straight between the two terminal stations, but this is not always possible due to various practical difficulties such as intermediate obstruction or topography. A road which is economical with low initial investment may not be the most economical in terms of maintenance or VOC. Thus it may be seen that, alignment can fulfil all the requirements simultaneously. Hence factors controlling alignment are :- i) Obligatory points

There are control points governing highway alignment. These points are classified as :-

a) Points through which alignment should pass

i) Bridge site :- The bridge can be located at straight and permanent path not at curved and skew crossings, and also where abutment and pier can be strongly founded.

ii) Mountain :- Alternatives are to construct a tunnel or to go around the hills. The suitability depends on factors like topography, site conditions and construction and operation cost.

iii) Intermediate town : Alignment may be slightly deviated to connect an intermediate town or village.

b) Points through which the alignment should not pass.
i) Religious places
ii) Very costly structures
iii) Lakes / ponds

2) Traffic : Based on origin – destination data of the area, the desire lines should be drawn. & also based on traffic flow pattern.

3) Geometric design : factors such as gradients, radius of curve, sight distance etc. govern alignment. The alignment are finalized such that the obstructions to visibility do not restrict the minimum requirements of sight distance.

4) Economics : All 3 costs i.e construction, maintenance and operating cost should be minimum. The construction cost can be decreased by maintaining a balance between cutting and filling.

5) Other considerations : There are drainage consideration political consideration and monotony. The vertical alignment is often guided by drainage consideration such as sub-surface drainage, water level, seepage flow & high flood levels. A foreign territory coming across the alignment will necessitate the deviation of horizontal alignment. In flat terrain, even though it is possible to have a very long stretch of road which is absolutely straight may be monotonous for driving, hence bends or road side amenities are recommended

Engineering surveys for highway alignment

Stages of engineering surveys.

Before alignment, surveys are carried out.

1) Map study
2) Reconnaissance survey
3) Preliminary survey
4) Final location and detailed surveys.

1) Map Study

It is possible to suggest routes, if topographic map is available. The main features are shown on these maps.

Alignment can be located on the map from the following details available on the map

*) Alignment avoiding valleys, ponds or lakes
*) When the road has to cross the hills or mountains
*) Approximate location of bridge site for crossing rivers, avoiding bend.
*) When road is to be connected between two stations, one at the top and other on the foot of the hill. then alternate routes can be suggested.

Thus from map study alternate routes can be suggested. It gives rough guidance of the routes to be further surveyed.

2) Reconnaissance survey

It is second stage of highway alignment. In this, the engineer visits the site and examines the general characteristics of the area before deciding the most feasible routes for detailed studies. The details are collected rapidly through the simple survey instruments. The details which are not available in

maps are collected through this survey and noted down. The details collected include

a) Valleys, ponds, lakes, marshy land, ridge, permanent structures and other obstructions which are not available in map.

b) Values of gradients, length of gradients and radius of curves.

c) No. and type of cross drainage structures, max. FL and natural GWL along probable routes.

d) Soil type and geological features.

e) Sources of construction materials, water and location of stone quarries.

3) Preliminary survey

The main objectives are:

*) To survey the various alignment proposed during reconnaissance and collect physical information & details of topography, drainage and soil.

+) To compare the different proposals for good alignment.

*) To work out the cost and estimate of the materials for alternate proposals.

It is carried out by following methods

a) Conventional approach – where survey party carries out surveys with various equipments, collecting topographical and other data & carrying out soil survey.

b) Rapid approach: by aerial survey taking rapid aerial photographs and by photogrammetric and photo interpretation methods for obtaining topographic and other maps including details of soil and geology.

c) Modern techniques by use of GPS

The procedure of conventional methods of preliminary survey are :

a) Primary Traverse

1st step in preliminary survey is to establish primary traverse. In this angles for the alignment are measured through theodolite.

b) Topographical Features:

After establishing center line, topographical features are recorded. All geographical and other man-made features along the traverse & for a certain width on either side are surveyed and plotted.

c) Levelling Work

It is carried to ~~to~~ give centre line profiles & typical c/s. Permanent & temporary BM should be first established at appropriate locations & levels should be connected to GTS datum. The levelling work is carried to obtain approximate earth work. To draw contours, c/s levels should be taken at suitable intervals.

d) Drainage studies and hydrological Data

These are collected to estimate the type, number and approximate size of cross drainage structures.

e) Soil survey

It is an essential part of preliminary survey as suitability of proposed location is finally decided based on soil survey data. The soil sample up to a depth of 1 to 3 m is collected by post hole Auger or any other methods, and the soil is tested for various properties

f) Material survey:

The survey for the materials such as stone aggregates, soft aggregates, cement, lime, brick & their

locations may be ascertained.

3) Traffic survey : Traffic surveys are conducted in order to obtain the number of traffic lanes and roadway width, pavement design and economic analysis of the highway project. It is done for 24 hrs for 7 days.

After this final, centre line is decided in the office before the final location survey.

4) Final location and detailed survey.

The alignment finalised at the design office after preliminary survey is to be first located on field by establishing centre line using location survey. This is done by transit theodolite. The centre line stakes are driven at suitable intervals, 50m for plain terrains & 20m for hilly terrains.

Detailed survey :

Temporary BM are fixed at 250m. & at all drainage & under H.C. works

Then levelling work is done

C/S levels taken — 50m Plain
20 hilly

All river crossings, valleys should be surveyed & topographical details are noted down.

Then detailed soil survey is carried out

CBR value may be determined for designing the pavement.

The data during the detailed survey should be elaborate and complete for preparing detailed plans, designs and estimates of the project.

Reports and drawings for new and re aligned projects.

Highway Projects

New HW project – plan, design & construct new roads

Re design & re-alignment

Once HW is constructed, after development takes place, subsequent changes becomes very difficult. A badly aligned HW inc transportation cost and also strain drivers & passengers. ∴ proper investigation & planning is imp in road proj keeping in view present day needs as well as future developments of the region.

New HW project

1) Route selection, finalisation of HW alignment & geometric design details
2) Collection & testing of materials, mix design of pavement materials and design details of pavement layers.
3) Construction stages including quality control.

1) Route selection :- is done by keeping in view the requirements of alignment & the geological, topographical & other features. Geometric design std's should be taken care such that they can be upgraded in future, without realigning. After alignment is finalized. the plans & working drawings are prepared.

2) Materials and design

They collect soil sample from selected route & tested in order to design required pavement thickness & the design of embankment & slopes. The basic materials such as aggregates are also tested & stacked along the road. Mix design tests are carried out.

Pavement thickness is designed based on traffic,

stability and drainage conditions of the subgrade and the type and thickness of pavement layers chosen for the construction.
CBR mtd is recommended by IRC for designing the thickness of flexible pavements.

3) Construction — 2 stages
   i) Earth work : It consists of excavation & construction of embankments. During excavation, HW cuts, earth slopes, their protection & construction of drainage N/W are taken care of. HW embankments may be best constructed by compacting the soil in layers under controlled moisture and density using rollers.
   ii) Pavement Construction
   It is taken up starting with preparation of subgrade and the construction of sub base, base and surface courses of the pavement.

Steps in new project work
1) Map study — using topographic maps
2) Reconnaissance survey — on the spot inspection of the site
3) Preliminary survey : Topographic details & soil survey, consideration of geometric design, preparation of plans & comparison of alternate routes, economic analysis & selection of final alignment.
4) Location of final alignment
5) Detailed survey — preparation of L/S & C/S, computation of earth work quantities and other construction materials & checking details of geometric design elements.
6) Materials survey
7) Design — embankment, cut slopes, foundation of embankments, bridges, pavement layers & cross drainage str's.
8) Earth work — cutting & filling

9) Pavement construction – subgrade, sub base, base & surface courses.

10) Construction controls :- Quality control tests & check for finished road surface such as unevenness, camber, super elevation & extra widening of pavement at curves.

11) Construction Planning and Programming :- In order to minimize the construction cost and time, it is essential to resort to appropriate approaches such as use of critical Path Method (CPM) and Project evaluation and review Technique (PERT).

Re Alignment Project

Necessity

Most of the present highways in India, have been upgraded in stages from the local roads of pre automobile era to the roads of present day automobile traffic.

Types of improvement

1) Improvement in hztl alignment design elements such as radius, super elevation, transition curve, adequate sight distance, elimination of reverse curve and zigzags etc.
2) Improvement of vertical alignment – like steep gradients, chges in summit curves, correction of undulations like humps, any dips etc.
3) Raising the level of portion of the road – ∵ floods
4) Re construction of weak and narrow bridges and culverts
5) Construction of over and under bridges
6) Construction of bypass to avoid road running through town.
7) Defence requirements.

General principles of Re-Alignment

1) While improving hzll alignment, improvement should be made by considering whole alignment and not on piece meal basis.
2) While improving vertical alignment, attempts should be made to provide Overtaking sight distance. If not possible to provide OSD, at least safe stopping sight distance should be available for design speed.
3) The corrections of minor undulations do not involve high cost & so it is divisable to provide suitable vertical transition curves for shock free movement of vehicles.
4) The roads submerged under water should be raised
5) While reconstructing bridges separate surveys should be carried out.
6) The deciding factor for under & over bridges is based on intensity of traffic in tonnes per day.
7) The necessity to provide alternate routes to bypass through traffic is assessed from origin and destination studies.

Steps in Re-Alignment Project

1) Reconnaissance of the stretch of road
2) Survey of existing road
3) Observations of spot levels along CL of road.
4) Soil survey of land for re-alignment
5) Finalisation of design features of re-aligned roads.
6) Preparation of drawings, and marking out CL.
7) Earth work and preparation of subgrade, construction of new bridges and culverts
8) Checking geometric design elements
9) Design & construction of new highway pavements.

Preparation of Drawing for Re-Alignment Project.

The drawings for re-alignment project should show all existing features of road as well as proposed improvements.

The foll drawings would be needed.

1) Plan showing existing road, proposed re-alignment, contours & all other features of importance
2) Longitudinal sectn showing ground elvation
3) C/S showing existing highway.

20/11/2020

Module - 2

Highway geometric design of hztl alignment elements : Cross sectional elements - width, surface, camber, sight distances - SSD, OSD, ISD, HSD, radius of curve, Transition curve, Design of hztl and vertical alignment - curves, super-elevation, widening, gradients, summit and valley curves.

Geometric design of Highway deals with dimensions and layout of visible features of HW such as alignment, sight distances and intersections.

Geometric design of highways deals with foll. elements :-

i) Cross section elements — friction, camber, paved width
ii) Sight distance considerations — SSD, OSD, ISD, HSD
iii) Horizontal alignment details — Hztl curve, design speed, super elevation, pavement width of pave, Transition curve
iv) Vertical alignment details — gradient, summit & valley curves
v) Intersection elements

Factors controlling geometric elements are :-

1) Design speed - it the maximum allowable speed. Design speed depends upon terrain and Importance of road.

Terrain	cross slope		
Plain	(0-10%)	High	EW
Rolling	(10-25%)		NH
Hilly	(25-60%)		SH
Steep	(>60%)	Low	MDR
			ODR
			VR

2) Topography — "

3) Traffic factors :- Different vehicle classes are often necessary to consider some standard vehicle as the design vehicle. The important human factor, which affect traffic behaviour include physical, mental and psychological characteristics of drivers and pedestrians.

4) Design hourly volume and capacity

Reasonable value of traffic volume is decided for the design and this is called the design hourly volume.

5) Environmental and other factors

Environmental factors such as aesthetics, landscaping air pollution, noise pollution and other local conditions should be given due consideration in the design on road geometrics.

Highway cross section elements

Pavement surface characteristics

Surface characteristics of pavement are friction, unevenness, light reflecting characteristics and drainage of surface water.

1) Friction

It is to avoid lateral skidding of vehicles

i) Longitudinal coeff. of friction - along length of road
- to stop vehicle on emergency (SSD)

It will be in the range of 0.35 to 0.4

For speeds more than 80 kmph — use 0.35 f
and for lower speed — 0.4

2) Lateral friction / side friction
- used on hill curves

Value is const — 0.15

Friction - reduces for wet road surface, old tyres if no bottom on them, & too dry surface.

If tyre pressure = 7 kg/cm²

↑ f_p — ↓ f

↓ f_p — ↑ f

② Pavement unevenness

This causes inc in fuel consumption, VOC, comfort and safety. It also increases fatigue and accidents.

Unevenness Index (UI) – summulative vertical undulations per 1 km length

ie cm/km or mm/km

$VI = y_1 + y_2 + y_3 + \cdots$

For good roads : VI < 150 cm/km

if it is more comfort level reduces.

VI is measured by Bump indicator / Roughometer.

3) Light reflecting characteristics

Night visibility very much depends on light reflecting characteristics. The glare caused by head lights is ~~so~~ high on wet surface, than on dry surface. white pavement ~~colour~~ surface gives good visibility at night. Black top pavement surface on the other hand provides very poor visibility.

4) Cross slope or Camber

slope across the carriageway.

Slope along the road – longitudinal slope – gradient

Purpose – to drain away rain water.

Camber depends on

1) Type of road surface (superior road : ↓C)
   - CC, hig BT
   - Thin BT
   - WBM
   - Earth roads (↑C)

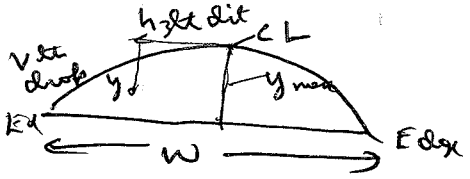
2) Rainfall – Heavy (↑C)
   low (↓C)

Camber values recommended by IRC

Type of road surface	High Rainfall	Low rainfall
CC / high BT	1 in 50	1 in 60
Thin BT	1 in 40	1 in 50
WBM / gravel	1 in 33	1 in 40
earth	1 in 25	1 in 33

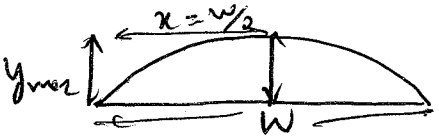
Types of Cambers

1) Parabolic camber – used in flexible pavements (BT, WBM, gravel, earth)



$$y = \frac{2x^2}{NW}$$

1 in N
1 in 60
N = 60



$$y_{max} = \frac{2(W/2)^2}{NW}$$

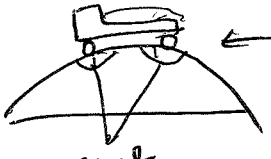
$$y_{max} = \frac{W}{2N}$$

max. central rise w.r.t to edges

Adv : easy to construct

camber board – it is fixed at bottom of pavement and moved after pouring material

Disadv : At the center, there is comfort for driving. But at edges, while driving, driver feels very high camber, vehicle get tilted due to high slope towards edges.

