CBCS SCHEME

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

18CV56

Fifth Semester B.E. Degree Examination, Jan./Feb. 2021
Highway Engineering

Time: 3 hrs. Max. Marks: 100

Note: 1. ***Answer any FIVE full questions, choosing ONE full question from each module.***
2. ***Assume the missing data, if any, as per IRC codes.***

Module-1

1 a. List the objectives and functions of the following in Highway development in India.
i) Indian Roads congress
ii) Central Road Research Institute. **(06 Marks)**

b. What is the contribution of KRDCL and KSHIP in the road development in Karnataka? **(08 Marks)**

c. List and elaborate the various advantages and disadvantages of Road transport compared with other modes of transport. **(06 Marks)**

OR

2 a. Elaborate on various salient features of VISION 2021. **(06 Marks)**

b. What are the various factors affecting highway alignment? Explain each one, in detail with the help of neat sketches. **(08 Marks)**

c. What are the objectives of preliminary survey in highway Alignment? Enumerate the detail to be collected in it. **(06 Marks)**

Module-2

3 a. Calculate the stopping sight distance on a highway for a vehicle moving at 80kmph on a
i) Level Road
ii) On a road having 1 in 100 grade (ascending and descending)
Assume other data as per IRC recommendations. **(08 Marks)**

b. Explain PIEV theory with a neat sketch. **(06 Marks)**

c. What are the various factors affecting friction? Also explain skid and slip failures, in detail. **(06 Marks)**

OR

4 a. Enumerate the steps for practical design of super elevation considering mixed traffic. **(06 Marks)**

b. Find the total width of pavement on a horizontal curve for a two lane National highway to be aligned along a rolling terrain with ruling minimum radius. **(08 Marks)**

c. List the various objects of providing a horizontal transition curve? Also explain the various shapes of transition curve and ideal transition curve. **(06 Marks)**

Module-3

5 a. List and explain the various desirable properties of subgrade soil as highway material. **(06 Marks)**

b. List the various properties of coarse aggregate and the tests to be conducted to find each property of course aggregate. **(06 Marks)**

c. How do you find CBR value in the Laboratory? Explain the test procedure with a neat sketch. **(08 Marks)**

OR

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

Mean settlement value, in mm	0.0	0.26	0.52	0.76	1.02	1.26	1.53	1.76
Load values, in Kg	0.0	540	1010	1290	1510	1550	1730	1900

(08 Marks)

b. What do you understand about HRB soil classification? Explain in detail? **(06 Marks)**

c. Calculate the ESWL of a dual wheel assembly arraying 2044kg each for a trail pavement thickness values of 150, 200 and 250mm, if the centre to centre spacing between the two tyres = 270mm, clear gap between the wall of the tyres = 110mm **(06 Marks)**

Module-4

7 a. With a neat sketch, explain the method of determining the aggregate- bituminous mixes proportioning by Rothfuch's method. **(08 Marks)**

b. List the explain the various construction steps in the WMM base construction. **(06 Marks)**

c. What do you understand by Tack coat and Prime coat? List the various objectives of providing these in pavements. **(06 Marks)**

OR

8 a. Explain the various steps in the construction of Dense bituminous macadam pavement. **(10 Marks)**

b. Step by step, explain in detail, construction of Dry Lean Concrete sub base course. **(10 Marks)**

Module-5

9 a. List the objects of
   i) Surface drainage
   ii) Sub surface drainage of roads. **(06 Marks)**

b. What are various cross drainage structure? Explain each one of those. **(05 Marks)**

c. What do you understand by
   i) Lowering of water table
   ii) Control of seepage flow
   iii) Control of capillary rise.

Explain with neat sketches. **(09 Marks)**

OR

10 a. Compare the annual costs of a 2 lane road for two types of pavement structures
   i) WBM with thin bituminous surface at a total cost of Rs 100 lakhs per km, life of 10 years, interest at 10%, with a salvage value of Rs 2.50 lakhs after 10 years, and annual average maintenance cost of Rs 5 lakhs/km
   ii) Bituminous macadam base and bituminous concrete surface, with a total cost of Rs 200 lakhs/km, life of 15 years, interest at a rate of 8%, salvage value of 3.50 lakhs at the end of 15 years, with annual average maintenance cost Rs 7.5 lakhs/km. Comment which one is more economical? **(08 Marks)**

b. What is Public Private Partnership? How it will help the Road projects in India? Explain. **(06 Marks)**

c. What are the various advantages and disadvantages of Benefit cost ratio method? Explain the method with formulae. **(06 Marks)**

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FIFTH SEMESTER B.E. DEGREE EXAMINATION, JAN/FEB 2021
HIGHWAY ENGINEERING (18CV56)

1.a.

IRC:-

• IRC was formed in the year 1934.

• The main objectives are:

(a) to provide forum for regular pooling of experience and ideas on all matters that effect the planning, construction and maintenance of roads in India, and
(b) to recommend standard specifications to provide a platform for the expression of professional opinion on matters relating to road engineering.
• It publishes journals, research publications**,** standard codes, specifications, guide lines and other special publications on various aspects of highway engineering.

