14CE701/CE411

Hall Ticket Number:

IV/IV B.Tech (Regular/Supplementary) DEGREE EXAMINATION

October, 2018 **Civil Engineering**

Seventh Semester **TRANSPORTATION ENGINEERING-I**

Time: Three Hours **Maximum:** 60 Marks

Answer Question No.1 compulsorily. (1X12 = 12 Marks)

Answer ONE question from each unit. (4X12=48 Marks)

1. Answer all questions (1X12=12 Marks)
   a) What are classified roads in Nagpur plan?
   b) Write short notes on IRC and CRRI.
   c) Define Super elevation.
   d) Define stopping sight distance.
   e) List Various factors that govern geometric design of highways.
   f) Explain the difference between Tar and Bitumen.
   g) Define Relative stiffness of slab to sub-grade.
   h) Explain the significance of dowel bars in rigid pavements
   i) Define sub-surface drainage.
   j) List out the test used to find out strength and toughness of an aggregate.
   k) List out various types of road markings.
   l) Mention various maintenance steps involved in the maintenance of flexible pavement.

UNIT I

2. a) Explain Jayakar committee recommendations. 6M
   b) Discuss various road patterns with neat sketch. 6M

(OR)

3. a) Derive an expression for extra widening on curves with a neat sketch. 6M
   b) Calculate the overtaking sight distance required if the speed of overtaking vehicle is 100Km/hr and speed of overtaken vehicle is 80Km/hr and reaction time is 2.5 seconds. Assume any other data required. 6M

UNIT II

4. a) What is CBR? Explain the laboratory procedure to determine CBR of soil with neat sketch 6M
   b) Explain the laboratory procedure to determine Aggregate crushing strength with neat sketch 6M

(OR)

5. a) Explain various design factors to be considered while design of flexible pavement. 6M
   b) Write various equations to calculate wheel load stresses in cement concrete pavement according to Westerguard and explain various terms involved. 6M

UNIT III

6. a) Explain various steps involved in the construction of Water bound Macadam Pavements. 6M
   b) Explain various failures of Cement concrete pavements with neat sketch. 6M

(OR)

7. a) Explain in detail various precautions to be taken while drainage is provided in water logged areas. 6M
   b) Discuss the importance of highway drainage. What are the requirements of good highway drainage system? 6M

UNIT IV

8. a) What are the different road user characteristics which effect the road design? Briefly Explain 6M
   b) Write a detailed note on various uses of Traffic volume studies 6M

(OR)

9. a) Explain Webster method of signal design in detail 6M
   b) Explain various advantages and disadvantages of at grade and grade separated intersections. 6M

14CE701/CE411

SCHEME OF EVALUATION

October, 2018 **Civil Engineering**

Seventh Semester **TRANSPORTATION ENGINEERING-I**

Time: Three Hours **Maximum:** 60 Marks

Answer Question No.1 compulsorily. (1X12 = 12 Marks)

Answer ONE question from each unit. (4X12=48 Marks)

1. Answer all questions (1X12=12 Marks)

a) What are classified roads in Nagpur plan?
Sol: National Highways, State Highways, Major District Roads, Other District Roads and Village Roads.

b) Write short notes on IRC and CRRI.
Sol: The Indian Road Congress (IRC) was constituted to provide a forum for regular pooling of experience, technical knowledge and ideas on all matters related to the planning, construction and maintenance of roads in India.
The Central Road Research Institute (CRRI) is one of the national laboratories of the Council of Scientific and Industrial Research (CSIR). The institute is mainly engaged in carrying out applied research in various aspects of highway engineering and offers technical advice to state governments and the industries on various problems concerning roads.

c) Define Super elevation.
Sol: In order to counteract the effect of centrifugal force and to reduce tendency of the vehicle to overturn or skid, the outer edge of the pavement is raised with respect to the inner edge, thus providing a transverse slope throughout the length of the horizontal curve. This transverse inclination to the pavement surface is known as Superelevation.

d) Define stopping sight distance.
Sol: Stopping sight distance (SSD) is the minimum sight distance available on a highway at any spot having sufficient length to enable the driver to stop a vehicle travelling at design speed, safely without collision with any other obstruction.

e) List Various factors that govern geometric design of highways.
Sol: i) Design Speed ii) Topography or terrain iii) Traffic factors iv) Design hourly volume and Capacity v) Environmental and other factors.

f) Explain the difference between Tar and Bitumen.
Sol:
Tar: It is obtained from Destructive Distillation (Burning in Specific Condition of Temperature, Without Presence of Oxygen) of Bituminous Coal.
Bitumen: It is a black viscous mixture of hydrocarbons obtained naturally or as a residue from petroleum distillation.