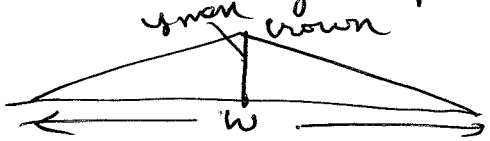


← continuous travelling of vehicle on central portion, there may be rut formation, i.e longitudinal groove.

To prevent ruts, high quality materials should be used, Not in use presently

2) Straight line camber

Used in rigid pavements (RCC, CC)



Disadv: Sharp crown

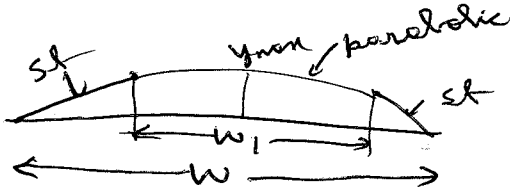
Adv: Flatter edges

V	H
1	N
y_{max}	$W/2$

$$\therefore y_{max} = \frac{W}{2N}$$

Same as y_{max} of parabolic

3) Combination camber (combined)



Adv of both are added but end disadv are eliminated

Present scenario, this type of camber is used.

$$y_{max} = \frac{W}{2N}$$

Eqn of parabola $\Rightarrow y = \frac{2x^2}{NW_1}$ for parabolic zone only.

Pb: In a district where rainfall is heavy, major district road of WBM pavement, 3.8 m wide, and a state highway of bituminous concrete pavement, 7.0 m wide are to be constructed. What should be the height of the crown with r.t. the edges in the two cases?

Soln: For WBM road

1 in 33 — heavy rainfall

$$y_{max} = \frac{W}{2N} = \frac{3.8}{2 \times 33} = 0.058\ m$$

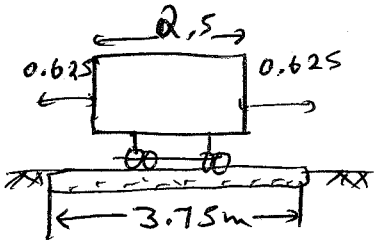
For Bituminous conc. road

cross slope — 1 in 50

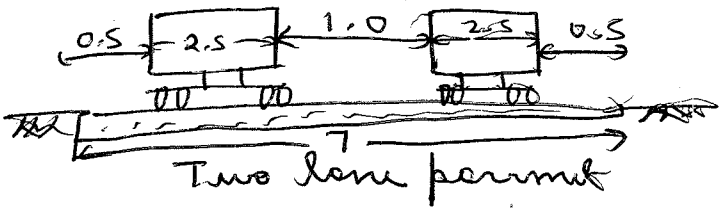
$$y_{max} = \frac{7}{2 \times 50} = 0.07\ m$$

5) Width of pavement or carriageway

Width of pavement depends on width of traffic lane



For single lane pavement



The width of carriageway for ~~Stff~~ various classes of roads standardized by IRC are ~~shown~~

Class of road	Width of carriageway
i) Single lane	3.75m
ii) 2 lanes without kerbs	7m
iii) " with "	7.5m
iv) Intermediate carriageway	5.5m
v) Multi lane pavements	3.5 m per lane

Sight Distance

i) The clear visible distance ahead of driver for various operations on the road.

There may be some sort of obstructions. ∴ Visible distance to driver should be allowed. SD situations considered in design are :-

i) SSD
ii) OSD
iii) ISD
iv) HSD

Stopping SD (SSD)

The clear visible distance ahead of driver to stop the vehicle (which is moving with design speed) on emergency.

*) This is the min. sight distance for which all the roads must be designed (IRC-66)

SSD has two components

i) Lag distance

This is the distance travelled by the vehicle during the reaction time of driver with constant design speed.

*) The distance travelled during perception and brake reaction time.

*) The time interval between the instant the drivers sights a dangerous obj for which a stop is necessary and the instant the brakes are applied.

+) It depends on

*) age *) sex - males require lesser reaction time
*) alertness and visual acuity of the driver
*) atmospheric visibility - fog, smog
*) Vehicle design
*) the size and type of the object.

Reaction time is based on PIEV Theory.

*) Perception : Time required to see an object (function of eyes and ears)

*) Intellection : Time required for understanding the situation (Function of brain)
signal recived by brain and analyzed.

*) Emotion : (reaction time required to react to the situation (fear, anger etc) from brain.

*) Volition : (Then signal is sent to hands and legs to apply brakes)
Application of brake (function of hands or legs).

For entire process, for an average driver, it takes 2.5 sec (IRC recommends)

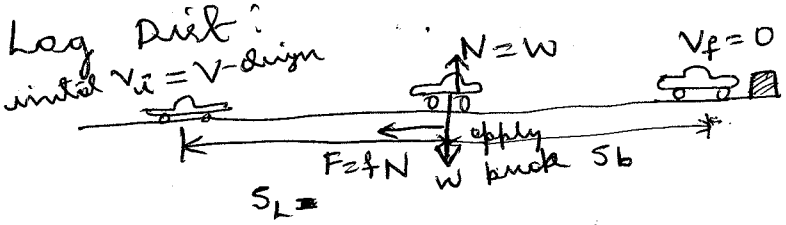
For active driver it is less.

ii) Braking distance (S_b)

The distance required for the vehicle to stop complitely.

*) It can be analyzed by work energy principles

Derivation of SSD



$S_L = V \times t$

W.E eq^n

WD = chg in KE

$-F S_b = \frac{1}{2} m (V_f^2 - V_i^2)$

$= \frac{1}{2} \frac{W}{g} (0 - V^2)$

$-fN S_b = \frac{1}{2} \frac{W}{g} (0 - V^2)$

$-fW S_b = \frac{1}{2} \frac{W}{g} (-V^2)$

$S_b = \frac{V^2}{2gf}$

f = coff of longitudinal friction

$SSD = S_L + S_b$

$$SSD = Vt + \frac{V^2}{2gf}$$

This eqn is valid if road is flat, no gradient and brake is perfect.

Coeff of longitudinal friction					
Speed (Kmph)	≤ 30	40	50	60	≥ 80
f	0.4	0.38	0.37	0.36	0.35

*) pt to note: as the speed increases, f dec.
*) IRC recommended f value is based on 50% brake efficiency

Coeff. of longitudinal friction (f) depends on
*) Speed
*) Tyre pressure - (buttom on type)
*) Conditions of tyre thread
*) Type and condition of pavement

ii) SSD with brake efficiency

Braking efficiency (η)

$$SSD = S_L + S_b$$

$$= Vt + \frac{V^2}{2g(\eta f)}$$

< breaks are not const as friction is not in a position to develop fully we multiply by 'η'- brake efficiency or if loss at brakes ↓ 20%, $\eta = 0.8$

If η is not given - then breaks are correct $\eta = 1$

Braking efficiency (η)
*) The efficiency of the brakes depends upon the age of the vehicle, vehicle characteristics etc.
*) If the brake efficiency is 100%, the vehicle will stop the moment the brakes are applied.
*) But practically, it is not possible to achieve 100% brake efficiency.
∴ IRC consider 50% i.e 0.35 to 0.4.

iii) SSD with gradient

Gradient (G)

+G / −G

Upward G downward G

Gradient is taken as ratio $2\% = \frac{2}{100}$

$SSD = S_L + S_b$

$= Vt + \frac{V^2}{2g(f \pm G)}$ — refer

If both η & G are given we should use both

iv) SSD with gradient and brake efficiency

There may be cases where brakes may not work properly at gradients.

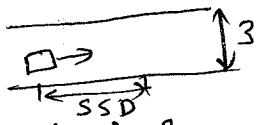
+G / −G

$SSD = S_L + S_b$

$= Vt + \frac{V^2}{2g(\eta f \pm G)}$

v) Safe SSD (ISD)

It depends on no. of lanes on the road and direct^n of traffic.



single lane – with one way traffic – no opp dir vehicles

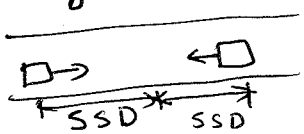
For this vehicle to stop – it is due to obstruction on road.

Single lane (O/W)

safe SSD = SSD (η & G should not be considered)

$= Vt + \frac{V^2}{2gf}$

Single lane (two way traffic)



both should & must stop to avoid accident

∴ requires SSD

∴ Safe SSD = 2 SSD This twice of SSD is called intermediate SD (ISD)

= ISD

↓

single lane (T/W)

Module - 3

Pavement materials: Subgrade soil – Desirable properties- HRB soil.
Classification - Determination of CBR and modulus of subgrade reaction with problems aggregates - Desirable properties and tests, Bituminous materials. Explanation on tar, bitumen, cutback and emulsion - tests on bituminous material. Pavement Design: Pavement types component parts of flexible and rigid pavements and their function. ESWL and its determination (graphical method only) Examples.

Pavement Materials
1) Subgrade soil
2) Aggregates
3) Bituminous Materials

Subgrade

It is the lower most layer of soil, over which various other layers are constructed.
Natural subgrade – Undisturbed soil beneath the pavement
Compacted " – Soil compacted by controlled movement of heavy compactors.

Desirable properties

The desirable properties of soil as a highway material are
i) Stability – possess adequate stability / resistance to permanent deformation under loads.
ii) Incompressibility
iii) Permanency of strength
iv) Minimum changes in volume and stability under adverse conditions of weather and ground water
v) Good drainage and (is essential to avoid excessive moisture retention
vi) Ease of compaction – higher dry density

Highway Research Board (HRB) Soil Classification.

Also called American Association of State Highway officials (AASHO) classification.

Soils divided — A-1 to A-7 (7 groups)

A-1, A-2, A-3 soils → granular soils
(% age fines passing 0.074 mm sieve being less than 35).

A-4, A-5, A-6 & A-7 → fine grained or silt-clay soils.
(passing 0.074 mm sieve being greater than 35%)

1) A-1 — soils are well graded
   i) A-1-a — consists stone fragments & gravel
   ii) A-1-b — coarse sand.

2) A-2 — granular soil
   sub-groups - A-2-4, A-2-5, A-2-6, A-2-7.

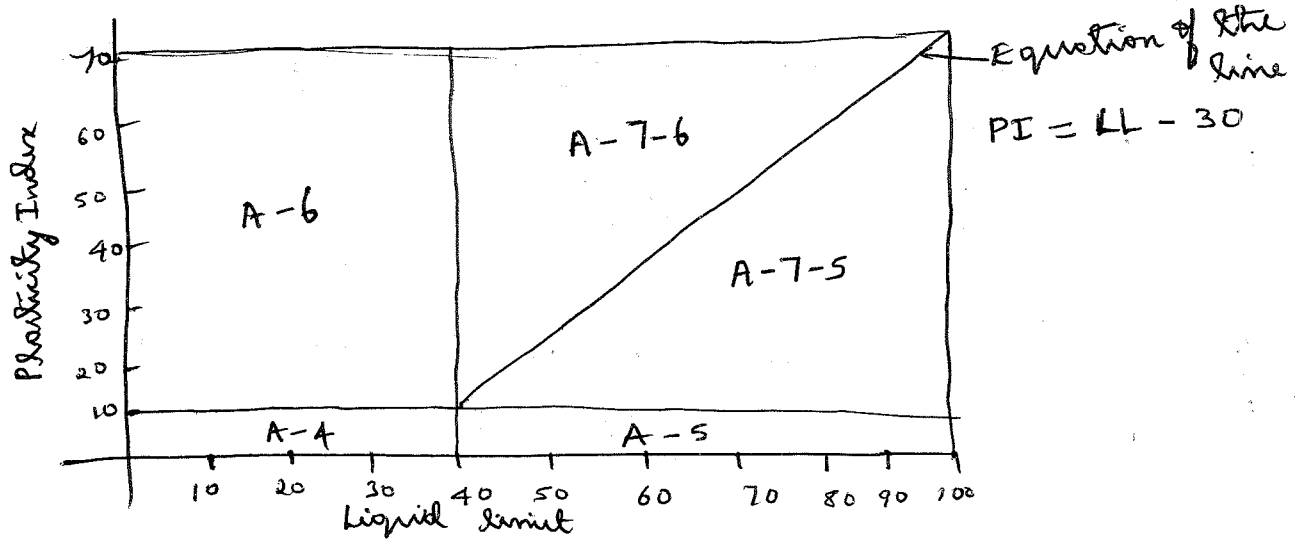
3) A-3 - uniformly graded medium or fine sand (beach sand)

4) A-4 - silty soil
   LL - < 40
   PL - < 10

5) A-5, silty soil
   PI - < 10%. LL ≥ 40%.

6) A-6, plastic clays
   PI > 10%. LL < 40%.

7) A-7 - clayey soil
   LL > 40%. PI > 10%.



Plasticity chart of HRB Soil Classification

Group Index (GI)

It is the number assigned to soil based on the physical properties like particle size, liquid limit and plastic limit. It varies from 0 to 20

GI ↓ → quality of sub-grade ↑

$$GI = 0.2a + 0.005ac + 0.01bd$$

where, a = % of soil passing 0.075 mm sieve in excess of 35%, not exceeding 75%, expressed as a whole number from 0 to 40.

b = % of soil passing 0.075 mm sieve in excess of 15% not exceeding 55% expressed as a whole no. from 0 to 40.

c = Liquid limit in excess of 40%, not exceeding 60%, expressed as a whole number from 0 to 20.

d = Plasticity Index in excess of 10% not exceeding 30% expressed as a whole number from 0 to 20

Properties of sub grade

1) Strength related property - CBR
2) Stiffness related - Plate load test

California Bearing Ratio test (CBR) (Lab test) (IS : 2720, P16). - Part 16

It is the relative shear strength i.e bearing capacity of the soil subgrade w.r.to crushed aggregate & is expressed as percentage.

*) It is penetration test - ∵ we apply load on plunger to know the penetration.

Procedure of CBR test

1) Sieve the sample through 20mm IS sieve. Take 5kg of the sample of soil specimen. Add water to the soil in the quantity such that OMC is reached.
2) Then soil and water are mixed thoroughly. Spacer disc is placed over the base plate at the bottom of mould and a coarse filter paper is placed over the spacer disc.

*) The prepared soil is then filled one fifth of the mould. ~~with the prepared~~ That layer is compacted by giving 56 evenly distributed blows using hammer of wt. 4.89kg

*) After fifth layer, excess soil is struck off. Remove base plate and invert the mould. Then it is clamped to baseplate.

*) Surcharge weights of 2.5kg is placed on top surface of soil. Mould containing specimen is placed in position on the testing machine.

*) The penetration plunger is brought in contact with the soil and a load of 4kg is applied so that contact between soil and plunger is established. Then dial readings are adjusted to zero.

*) Load is applied such that penetration rate is 1.25mm per minute. Load at penetration of 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 7.5, 10 and 12.5 mm are noted.

