CBCS SCHEME

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18CV56

Fifth Semester B.E. Degree Examination, June/July 2023
Highway Engineering

Time: 3 hrs. Max. Marks: 100

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. **(10 Marks)**

b. 3 New Roads R1, R2 and R3 are to be completed in a District during five year period. Using the data given below workout the order of priority for placing the plan program by the principle of maximum utilities per unit length. Adopt utility unit of 0.5 < 2000 , 1.0 for 2000 – 5000 and 2.0 for > 5000 , 1.0 for 1000 t of agricultural product and 1.0 for 100 t of Industrial products. **(10 Marks)**

Road	Length	No. of Villages served population			Productivity 1000 tonnes	
		< 2000	2000-5000	> 5000	Agriculture	Industries
R1	15	10	8	3	15	1.2
R2	12	16	3	1	11	0.0
R3	18	20	10	2	20	0.8

OR

2 a. Write short note on :
i) NHDP ii) PMGSY iii) KSHIP iv) KRDCL. **(10 Marks)**

b. List out the factors affecting alignment and explain important stages of Engineering Survey of Highway Alignment. **(10 Marks)**

Module-2

3 a. Explain briefly two important surface characteristics influencing Highway Geometric Design. **(10 Marks)**

b. The speeds of overtaking and overtaken vehicles are 70 and 40 kmph respectively on a two way traffic road. The average acceleration during overtaking operation is assumed as $0.99 m/sec^2$.
i) Calculate safe overtaking sight distance.
ii) What is the minimum length of overtaking zone?
iii) Draw a neat sketch of overtakes zone indicating the positions of sign posts. **(10 Marks)**

OR

4 a. Enlist the gradients encountered in vertical Alignment and explain briefly. **(10 Marks)**

b. A vertical summit curve is formed at the intersection of 2 gradients , +3.0% and -5.0%. Design the length of summit curve to provide a SSD for a design speed of 80 kmph. Assume missing data suitably. **(10 Marks)**

Module-3

5 a. With a neat sketch, illustrate conduction of Plate Load test to determine modulus of subgrade reaction. **(10 Marks)**

b. List the desirable properties of Bitumen and tests to be conducted on Bitumen. **(10 Marks)**

OR

6 a. Draw and explain the Component part and functions of each component of Flexible and Rigid pavement. **(10 Marks)**

b. The CBR test results are as follows. Apply correction and determine the CBR value of the soil. **(10 Marks)**

Load in kgs	0	2	4	9	20	34	49	74	92	118	125
Penetration in mm	0	0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0	7.5	10.0

Module-4

7 a. Briefly outline the design procedure of soil aggregate mixes by Ruth fatch method. **(10 Marks)**

b. Enumerate the requirements , specification of materials and construction steps for Wet Mix Macadom (WMM). **(10 Marks)**

OR

8 a. Explain briefly the construction procedure of Bitumen concrete (BC) with Quality control checks as per MORTH. **(10 Marks)**

b. List the quality checks on Cement Concrete Pavement (PQC) carried out both in the laboratory and at field. **(10 Marks)**

Module-5

9 a. Explain the significance and requirements of a Highway Drainage System. **(10 Marks)**

b. Explain with sketches, how the subsurface drainage system is provided to lower the GWT. **(10 Marks)**

OR

10 a. Explain the following with respect to Highway Financing :
i) BOT ii) BOOT iii) VOC. **(10 Marks)**

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

Item	Total cost Rs. in lakhs	Estimated life, years	Rate of interest, %
Land	35.0	100	6
Earth work	40.0	40	8
Bridges, culvert and drainage	50.0	60	8
Pavement	100.0	15	10
Traffic signs and Road Items	15.0	5	10

The average cost of maintenance of the road is Rs 1.5 lakhs per year. **(10 Marks)**

* * * * *

Q. No 1a Mention the different modes of transportation. Explain the characteristics of road transport in comparison with other system. (10 M)

Different modes of transportation

a) Land → Roadways or highways
→ Railways.

b) Water

c) Air

Characteristics of road transport:

a) Roads are used by different modes of vehicles like bike, passenger cars, carts etc.

b) Road transportation infrastructure requires less initial investment compared other modes of transportation.

c) Road transport offers complete freedom than any other type of transportation.

d) Speed on the road can be varied immediately than other type of transportation.

e) Road transport has high flexibility than any Other transportation.

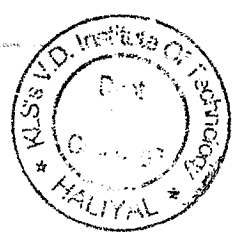
f) Road transport is the only transport which can give door to door service compared to other type of transportation.

Q.No.16. 3 new roads R_1, R_2 and R_3 are to be completed in a District during five year period. Using the data given below workout the order of priority for placing the plan program by the principle of maximum utilities per unit length. Adopt utility unit of 0.5 <2000, 1.0 for 2000-5000 and 2.0 for >5000. 1.0 for 1000t of agricultural product and 1.0 for 100t of industrial products.