g) Define Relative stiffness of slab to sub-grade.
Sol: A certain degree of resistance to slab deflection is offered by the sub-grade. The sub-grade deformation is same as the slab deflection. Hence the slab deflection is direct measurement of the magnitude of the sub-grade pressure. The term
radius of relative stiffness l in cm is given by the equation

$$l = \sqrt[4]{\frac{Eh^3}{12K(1-\mu^2)}}$$

Where E is the modulus of elasticity of cement concrete in kg/cm^2 (3.0×105), μ is the Poisson's ratio of concrete (0.15), h is the slab thickness in cm and K is the modulus of sub-grade reaction.

h) Explain the significance of dowel bars in rigid pavements.
Sol: Dowel bars are short steel bars that provide a mechanical connection between slabs without restricting horizontal joint movement. They increase load transfer efficiency by allowing the leave slab to assume some of the load before the load is actually over it.

i) Define sub-surface drainage.
Sol: Diversion or removal of excess soil water from sub grade is termed as sub-surface drainage.

j) List out the test used to find out strength and toughness of an aggregate.
Sol: Aggregate Crushing Value test and Aggregate Impact Value test.

k) List out various types of road markings.
Sol: The road markings are classified as longitudinal markings, transverse markings, object markings, word messages, marking for parkings, marking at hazardous locations etc

l) Mention various maintenance steps involved in the maintenance of flexible pavement.
(a) Routine maintenance/repairs: These include filling up of pot holes and patch repairs, crack filling, crack sealing, fog seal/spray, slurry seal and crack prevention course.
(b) Periodic maintenance: These include renewals of wearing course of pavement surface and preventive maintenance of various items.
(c) Special repairs: These include strengthening of pavement structure or overlay construction, reconstruction of pavement, widening of roads, repairs of damages caused by floods, etc.

UNIT I

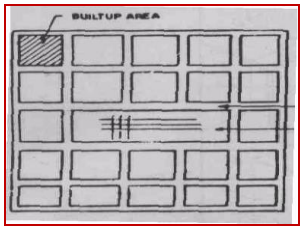
2. a) Explain Jayakar committee recommendations. 6M
Sol: In 1927 Jayakar committee for Indian road development was appointed. The major recommendations and the resulting implementations were:

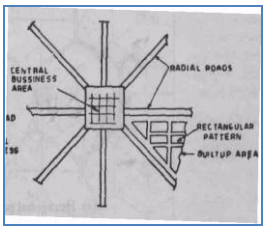
- Committee found that the road development of the country has become beyond the capacity of local governments and suggested that Central government should take the proper charge considering it as a matter of national interest.
- They gave more stress on long term planning programme, for a period of 20 years (hence called twenty year plan) that is to formulate plans and implement those plans within the next 20 years.
- One of the recommendations was the holding of periodic road conferences to discuss about road construction and development. This paved the way for the establishment of a semi-official technical body called Indian Road Congress (IRC) in 1934. The Indian Road Congress (IRC) was constituted to provide a forum for regular pooling of experience, technical knowledge and ideas on all matters related to the planning, construction and maintenance of roads in India. 3M
- The committee suggested imposition of additional taxation on motor transport which includes duty on motor spirit, vehicle taxation, license fees for vehicles plying for hire. This led to the introduction of a development fund called Central road fund in 1929. This fund was intended for road development.

Central Road Fund (C.R.F)

- Extra 2.64 Paise per litre of petrol were charged from consumers to build up this road development.
- 20% of annual revenue is to be retained as a central reserve.
- Balance 80% is allotted by the central govt to various states based on actual consumption petrol or levy collected on sale of petrol.
- CRF are maintained by the accountant General of central revenue and control on the expenditure is exercise by the Roads wing of Ministry of Transport.
- At present revised cess collected on petrol and HSD towards CRF is @ Rs.2/- per litre.
- A dedicated research organization should be constituted to carry out research and development work. This resulted in the formation of Central Road Research Institute (CRRI) in 1950. The Central Road Research Institute (CRRI) is one of the national laboratories of the Council of Scientific and Industrial Research (CSIR). The institute is mainly engaged in carrying out applied research in various aspects of highway engineering and offers technical advice to state governments and the industries on various problems concerning roads. 3M

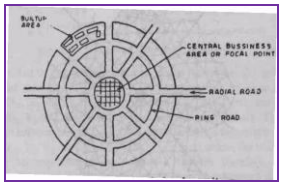
b) Discuss various road patterns with neat sketch. 6M
Sol: The various road patterns may be classified as follows:
i. Rectangular or block pattern ii. Radial or star and block pattern