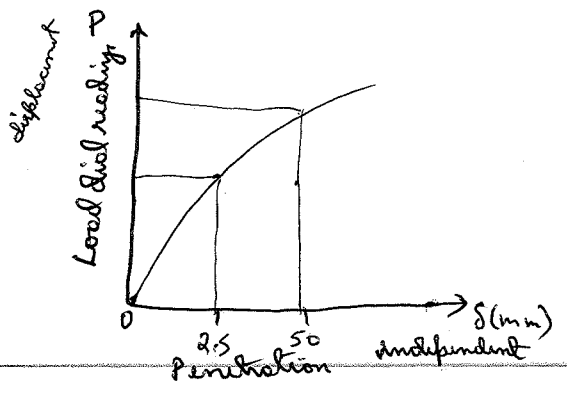
Mould dia – $d_i = 150mm$

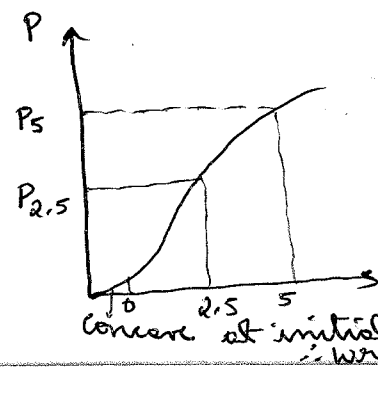
hgt = 175mm

Standard loads adopted for different penetrations for the standard material i.e crushed aggregate powder.

Penetration of Plunger (mm)	Standard Load (Kg)	Unit standard load (kg/cm²)
2.5	1370	70
5.0	2055	105

A graph of load versus penetration is plotted. From the graph the loads corresponding to 2.5mm (say P_1) and 5mm (say P_2) are obtained to calculate the CBR.





The causes for initial concavity of load-penetration curve calling for the correction in origin are due to: i) the bottom surface of plunger of soil specimen not being truly hztl, ii) the top layer of the specimen being too soft or irregular.

The CBR value is calculated using relation:

$$CBR\% = \frac{\text{Load sustained by the specimen at 2.5 or 5.0 mm penetration}}{\text{Load sustained by std. agg. at the corresponding penetration level}} \times 100$$

$$(CBR\%)_{2.5} = \frac{P_{2.5}}{1370} \times 100$$

$$(CBR)_{5mm} = \frac{P_5}{2055} \times 100$$

If $CBR_{2.5} > CBR_5$, the $CBR_{soil} = CBR_{2.5}$

If $CBR_5 > CBR_{2.5}$ ← rare case due to some errors repeat exp.

After repition, $(CBR)_{soil}$ = higher of $(CBR)_{2.5}$ & $(CBR)_{5.0}$

Problem:

The load penetration values of CBR tests conducted on two specimens of a soil sample are given. Determine the CBR value of the soil if 100 division of the dial represents 190 kg load in the calibration chart of the proving ring.

Penetration of plunger, mm	Load dial readings, div.	
	Sp. No. 1	Sp. No. 2
0	0	0
0.5	8	0.5
1.0	15	1.5
1.5	23	2.5
2.0	29	6.0
2.5	34	13
3.0	37	20
4.0	43	30
5.0	48	38
7.5	57	50
10.0	63	58
12.5	67	63

Soln :- Sp. No. 1

Load at 2.5mm penetration $= 34 \times \frac{190}{100} = 64.6$ kg.

CBR value at 2.5 mm " $= \frac{64.6 \times 100}{1370} = 4.7\%$

CBR value at 5mm " $= \frac{48 \times 190 \times 100}{100 \times 2055} = 4.4\%$

∴ CBR value of Sp. No1 = 4.7%

Sp No. 2

As, curve has initial concavity, correction is required. A tangent AC is drawn from the steepest portion A of the curve to intersect the x-axis at C, which is the corrected origin for this specimen. The penetration values are measured from this corrected origin C.

CBR value at 2.5mm penetration $= \frac{32.5 \times 190 \times 100}{100 \times 1370}$

$= 4.5\%$

CBR value at 5 mm penetration $= \frac{47 \times 190}{2055} = 4.3\%$

CBR value of sp. no. 2 = 4.5%

Therefore mean CBR value of soil sample $= \frac{4.7 + 4.5}{2}$

$= 4.6\%$

~~Plate~~ Modulus of subgrade reaction (K) of subgrade soil

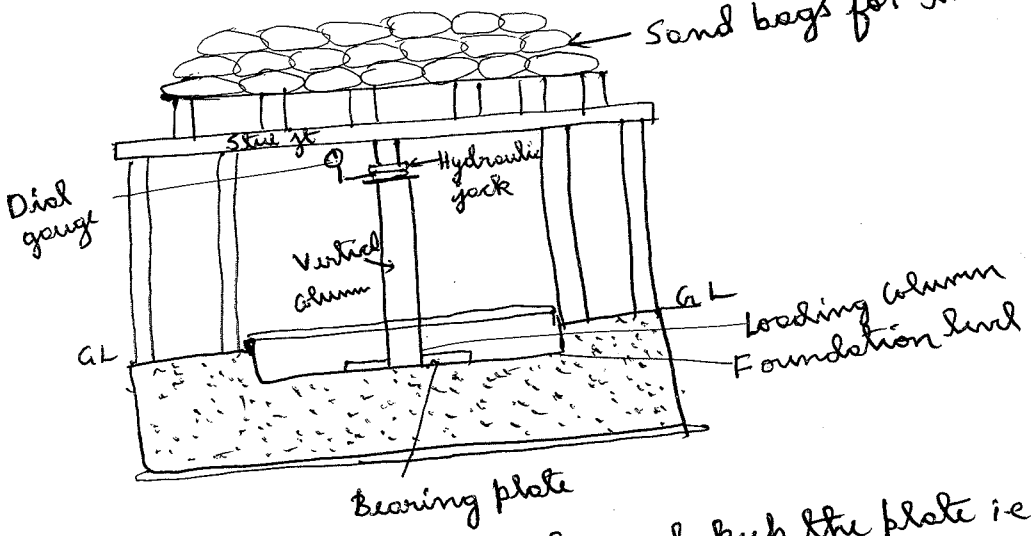
Modulus of subgrade reaction is the reaction pressure sustained by the soil sample under a rigid plate of standard diameter (75cm) per unit settlement measured at a specified settlement. IRC specifies that the K value be measured at 1.25 mm settlement.

Plate load test

The plate bearing test is devised to evaluate the supporting power of subgrades or any other pavement layer by using plates of larger diameter. It was originally meant to find modulus of subgrade reaction in the Waterways

analysis for wheel load stresses in cement concrete pavements.

Test Procedure



Dig trench, fill subgrade and keep the plate i.e Mild steel.

In transportation - we use circular plates.

Soil mechanics - square, rectangular or circular are used over which there is loading column.

Total set up is reaction frame over which we have sand bags. If we operate proving ring, settlement comes on to the soil i.e subgrade. For particular settlement, load can be detected through dial gauge → to determine settlement or deflection

proving ring → resisting force.

Standard size of plate - 75 cm — MS rigid CRC → K is determined

common size is 30 cm.

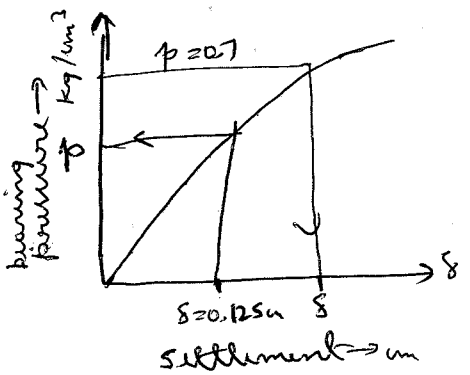
Modulus of subgrade reaction (k)

K may be defined as the pressure sustained per unit deformation of subgrade at specified deformation or pressure level, using specified plate size.

$$\text{pressure, } p = \frac{P}{A_p} = \frac{P}{\pi a^2}$$

a → radius of plate

$$K = \frac{p}{\delta} \rightarrow \text{stiffness parameter}$$



Method-1, Fix $\delta = 0.125\,cm = 1.25\,mm$

↓

By IRC $\quad K = \frac{p_{0.125}}{0.125\,cm} = \frac{kg/cm^2}{cm} = kg/cm^3$

Method-2

fix $p = 0.7\,kg/cm^2$

$$K = \frac{p}{\delta} = \frac{0.7}{\delta_{0.7}}$$

If we fix, parameter, always fix independent parameter 'δ'.

Then 'k' value are valid for plate size of 75cm, other sizes correction factors are applied for 'k'.

$$K_{soil} = K_\phi [1.21\phi + 0.078]$$

$$K_{soil} = K_{75} [1.21 \times 75/100 + 0.078]$$

$$K_{soil} = K_{75}$$

If $\phi = 30\,cm$

$$K_{soil} = K_{30\phi} [1.21 \times 30/100 + 0.078]$$

$$K_{soil} = 0.44 (K_{30\phi})$$

Modulus of elasticity (E) can be estimated by plate load test & empirical formulas are given by Boussinesq to find stress distribution on homogenous soil.

For rigid plate (MS) (rough bottom surface)

$$E = \frac{1.18\, p\, a}{\delta}$$

For rubber plate (flexible type) (rough inflated rubber tyre)

$$E = \frac{1.5\, p\, a}{\delta}$$

p = pressure on soil

a = radius of plate

δ = settlement

In fluid, MS plate is used.

If value of E is const, then K is inversely proportional to a or $K a$ is const i.e $K a = K_1 a_1$ or $K = \frac{K_1 a_1}{a}$

Limitations of PLT

a) It gives elastic settlement – (i.e plastic & long settlement)

b) It does not give consolidation of soil

c) It requires loss of time to setup the exp

Eg) A plate load test was conducted on a soaked subgrade during monsoon season using a plate diameter of 30cm. The load values corresponding to the mean settlement dial readings are given. Determine the modulus of subgrade reaction for the standard plate.

Mean settlement values, mm	0	0.24	0.52	0.76	1.02	1.23	1.53	1.76
Load values kg	0	460	900	1180	1360	1480	1590	1640

Soln :- Load value p_1 corresponding mean settlement value of $\Delta = 0.125$ cm is determined = 1490 kg

$$\text{Unit load } p_1 = \frac{1490}{\pi 15^2} \text{ kg/cm}^2$$

Modulus of subgrade reaction K_1 for 30cm dia plate

$$K_1 \frac{p_1}{\Delta} = \frac{1490}{\pi \times 15^2 \times 0.125} = 16.86 \text{ kg/cm}^3$$

K for std plate of dia 75cm

$$\frac{k_1 a_1}{a} = \frac{16.86 \times 30}{75} = 6.75 \text{ kg/cm}^3$$

Aggregates - Desirable properties and tests

1) Toughness of aggregates

*) Toughness is resistance to impact

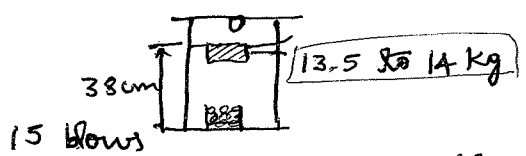
*) Determined by aggregate impact test

IS : 2386 (Part IV)

*) Aggregates sized 10mm - 12.5mm are used

*) Weight of hammer : 13.5 to 14 kg

*) Height of fall : 38 cm



Sieve on 2.36mm - then collect aggregate passing

$$\text{Agg. Impact value (AIV)} = \frac{\text{wt. passing}}{\text{Total wt.}} \times 100$$

↑ AIV : ↓ toughness (∵ more wt passing, powder)

AIV	%
Bit carpet conc / Cement Conc	30
Bit bound macadam base course	35
WBM base course with bit. surfacing	40

For top layers, AIV is less.

ii) Strength of Aggregate

*) Resistance to gradual load

+) Determined using agg. crushing test

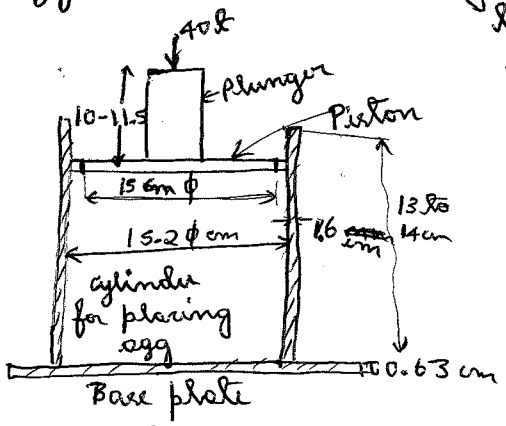
Agg – 12.5mm – 10mm

↘ load is increased upto 40t gradually

Then sieve on 2.36mm

$$ACV = \frac{\text{wt passing}}{\text{Total wt}} \times 100$$

↑ACV — ↓ Strength.



Specification – ACV

	%
Bit. carpet conc / cement concrete	30
Bit. bound Macadam base course	35
WBM base course with bit surfacing	40

iii) Soundness test

Soundness test is intended to study the resistance of aggreg -ates to weathering action, by conducting accelerated weathering test cycle.

Dry agg – then immersed in soln of $NaSO_4$ / $MgSO_4$ for 16 – 18hr Then dried in oven for 105 – 110°C – one cycle of immersion & drying

No. of cycles are decided based on exptns.

After completing cycles, the sample is sieved & each fraction of agg is examined and SA is carried to note variation in grader

50–40 – avg – 45mm

Width of thickness gauge

= 0.6 avg ← flakiness

= 0.6 × 45

= 27mm

As general guidance

avg wt of agg to be used in pavement constn

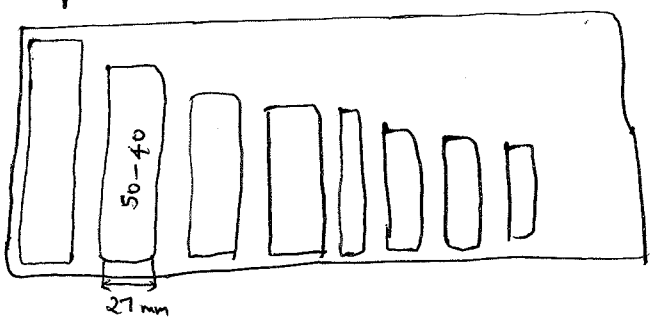
after 10 cycles ≯ 12% $NaSO_4$

18% $MgSO_4$

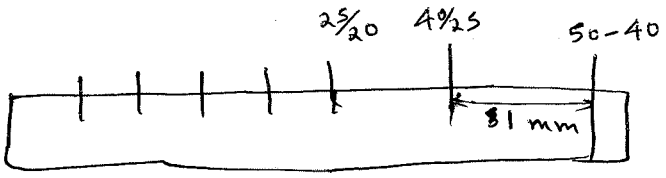
IRC 5at/day – 12% – for bit bound & surface course

– 18% –

iv) Shape test



Thickness gauge (Flakiness index)



Length gauge (Elongation Index)

If certain aggregate is not passing through certain slot we call it as elongated agg. and we need to eliminate that. Length of length gauge
$= 1.8 \times (avg)$
$= 1.8 \times 45 = 81 mm$

iv) Hardness
It is resistance to abrasion or resistance to scratching/ rubbing action.
Hardness test : *) Los Angeles abrasion - most common
*) Duvals abrasion
*) Dorey's "

a) Los Angeles abrasion test is not direct abrasion test, it gives impact + abrasion

Attrition - rubbing action between particle of same nature
Abrasion - " " " " of diff. nature
mainly tyre and aggregate.