• Provides a platform for expression of professional opinion on matters relating to roads and road transport.

• Played an important role in the formation of three road development programs in India.

• It works in close collaboration with Roads Wing of the Ministry of Transport. • CRRI was formed in the year 1950 at New Delhi.

• The main objectives of CRRI are:

CRRI

i) To carry out the basic and applied research for investigation, design, construction and maintenance of different types of roads and runways.
ii)To carry out research on road traffic and transportation, including traffic safety and transport
iii)To render technical advice and consultancy services to various organizations.
iv) To arrange for utilization of results of research by extension unit, display centers etc.
v)To conduct refresher and training courses for staff of other research Institutions, Universities and highway Departments.
vi)To develop labor intensive methods and manual aids for the construction of low-cost all-weather roads.

1.b.

KSHIP:-

- It is an initiative of Government of Karnataka for the improvement of road network of the state with World Bank assistance.
- PWD carried out Strategic Option Study (SOS) during 1996 on a road network of 13,362 Km comprising SH and MDRs and the study identified 2888 Km of road for prioritized improvements.
- The main objectives are: 1. Upgrade about 615 Km of SH in Karnataka and strengthen capacity of PWD of Government of Karnataka to develop, upgrade and maintain state road network.

2. Improve core road network in Karnataka. Core road includes SH and heavy traffic MDRs.

3. Improving existing road network involving rising of formation levels, strengthening of pavements, widening and realignment of roads wherever necessary.

4. Enhance capacity and quality of core SH network, provide safer transit on selected corridors, improve allocation and provide adequate funding for road sector, provide more efficient and effective network management.

1.c.

Advantages:-

Road transport offers quick and assured deliveries.

• Roads provides good commercial links between cities.

• Roads can be constructed at comparatively lower cost.

• Roads transport offers a flexible service, free from fixed schedules.

• Road transport offers door to door service.

• Roads helps in the growth of trade and other economic activities.

• For short haults road transport is the only economical means.

Disadvantages:

 One of the serious disadvantage of road transport is its poor record of safety.

• The poor construction and maintenance of roads contribute to overall increase of the operation cost of vehicles.

• Road transport has been one of the major causes for environmental pollution.

• Road transport has low carrying capacity of passengers and goods .

• Road transport consumes greater energy.

• Road transport has caused problem of parking in cities streets.

2.a.

Some salient features of vision-2021 are:

1) Road network shall be expanded as NH, SH, MDR, ODR & VR.

2) Half NH should have 4 or 6 lanes and the remaining should have 2 lane carriageways with hard shoulders.

3) 10,000 Km of SH should have 4 lanes and the balance should have 2 lanes.

4) 40% of MDR should have 2 lane carriageways.

5) Maintenance of existing assets should receive adequate attention.

6) Up gradation of construction technology through innovative procedures and specifications.

7) Road safety to be enhanced through engineering measures.

8) Training of young engineers should receive attention.

9) Environmental concerns by road traffic are to be addressed.

2.b.

The various factors, which control the highway alignment, in general may be listed as:

- Obligatory points
- Traffic
- Geometric design
- Economics

- Other considerations

1) Obligatory Points: -These control points may be divided in to two categories:

i) Points through which the alignment is to pass

ii) Points through which the alignment should not pass.

Obligatory points Through Which the Alignment Should Pass

a) **Bridge site**: The bridge can be located only where the river has **straight and permanent** path. It should not be curved and skew crossing should be avoided as possible.

b) **Mountain:** While the alignment passes through a mountain, the various alternatives are to either construct a tunnel or to go around the hills.

ii) Obligatory points through which the road should not pass also may make it necessary to deviate from the proposed shortest alignment. The obligatory points, which should be avoided while aligning a road, include religious places, very costly structures.

2)Traffic: -

- The alignment should suit the traffic requirements.
- The origin- destination data of the area, the desire lines should be drawn.

3)Geometric design: -

- Geometric design factors such as gradient, radius of curve and sight distance also would govern the final alignment of the highway.
- The absolute minimum sight distance, which should invariably be available in every section of the road, is the safe stopping distance for the fast-moving vehicles.

4)Economy: -

- The alignment finalized based on the above factors should also be economical.
- The initial coast of construction can be decreased if high embankments and deep cuttings are avoided and the alignment is choosing in a manner to balance the cutting and filling.

5)Other considerations: -

- Various other factors, which may govern the alignment, are drainage considerations, hydrological factors, political considerations and monotony.
- The vertical alignment is often guided by drainage considerations.
- In a flat terrain it is possible to have a very long stretch of road, absolutely straight without horizontal curves.

2.c.

The main objectives of the preliminary surveys are:

- ✓ To survey the various alternate alignments proposed after the reconnaissance and to collect all the necessary physical information and details of topography, drainage and soil.
- ✓ To compare the different proposals in view of the requirements of a good alignment.
- ✓ To estimate quantity of earthwork materials and other construction aspects and to work out the cost of alternate proposals.
- ✓ To finalize the best alignment from all considerations.