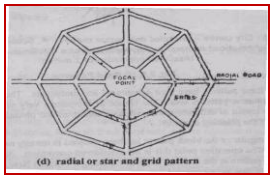


2M

iii. Radial or star and circular pattern

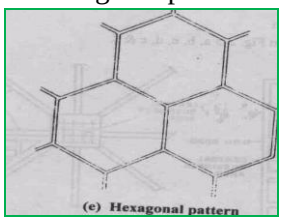


iv. Radial or star and grid pattern



2M

v. Hexagonal pattern



Each of these patterns has its own advantages and limitations. There can be a number of other geometric patterns also. The choice of the pattern very much depends on the locality, the layout of different towns, villages, industrial and production centres and on the choice of the planning engineer. 2M

(OR)

3. a) Derive an expression for extra widening on curves with a neat sketch. 6M

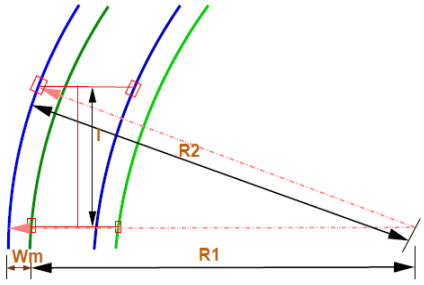
Extra Widening required on curves for two reasons

1.Due to rigidity of wheel base and off tracking of outer wheels (mechanical Widening)

2.Drivers' tendency to keep away on outer edge for more visibility (Psychological widening)

Mechanical widening:

- When a vehicle negotiates a horizontal curve, the rear wheels follow a path of shorter radius than the front wheels, known as off-tracking.
- Off-tracking requires more width of a road space for vehicle to manoeuvre.
- Trailer trucks need extra carriageway.
- In addition speeds higher than design speed causes transverse skidding, requiring additional width for safety purpose.



Extra widening at a horizontal curve

Derivation: Let

R1 : is radius of outer track line of rear wheel,

R2 : is radius of outer track line of front wheel,

l : is distance between front and rear wheel,

n : is number of lanes,

Then, Mechanical widening is:

$$\begin{aligned} R_2^2 &= R_1^2 + l^2 \\ &= (R_2 - W_m)^2 + l^2 \\ &= R_2^2 - 2R_2W_m + W_m^2 + l^2 \\ 2R_2W_m - W_m^2 &= l^2 \end{aligned}$$

Therefore, for single lane

$$W_m = \frac{l^2}{2R_2 - W_m}$$

If, n lanes,

$$W_m = \frac{nl^2}{2R_2 - W_m}$$

For large radius, $R_2 = R$, then W_m is small compared to R , Therefore,

$$W_m = \frac{nl^2}{2R}$$

4M

Psychological Widening:

- To provide greater maneuverability of steering at higher speeds, drivers have tendency to drive close to the edges of the pavement on curves.
- Some extra space is to be provided for more clearance for the crossing and overtaking operations on curves.
- IRC proposed an empirical relation for psychological widening at curves :

$$W_{ps} = \frac{v}{2.64\sqrt{R}}$$

Total widening needed at a horizontal curve

We = Wm + Wps

We = $nl^2/2R + v/2.64\sqrt{R}$ (v is in m/s)

We = $nl^2/2R + V/9.5\sqrt{R}$ (V is in Kmph) 2M

b) Calculate the overtaking sight distance required if the speed of overtaking vehicle is 100Km/hr and speed of overtaken vehicle is 80Km/hr and reaction time is 2.5 seconds. Assume any other data required. 6M

Sol: As per given data V = 100 Kmph, Vb = 80 Kmph, t = 2.5sec, and Assume A = 1.92kmph/Sec

For One way traffic: OSD = $d_1 + d_2$

For Two way traffic: OSD = $d_1 + d_2 + d_3$

$d_1 = v_b.t$ in m, $d_2 = b + 2s$

'S' is spacing of vehicles = $0.7v_b + 6$ or $0.2 V_b+6$

If T is time taken for overtaking process,

$b = v_b T$

When distance travelled by uniformly accelerating body with initial velocity of v_b and acceleration of 'a' m/sec^2 then,