In los angeles - steel balls and agg.
after certain revolution, take out agg and sieve it on 17mm.

Los angeles value (LAV) $= \frac{\text{wt passing}}{\text{Total wt}} \times 100$

↑ LAV — ↓ hardness
inc in soft agg.

LA Abrasion values
1) Bit. bound Macadam - 50
2) WBM surfacing course - 40
3) Bit. penetration macadam - 40
4) Bit surface dressing, cement conc, surface course - 35

b) Micro Duvals Abrasion test
It is small scale test, it is also impact and abrasion test. There are 2 cylinders & inert steel balls & agg.

Benefits *) Smaller equipment size
*) Lower sample quantities
*) Two samples can be tested at the same time

3) Dorry Abrasion Test
The test measures resistance of aggregates to surface wear by abrasion.
Abrasion bet^n – steel rotating disc and aggregate
It gives surface wear and tear and pure abrasion, disc rotates.
i) Test involves in subj a cylindrical specimen of 25cm hgt and 25 cm dia to the abrasion against rotating metal disc sprinkled with quartz sand.
ii) The loss in wgt of cylinder after 1000 revolutions of the table is determined.
iii) The hardness of the rock sample is expressed in an empirical formula.
iv) Hardness = 20 – (Loss in grams /3)
v) Good agg should show an abrasion value of not less than 11
This is usually for tiles and flooring stones.

4) Shape Test.
To find shape of agg. used for road we prefer angular shape in general, for good interlocking / bond. If agg are too thin / long they may break and give less strength.
1) Flakiness index – too thin.
2) Elongation " – " long.

Two indices
FI – Flaky : least dimension (thickness) ≤ 0.6 time avg size
such agg are removed from road construct^n
Thickness gauge.
FI – 1 kg sample, removed from thickness gauge if the agg coming out of gauge, are thin agg are flaky.

$$FI = \frac{\text{wt of agg passing}}{\text{Total wt}} \times 100$$

EI – max. dimension (length) > 1.8 (avg) should be removed
if such % age is high – less strength –
Length gauge

$$EI = \frac{\text{wt of agg. not passing}}{\text{wt. of non flaky agg.}} \times 100$$

(Total wt − wt of flaky)

Among FI & EI, 1st test should be conducted is FI & then EI., 1st FI & then EI

vi) Specific gravity

Sp. gr ranges from 2.6 to 2.8 for FA or CA

For CA – density basket method

For FA – pycnometer method

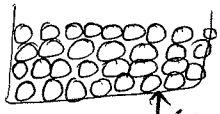
Water absorption test

Agg is immersed in H_2O, after immersion WA should not be more than 0.6%. If more WA, then agg. has more voids, crack and less strength.

Angularity Number ; IS : 2386 - Part I

It is voids in excess of 33% of rounded agg.

Why 33%,



↑container and purfectly spherical balls.

Vol. of voids = 33%. This is for "

& V_{solids} = 67%.

i) Then if we take angular agg

V_V = 40%

AN in voids is excess of 33%.

∴ AN = 40 − 33 = 7

ii) V_V = 30%., no excess voids

AN = 0%.

Max. AN → then more coarser is agg. value.

$$AN = 67 - \frac{100w}{C G_s}$$

W → mass wt. of agg filling cylinder

C – wt of H_2O reqd to completely fill the cylinder (i.e vol. of cylinder)

G_s – sp. gr of agg.

Angularity Index – given by Mudrock based on AN.

AN – range is 0 to 11

$$AI = \frac{3(AN)}{20} + 1$$

which talks about angularity of agg ↑ → good interlocki-ng.

Range of AI = 1 to $\frac{3(11)}{20} + 1 = 2.65$

1 to 2.65

↑ Angular agg → ↑ AI

vii) Bitumen Adhesion

Bitumen and tar adhere well to all normal types of road aggregates provided they are dry and are free from dust. The adhesion problems are observed due to presence of water. This can be removed by drying. Secondly there is stripping of binder from coated aggregate due to presence of water which is experienced only with bituminous mixtures which are permeable to water.

Bituminous Materials

2 types — 1) Bitumen < cutback / Emulsion

2) Tar

Bitumen: All the crude petroleums contain considerable amts of water along with crude oil. Hence it is dehydrated first before distillation. General types of distillation process are fractional and destructive distillation. In fractional distillation the various volatile constituents are separated at successively higher temperatures without substantial chemical change. The successive fractions obtained yield gasoline, naptha, kerosene and lubricating oil, the residue would be petroleum bitumen. In destructive distillation the material undergoes chemical change under the application of extreme heat and pressure. The process is usually applied for manufacture of tar.

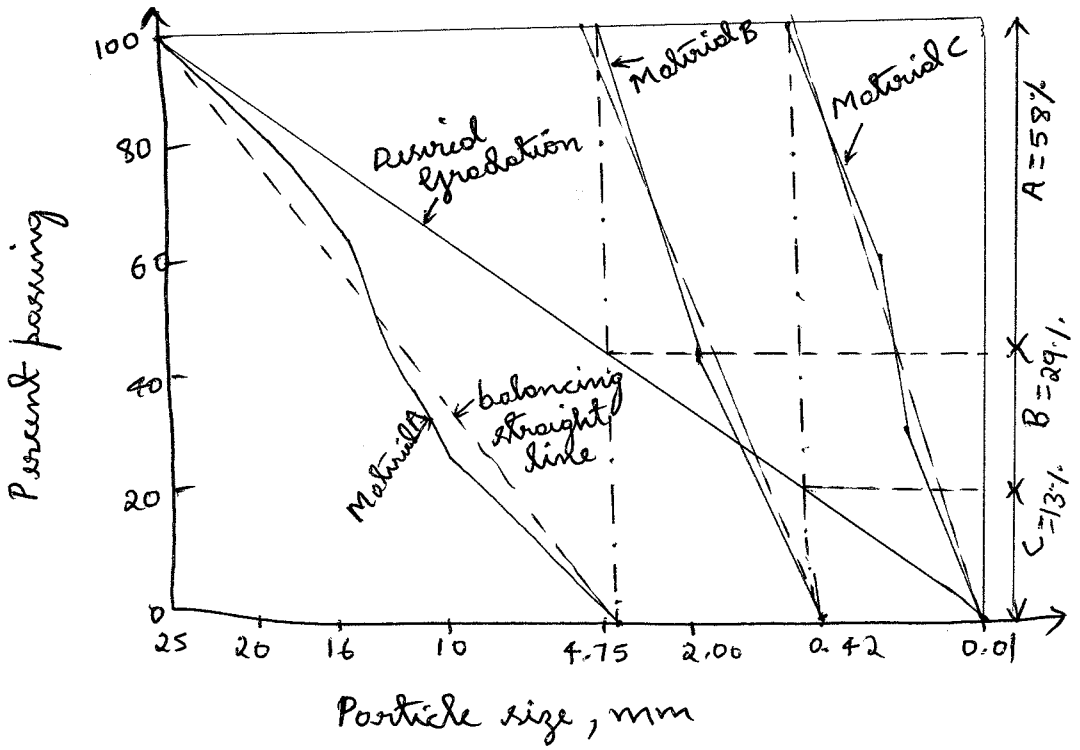
The viscosity of bitumen is reduced some times by a volatile diluent, this material is called cutback. When bitumen is suspended in finely divided condition in an aqueous medium

Module-4

Pavement Construction : Design of soil aggregate mixes by Rothfuchs method. Uses and properties of bituminous mixes and cement concrete in pavement construction. Earthwork: cutting and filling. Preparation of subgrade, specification and construction of i) Granular sub base ii) WBM Base iii) WMM base iv) Bituminous macadam v) Dense BM vi) Bituminous concrete vii) Dry lean concrete sub base and PQC viii) Concrete roads.

Proportioning of materials by Rothfutchi's Method

This method is used when a number of materials have to be mixed together for obtaining a desired or design gradation.



Uses and properties of bituminous mixes and cement concrete in pavement construction.

The aim of mix design is to obtain an economical blend using proper gradation of coarse agg, F.A, filler & adequate amt of bit binder to fulfil the properties of mix

Desirable Properties

i) Stability

It is the resistance of paving mix to deformation under the load. Depending upon the specification or field condition, it is influenced by density of the mix or percentage voids in the compacted mix.

If V↓ — S↑ — strength↑

But there must be min. voids which would provide space on necessary densification which takes place under traffic movement, if no voids, then bit layer bleeds causing skidding.

ii) Durability

It is the resistance of the mix against weathering and abrasive actions. Due to weathering, bit mix gets hardened which may cause cracks or plastic failure.

iii) Flexibility

It is the property which measures the load bending strength. Shrinkage cracks are due to volume change in the binder due to aging. Brittleness is due to repeated bending of the surface due to traffic loads. Higher bit content gives better flexibility and less fracture.

iv) Skid resistance

It is the resistance of finished pavement against skidding which depends on surface texture.

If bit. content↑ — more slippery

∴ bit content should be optimum to have better skid resistance.

v) Workability

It is ease with which the mix can be laid & compacted to max. density. It is the function of gradation of aggregate, their shape and texture, bit content & its type

Preparation of Subgrade

The essential requirements of material are as follows

Parameter	Requirement
Liquid limit	50 % Max
Plasticity Index	25 % Max
Free swell index	50 % Max
Max. dry density (heavy compaction)	1.75 g/cc Min

5 steps involved in the preparation of subgrade

i) Loosening of soil
ii) Spraying of water to obtain OMC
iii) Mixing of soil and water
iv) Rolling to achieve density
v) Repeating the steps for subsequent layers
vi) Ensuring the quality control checks
vii) Determination of CBR value of subgrade soil in the laboratory

Construction of Pavements

It includes

i) Materials with IRC specification
ii) Spreading of materials & spraying of water if required.
iii) Rolling - is done starting from lower edge and proceeded towards the centre or upper edge of carriageway with a min. one-third overlap between each run of the roller. with rolling speed < 5 kmph. for atleast 98 % of max. density
iv) Checking of finished surface by measuring unevenness and undulations with 3m straight edge and comparing with specification.
v) Opening to traffic if it is surface layer after 24 hrs.
vi) Ensuring the quality control checks during construction for various parameters.

Pavement Quality Concrete (PQC)

It is that concrete which is used mostly for highway and road construction and it differs from normal conventional concrete by using 32mm size aggregate and hence requires little more cement content.

As per IRC, min M40 — cement concrete
Min flexural strength = 45 kg/cm²
M50 — white topping of pavements

Earthwork

It is a term for all operations required to construct the excavated areas and the embankments of a project.

Embankment (Filling): It consists of a series of compacted layers or lifts of suitable material placed on top of each other until the level of the subgrade surface is reached. It is constructed by spreading loose soil and compacting the same at OMC.

Based on soil type, compacting equipment & density, the compacted thickness of each layer generally varies from 100–300mm.

The various steps involved in the construction of embankment are as follows:-

i) Spreading of soil in loose condition
ii) Spraying of water so as to obtain OMC
iii) Mixing of soil and water
iv) Rolling to achieve specified density
v) Repeating the above steps for subsequent layers.
vi) Ensuring the quality control checks during construction for liquid limit, plasticity index, free swell index and density (For every 1000m²)

Cutting

i) The bottom of cutting is loosened to the required depth (200 to 250mm)
ii) Water is added to ensure that water content is equal to the OMC of the soil.
iii) It is then compacted to achieve a min of 95% maximum dry density.

1) Granular Sub Base (GSB)

Scope : This work shall consist of laying and compacting well-graded material on prepared subgrade in accordance with the requirements. The material shall be laid in one or more layers as sub-base as necessary according to lines, grades and cross-sections shown on the drawings.

Materials : Natural sand, moorum, gravel, crushed stone or combination.

Liquid limit	25 % Max
Plasticity Index	6 % Max
Percent fines (passing 75μ sieve)	10 % Max
CBR Value	30% Min for sinp roads
	25% Min for other roads

Construction

Preparation of subgrade : Prior to laying of sub-base, the already ~~prepared~~ finished subgrade shall be prepared by removing all vegetation & other extraneous matter, then sprinkled with H_2O if necessary and rolled with 2 passes.

Spreading : The sub base material shall be spread with motor grader which has hydraulic controls suitable for initial adjustment & for maintaining slope & grade. Moisture content is checked.

Rolling : Smooth wheeled roller — thickness of compacted layer ≯ 100 mm

Vibratory roller upto 225 mm

Rolling shall commence at the edges & progress towards the centre. Each pass of the roller shall uniformly overlap not less than 1/3rd of the track made in the preceding pass.

Speed ≯ 5km/hr

Density — 98 %

Surface finish : It is checked for longitudinal & cross sectional profile in respect of undulations (tolerance limit −20 to +6mm)

Quality Control of work : samples are subj to tests to check liquid limit, Plasticity index, gradation, OMC, MDD & CBR. After rolling, tests are carried out

2) Water Bound Macadam (WBM) Base

Scope : ~~It~~ The pavement BC of consists of clean crushed aggregates, mechanically interlocked by rolling and voids binding together with screenings and binding material and water laid on subgrade or sub-base.

Materials

CA

AIV — 40% Max

FI & EI — 30% Max

Grading	I	II	III
Size (mm)	90-45	63-45	53-22.4
Compacted thickness	100	75	75

Screenings

Gradation	A	B
Size	13.2	11.2
Remarks	For I & II	For II & III

Binding Material

PI — 6% Max.

Construction Operations

1) Preparation of subgrade / sub-base ÷ Ruts and soft yielding places should be corrected. Surface should be free of dust. If WBM is directly over the subgrade, a 25 mm thick screenings of grade B should be spread.

2) Spreading of CA - Uniformly & evenly. Compacted thickness should not exceed the specified value for grading used.

3) Rolling : edge to center, Each pass ≯ 1/3rd pass

Speed ≯ 5 km/hr

4) Application of screenings : Screenings are applied to fill the voids. The surface is rolled so that screenings settle in to voids of the C.A. The surface is sprinkled with water and rolled.

5) Application of Binding material : The binding material is applied in 2 or more layer. after application, it is sprinkled with water and rolled. After final application, the layer is allowed to dry overnight. On next day, hungry spots are located and corrected.