The procedure of the conventional methods of preliminary survey the given steps:

1) *Primary survey*
2) *Topographical features*
3) *Levelling work*
4) *Drainage studies*

5) *Soil survey*
6) *Material survey*
7) *Traffic survey*

3.b.

PIEV Theory : According to this theory the total reaction time of the driver is split into four parts, viz., time taken by the driver for :

(i) Perception
(ii) Intellection
(iii) Emotion, and
(iv) Volition

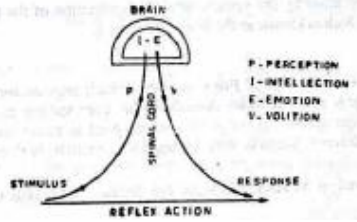
Perception time is the time required for the sensations received by the eyes or ears to be transmitted to the brain through the nervous system and spinal chord. In other words, it is the time required to perceive an object or situation.

Intellection time is the time required for understanding the situation. It is also the time required for comparing the different thoughts, regrouping and registering new sensations.

Emotion time is the time elapsed during emotional sensations and disturbance such as fear, anger or any other emotional feelings such as superstition etc. with reference to the situation. Therefore the emotion time of a driver is likely to vary considerably depending upon the problems involved.

Volition time is the time taken for the final action.

It is also possible that the driver may apply brakes or take any avoiding action by the reflex action, even without thinking. The PIEV process has been illustrated in Fig. 4.12.



3.c.

Various factors that affect friction are:

- Type of the pavement (like bituminous, concrete, or gravel),
- Condition of the pavement (dry, wet or oil spilled etc),
- Macro texture of the pavement
- Condition of the tyre (new or old), and
- Speed of the vehicle.
- Brake efficiency
- Load & tyre pressure
- Temperature of pavement & tyre.

Friction between the wheel and the pavement surface is a crucial factor in the design of horizontal curves and thus the safe operating speed. Lack of adequate friction can cause skidding or slipping of vehicles.

- Skidding happens when the path travelled along the road surface is more than the circumferential movement of the wheels due to friction.
- Slip occurs when the wheel revolves more than the corresponding longitudinal movement along the road.

4.a.

IRC suggests following design procedure:

Step 1: Find e for 75 percent of design speed, neglecting f, i.e. $e_1 = \frac{(0.75v)^2}{gR}$.

Step 2: If $e_1 \leq 0{:}07$, then $e = e_1 = \frac{(0.75v)^2}{gR}$ else if $e1 > 0{:}07$ go to step 3.

Step 3: Find f_1 for the design speed and max e, i.e. $f_1 = \frac{v^2}{gR} - e = \frac{v^2}{gR} - 0.07$. If $f1 < 0{:}15$, then the maximum e = 0:07 is safe for the design speed, else go to step 4.
Step 4: Find the allowable speed v_a for the maximum e = 0:07 and f = 0:15,

$$v_a = \sqrt{0.22gR}$$

If $v_a \geq$ v design is adequate, otherwise use speeds adopt control measures or look for speed control measures.

4.c.

There are five objectives for providing transition curve and are given below:
1.to introduce gradually the centrifugal force between the tangent point and the beginning of the circular curve, avoiding sudden jerk on the vehicle. This increases the comfort of passengers.
2. to enable the driver turn the steering gradually for his own comfort and security,
3. to provide gradual introduction of super elevation,
4. to provide gradual introduction of extra widening.
5. to enhance the aesthetic appearance of the road.
Different types of transition curves are spiral or clothoid, cubic parabola, and Lemniscate. IRC recommends spiral as the transition curve because it fulfills the requirement of an ideal transition curve, that is;
(a) rate of change or centrifugal acceleration is consistent (smooth), and
(b) radius of the transition curve is ∞ at the straight edge and changes to R at the curve point ($Ls \propto 1 R$) and calculation and field implementation is very easy.

5.a.
The desirable properties of sub grade soil as a highway material are

- Stability
- Incompressibility
- Permanency of strength
- Minimum changes in volume and stability under adverse conditions of weather and ground water
- Good drainage, and
- Ease of compaction

The soil should possess adequate stability or resistance to deformation under loads and should possess resistance to weathering thus retaining the desired subgrade support. Minimum variation in volume will ensure minimum variation in differential expansion and differential strength values. Good drainage is essential to avoid excessive moisture retention and to reduce the potential frost action. Ease of compaction ensures higher dry density and strength under particular type and amount of compaction.

5.b.
Aggregates:- The desirable properties of sub grade soil as a highway material are:
Strength

- ✓ The aggregates should be strong to withstand the stresses due to traffic wheel load.

- ✓ Aggregates used in top layers of pavements I.e. wearing course have to be capable of withstanding high stresses in addition to wear and tear hence should posses resistance to crushing.

Hardness

- ✓ The aggregate used in surface course are subjected to constant rubbing or abrasion due to moving traffic.
- ✓ They should be hard enough the wear due to abrasive action of traffic.