T = $\sqrt{4s/a}$ sec $\approx$ $\sqrt{14.4s/A}$

d_3 = v.T 3M

OSD = vb.t + vb.T + 2s + v.T

= 0.278Vb.t + 0.278Vb.T + 2s + 0.278V.T

By using the above equations

S = 22m, T = 12.84 s, b = 285.6m, d1 = 55.6m, d2 = 329.6m, d3 = 356.95m

For One way traffic: OSD = $d_1 + d_2$ = 55.6+ 329.6 = 385.2m

For Two way traffic: OSD = d1 + d2 + d3 = 55.6+ 329.6+356.95= 742.15m 3M

UNIT II

4. a) What is CBR? Explain the laboratory procedure to determine CBR of soil with neat sketch. 6M

Sol: The California bearing ratio (CBR) is a penetration test for evaluation of the mechanical strength of natural ground, subgrades and base courses beneath new carriageway construction. It was developed by the California Department of Transportation before World War II.

It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material.

CBR Test: California Bearing Ratio (CBR) test was developed by the California Division of Highway as a method of classifying and evaluating soil-sub grade and base course materials for flexible pavements. CBR test, an empirical test, has been used to determine the material properties for pavement design. Empirical tests measure the strength of the material and are not a true representation of the resilient modulus. It is a penetration test wherein a standard piston, having an area of 3 in^2 (or 50 mm diameter), is used to penetrate the soil at a standard rate of 1.25 mm/minute. The pressure up to a penetration of 12.5 mm and it's ratio to the bearing value of a standard crushed

rock is termed as the CBR. In most cases, CBR decreases as the penetration increases. The ratio at 2.5 mm penetration is used as the CBR. In some case, the ratio at 5 mm may be greater than that at 2.5 mm. If this occurs, the ratio at 5 mm should be used. The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions. The test procedure should be strictly adhered if high degree of reproducibility is desired. The CBR test may be conducted in re-moulded or undisturbed specimen in the laboratory. The test is simple and has been extensively investigated for field correlations of flexible pavement thickness requirement.

2M

Test Procedure:

• 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.

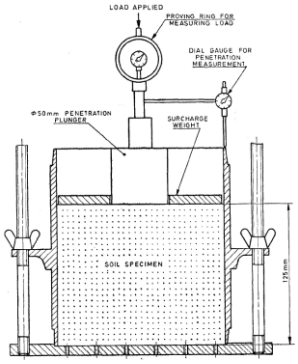
• The specimen in the mould is soaked in water for four days and the swelling and water absorption values are noted. The surcharge weight is placed on the top of the specimen in the mould and the assembly is placed under the plunger of the loading frame.

• 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 = (load carries by specimen/ load carries by standard specimen) × 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.



CBR Test 4M

b) Explain the laboratory procedure to determine Aggregate crushing strength with neat sketch. 6M

Sol: The aggregate passing through 12.5mm sieves and retained on 10mm IS sieve is selected for standard test. The aggregates should be in surface dry condition before testing. The aggregate may be dried by heating at a temperature of 100^0C to 110^0C for a period of 4 hours and is tested after being cooled to room temperature.

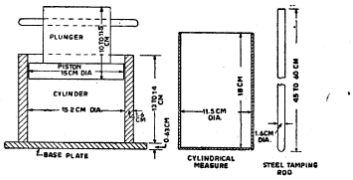
The cylindrical measure is filled by the test sample of aggregate in three layers of approximately equal depth, each layer being tamped 25 times by the rounded end of the tamping rod. After the third layer is tamped, the aggregates at the top of the cylindrical measure are leveled off by using the tamping rod as a straight edge. About 6.5kg of aggregate is required for preparing two tests samples. The test samples thus taken are then weighed. The same weight of the sample is taken in the repeat test.

The cylinder of the test apparatus is placed in position on the base plate; one third of the sample is placed in the cylinder and tamped 25 times by the tamping rod. Similarly, the other two parts of the test specimen are added, each layer being subjected to 25 tampings. The total depth of the material in the cylinder after tamping shall however 10cm. The surface of the aggregates is leveled and the plunger inserted so that it rests on this surface in level position. The cylinder with the test sample and plunger in position is placed on compression testing machine. Load is then applied through the plunger at a uniform rate of 4 tonnes per minute until the total load is 40 tonnes, and the load is released. Aggregates including the crushed portion are removed from the cylinder and sieved on a 2.36mm IS sieve. The material which passes this sieve is collected. 4M

The above crushing test is repeated on second sample of the same weight in accordance with above test procedure. Thus two tests are made for the same specimen for taking an average value.

The aggregate crushing value is defined as the ratio of weight of fines passing the specified IS sieve

to the total weight of the sample expressed as percentage.