Sprinkling & gravity

6) Surface finish: The max. diff b/t road surface & underside of 3m straight edge should be -15mm and +15mm.

7) Quality Control of work - To check AIV and shape at the rate of one sample per 200 m^3. The sample of agg & Binding mat are subjected to test to check gradation at rate of one sample per 100 m^3.

3) Wet Mix Macadam (WMM)

Scope : This work shall consist of laying and compacting clean, crushed, graded aggregate and granular material, premixed with water, to a dense mass on a prepared subgrade / sub-base / base or existing pavement.

Materials

CA
Los Angelis value - 40% max
AIV — 30% Max

F & EI - 30% max
grading - 53mm & down

PI — 6% Max

Construction operations

1) Preparation of Sub base
2) Provision of lateral confinement : By laying materials in adjoining shoulders along with WMM.
3) Preparation of Mix : The WMM is prepared in the mixing plant of suitable capacity having provision for controlled addition of water equal to OMC.
4) Spreading of Mix : It is transported to site, spread uniformly by paver finisher or by motor grader
5) Rolling : Smooth wheeled roller
thickness ≯ 100mm / else vibratory roller
lower to higher edge
Each pass - overlap ≮ 1/3rd of track in preceding mass
speed ≯ 5 Km/hr
98% dry density
6) Setting & Drying - The surface is allowed to dry for 24 hrs. To traffic shall not be allowed until W.C has been laid.
7) Surface Finish : The max allowable difference between the road surface & the underside of 3m straight edge should be -10mm and +10mm.
8) Quality control of Work : Tests are conducted to check abrasion, Impact value & shape at rate of one sample per 200 m^3.

To check gradation - at a rate of one sample per 100m3
Finer material to PI at a rate of one " " 25m3

4) Bituminous Macadam (BM)

Scope : It consists of crushed agg and bitumen binder heated & mixed in a hot mix plant at specified temperature transported to site, laid with paver & compacted by roller. Thickness - 50-100 mm & suitable as only base or binder course.

Materials

CA →	LAAV (AIV)	— 40% (30% max)
	F & EI	— 30% Max
	WA	— 2% Max
	Soundness (5 cycles)	< 12% max ($CaSO_4$) / 18% " ($MgSO_4$)
	Grading	— 1 (40 mm)
Binder	Grade	- VG-30 / VG-20
	Quantity	3-3.5%
	Stripping value	Min retained coating 95%

Construction

Preparation of surface - dust is removed by using high pressure jet from a compressor.

Appln of prime coat / tack coat : This is liquid application of suitable binder.

Mixing : Mix should be prepared in a hot mix plant, yielding a mix of uniform quality with thoroughly coated aggregates.

Spreading of Mix : The premix shall be spread, levelled and tamped by mechanical paver finisher.

Rolling :

Surface finish : Tolerance limit -6 mm and +6 mm

Quality control tests

Abrasion / Impact & Shape	— one sample / 50m3
W.A	— 3 samples for each source of supply
Soundness	— 1 sample " " " " "
Grading	— 2 " / day / plant
Stripping	— 3 samples for each source of supply.
Quality & temp of binder	— At regular intervals

5*) Dense Bituminous Macadam (DBM)

Scope: It is used mainly but not exclusively, in base/binder & profile corrective courses. It is also used as road base material.

→ Thickness of a single layer shall be 50–100mm.

Materials

CA	LAAV/AIV	35% max / 27% max
	F & EI	30% max
	WA	2% Max
	Soundness 5 cycles	12% max ($CaSO_4$)
		18% ($MgSO_4$)
Binder	Grade	VG 30 — generally used
		VG 20 — cold regions
	Quantity	Based on stability test
	Stripping value	Min retained coating 95%
Bit Mix	Marshall stability value	9 KN Min
	Flow value	2–4 mm

Construction

Preparation of surface

Application of prime coat / tack coat

Preparation of mix and transportation

Spreading of Mix

Rolling

Surface finish — (Tolerance limit – 8 mm & + 8 mm)

Quality Control tests

Test	Rate
A/IVT	1 sample per $50m^3$
WA	3 " for each source of supply
Soundness	1 " " " " " "
Stripping	3 " " " " " "
Grading	Two samples / day / plant

Quality & temp of binder — At regular intervals

Mix stability, flow value — one set of 3 samples per 400t of mix.

6) Bituminous Concrete

Scope: It is used as wearing course. This work shall consist of construction in a single or multiple layers of BC on a previously prepared bituminous bound surface, layer thickness 25–100mm

Materials

CA	LAAV/AIV	30%. (24%. max)
	FI & EI	30%. max
	WA	2%. max
	Soundness (sujdy)	12%. max ($CaSO_4$)
		18%. ($MgSO_4$)
Binder	Grade	VG30
		VG-20
	Quantity	Based on stability test
	Stripping value	Min retained coating 95%.
Bit Mix	Marshall stability value	9KN min
	Flow value	2–4 mm

Construction

1) Preparation of surface
Application of tack coat
Preparation of Mix & transportation
Spreading of Mix
Rolling
surface finish – (Tol. limit –3mm and +3mm)
Quality control tests

Test	Rate
A/I & shape	one sample per 50m³
WA	3 " for each source of supply
Soundness	1 " " " " " "
Grading	Two samples/day/plant
Stripping	2 samples for each source of supply
Quality & temp of binder	At regular intervals
Mix-stability, flow value	one set of 3 samples per 400t of mix.

7) Dry lean concrete (DLC) sub base

Adv – i) it provides smooth surface
ii) Prevents water entering through joints & cracks
iii) Prevents mud pumping phenomenon.
iv) Enhances the support of subgrade & reduces the slab thickness.
v) Improves the load transfer at the joints.

Materials — specification

Cement — OPC or Portland slag cement or Portland pozzolana cement

Coarse agg — WA – 2% max
Abrasion value – 35% Max
Soundness – $CaSO_4$ ($MgSO_4$) = 12% max (18% max)
Size – 25 mm max

FA — clean natural sand or crushed stone or mixture of both

CA + FA — gradation as specified

Water — clean and free from salts, acids and vegetable matter, which are harmful to be finished concrete

Proportion of Materials

i) The mix should be proportioned with max. agg – cement ratio of 15 : 1.
ii) The min. cement content in DLC should not be less than 150 kg per m^3 of concrete.
iii) The average comp. strength of each group of 5 cubes should not be less than 10MPa at 7 days.

Construction.

Preparation of subgrade : A day before placing of DLC, the subgrade surface should be given a fine spray of water and rolled with one or two passes after a lapse of 2–3 hrs in order to stabilize the loose surface.

Preparation of Mix and Transportation : The mix is prepared in mechanized batching & mixing plant and is transported to site by tipper trucks.

Placing of mix : DLC should be laid by paver with electronic sensor. The paver should have tamping bars to give good initial compaction to the sub-base.

Compaction : Tandem smooth wheled vibratory rollers are used is carried out immediately after the material is laid & levelled.

Surface finish — Tolerance limit −10mm to +10mm

Curing — It is done by covering the surface by gunny bags, which is kept moist for min. period of 7 days by sprinkling water.

Quality Control Tests

Test	Rate
Cement	- Once for each source of supply
Coarse and Fine Aggregate	- Once for each source of supply
Water	- Once for approval
Comp. strength of concrete	- Three sample per 1000m² (taken from uncompacted material at three different locations
In situ Density	— Three locations, equally spaced along a diagonal that bisects each 2000m²
Thickness	- should not be 10mm less than specified thickness

5) Concrete roads

Scope : The work shall consist of construction of unreinforced, dowel jointed plain cement concrete conforming lines, grades and cross sections.

CC roads require high initial investment. Transverse & longitudinal joints are unavoidable in this construction. There are planes of weakness, ∴ no. of jts provided should be min.

cement conc. roads are constructed under the foll. groups.

1) Construction of pavement slabs
2) Construction of joints

1) Construction of cement concrete pavement slab

Various specifications for construction of CC pavements on

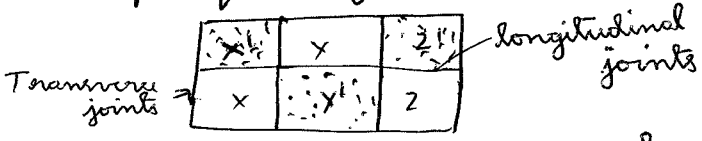
i) Cement grouted layer

ii) Rolled concrete layer
iii) Cement Concrete slab.

i) Cement grouted layer – Open graded aggregates – 18–25 mm size laid on prepared subgrade & dry rolled.
Grout is made of coarse sand, cement & water is prepared C : S – 1 : 1½ to 1 : 2½.
Wetting agent is added to provide fluidity.
Grout is applied on surface to seep through aggregate matrix

ii) Rolled Concrete layer – Lean mix of agg, sand, cement and water is prepared and laid on the prepared, subgrade or sub-base course. Rolling is done before final setting time of cement. Curing is done as per conventional method.
These both are used only for base course only.

iii) Cement concrete slabs :
These serve as both base and surface course.
Two modes of construction of CC slab.
a) Alternate bay Mtd :- construction – constructing a bay or one slab in alternate succession leaving the next bay to follow up after a gap of one week.



b) Continuous bay Mtd : all the slabs are laid in sequence i.e X¹Y²Z¹

Materials : Cement, CA, FA and water, steel wire fabric or bar mats, joints filler & sealer.

C.A : ACV – 30% max
AIV – 30% – Max
LAAV – 30% max
Soundness, avg loss in wt after 1 cycle – 12% max – (Na_2SO_4)
18% max – ($MgSO_4$)

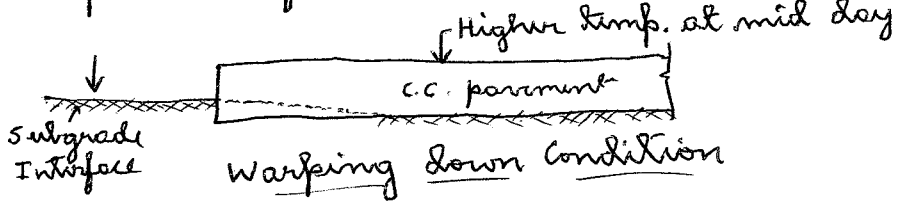
Plants & Equipment : Concrete mixer, batching device, wheel barrow, vibrating screed, internal vibrators, float (for smoothing), straight edge, belt, fibre brush.
(to check finished surface) (To make broom marks)

Construction steps for CC slab.

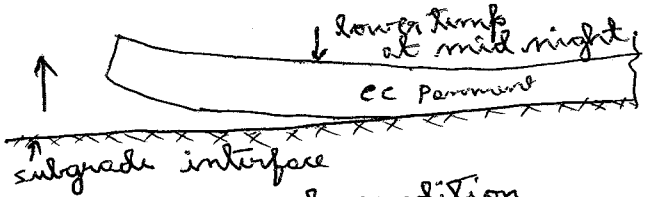
1) Preparation of subgrade & sub base
2) Placing of forms.
3) Batching of material & Mixing
4) Transporting and placing of concrete
5) Compaction and finishing
   i) Floating & straight edging
   ii) Belting, brooming & edging
6) Curing of Cement concrete

Construction of jts in CC pavements

Joints are provided in cement concrete roads for expansion, contraction & warping of slabs due to variation in the temperature of slabs.

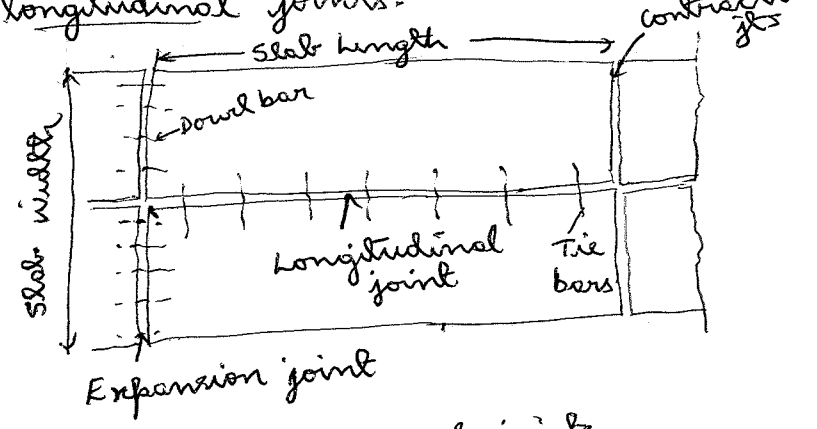


Warping down Condition



Warping up condition

To minimise the temp. stresses in pavement slab, expansion, contraction, warping and construction jt's are provided transversely across the full width of pavement. Two lanes are also jointed together by jt known as longitudinal joints.



Location of joints

Module - 5

Highway Drainage : Significance and requirements, surface drainage system and design - examples, sub surface drainage system, design of filter materials. Types of cross drainage structures, their choice and location.

Highway Economics : Highway user benefits, VOC using charts only, Examples, Economic analysis - annual cost method, benefit cost ratio method - NPV - IPR methods - examples. Highway financing BOT - BOOT concepts.

Highway Drainage

Highway drainage consists of removing or controlling surface water and subsurface water away from the road surface and the subgrade supporting it.

Significance of Drainage

Highway drainage is required to mitigate the effects due to water and moisture variation that are listed below as:

i) Road subgrade may be softened & its bearing capacity is reduced
ii) Variation in moisture content in expansive soil causes variation in the volume of subgrade and thus failure of road.
iii) Presence of moisture at freezing temperature may damage road due to frost action.
iv) Road surface becomes soft & loses its strength
v) Erosion of side slopes, side drains & formation of gullies may result if proper drainage conditions are not maintained.
vi) Formation of pot holes due to stripping of binder in presence of water.
vii) Failure of rigid pavement by mud pumping
viii) Erosion of soil from unsurfaced roads and slopes of embankment.
ix) Erosion of shoulder materials causing considerable damage to the roads.
x) Stagnation of water on the road surface makes it slippery resulting in accidents.

Requirements of HW Drainage s/m

i) Surface water from carriageway & shoulder should be effectively drained off without allowing it to percolate to the subgrade.
ii) Surface water from the adjoining land should be prevented from entering the roadway.
iii) The side drain should have sufficient capacity and longitudinal slope to carry away all the surface water collected.
iv) Flow of the water across the road and shoulders along slopes should not cause erosion or form cross cuts.
v) Seepage and other sources of underground water should be drained off by the sub surface drainage system.
vi) Highest level of ground water table should be kept well below the level of subgrade, preferably by atleast 1.2 m.

Surface Drainage s/m

The surface water is to be collected & then disposed off. The H_2O is 1st collected in longitudinal drains, generally in side drains and then the water is disposed off at the nearest stream, valley or water course. Cross drainage str's like culverts and small bridges may be necessary for the disposal of surface water from the road side drains.