Toughness

- ✓ Aggregates in pavements are subjected to impact due to moving wheel loads.
- ✓ Severe impact like hammering is seen when heavily loaded steel tyred vehicles move on WBM roads.

Durability

- ✓ They should be durable and should resist disintegration due to action of weather.
- ✓ The property of the stones to withstand adverse action of weather is called soundness.

- ✓ The aggregates are subjected to physical and chemical action of rain and ground weather and hence road stones should be sound enough to withstand weathering action.

Shape of aggregates

- ✓ Flaky and elongated aggregates will have less strength compared with cubical, angular or rounded particles.

Adhesion with Bitumen The aggregates used in bituminous pavements should have less affinity with water or else bituminous coating on the aggregate will be stripped off in presence of water.

Test for Road Aggregates:-

1. Crushing test
2. Abrasion test
3. Impact test
4. Soundness test
5. Shape test
6. Specific gravity and water absorption test
7. Bitumen adhesion test

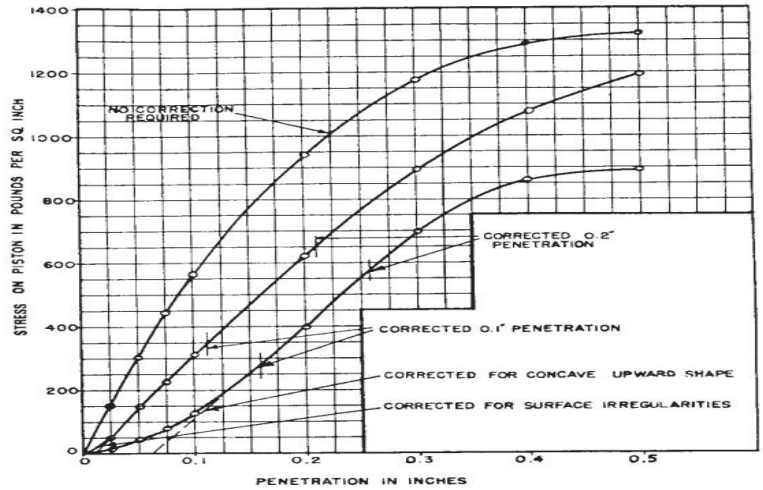
5.c.

- The laboratory CBR apparatus consists of a mould 150 mm diameter with a base plate and a collar, a loading frame and dial gauges for measuring the penetration values and the expansion on soaking.
- The specimen in the mould is soaked in water for four days and the swelling and water absorption values are noted. The surcharge weight is placed on the top of the specimen in the mould and the assembly is placed under the plunger of the loading frame.
- Load is applied on the sample by a standard plunger with dia of 50 mm at the rate of 1.25 mm/min. A load penetration curve is drawn. The load values on standard crushed stones are 1370 kg and 2055 kg at 2.5 mm and 5.0 mm penetrations respectively.

- CBR value is expressed as a percentage of the actual load causing the penetrations of 2.5 mm or 5.0 mm to the standard loads mentioned above. Therefore,

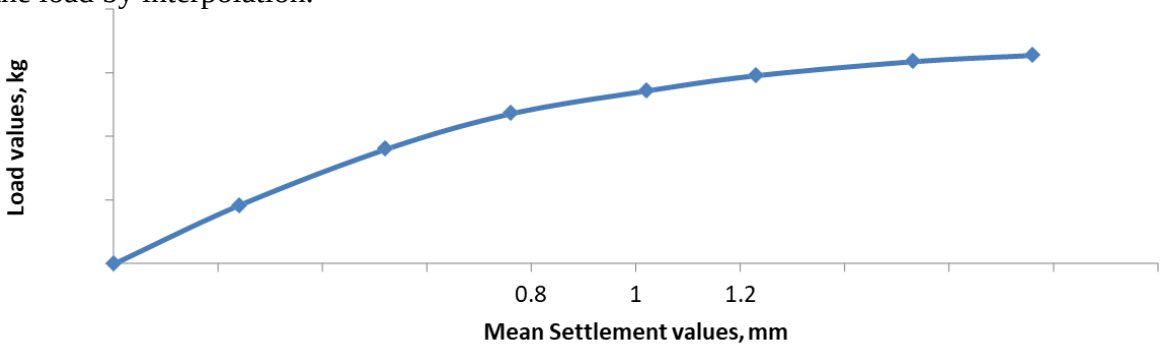
$$CBR = \frac{\text{load carries by specimen}}{\text{load carries by standard specimen}} \times 100$$

- Two values of CBR will be obtained. If the value of 2.5 mm is greater than that of 5.0 mm penetration, the former is adopted. If the CBR value obtained from test at 5.0 mm penetration is higher than that at 2.5 mm, then the test is to be repeated for checking. If the check test again gives similar results, then higher value obtained at 5.0 mm penetration is reported as the CBR value. The average CBR value of three test specimens is reported as the CBR value of the sample.



6.a.

Find the load for corresponding settlement Δ=0.125cm by plotting the tabulated data or find the load by interpolation.