Road	Length	No. of villages Served population			Productivity 1000 tonnes	
		<2000	2000-5000	>5000	Agriculture	Industries
R_1	15	10	8	3	15	1.2
R_2	12	16	3	1	11	0.0
R_3	18	20	10	2	20	0.8

Road	Length	No. of Villagers Served population			Productivity 1000 tons	
		<2000 (0.5)	2000-5000 (1.0)	>5000 (2.0)	Agriculture 1.0	Industries 10
R_1	15	5 +	8 +	6 +	15 +	12 = 46
R_2	12	8 +	3 +	2 +	11 +	0 = 24
R_3	18	10 +	10 +	4 +	20 +	8 = 52

Road	Max. Utility	Utility/Unit	Priority
R_1	46	46/15 = 3.06	I
R_2	24	24/12 = 2	III
R_3	52	52/18 = 2.88	II



∴ Priority is as follows $R_1 > R_3 > R_2$

Q.No.2 Write a short notes on

a) i) NHDP:

National Highway Development Program

Govt. of India started NHDP in the year 1998. Under the leadership of prime minister Shri. Atal Bihari Vajpeyi. Following are the features of NHDP with 8 phases.

a) Project is managed by NHAI.

b) To upgrade and widen major highways.

c) NHDP represents 49,260 kms of roads.

d) Golden quadrilateral was introduced during NHDP.

e) Bharath mala project is the ongoing project under NHDP.

ii) PMGSY

Pradhan Mantri Grama Sadak Yojana

Started in the year 2000 with the following objectives.

a) PMGSY is specially for village roads.

b) Provided with all weather roads.

c) Rigid pavements (Concrete roads are constructed)

d) Targets were made to construct drains, culverts and bridges.

e) Looked by Panchayat and Rural development department.

iii). KSHIP :

Karnataka State Highways Improvement Program

a). Established by goverment of Karnataka

b). In the year 1996.

c) Aiming to upgrade and coiden the State highway and Major district roads.

Followed by : Landacquistion and Major maintenan

iv). KRDCL :

Karnataka Rural Development Corporation Limite

a). Established in the year 21st July 1999 by goverment of Karnataka.

b). KRDCL works under PWD and IWT.

c). To promote road works and bridges

Q. 2b. List out the factors affecting the alignment and explain importantstages of Engineering survey of highway Alignment.

factors affecting the alignment :

a). Obligatory points

b). Traffic

c). Cuometry design

d) Economics

e). Other consideration.

Explanation on important stages of Engineering survey:

a). Map study: First step of engineering survey where maps from "Survey department of India" are collected for basic information of the construction field.

b). Reconnaissance survey: Second step, where site visit is recommended by the engineering team. Only site features are observed and informations are recorded in map.

c). Preliminary survey: Third step, in which traversing is carried out, boundaries are fixed. Soil samples are collected, Existance of ground water table is verified.

d). Final location and detail survey: Final stage, of engineering survey where detail inspection, surveys are carried out. Finally reports are prepared like drawing, estimation etc.

Q.N3a Explain briefly two important suface Characteris influencing highway Geometric Design.

a). Camber.

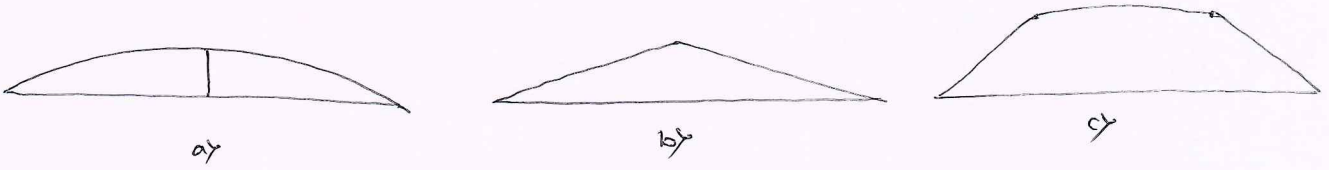
b). Carriageway.

a). Camber:

Cross slope on the pavement surface is known as camber. It is also known as "Central Crown"

Types of camber:

a). Parabolic b). Straight line c) Combination of Straight and Parabolic.



a) b) c)

Minimum amount of camber to be provided as per IRC = 1.7% ⇒ Thick bituminous surface with low rainfall area.

Importance of camber:

1). To drain of water retain on surface of road.

2). To prevent entry of water in to the pavement layers.

3). To prevent entry water in to the bituminous layers.

Maximum amount of camber as per IRC = 4.0%.

Earthen roads for heavy rainfall area.

b). Carriage way:

Case which is reserved for traffic movement is called carriage way.

As per IRC width of carriage ways are as follows.

a). Single lane : 3.75 mts

b). Double lane : 7.00 mts

c). Triple lane : 10.50 mts

d) Additional lane : 3.50 mts

e). Intermideate road : 5.50 mts

Importance of carriage way:

a). Width of carriage way mainly depends up on width of traffic lane.

b). Number of lanes.

c). The lane width is increased to 3.75 m if there is a raised kerb.

Q.36. The Speeds of overtaking and overtaken vehicle are 70 and 40 kmph respectively on a two way traffic road. The average acceleration during overtaking operation is assumed as 0.99 m/sec^2.

i). Calculate safe overtaking sight distance.

ii). What is the minimum length of overtaking zone

iii). Draw a neat sketch of overtaking zone including the position of sign posts.