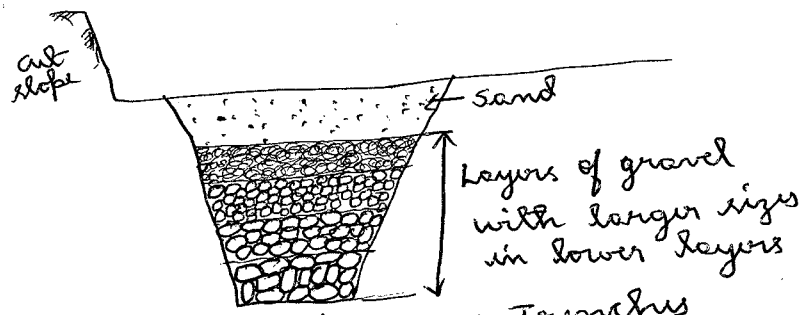
Collection of Surface Water

The water from the pavement surface is removed by providing the camber or cross slope to the pavement.

Before the water is laid to side drains, water from shoulders is also drained.

Drains of rural roads are trapezoidal shape with open kutcha- provided 11st to road alignment called longitudinal drains. In embankments, they are provided on one/both sides beyond the toe, in cuttings, drains are installed on either side of the formation.

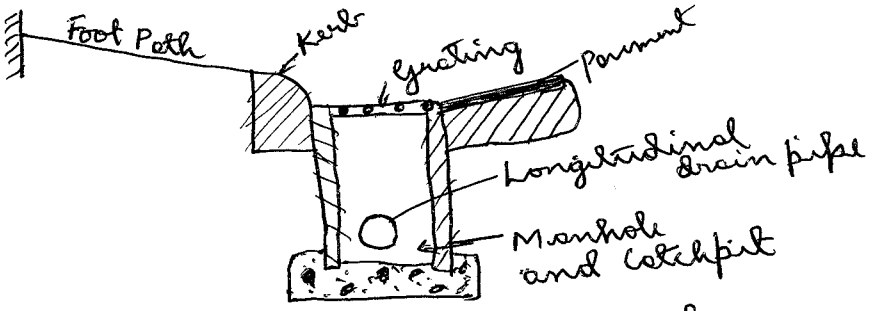
In places where there is restriction of space, covered drains or drainage trenches properly filled with layers of coarse sand and gravel may be used.



Covered Drainage Trenches

In urban roads, because of limitation of land width and also presence of foot path, it is necessary to provide under ground longitudinal drains.

Water drained from the pavement surface can be carried forward in the longitudinal ~~drains~~. ~~Water drained from the pavement~~ dirⁿ between kerb and the pavement for short distances. This water may be collected in catch pits at suitable intervals and lead through under ground drainage pipes. Section of typical catch pit with grating to prevent the entry of rubbish into the drainage s/m is shown



Surface D.S in Urban roads

Design of surface Drainage S/m

It is divided into two phases:-

i) Hydrologic analysis
ii) Hydraulic "

i) Hydrologic Analysis

The main objective is to estimate the maximum quantity of H_2O expected to reach the element of the drainage system under consideration. A portion of precipitation, during the rain fall infiltrates into the ground & some gets evaporated

The remaining portion of water flows over the surface termed as run-off.

Factors affecting run-off are :- i) rate of rainfall, type of soil and moisture condition, topography of the area, type of ground cover like vegetation.

To estimate the peak run-off water, the rational formula is

$$Q = C.i.A_d$$

where Q = run off, m^3/sec

C = run off coeff, expressed as a ratio of R/o at rate of rainfall

i = intensity of rainfall, mm/sec

A_d = drainage area in $1000m^2$

Run off coeff, C

It depends on type of surface and its slope. The C values are, a) 0.8 to 0.9 – bit & cement concrete pavements

b) 0.35 to 0.7 for gravel and WBM "

c) 0.4 to 0.65 for impervious soil

d) 0.3 to 0.55 for soil covered with turf

e) 0.05 to 0.3 for pervious soils.

Drainage Area, A_d

The drainage area from which the surface water is expected to flow to a side drain is determined with the aid of a contour map or by studying the topography of the drainage area. This area is expressed in units of 1000 square metre to obtain the value of A_d.

When the drainage area, A_d consists of several types of surfaces with different values of run-off coeff C_1, C_2, C_3 – and if their respective areas are A_1, A_2, A_3 --- the weighted average value of run-off coeff, C is

$$C = \frac{A_1C_1 + A_2C_2 + A_3C_3}{A_1 + A_2 + A_3}$$

Design value of rainfall intensity, 'i'

'i' is determined for expected duration of storm and frequency of occurrence. ∴ the inlet time for the storm water to flow from the remotest point in drainage area to the drain inlet is estimated using chart.

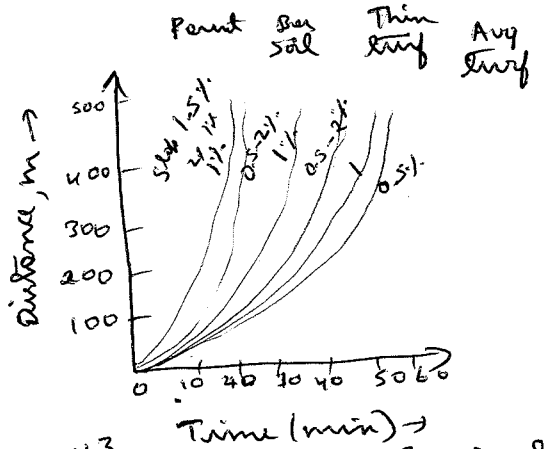


Fig 11.3 Time of flow to in-let

The time for water to flow through the drain between the inlet and outlet points is determined based on the allowable velocity of flow in the drain, which generally ranges from 0.3 to 1.5 m/sec. depending on soil type.

The frequency of occurrence of storm or the 'return period' may be taken as 5, 10, 25 or 50 years. From chart, the design value of rainfall intensity, i is found corresponding to the duration of storm and the selected value of frequency.

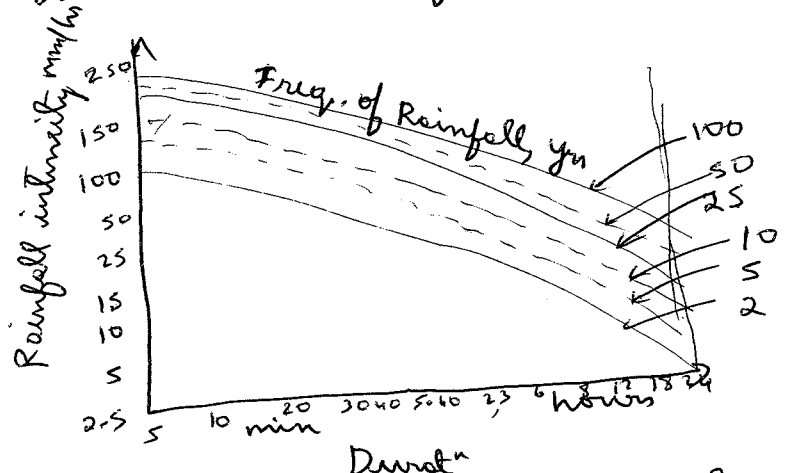


Fig 11.4 : Typical rainfall intensity – duration curves

ii) Hydraulic Design

Hydraulic design elements of drains

Once the design runoff 'Q' is determined, the next step is hydraulic design of drains. The side drains & partially filled culverts are designed based on the principles of flow through open channels.

If Q – q/ty of surface H_2O (m^3/s) to be removed by side drain

V – allowable velocity of flow (m/s) on side drain

the area of C/S A of the channel (m^2) is found from eqn.

$$Q = AV$$

The desirable values of velocity of flow are,

0.3 to 0.5 m/s — sand and silt
0.6 – 0.9 . for loam
0.9 – 1.5 – for clay
1.2 – 1.5 – for gravel
1.5 – 1.8 – for good soil covered with grass.

Mannings formula to determine velocity

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

Here, V – avg velocity of flow, m/s
n – Mannings roughness coeff.
R – hydraulic radius m $(\frac{A}{P})$
S – Longitudinal slope of channel.

n = 0.02 – for ordinary earth
n = 0.005 to 0.1 for earth with heavy vegetation or grass
n = depends on type of lining for lined channels
n = 0.013 – well finished concrete
n = 0.04 – rough rubble & riprap.

& Then S can be determined.

Hydraulic Design Data

The data collected for design of side drain are :-

i) Total road length & width from where water is expected to flow.
ii) Run of coeff. of diff types of surfaces and their areas.
iii) Distance from farthest point in the drainage area to the inlet of the side drain. & average value of slope.
iv) Type of soil, value of roughness coeff & the allowable velocity of flow.
v) Rain fall data including average intensity & frequency of recurrence of flood.

Modified

CBCS SCHEME

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

15CV63

Sixth Semester B.E. Degree Examination, June/July 2019
Highway Engineering

Time: 3 hrs. Max. Marks: 80

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

Module-1

1 a. Mention different modes of transportation. Explain the characteristics of road transport in comparison with other systems. **(08 Marks)**

b. Determine the length of different categories of roads in a state in India by the year 2021 as per 3rd year road plan formulae. The area of state is 3,08,000 km^2. Number of Towns as per 1981 census was 276. Overall road density aimed at 82km per 100km^2. **(08 Marks)**

OR

2 a. What are the types of roads and its classification? Briefly outline classification or urban roads. **(08 Marks)**

b. Three new roads A, B and C are to be completed in a district during a five year plan period. Workout the order of priority for phasing the plan programme by maximum utility principle, from the data given below. Adopt utility unit of 1.0 for serving a village with population range 2000-5000, for catering for 1000T of agricultural products or per 100T of industrial products. Assume any other required data suitably.

Road	Length km	Number of village served population			Productivity 1000T	
		<2000	2000 – 5000	>5000	Agricultural	Industrial
A	15	10	8	3	15	1.2
B	12	16	3	1	11	0.0
C	18	20	10	2	20	0.8

(08 Marks)

Module-2

3 a. Clarify the features of ideal alignment and enumerate factors affecting alignment. **(08 Marks)**

b. Write a brief outline on engineering surveys. **(08 Marks)**

OR

4 a. With neat sketches illustrate different cross section elements. **(08 Marks)**

b. The speed of overtaking and overtaken vehicles are 70 and 40 kmph respectively on a two way traffic road. If the acceleration of overtaking vehicle is 0.99 m/sec^2.

i) Calculate safe overtaking sight distance.
ii) Mention the minimum length of overtaking zone
iii) Draw a neat sketch of the overtaking zone and show the positions of the sign posts.

(08 Marks)

Module-3

5 a. With neat sketches illustrate conduction of plate load test to determine modulus of subgrade reaction. **(08 Marks)**

b. Distinguish between :

i) Tar and Bitumen
ii) Cutback and Emulsion. **(08 Marks)**

OR

6 a. Enumerate different types of pavements with their component parts and functions of each component. **(08 Marks)**

b. Calculate ESWL of a dual wheel assembly carrying 2004 kg each for pavement thickness of 15, 20 and 25 cms. Centre to centre tyre spacing = 27cm and distance between the walls of the tyres = 11cm. Use graphical method. **(08 Marks)**

Module-4

7 a. Briefly outline the design procedure of soil aggregate mixes by Rothfuch's method. **(08 Marks)**

b. Explain the procedure of marshall mix design of Bituminous mixes. **(08 Marks)**

OR

8 a. Enumerate in detail the requirements, specifications of materials and the construction steps for a wet mix macadam (WMM) layer. **(08 Marks)**

b. Explain in detail the requirements, specifications of materials and the construction steps for pavement quality concrete. **(08 Marks)**

Module-5

9 a. Explain with sketches how the subsurface drainage system is provided to lower the water table. **(08 Marks)**

b. The maximum quantity of water expected in one of the open longitudinal drains on clayey soil is 0.9 m^3/sec. Design the cross section and longitudinal slope of trapezoidal drain assuming the bottom width of the trapezoidal section to be 1.0m and cross slope to be 1.0 vertical to 1.5 horizontal. The allowable velocity of flow in the drain is 1.2 m/sec and n = 0.02. **(08 Marks)**

OR

10 a. Briefly describe the different methods of economic analysis of a highway. **(08 Marks)**

b. Calculate the annual cost of a stretch of a highway from the following particulars:

Item	Total cost (Rs. in lakh)	Estimated life (years)	Rate of interest (%)
Land	12	100	6
Earthwork	9.0	40	8
Bridges and culverts	7.5	60	8
Pavement	14	15	10

(08 Marks)

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

10CV63

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

Transportation Engineering – II

Time: 3 hrs. Max. Marks:100

Note: 1. ***Answer any FIVE full questions, selecting at least TWO questions from each part.***
2. ***Missing data if any may be suitably assumed.***

PART – A

1 a. Draw a neat cross section of a B.G. track in cutting for double line on a straight track and indicate the important dimensions. **(06 Marks)**

b. Define creep of rails. Explain the method of measurement of creep. **(06 Marks)**

c. Briefly explain the methods of welding of rails. Indicate the suitability of each. **(08 Marks)**

2 a. Write a brief note on Pandrol clip. **(06 Marks)**

b. Write equations for tractive resistance due to "starting" and "acceleration". Explain the terms in the equations. What would be the gradient for a B.G, track when the grade resistance together with curve resistance due to a curve of 3° shall be equal to the resistance due to ruling gradient of 1 in 100? **(06 Marks)**

c. What is meant by "crib ballast", "box ballast" and "ballast cushion"? Explain the functions of ballast. **(08 Marks)**

3 a. Explain ruling gradient and momentum gradient.
If the ruling gradient is 1 in 150 on a particular section of M.G track and at the same time a curve of 4° is situated on the gradient, what should be the allowable gradient? **(06 Marks)**

b. What is negative cant? For an unsymmetrical split, explain the method of determining the allowable speed on main track when speed on branch track is given. **(06 Marks)**

c. Find the length of transition curve on a B.G. track using the following data:
Maximum speed = 80 kmph
Cant provided = 75 mm
Rate of change of radial acceleration = 0.3 m/s^3
Radius of curve = 350 m. **(08 Marks)**

4 a. With the help of suitable diagram(s), explain "Switch angle", "heel divergence", "throw of switch" and "crossing number". **(06 Marks)**

b. Calculate the elements of a B.G. turnout using the following data:
Number of crossing = 12
Heel divergence = 133 mm
Switch angle = 1°8′
Show the elements on the diagram. **(06 Marks)**

c. With a neat sketch, explain (i) turn table (ii) shunting signal. **(08 Marks)**

PART – B

5 a. Sketch the layout of an airport and indicate the components. Explain the functions of the components. **(06 Marks)**

b. What is wind rose? With the diagram of any one type of wind rose, explain the method of getting the best orientation for runway. **(06 Marks)**

c. Briefly explain the various aircraft characteristics that affect the planning and design of airports. **(08 Marks)**