- From plot the load at 0.125cm settlement = 1490kg

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

Modulus of subgrade reaction K_1 for 30 cm diameter plate

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

Modulus of subgrade reaction K for standard plate of dia. 70 cm.

$$= \frac{K_1 a_1}{a} = \frac{16.86 \times 30}{75} = 6.75 \text{ kg/cm}^3$$

6.b.

The HRB or AASHO system of soil classification was developed in 1929 as the Public Road Administration Classification System. . According to this system, soil is classified into seven major groups: A-l through A-7. Soils classified under groups A-1, A-2 and A-3 are granular materials of which 35% or less of the particles pass through the No. 200 sieve. Soils of which more than 35% pass through the No. 200 sieve are classified under groups A-4, A-5, 4-6, and A-7. These soils are mostly silt and clay-type materials.

A-1 soils are well graded mixture of stone fragments, gravel coarse sand, fine sand ad non-plastic or slightly plastic soil binder.

A-2 group of soils include a wide range of granular soils ranging from A-1 to A-3 groups, consisting of granular soils up to 35% fines of A-4, A-5, 4-6 or A-7groups.

A-3 group of soil consists mainly of uniformly graded medium or fine sand similar to beach sand or desert blown sand. Stream deposited mixtures of poorly graded fine sand with some coarse sand and gravel are also included in this group.

A-4 soils are generally silty soils, non-plastic or moderately plastic in nature with liquid limit and plasticity index < 40 & 10 respectively.

A-5 soils are also silty soils with plasticity index < 10%, but liquid limit > 40%.

A-6 group of soils are plastic clays, having high values of plasticity index > 10%, but liquid limit <40%.

A-7 soils are also clayey soils as A-6 soils, but with high values of both liquid limit and plasticity index. These soils have low permeability and high volume change properties with changes in moisture content.

6.c.

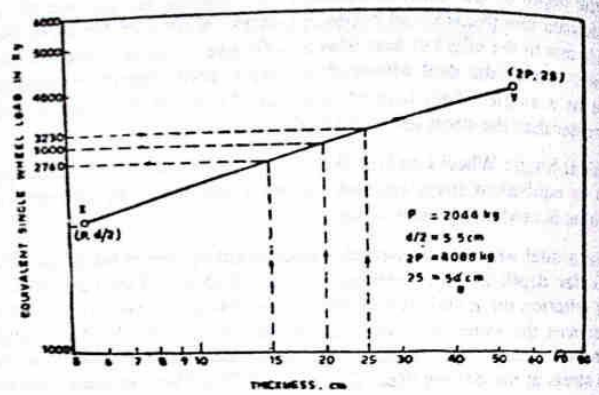


Fig. 7.7 ESWL Calculation (Example 7.1)

Solution

Here P = 2044 kg; 2P = 4088 kg; d = 11 cm; S = 27 cm

X and Y points are plotted on a log-log graph between ESWL and pavement thickness (See Fig. 7.7).

X has coordinates (P, d/2) = (2044, 5.5)

Y has coordinates (2P, 2S) = (4088, 54)

On the X-axis, points corresponding to pavement thickness of 15, 20 and 25 cms are marked and vertical lines are drawn from these points to intersect the line XY. Horizontal lines are now drawn from these points on line XY to meet the Y-axis , to obtain the corresponding ESWL values at these pavement thickness. ESWL values thus obtained are

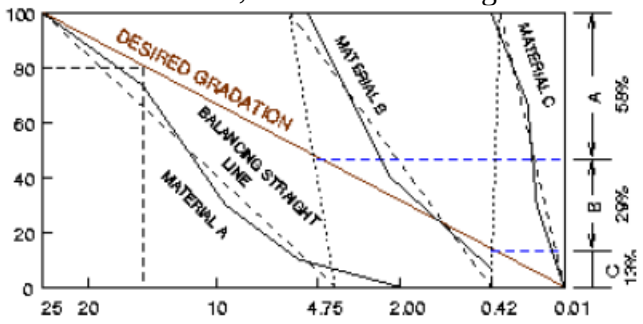
Pavement thickness cm	ESWL kg
15	2760
20	3000
25	3230

7.a.

This method is used when a number of materials have to be mixed together for obtaining appropriate gradation. The gradation may be decided either based upon recommended grain size
distribution charts or by any equation like Fuller's gradation.
It is done to proportionate materials for Marshall Mix design. I S sieves of sizes 63, 50, 40, 31.5,
25, 20, 16, 12.5, 10, and 6.3mm are required.

Procedure:

1. On a graph paper when Y-axis represents percent passing and X-axis representing particle size a diagonal line is drawn from point corresponding to 100 percent particles passing i.e maximumparticle size passing to a point corresponding to zero percentage passing i.e smallest particle size.
2. For different material say A, B and C sieve analysis has to be done and percentage finer has tobe calculated at each range of particle size for all the materials.
3. The balancing straight lines of A, B and C are obtained by allowing only minimum of the areas on the center sides of the balancing lines.
4. The opposite ends of the balancing line of A and B are joined (i.e zero point passing of material A is pointed with 100 percent passing B). Similarly the opposite ends of the balancing lines of B and C are joined.
5. The points where these lines meet the desired gradation line represent the proportions in which type materials A, B and C are to be mixed. These values may be read from the Y axis by projecting the Points of intersection, as shown in the figure below.