→ Speed of overtaking vehicle, $V = 70$ kmph $= 70/3.6 = 19.4$ m/s

Overtaken vehicle, $V_b = 40$ kmph $= 40/3.6 = 11.1$ m/sec

Average acceleration during overtaking $a = 0.99$ m/sec^2

Overtaking sight distance for two way traffic $t = 2$ sec

$d_1 = V_b t = 11.1 \times 2 = 22.2$ m

$d_2 = V_b T + 2S$ $\quad S = (0.7V_b + 6)$ $\quad T = \sqrt{4S/a}$

$S = (0.7 \times 11.1 + 6)$

$= 13.8$ m

$T = \sqrt{\frac{4 \times 13.8}{0.99}}$

$T = 7.47$ sec

$d_2 = 11.1 \times 7.47 + 2 \times 13.8 = 110.5$ m

$d_3 = VT = 19.4 \times 7.47 = 144.9$ m

Overtaking sight distance

$OSD = d_1 + d_2 + d_3 = 22.2 + 11.05 + 244.9$

$= 277.6$ m

b). Minimum length of overtaking zone

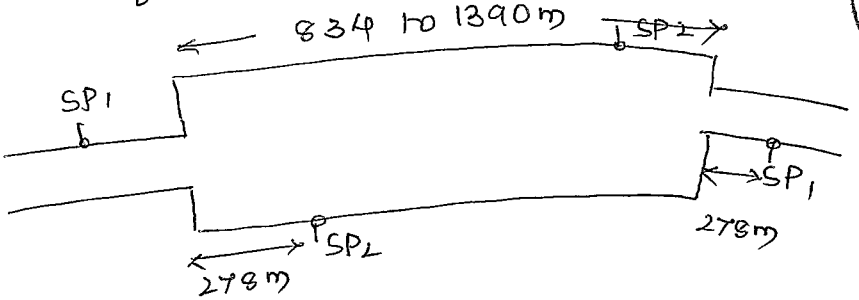
$= 3(OSD) = 3 \times 278 = 834$ m

c). Desirable length of overtaking zone

$= 5\,OSD$

$= 5 \times 834 = 1390$ mts

The details of the overtaking zone are,



Q.4b: Enlist the gradients encountered in vertical alignment and explain briefly.

Types of Curves in vertical alignment.

a). Summit curve.

b). Valley curve.

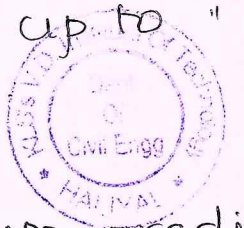
Types of gradients are:

i) Ruling gradient: The maximum gradient within which the designer attempts to design the vertical profile of a road. 1 in 30 in plain & 1 in 10 in mountainous

ii). Limiting gradient: Where topography of a place compels adopting steeper gradient than the ruling gradient "limiting gradient"

is used in view of enormous increase in cost in constructing roads with gentler gradients.

c) Exceptional gradient: In some extra ordinary situation it may be unavoidable to provide still steeper gradients than limiting gradients at least for short stretches and such cases the steeper gradient up to "exceptional gradient" may be provided



d) Minimum gradient: The road can be level, with little or no gradient. In such cases there will be problem of drainage. Though the surface water can be drained off to side drains by providing proper camber on the pavement surface and cross slope on the shoulders a certain longitudinal slope is essential.

Q.4b. A vertical summit curve is formed at the intersection of 2 gradients, +3% and -5%. Design the length of summit curve to provide a SSD for a design speed of 80 kmph. Assume missing data suitably.

⇒ Design speed $v = 80$ kmph, gradient $n_1 = 3\%$ and $n_2 = -5\%$

a) Determination of safe stopping sight distance

$$SSD = 0.278vt + \frac{v^2}{254f}$$

Assume, $t = 2.5$ sec, $f = 0.35$, $v = 80$ kmph

$$= 0.278 \times 80 \times 2.5 + \frac{80^2}{254 \times 0.35}$$

$= 55.6 + 72.0 = 127.6 \simeq 128$ mts

b). Determination of length of summit curve

$$N = 0.03 - (-0.05) = 0.08$$

L > SSD

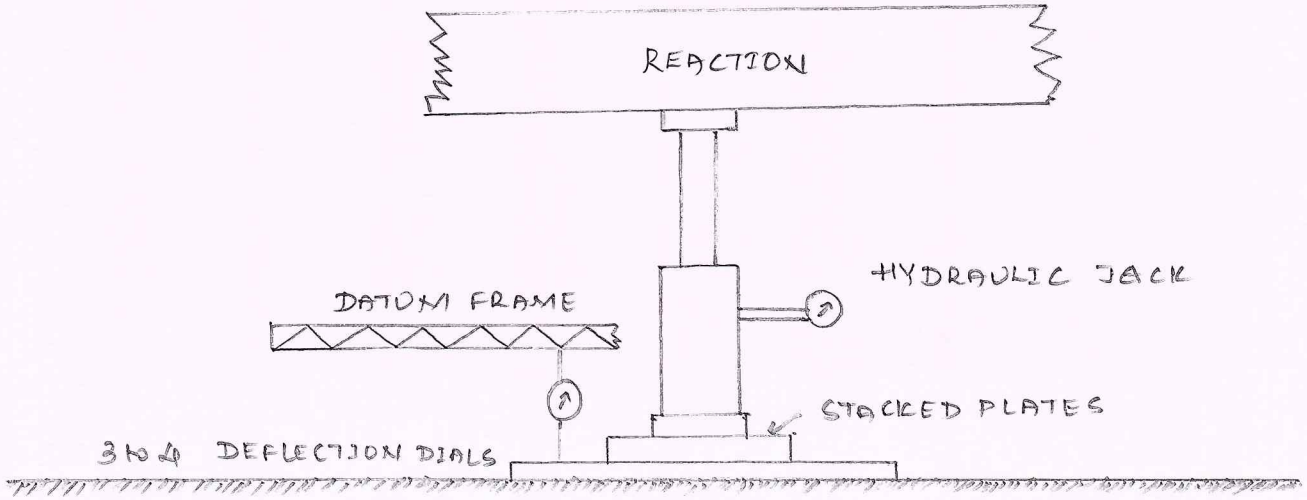
$$L = \frac{NS^2}{4.4} = \frac{0.08 \times 128^2}{4.4} = 297.9 = 298 \text{ mts}$$

∴ Value of summit curve length L is greater than SSD of 128 m as per the assumption

∴ Length of summit curve L = 298 mts

∴ The minimum specified length of summit curve is 50 m and therefore design length of summit curve = 298 mts

Q.5a. With the neat sketch, illustrate condition of plat load test to determine modulus of subgrade reaction.