6 a. Briefly explain the various runway geometrics, as per ICAD. **(06 Marks)**

b. Design an exit taxiway which joins a runway and a main parallel taxiway. Total angle of turn = 40°, turn off speed = 65 kmph. **(06 Marks)**

c. Define basic runway length. Explain the various corrections (with equations) to be applied for the basic runway length. **(08 Marks)**

7 a. What are the advantages and disadvantages of tunnels? **(06 Marks)**

b. The centre line of a tunnel is represented by two plumb lines C and D, 4 m apart, hanging vertically on a shaft, the whole circle bearings of line CD being 80°40′15″. A theodolite is set up underground at a point A, distant 3.902 m and roughly east of nearer plumb line D and the observed value of the angle CAD is found to be 16′12″. Calculate bearing of the line CA and the perpendicular distance of A from the centre line of the tunnel. **(06 Marks)**

c. Explain liner plate method of tunneling. **(08 Marks)**

8 a. How are harbours classified based on their utility and situation? What are the requirements of commercial harbor? **(06 Marks)**

b. Write a brief note on tetrapods. **(06 Marks)**

c. Write plan and enlarged cross section of dry dock. Briefly explain. **(08 Marks)**

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CBCS SCHEME

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

15CV561

Fifth Semester B.E. Degree Examination, June/July 2019
Traffic Engineering

Time: 3 hrs. Max. Marks: 80

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

Module-1

1 a. Explain the interdependency of "land use and transport" with a diagram. **(10 Marks)**

b. Discuss briefly the PIEV theory. **(06 Marks)**

OR

2 a. Describe the fundamentals of traffic flow. **(06 Marks)**

b. A passenger car weighing 3 tonnes is required to accelerate at a rate of $3m/sec^2$ in the first gear from 9 speed of 10 kmph to 25kmph. The gradient is +1% and road has a black topped surface. The frontal projection are of the car is $2m^2$. The car tyres have radius of 0.33m. The rear axle gear ratio is 3.82 : 1 and the first gear ratio is 2.78 : 1. Calculate the speed of the engine. The radius and deformation factor for tyres is 0.36 and 0.95 respectively. Assume transmission efficiency as 0.88 and f = 0.02, $c_a = 0.39$. **(10 Marks)**

Module-2

3 a. Explain the different types of classified volume survey presentation. **(06 Marks)**

b. Two vehicles A and B approaching at right angles, A from west and b from south, collide with each other. After collision, vehicle 'A' skids in a direction 50° N of west and vehicle 'B' 60°E of north. The initial skid distances of vehicles 'A' and 'B' are 38m and 20m respectively before collision. The skid distance after collision are 15m and 36m respectively. If the weights f vehicles 'A' and 'B' are 4.0 and 6.0T. Calculate the original speeds of vehicle. Assume f = 0.55. **(10 Marks)**

OR

4 a. Explain concept of Level Of Service (LOS) and its applications. **(06 Marks)**

b. The table Q4(b) below gives the consolidated data of spot speed studies on a section of a road. Determine : i) the upper and lower values or speed limits for installing speed regulations ii) modal speed for the range.

Table Q4(b) : Speed Studies

Speed range kmph	Number of speed observations	Speed range kmph	Number of speed observations
0 – 10	0	50 – 60	216
10 – 20	11	60 – 70	68
20 – 30	30	70 –80	24
30 – 40	105	80 – 90	0
40 – 50	233		

(10 Marks)

Module-3

5 a. At a right tangled intersection of two roads, road 1 has four lanes and road 2 has two lanes with a width of 12m and 6.6m respectively. The volume of traffic approaching the intersection during design hour are 900 and 743 PCU/hr on the two approaches of road2. design the signal timings as per IRC. **(12 Marks)**

b. Explain the significant roles of traffic control personnel. **(04 Marks)**

OR

6 a. Explain the three types of traffic sings with 3 examples for each with diagrams. **(10 Marks)**

b. Explain the design factors to be considered for design of rotary intersection. **(06 Marks)**

Module-4

7 a. Describe the causes of road accidents and also suggest preventive measures to control accidents. **(08 Marks)**

b. Describe the various environmental hazards due to traffic in urban areas. **(08 Marks)**

OR

8 a. Explain the arrangement of street lighting in urban areas and show the lighting arrangement sketch for signalized and rotary intersections. **(08 Marks)**

b. Explain the importance and promotion of non motorized transport. **(08 Marks)**

Module-5

9 a. Explain the various method of traffic segregation. **(08 Marks)**

b. Explain the concept of area traffic management system control (ATC) with an example. **(08 Marks)**

OR

10 a. Explain applications of Intelligent Transport System (ITS). **(08 Marks)**

b. Explain parking pricing and congestion pricing methods to control traffic management. **(08 Marks)**

* * * * *

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

Assignment

Date	26	11	2020

Assignment No.	I	**Maximum Marks**	10
Course/Subject Title	Highway Engineering	**Course/Subject Code**	18CV56
Semester	V A	**Scheme**	CBCS – 18
Course Co-ordinator	Ms. Supriya Xavier Lopes		

Course Outcome Statements : After the successful completion of the course, the students will be able to	
CO1	**Explain** the principles of transportation including the present scenario of road development in India
CO2	**Select** a new alignment and re-alignment of existing roads
CO3	**Design** the geometrics of the road as per IRC recommendations
CO4	**Explain** the properties of pavement materials for the design
CO5	**Explain** the techniques of construction for various types of pavements
CO6	**Evaluate** highway economics and also to design a suitable drainage system

Note : Answer all the questions.

Q. No.	Question	Marks	RBT Level	CO
1	While aligning a HW in a built up area, it was necessary to provide a horizontal circular curve of radius 325m. Design the following geometric features i)Superelevation ii)extra widening of pavement iii)length of transition curve. Data available are, design speed = 65 kmph, length of wheel base of largest truck = 6m, pavement width = 10.5m.	2	L3	3
2	A state HW passing through a rolling terrain has a horizontal curve of radius equal to the ruling min. radius. I) Design all the geometric features of this curve. ii) specify the min. set back distance from the center line of the two lane HW on a inner side of the curve up to which the buildings etc. Obstructing vision should not be constructed so that ISD is available throughout the circular curve. Assume the length of circular curve greater than the SD.	2	L3	3
3	On the same lane of a road a car A is following car B at a center distance of 25m. Both cars are travelling at a speed of 100kmph, when car a attempts to overtake car B at a uniform acceleration of 0.8 m/s^2. After travelling for 5sec at that acceleration, it increases the acceleration rate to overtake car B and comes to a position 20m in front of car B in another 5 secs. What is the distance travelled by car A during total period of acceleration?	1	L3	3
4	Determine the following for a road on horizontal curve in plain of radius 500m. The design speed is 100kmph and f = 0.15. a) superelevation required on road, when full lateral friction come into play. b) f when no superelevation is provided. c) equilibrium super elevation. d) superelevation for mixed traffic when speed is now change to 60 kmph.	1	L3	3
5	The extra widening required for 2 lane NH at a horizontal curve of 300m radius, considering a wheel base of 8m and a design speed of 100 kmph.	1	L3	3
6	A 3 lane (O/W) road with total width of 10.5 m is considered on a horizontal curve of 550 m. The length of the curve is 40 m. Determine the clearance from the center line of inner lane to the inner side obstruction when the SD required on the road is a) SSD =250 m b) OSD = 450 m.	1	L3	3
7	A transition curve required for a two lane single carriageway road (of total width on curve of 7.3m) with a design speed of 85 kmph to connect a horizontal curve of radius 200 m. Assume value of C = 0.7 m/s^3. The rate of introduction of super elevation is 1 in 150, the road is passing through rolling terrain. Pavement is rotated about inner edge. Calculate the following, i) the min, transition length(L) 2) Shift(S).	1	L3	3
8	A vertical crest curve on a two lane single carriageway road with a design speed of 85 kmph is to be built in order to join an ascending grade of 4% with a descending grade of 2.5%. The motorist eye height is assumed to be 1.05m while the object height is assumed to be 0.26 m. i) Calculate the min. curve length required in order to satisfy the requirements of min. SSD. Reaction time of driver is 2.5s and coefficient of longitudinal friction is 0.35. ii) distance of heighest point from the beginning of 4% gradient.	1	L3	3

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

Assignment

Date	26	11	2020

Last date for submission	05	12	2020

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

25/11/20
Course Coordinator
(Faculty in charge)

11/01/2021
Coordinator
DQAC

Program Coordinator
(HOD, Civil)

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

USN										

Course/Subject Title	Highway Engineering	Course/Subject Code	18CV56
Semester	V – A	Scheme	CBCS – 18
Date	01.12.2020	CIE No.	I
Time	10:30 to 11:30 AM	Max. Marks	30

Course Outcome Statements : After the successful completion of the course, the students will be able to	
CO1	**Explain** the principles of transportation including the present scenario of road development in India
CO2	**Select** a new alignment and re-alignment of existing roads
CO3	**Design** the geometrics of the road as per IRC recommendations
CO4	**Explain** the properties of pavement materials for the design
CO5	**Explain** the techniques of construction for various types of pavements
CO6	**Evaluate** highway economics and also to design a suitable drainage system

Note :Answer any one full question from each Part. Missing data may be assumed suitably.

Q. No.		Question	Marks	RBT Level	CO
		Part A			
1	a)	**Explain** the map study is the alignment of a highway project.	5	L2	2
	b)	**List** different modes of transportation. **Explain** the characteristics of road transport on comparison with other system.	10	L1, L2	1
2	a)	**What** are the main objectives of preliminary survey and steps followed in the preliminary survey by conventional method.	6	L1	2
	b)	**What** are the types of roads and its classification? Briefly **outline** classification on urban roads.	9	L1, L2	1
		Part B			
3	a)	**Explain** different cross sectional elements.	9	L2	
	b)	**Evaluate** the minimum sight distance required to avoid a head on collision of two cars approaching from the opposite directions at 90 and 60 kmph. Assume a reaction time of 2.5 seconds, coefficient of friction 0.7 and brake efficiency of 50% in either case.	7	L5	3
4	a)	**Explain** the PIEV theory with a neat diagram.	6	L2	
	b)	The speed of overtaking and overtaken vehicles are 70 and 40 kmph respectively on a two way traffic road. If the acceleration of overtaking vehicle is 0.99 m/sec^2. i)**Find** the safe overtaking sight distance. ii)**Evaluate** the minimum length of overtaking zone. iii)**Formulate** a neat sketch of the overtaking zone and show the positions of the sign posts.	9	L1, L5, L6	3

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

Course Coordinator
(Faculty in charge)

Coordinator
DQAC

Program Coordinator
(HOD, Civil)

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

Scheme of Valuation

Course/Subject Title	Highway Engineering	Course/Subject Code	18CV56
Semester	V-A	CIE No.	I
Date	1/12/2020	Max. Marks	30

Q.	Solution	Marks
	Part A	
1) a)	Map study – 5 points	5
b)	Different modes of transportation	4
	Characteristics of road transport – 6 points	6
2) a)	Objectives of preliminary survey	3
	5 steps	3
b)	classification of roads	9
	Part-B	
3) a)	Cross sectional elements	
	Friction – (2)	
	Pavement unevenness – (2)	9
	Light reflecting characteristics – (2)	
	Chamber – (3)	
b)	Problem	
	Formula of SSD	1
	SSD for 1st car = 153.6 m	2
	" " 2nd " = 82.2 m	2
	∴ SD = 235.8 m	2
4) a)	PIEV Theory – 4 points	4
	Diagram	2

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(Faculty in charge)

Coordinator
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Scheme of Valuation

Q.	Solution	Marks
4) b)	Problem OSD, $d_1 = 22.2m$ $d_2 = 110.5m$ $d_3 = 144.9m$	3
	i) OSD = 278m	3
	ii) Min. length of OZ = 834m	3
	iii) Sketch	

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Department of Civil Engineering

USN										

Course/Subject Title	Highway Engineering	Course/Subject Code	18CV56
Semester	V – A	Scheme	CBCS – 18
Date	24.12.2020	CIE No.	II
Time	11:30 to 12:30 AM	Max. Marks	30

Course Outcome Statements : After the successful completion of the course, the students will be able to	
CO1	**Explain** the principles of transportation including the present scenario of road development in India
CO2	**Select** a new alignment and re-alignment of existing roads
CO3	**Design** the geometrics of the road as per IRC recommendations
CO4	**Explain** the properties of pavement materials for the design
CO5	**Explain** the techniques of construction for various types of pavements
CO6	**Evaluate** highway economics and also to design a suitable drainage system

Note :Answer any one full question from each Part. Missing data may be assumed suitably.

Q. No.		Question	Marks	RBT Level	CO
		Part A			
1	a)	**Distinguish** between bitumen and tar.	5	L2	4
	b)	**Define** the modulus of sub grade reaction. With the sketch **explain** the plate load test for determining the k value.	10	L1, L2	
2	a)	**Enumerate** different types of pavements with their component parts and functions of each component	7	L1	4
	b)	**Explain** the various properties of road aggregates.	8	L2	
		Part B			
3	a)	**Explain** briefly the steps of superelevation design.	8	L2	3
	b)	Horizontal HW curve of radius 400m and 200m in length. **Compute** the set back distances required from the center line on the inner side of the curve so as to provide for a) Stopping sight distance of 90m. b) Safe overtaking sight distance of 300m. The distance between the center lines of the road and the inner lane is 1.9 m.	7	L3	
	a)	**Explain** the design criterias to obtain the length of transition curve.	7	L2	3
	b)	The radius of a horizontal circular curve is 100 m. The design speed is 50 kmph and the design coefficient of lateral friction is 0.15. a) **Calculate** the superelevation required if full lateral friction is assumed to develop. b) **Calculate** the coefficient of friction needed if no superelevation is provided. c) **Calculate** the equilibrium superelevation if the presence on inner and outer vehicle should be equal.	8	L3	

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

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(Faculty in charge)

23/12/2020
Coordinator
DQAC

22/12/2020
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Department of Civil Engineering

Scheme of Valuation

Course/Subject Title	Highway Engineering	Course/Subject Code	18CV56
Semester	V - A	CIE No.	II
Date	24/12/2020	Max. Marks	30

Q.	Solution	Marks
	Part-A	
1) a)	Diff b/t bitumen and tar - 5 points	5
b)	Definition of modulus of sub grade reaction	2
	Sketch	3
	Explanation	5
2) a)	Flexible pavements - components & functions	4
	Rigid pavements - " " "	3
b)	Properties of road aggregates	
	Atleast 4 with explanation	8
	Part-B	
3) a)	5 steps of superelevation design	8
b)	Pb: if SSD < L_c	3
	$m' = 4.4m$	
	if SSD > L_c	4
	$m' = 26.8m$	
4) a)	Design criteria for length of transition curve	
	i) Rate of chg of centrifugal acceleration	3
	ii) Rate of introduction of superelevation	3
	iii) By empirical formula	1

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Scheme of Valuation

Q.	Solution	Marks
4) b)	Pb. Superelevation $e+f = \frac{V^2}{gR}$ a) $e = 0.047$ b) $f = 0.197$ c) $e = 0.197$	2 2 2 1

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Assignment

Date	11	01	2021

Assignment No.	II	**Maximum Marks**	10
Course/Subject Title	Highway Engineering	**Course/Subject Code**	18CV56
Semester	V A	**Scheme**	CBCS – 18
Course Co-ordinator	Ms. Supriya Xavier Lopes		

Course Outcome Statements : After the successful completion of the course, the students will be able to	
CO1	**Explain** the principles of transportation including the present scenario of road development in India
CO2	**Select** a new alignment and re-alignment of existing roads
CO3	**Design** the geometrics of the road as per IRC recommendations
CO4	**Explain** the properties of pavement materials for the design
CO5	**Explain** the techniques of construction for various types of pavements
CO6	**Evaluate** highway economics and also to design a suitable drainage system

Note : Answer all the questions.