Proportioning of materials

Thus, Proportion of materials A, B and C to be mixed for preparing Marshall mix design test specimen are obtained.

7.b. Following is the construction procedure for WMM:
1)Compaction test is carried out using selected grade of WMM material after removing the aggregates retained on 19 mm sieve and replacing it with materials passing 19 mm sieve and retained on 4.75 mm sieve.
2) The selected WMM is prepared in suitable mixing plant.
3) WMM mix is then transported to site and is spread to the required thickness, grade and cross slope.
4) The WMM layer is compacted using a vibratory roller and the thickness of each such layer < 200 mm.
5) Rolling is done from the lower edge and proceeded towards the center of the undivided carriageway with a minimum one-third overlap between each run of the roller.
6) If the total design thickness is > 200 mm, the base is constructed in 2 layers. After

compaction of the first layer, the second layer is laid by a mechanical paver finisher.
7) The WMM surface is checked for defects and allowed to dry.
8) After the WMM surface is dried for 24 hours, preparation for laying a bituminous layer may be started.

7.c.

This involves application of liquid bituminous binder of low viscosity over a granular or non-bituminous surface.
The application process is called as priming.
Objectives are (i) penetrates deep into the surface and plug or seal the voids.
(ii) coat and bond the loose soil particles on the surface.
(iii) render the surface of the base course water resistant.
(iv) permit the tack coat to be applied over the promed surface to provide proper adhesion between
the base and bituminous layer.
Prime coat *is an application of low viscous cutback bitumen to an absorbent surface like granular bases on which binder layer is placed.*
This involves application of low viscosity over either a primed granular surface or over an existing bituminous surface or cement concrete surface.
Objectives are (i) To provide adequate interface bond between the receiving surface and the new bituminous layer being overlaid. (ii) the layer do not penetrtae into the surface and plug the voids.
(iii) the bituminous layer is placed immediately over the tack coat.

8.a.

Construction Steps:

1) The receiving surface is prepared by patching up the pot-holes, sealing the cracks and filling up the depressions.
2) If the profile correction > 40 mm, a profile corrective course is laid separately using mechanical paver and compacted. In case of correction < 40 mm, pavement layer is spread with provision for the additional quantity of the mix.
3) Laying of dense graded bituminous work is to be taken up during dry weather, when atmospheric temperature > 10◦C.
4) Receiving surface is cleaned to remove loose materials and dust and tack coat is applied.
5) The dense graded bituminous mix is prepared under specified temperature in the hot mix plant and is then transported to the construction site in insulated covered vehicles.
6) The mix is spread using mechanical paver.
7) Rolling is done in 3 stages: (1) initial or break down rolling using tandem-wheel vibratory roller (2) intermediate rolling using pneumatic roller (3) final or finished rolling using smooth wheel roller.
8) Compaction density achieved shall be 92% laboratory density. It is checked by taking 150 mm diameter core samples.
9) Finished surface is checked using a straight edge; with maximum undulations not exceeding 5 mm in longitudinal profile and 4 mm in transverse profile. Average unevenness index for finished surface shall not exceed 2000 mm per Km.
10) Finished surface shall be opened to traffic after the entire depth of the bituminous layer cools down to temperature < 60◦C.

8.b.

Trial Mixes:- Trial mixes of dry lean concrete shall be prepared with moisture contents of 5.0, 5.5, 6.0, 6.5 and 7.0 percent. Optimum moisture and density shall be established by preparing cubes with varying moisture contents.

2). The sub-base shall be overlaid with Paving Quality Concrete (PQC) pavement not before 7 days after the sub-base construction.
3) Batching, Mixing & transporting:- The batching plant shall be capable of separately proportioning each type of material by weight. The capacity of batching and mixing plant shall
be at least 25 percent higher than the proposed capacity for the laying arrangements. Plant mixed
lean concrete shall be discharged immediately from the mixer, transported directly to the point
where it is to be laid and protected from the weather by covering with tarpaulin during transit.
4) Compaction:- The compaction shall be carried out immediately after the material is laid and
levelled. In order to ensure thorough compaction, rolling shall be continued on the full width till
there is no further visible movement under the roller and the surface is closed. The spreading, compacting and finishing of the lean concrete shall be arranged so as to ensure that the time between mixing of the first batch of concrete in any transverse section of the layer and the compaction and final finishing of the same shall not exceed 90 minutes, when the concrete temperature is between 25 and 30°C and 120 minutes, if less than 25°C.
5) Joints:- Day's work shall be stopped by vertical joints. The edge of the compacted material shall be cut back to a vertical face, when work starts next day.
6) Curing:- Curing shall be done by covering the surface by hessian cloth in two layers which shall be kept continuously moist for 7 days by sprinkling water. If water-curing is not possible, the curing shall be done by spraying with liquid curing compound.
7) Trial Length Construction:- The trial length shall be constructed (in two days), at least 14 days in advance of the proposed date of commencement of work. The length of trial construction shall be a minimum of 60 m length and for full width of the pavement. After the approval of the trial length construction has been given, the materials, mix proportions, moisture content, mixing, laying, compaction, plant, construction procedures shall not be changed.