The plate bearing test is used to evaluate the support power of subgrade insitu for use in pavement design by using relatively large diameter plates. The plate bearing test was originally devised to find modulus of subgrade reaction in Westergaard analysis for wheel load stresses in rigid pavements.

The test set up consists of a set of plates of diameter 750, 600, 450 and 300 mm. A loading device consisting of Jack and proving ring arrangements and reaction frame against which the jack can give a thrust to the plates.

Modulus of subgrade reaction:

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

$$K = \frac{0}{0.125} \text{ kg/cm}^2/\text{cm or kg/cm}^3$$

Q.5b. List the desirable properties of bitumen and tests to be conducted on bitumen.

Properties of bitumen:

Bitumen is available in a variety of types and grades. To judge the suitability of these binders various test have been specified by agencies like the BIS, ASTM etc.

a. Bitumen is a hydrocarbon materials.
b. Bitumen is found in various (liquid and solid

state and also in semi solid form.

c). Bitumen is soluble in carbon disulphide and carbon tetra chloride.

Various tests conducted on bitumen are:

a). Penetration test: To determine grade of bitumen

b). Viscosity test: To determine viscosity value of a bitumen.

c). Ductility test: To determine ductile property of a bitumen.

d). Softening point test: To determine softening tempreture of bitumen.

e). Flash and fire point test: To determine flash tempreture and fire tempreture of a bitumen

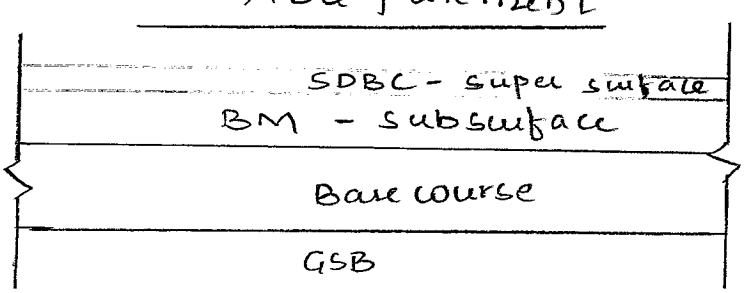
f). Specific gravity test

g). Loss on heating test

h). Solubility test.

2. 6a. Draw and explain the component part of and function of each component of flexible and rigid pavement.

Flexible pavement



Flexible pavement:

a) Soil subgrade: A layer which is naturally available or a compacted layer of soil which is borrowed from pit. Supports all other pavement components.

b)

b) GSB: Granular Sub Base:

Acts as a effective drainage layer of pavement structure.

Coarse aggregates present in the layer sustains the load coming on it.

c) Base course:

which can sustain the wheel load stresses & disperse through the larger area.

A good base course layer increases the load carrying capacity.

d) Surface course:

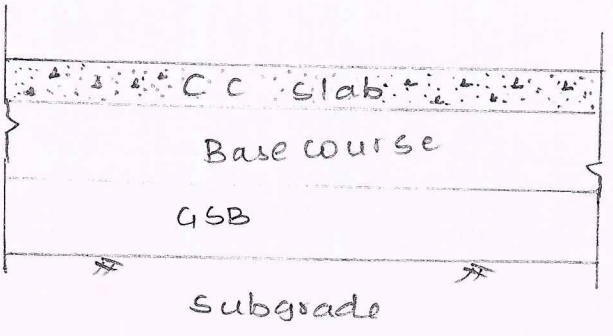
Acts as a seal coat and avoids entry of surface water into pavement layers.

Keeps subgrade dry and bind as its acts as per seal coat.

Transfer loads to below layer.

Comprises of dense graded bitumen and SDBC.

Rigid Pavement



Function of Cement concrete slab:

a). Provides a flat and hard suface.

b). Top most layer of Rigid pavement.

c). Comprises of concrete and HYSD bars.

d). Distributes load from CC slab to other layers

e). Controlls all the load coming on it & distributes uniformly.

Q. 6b. The CBR test results are as follows. Apply Corrections and determine the CBR value of the soil.

From the graph it is observed that

Load at 2.5mm penetration = 74kg

$$\therefore CBR_{@2.5mm} = \frac{74}{1370} \times 100 = 5.40\%$$

Load at 5.0mm penetration = 109kg

$$\therefore CBR_{@5.0mm} = \frac{109}{2055} \times 100 = 5.30\%$$

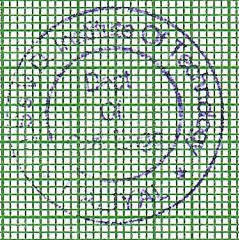
$\therefore CBR_{@2.5mm} > CBR_{@5.0mm}$ after correction

Hence the CBR value is Accepted.