Q. No.	Question	Marks	RBT Level	CO
1	Explain Wet Mix Macadam.	2	L2	5
2	Explain pre[parathion of subgrade.	2	L2	5
3	Explain Bituminous Concrete layer.	2	L2	5
4	Write a note on Earthwork	2	L2	5
5	Explain ESWL and its determination.	2	L3	4

Last date for submission	**16**	**01**	**2021**

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

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Department of Civil Engineering

Assignment

Date	13	01	2021

Assignment No.	III	**Maximum Marks**	10
Course/Subject Title	Highway Engineering	**Course/Subject Code**	18CV56
Semester	V A	**Scheme**	CBCS – 18
Course Co-ordinator	Ms. Supriya Xavier Lopes		

Course Outcome Statements : After the successful completion of the course, the students will be able to	
CO1	**Explain** the principles of transportation including the present scenario of road development in India
CO2	**Select** a new alignment and re-alignment of existing roads
CO3	**Design** the geometrics of the road as per IRC recommendations
CO4	**Explain** the properties of pavement materials for the design
CO5	**Explain** the techniques of construction for various types of pavements
CO6	**Evaluate** highway economics and also to design a suitable drainage system

Note : Answer all the questions.

Q. No.	Question	Marks	RBT Level	CO
1	Briefly explain the different methods of economic analysis of a highway.	5	L2	6
2	Explain in brief the various factors affecting the vehicle operation cost.	5	L2	6

Last date for submission	**16**	**01**	**2021**

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

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Department of Civil Engineering

USN										

Course/Subject Title	Highway Engineering	Course/Subject Code	18CV56
Semester	V – A	Scheme	CBCS – 18
Date	18.01.2021	CIE No.	III
Time	8:00 to 9:00 AM	Max. Marks	30

Course Outcome Statements : After the successful completion of the course, the students will be able to	
CO1	**Explain** the principles of transportation including the present scenario of road development in India
CO2	**Select** a new alignment and re-alignment of existing roads
CO3	**Design** the geometrics of the road as per IRC recommendations
CO4	**Explain** the properties of pavement materials for the design
CO5	**Explain** the techniques of construction for various types of pavements
CO6	**Evaluate** highway economics and also to design a suitable drainage system

Note : Answer any one full question from each Part. Missing data may be assumed suitably.

Q. No.		Question	Marks	RBT Level	CO
		Part A			
1	a)	**Explain** the Rothfuch's method of proportioning of materials.	7	L2	5
	b)	**List** down the materials and **explain** the specification and construction steps for WBM pavement.	8	L1, L2	
2	a)	**Explain** the construction of cement concrete pavements.	7	L2	5
	b)	**List** down the materials and **explain** the specification and construction steps for wet mix macadam base course.	8	L2	
		Part B			
3	a)	**Explain** with sketches how the subsurface drainage system is provided to lower the water table.	8	L2	6
	b)	**Briefly** describe the different methods of economic analysis of a highway.	7	L2	
4	a)	**List** the requirements of highway drainage system.	7	L1	6
	b)	**Explain** briefly the design of filter material used in subsurface drains.	8	L2	

RBT (Revised Bloom's Taxonomy) Levels : Cognitive Domain		
L1 : Remembering	L2 : Understanding	L3 : Applying
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Department of Civil Engineering

Scheme of Valuation

Course/Subject Title	Highway Engineering	**Course/Subject Code**	18CV56
Semester	V A	**CIE No.**	III
Date	18-01-2021	**Max. Marks**	30

Q.	Solution	Marks
		3
1) a)	Graph	4
	Explanation	2
b)	Materials of WBM	2
	specification	4
	Construction steps of WBM	
2) a)	Construction of cement concrete pavement slab	4
	Construction of joints in CC pavements	3
b)	Materials of Wet mix macadam	1
	specification	2
	Construction steps	5
		2
3) a)	Sketch	6
	Explanation of lowering the water table	
b)	Methods of analysis of a highway	2
	Annual Cost Mtd	2
	Rate of return Mtd	3
	Benefit Cost Mtd	
4) a)	Requirements of HW drainage s/m (6 points)	7
b)	Design of filter material - Graph	3
	Explanation	5

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Scheme of Valuation

Q.	Solution	Marks

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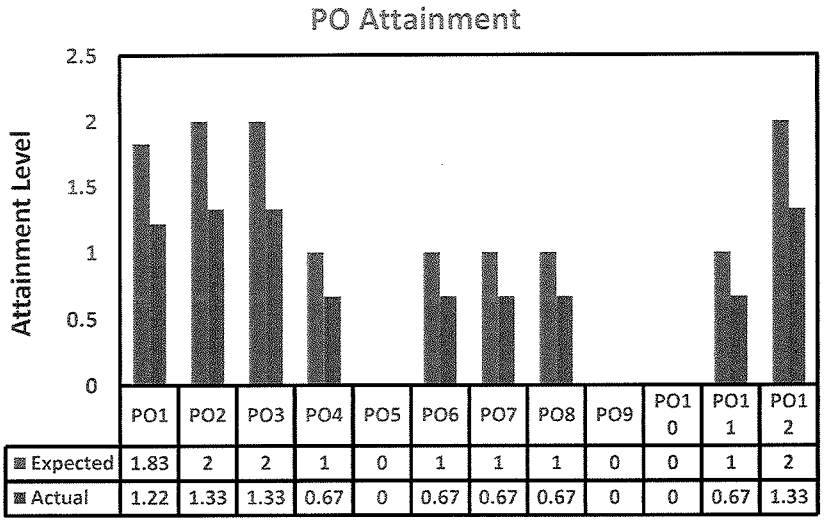
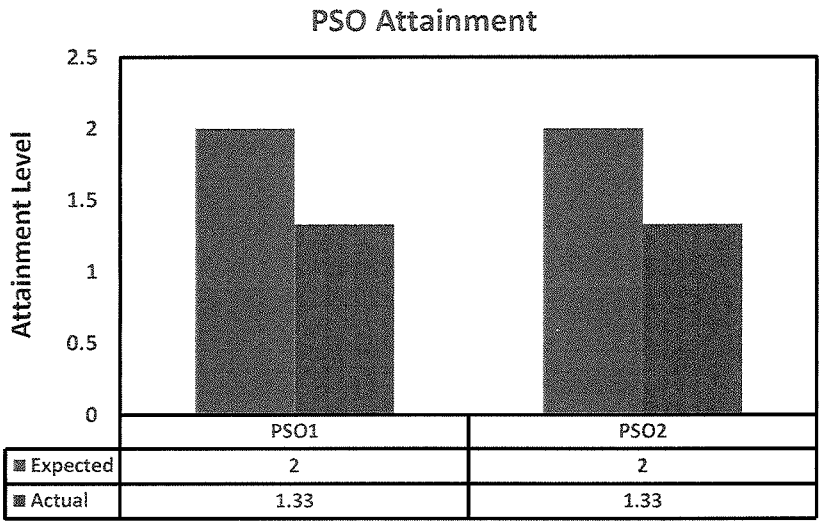
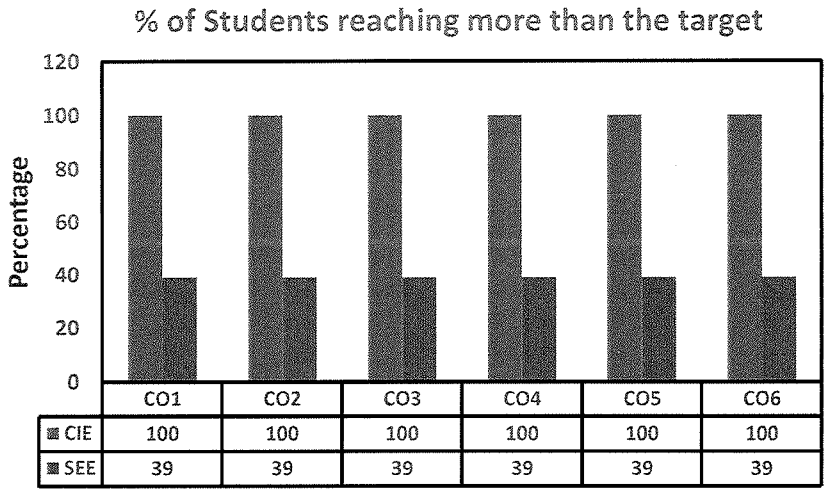
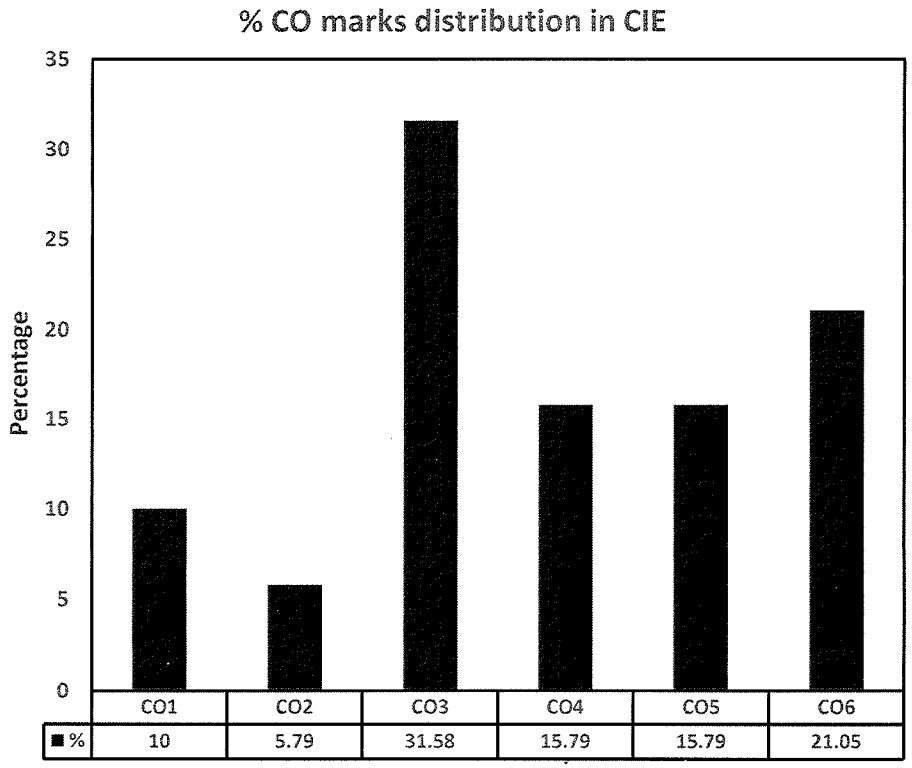


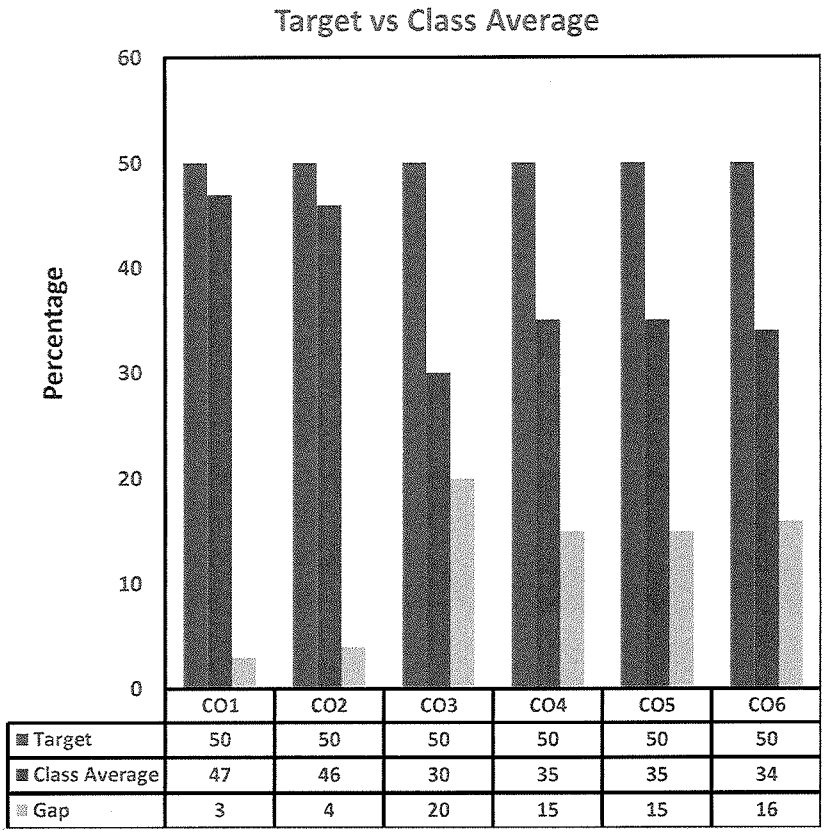
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
Expected	1.83	2	2	1	0	1	1	1	0	0	1	2
Actual	1.22	1.33	1.33	0.67	0	0.67	0.67	0.67	0	0	0.67	1.33



	PSO1	PSO2
Expected	2	2
Actual	1.33	1.33


% of Students reaching more than the target
Percentage
120
100
80
60
40
20
0
CO1 CO2 CO3 CO4 CO5 CO6
CIE 100 100 100 100 100 100
SEE 39 39 39 39 39 39


% CO marks distribution in CIE
Percentage
35
30
25
20
15
10
5
0
CO1 CO2 CO3 CO4 CO5 CO6
% 10 5.79 31.58 15.79 15.79 21.05



	CO1	CO2	CO3	CO4	CO5	CO6
Target	50	50	50	50	50	50
Class Average	47	46	30	35	35	34
Gap	3	4	20	15	15	16