9.a.

An increase in moisture content causes decrease in strength or stability of a soil mass the variation in soil strength with moisture content also depends on the soil type and the mode of stress application. Highway drainage is important because of the following reasons:-
1) Excess moisture in soil sub grade causes considerable lowering of its stability the pavement is likely to fail due to sub grade failure.
2) Increase in moisture cause reduction in strength of many pavement materials like stabilized soil and water bound macadam.
3) In some clayey soils variation in moisture content causes considerable variation in flume of sub grade. This sometimes contributes to pavement failure.
4) One of the most important causes of pavement failure by the formation of waves and corrugations in flexible pavements is due to poor drainage.
5) Sustained contact of water with bituminous pavements causes failures due to stripping of bitumen from aggregates like loosening or detachment of some of the bituminous pavement layers and formation of pot holes.
6) The prime cause of failures in rigid pavements by mud pumping is due to the presence of water in fine sub grade soil.
7) Excess water on shoulders and pavement edge causes considerable damage.
8) Excess moisture causes increase in weight and thus increase in stress and simultaneous

reduction in strength of the soil mass. This is one of the main reasons of failure of earth slopes and embankment foundations.
9) In places where freezing temperatures are prevalent in winter, the presence of water in the sub grade and a continuous supply of water from the ground water can cause considerable damage to the pavement due in frost action.
10) Erosion of soil from top of un surfaced roads and slopes of embankment, cut and hill side is also due to surface water.

9.b.

Type – 1: Cross drainage work carrying canal over the drain:- The structures falling under this type are

- Aqueduct
- Syphon Aqueduct

Type – 2: Cross Drainage work carrying Drainage over the canal :- The structures falling under this type are

- Super passage
- Canal Syphon

Type –3: Cross drainage works admitting Drain water into the canal :- The structures falling under this type are

- Level Crossing
- Canal inlets

Type 1:
Aqueduct (HFL is below the canal bed level)
• The canal bed is constructed much above the HFL
• The canal bed level is above the drainage/river bed level
• The canal full supply level is above the High flood level

Syphon Aqueduct (canal bed level is below the highest flood level)
• In a syphon aqueduct, canal "water" is carrier above the drainage but the **high flood level (HFL)** of drainage is **above the canal bed**. The drainage water flows under syphonic action and there is no presence of atmospheric pressure in the natural drain.
• The construction of the syphon aqueduct structure is such that, the flooring of drain is depressed downwards by constructing a vertical drop weir to discharge high flow drain water through the depressed concrete floor.
Type 2:
Super Passage:
• Canal FSL is well below the River bed level
• In super passage, free board is provided
• Both flow subjected to atmospheric pressure
• The river water level is above and canal water level is below

• Super passage structure carries drainage above canal as the canal bed level is below drainage bed level.

Canal Syphon:

• In a canal syphon, drainage is carried over canal similar to a super passage but the full supply level of canal is above than the drainage trough. So the canal water flows under syphonic action and there is no presence of atmospheric pressure in canal.

• When compared, super passage is more often preferred than canal Syphon because in a canal Syphon, big disadvantage is that the canal water is under drainage trough so any defective minerals or sediment deposited cannot be removed with ease like in the case of a Syphon Aqueduct.

• Flooring of canal is depressed and ramp like structure is provided at upstream and downstream to form syphonic action. This structure is a reverse of Syphon aqueduct.

Type 3:

Level Crossing:

When the bed level of canal is equal to the drainage bed level, then level crossing is to be constructed. This consists of following steps:

1. Construction of weir to stop drainage water behind it
2. Construction of canal regulator across a canal
3. Construction of head regulator across a Drainage

Canal inlets:

• In a canal inlet structure, the drainage water to be admitted into canal is very less. The drainage is taken through the banks of a canal at inlet. And then this drainage mixed with canal travels certain length of the canal, after which an outlet is provided.

9.c.

Lowering of water table:-

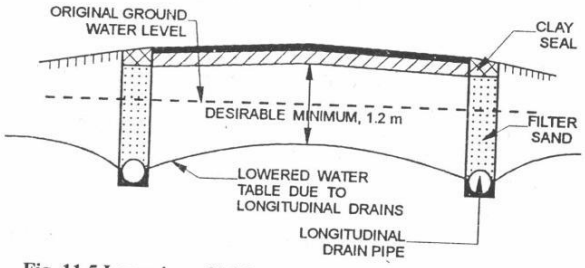


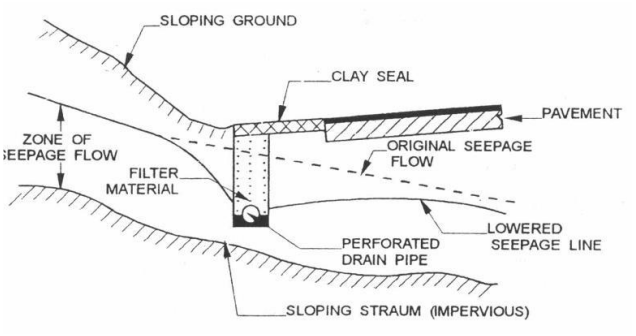
Fig. 11.5 Lowering of high water table in permeable soils

Highest level of WT should be 1.0 to 1.20 m below the sub grade in order to avoid excessive moisture content in the pavement layers.