(b)

On X axis 1 unit = 1 mm

Y-axis 1 unit = 10 kg



Load (kg) →

Penetration (mm) →

K 109 kg @ 5.0 mm

74 kg @ 2.5 mm

X-axis

Y-axis

CBR @ 2.5 mm = $\frac{74}{370} \times 100$

= 5.40 %

CBR @ 5 mm = $\frac{109}{2055} \times 100$

= 5.30 %

CBR @ 2.5 mm > CBR @ 5 mm

Q-7a Briefly outline the design procedure for soil aggregate mixes by "Ruth Futch method".

. In order to get good bonding between the aggregat or soil there should be a very good proportioning of different particle sizesin the given sample.

We have different methods for aggregate blending out of all 'Ruth Futch method" is considered to b a ideal method of aggregate blending.

⇒ a). Different materials are given andtheir particle size with % of siere passing are noted.

b). After listing the different materials with particl size, % of passing, a graph is plotted x-axis as particle size & Y-axis as % of passing.

c). A 45° line is drawn from origin such that for material A, B, C, considering % of passing on y-axis as refference, a line is joined to 45°line from Y-axis & joined to X-axis.

d). Now, on X-axis, point which is identified is considered as particle size. like this all particles are plotted on Y-axis

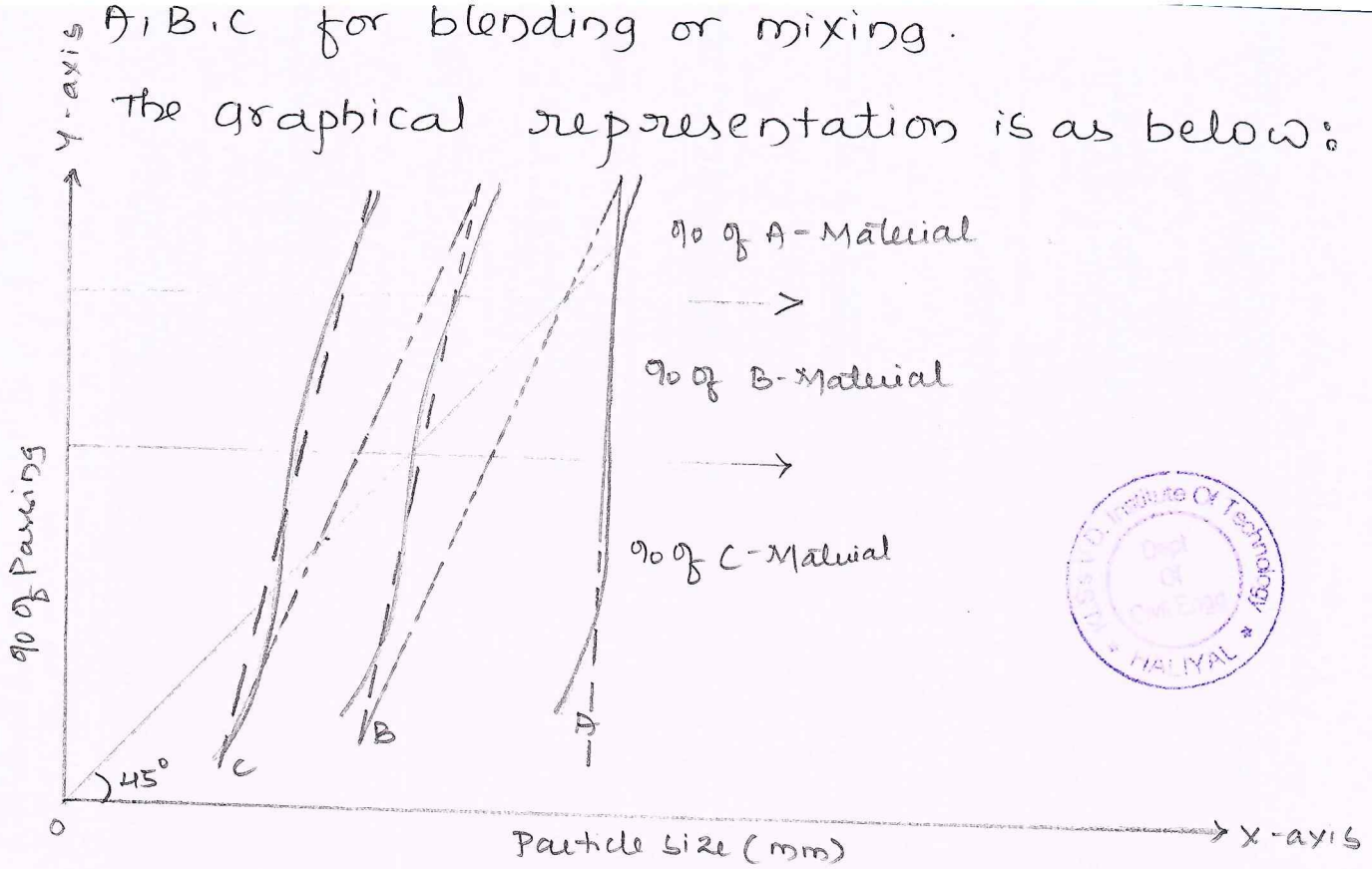
e). Curves are drawn with respect to given materials A, B, C and balancing lines are adjusted.

b). First point of balanced curve (1) is joined with last point of curve (2). like wise.

g). Point intersecting on 45° line is identified & joined to Y-axis, which gives % of material.

A, B, C for blending or mixing.

The graphical representation is as below:



Q-7b. Enumerate the requirements, specification of materials and construction steps for wet mix macadam (WMM).

Wet mix macadam: Consist of a well graded hard crushed aggregates and adequate proportions of water mixed thoroughly in a mixing plant. The wet mix is spread over the prepared sub base course with a mechanical paver and rolled to a dense mass.

Specifications of WMM:

Los angels abrasion value	: Less than 40%.
Aggregate impact value	: Less than 30%.
Combined flakiness & Elongation	: Less than 30%.
Plasticity index of material finer than 0.425 mm sieve	: Less than 6.0

Grading requirements of aggregates for wet mix macadam.

Q.8a. Explain briefly the construction procedure of soil aggregates Bitumen concrete (BC) with quality control check as per MORTH.

Construction procedure for Bituminous Concrete:

a). The recieving suface on which the dense graded bituminous mix is to be laid is prepared by patching the pot holes.

b) If profile correction required exceeds 40mm, a profile corrective course is laid separately.

c). The laying of dense graded bituminous work is to be taken by during dry weather.

d). The recieving suface is cleaned with a mechanical broom to remove loose material.

e). The dense graded bituminous mix is prepared and transported to site from bot mix plant.

f). The mix is spread using a hydrostatic paver finisher.

g). Rolling is started as soon as laying is done for short stretches.

h). The compacted density is acheived by taking 150mm core sample.

Quatity control tests as per MORTH.

a). Gradation of coarse aggregates.

b). Bitumen Extraction test → To check binder content

c). Thickness of BC layer to check quantity.

Sieve size mm	Passing the sieve % by weight	
	Grading -1	Grading-2
53	100	–
45	95-100	–
26.50	–	100
22.40	60-80	50-100
11.20	40-60	–
4.75	25-40	35-55
2.36	15-30	–
0.06	8-22	10-30
0.075	0-8	2-9

Construction steps:

a). compaction test is carried out in the laboratory using the selected grade of WMM material, after removing the fraction of aggregates retained on 19 mm sieve and replacing it with material passing 19 mm sieve.

b). The selected WMM mix is prepared in a suitable mixing plant like the "pug mill".

c). The WMM mix is transported to the site & spread using the self propelled type paver finisher.

d). The WMM layer is compacted using a vibratory roller of minimum static weight of 10 tonnes.

e). If the total design thickness of WMM base course is say 250 mm the base is constructed in two layers.

f) Surface of WMM is checked for defects.

g). After WMM layer is dried for at least 24 hours in dry weather.

Q. 8b. List the quality checks on cement concrete pavements (PQC) carried out both in the laboratory and at field.

Quality control checks on cement concrete pavements

a). The samples of coarse aggregates collected for preparation of CC mix are subjected to specified tests in the laboratory to decide the suitability.

b). The grading of the coarse and fine aggregates for PQC mix is checked and compared with specified gradation.

c). Samples of fresh CC mix are collected, cube and beam specimens are prepared and tested after 7 and 28 days curing periods.

d). The workability of CC mix is checked before starting the paving work.

e). After the CC pavements laid and compacted, the sides of the slab are checked to find hungry/ honeycombed surfaces and such surfaces are finished with cement mortar.

f). The regularity of finished pavement surface is checked with a 3m straight edge, 6 to 12 hours after laying.

g). Core Samples are to check density.

h). Sealant materials are subjected to specified test.

i). Presence of different types cracks are checked & recorded.

Q.9a. Explain the significance and requirements of a Highway Drainage System.

Significance:

a) By provision of surface drainage system like, camber, road side drains and cross drainage system across culverts and bridges. It avoids surface drainage water entering into pavement structures through, shoulders or pavement surfaces in later stage.

b) Removal of excess soil water from subgrade, ground water to the nearest water course through the appropriate planned subsurface drainage system

Requirements of highway drainage system:

a) The surface water from the carriage way should effectively drained off without allowing it into to subgrade.

b) The surface water from adjoining land should be prevented.

c) The side drains should be with sufficient capacity and longitudinal slope.

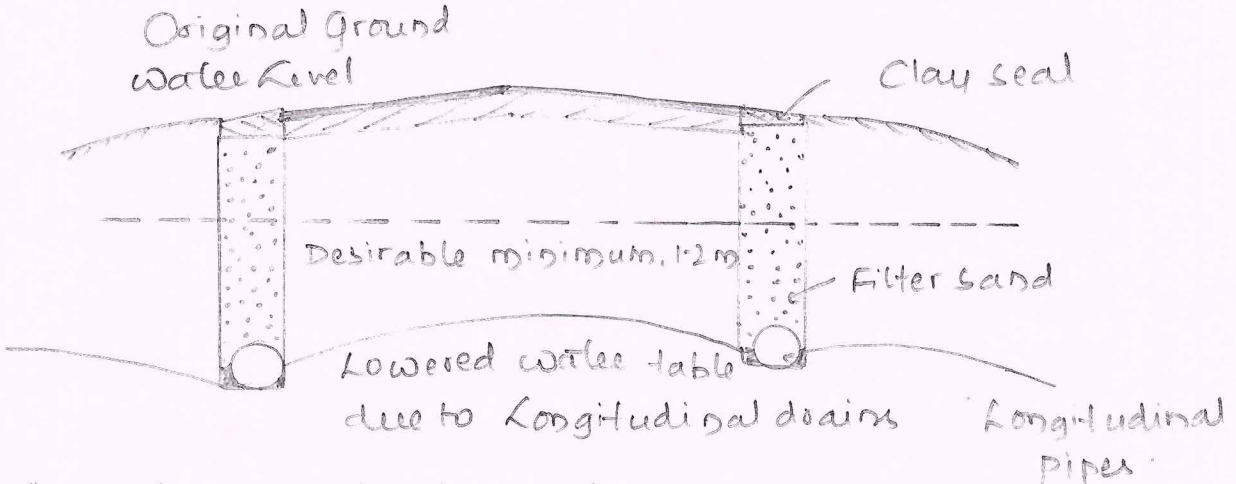
d) Flow of water should not cause any erosion on surface.

e) Seepage flow and other ground water actions should be controlled with proper subsurface drainage system.