- In places of high WT, embankment height should be 1.2 to 1.50m above ground level.
- In cases of permeable soil, construct longitudinal drainage trenches with drain pipe and filter sand.

Control of Seepage flow

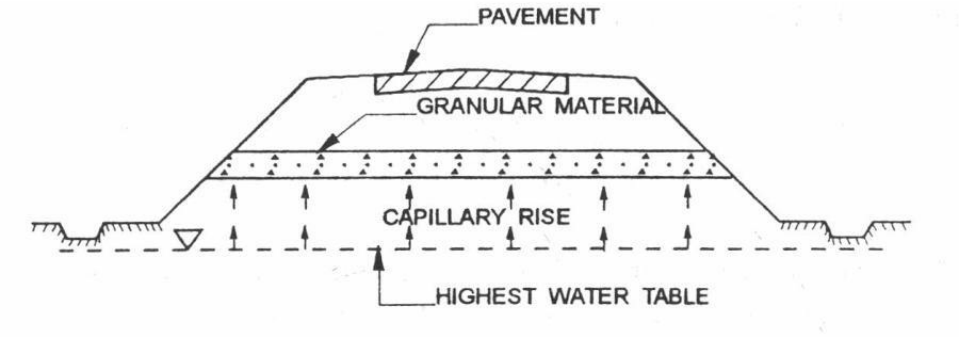
- Occurs when ground level as well as the impervious strata below are sloping.
- If the seepage zone depth < (0.6 to 0.9 m) from sub grade level, longitudinal drain in trench filled with filter material and clay seal may be provided to intercept the seepage flow.



Control of capillary rise

- The capillary rise may be checked by providing a suitable capillary cut-off by granular capillary cut-off and by impermeable capillary cut-off.

Granular Capillary cut-off:- A layer of granular material is provided during the construction of
embankment as shown in fig below. The thickness of this layer should be higher than the anticipated capillary rise within the granular layer.



10.a.

Annual average cost taking salvage value into consideration,

$$C_f = (C - V_s)\frac{i(1+i)^n}{(1+i)^n - 1} + i V_s + \text{average annual maintenance cost, M}$$

$$= (C - V_s)\,CRF_{(i,\,n)} + i V_s + M$$

(i) Annual cost of pavement with WBM base and thin bituminous surface course.

$$= (2.2 - 0.9)\,CRF_{(i=0.1,\,n=5)} + 0.1 \times 0.9 + 0.35$$

$$= 1.3 \times 0.2638 + 0.09 + 0.35 = \text{Rs. } 0.78294 \text{ lakhs}$$

(ii) Annual cost of the bituminous pavement

$$= (4.2 - 2.0)\,CRF_{(i=0.08,\,n=15)} + 0.08 \times 2.0 + 0.25$$

$$= 2.2 \times 0.11683 + 0.16 + 0.25 = \text{Rs. } 0.66703 \text{ lakhs}$$

The average annual cost of the bituminous pavement is lower and therefore works out to be more economical when compared with the pavement with WBM base course.

10.b.

1.A BOOT structure differs from BOT in that the private entity owns the works.

2. It is a public-private partnership (PPP) project model in which a private organization conducts a large development project under contract to a public-sector partner, such as a government agency.

3. It is often seen as a way to develop a large public infrastructure project with private funding.

4.The public-sector partner contracts with a private developer - typically a large corporation or consortium of businesses with specific expertise - to design and implement a large project.

5. The public-sector partner may provide limited funding or some other benefit (such as tax exempt status) but the private-sector partner assumes the risks associated with planning, constructing, operating and maintaining the project for a specified time period. During that time, the developer charges customers who use the infrastructure that's been built to realize a profit.

6. At the end of the specified period, the private-sector partner transfers ownership to the funding organization, either freely or for an amount stipulated in the original contract. Such contracts are typically long-term and may extend to 40 or more years.

10.c.

The principle of this method is to assess the merit of a particular scheme by comparing the annual benefits with the increase in annual cost.

$$\text{Benefit cost ratio} = \frac{\text{Annual benefits from improvement}}{\text{Annual cost of the improvement}}$$

$$= \frac{(R-R1)}{\text{total annual cost of the project}}$$

Where,
R = Total annual road user cost for existing highway
R1 = Total annual road user cost for proposed highway improvement

• The benefit-cost ratios are determined between alternate proposals and those plans which are not attractive are discarded.

• Then the benefit cost ratios for various increments of added investment are computed to arrive at the best proposal. In order to justify the investment, the ratio should be greater than 1.0.