Q.9 b. Explain with sketches, how the subsurface drainage system is provided to lower the GWT.

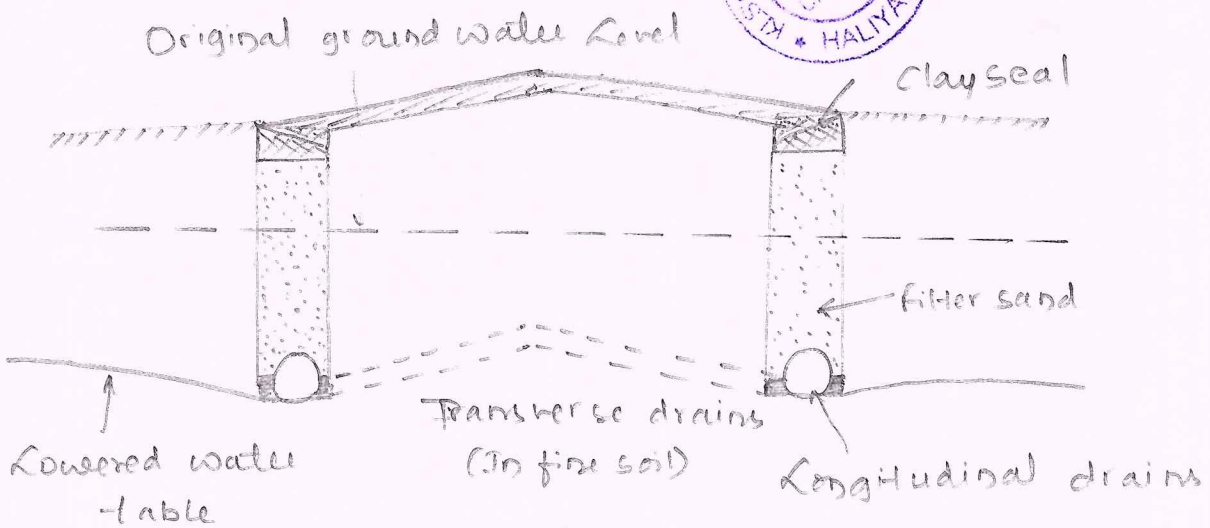
The water level in the permissible soil can be lowered using longitudinal drain pipes.

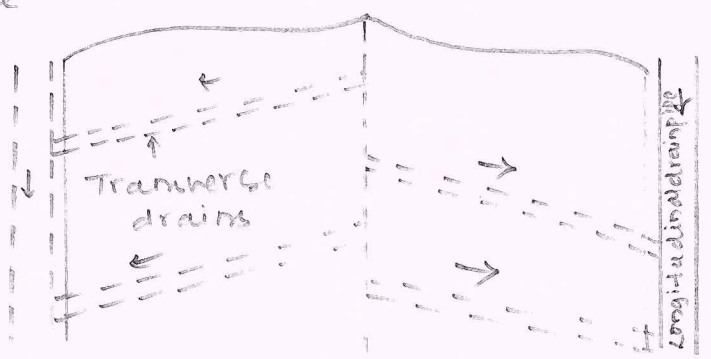
a)



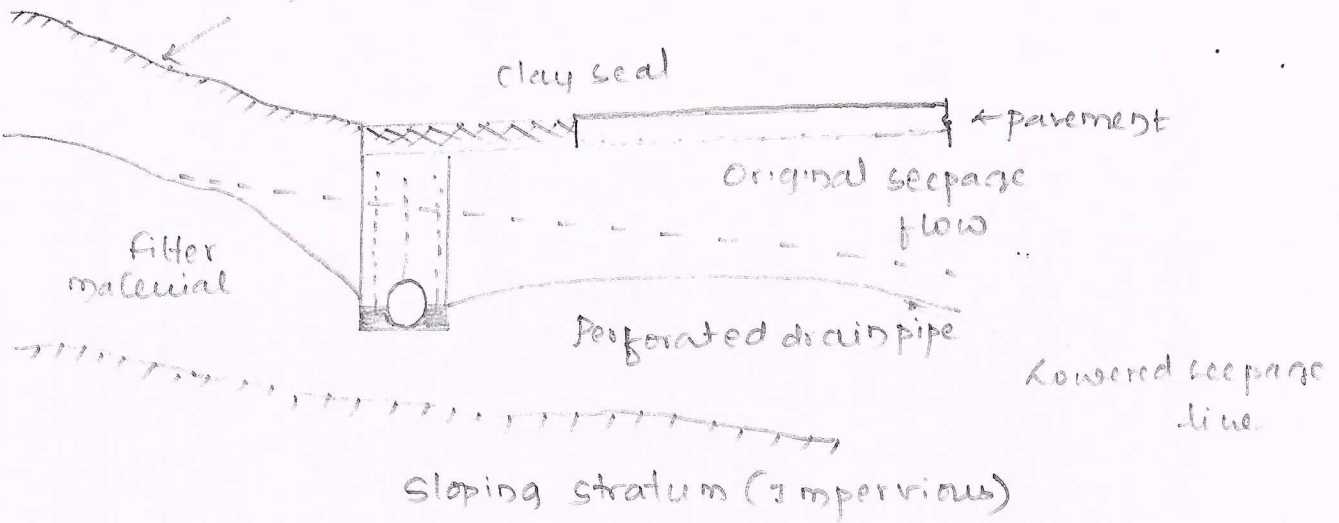
Lowering of high water table in permissible soils.

b)

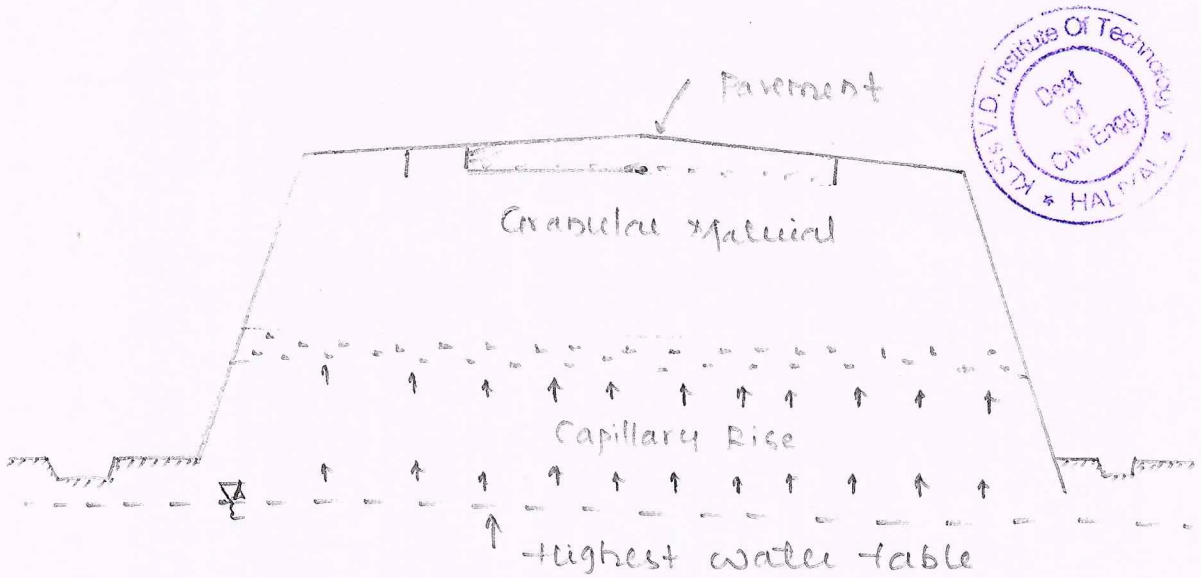




If the soil is relatively less permissible, the lowering of the ground water level may be adequate under the centre of pavement or in between two longitudinal drainage trenches.



when the general ground as well as the impervious strata below are sloping, seepage flow is likely to exist. If the seepage zone is at depth less than 0.6 to 0.9 m from the subgrade level.



Granular Capillary cut off

The thickness of the granular capillary cut off layer should be sufficiently higher than the anticipated capillary rise with in the granular layer, so that the capillary water cannot rise above the cut off layer.

Q.10a. Explain the following with respect to Highway Financing:

i). BOT: A contractual relashionship in which an organization hires a service provider to set up. known as "Build - Operate - Transfer".
Infrastructure development is done by private sector with investment and maintenace for a period of tim

Eg: NHAI

ii). BOOT: Build Operate Own and Transfer.

In this system, the prirate authority is responsibl for any issues regarding the road and it's development, because they own it for the concession period.

Eg: Toll ploza.

iii). VOC: Vehicle Operation cost:

The factors to be considered for evaluating vehicle operation cost (VOC) of motor vehicles would differ depending on the purpose of the analysis. The components of motor vehicle operation cost depends upon:

a). Cost per year such as interest on capital, depreciation cost, registration fees, insurance charges, garage rent etc.

b). Cost depends on distance travelled expressed as cost per vehicle-km.

c). Cost depend on travel speed are cost of fuel, oil & tyre wear.

d). Cost on condition of pavement, traffic factor, Accident cost.

10b. Calculate the annual cost of a stretch of highway from following particulars.

Item	Total cost Rs. in Lakhs	Estimated life, years	Rate of Interest, %
Land	35.0	100	6
Earth work	40.0	40	8
Bridges, Culverts and drainage	50.0	60	8
Pavement	100.0	15	10
Traffic Sign and Road Items	15.0	5	10

The average cost of maintenance of the road is Rs. 1.5 Lakhs per year.

Annual cost, $Cr = P\left[\frac{i(1+i)^n}{(1+i)^n-1}\right] = P \times CRF(i,n)$

a). Annual cost of land $= 35 \times \frac{0.06(1+0.06)^{100}}{(1+0.06)^{100}-1}$

$= 35 \times CRF$

$=$ Rs. 2.1063 Lakhs.

b). Annual cost of earth work = 40 × CRF = Rs. 3.3544 L

c). Annual cost of bridges = 50 × CRF = Rs. 4.04 L.

d). Annual cost of pavement = 100 × CRF = Rs 13.147 L

e). Annual cost of traffic sign = 15 × CRF

= 3.9570 L

f). Average maintenance cost = Rs. 1.5 L

g). Total annual highway cost = a+b+c+d+e+f+g

= 26.6049 L

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