Aggregate Crushing Test Apparatus 2M

(OR)

5. a) Explain various design factors to be considered while design of flexible pavement. 6M

Sol: The various factors to be considered for the design of flexible pavements are:

i) Wheel loads of heavy vehicles or traffic loads
ii) Subgrade soil
iii) Climatic factors
iv) Pavement component materials in different layers
v) Drainage and Environmental factors

Magnitude of Wheel loads/Traffic loads:

The thickness design of flexible pavement primarily depends upon the various factors associated with wheel loads of heavy vehicles. Higher magnitude of wheel load obviously need thicker pavement, provided other design factors are the same. The various wheel load factors to be considered in pavement design are, maximum wheel load, contact pressure, wheel load configuration such as dual or multiple wheel load assembly and the repetition of these loads during the design life of the pavement. Dynamic effects of transient loads due to moving vehicles may also be considered.

Wheel load and contact pressure:

The magnitude of the wheel load (P)and the loaded area (A) or the contact pressure (p) are to be taken in the account for the analysis of stresses and the stress distribution within the pavement. Contact pressure can be measured by the relationship:

Contact pressure, p = (Load on wheel/Contact area or of imprint) = (P/A).

If the loaded area or the contact area, A of the wheel load is assumed to be circular in shape of radius ‘a’, then the relationship between the load P, loaded area A

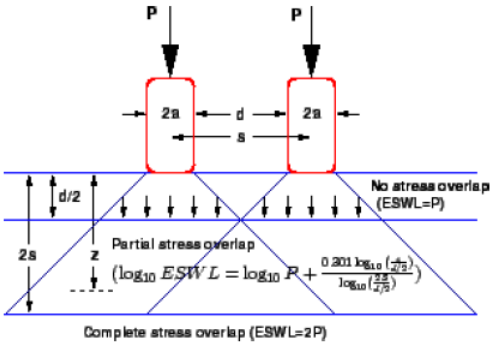
$$P = A/p == \pi a^2 p.$$

Equivalent single wheel load(ESWL):

To carry maximum load within the specified limit and to carry greater load, dual wheel, or dual tandem assembly is often used. Equivalent single wheel load (ESWL) is the single wheel load having the same contact pressure, which produces same value of maximum stress, deflection, tensile stress or contact pressure at the desired depth. The procedure of finding the ESWL for equal stress criteria is provided below.

This is a semi-rational method, known as Boyd and Foster method, based on the following assumptions:

- Equalancy concept is based on equal stress;
- Contact area is circular;
- Influence angle is 45^0 and
- Soil medium is elastic, homogeneous, and isotropic half space.



ESWL-Equal stress concept

where P is the wheel load, S is the center to center distance between the two wheels, d is the clear distance between two wheels, z and is the desired depth. 2M

Equivalent wheel load factors(EWLF)/(VDF):

If a particular pavement structure fails with N1 number of repetitions of load P1 kg and similarly if N2 number of repetitions of load P2 kg can also cause failure of the same pavement structure, then P1N1 and P2N2 are considered equivalent. Extensive Road Test studies were carried out then by the then 'American Association of State Highway Officials'(AASHO) allowing controlled movement of wheel loads of different magnitudes on experimental pavement stretches of different thickness. These studies were then carried out by AASHO with wheel loads of 5000, 6000, 7000, 8000, 9000, 10,000, 11,000 and 12,000 pounds. The analysis of developed from the 'AASHO Road Test' equations widely accepted for the determination of Equivalent Wheel Load Factors (EWLF).

$$\text{Equivalent Wheel Load Factor} = (\text{given wheel load P1/Standard wheel load, P})^4.$$
$$= (\text{given axle load/standard axle load})^4$$
$$\text{EWLF} = (P1/P)^4$$

Wheel/ Axle load studies:

Wheel or axle load distribution studies are carried out in order to determine the EWLF or VDF values of the heavy vehicle classes. The actual load of each set of wheels or axle is measured in the selected sample of each vehicle class. It is desirable to decide the sample size based on the number of heavy vehicles in each classified group of heavy vehicles so that even small number of vehicles of any class is not left out in the sampling process. However, in order to simplify the process, generally the sample size is decided based on the total number of all the heavy vehicles per day. The recommended minimum sample sizes for carrying out axle or wheel load distribution studies in major highway projects are:

20% if the number of vehicle class is less than 3000 per day

15% if the number of vehicle class is 3000 to 6000 per day

10% if the number of vehicle class is greater than 6000 per day.

Effect of moving loads:

As the speed of the vehicle increases, the rate of application of the stress on the pavement is also increased resulting in substantial reduction in the pavement deformation. Consequently, there is a reduction in the pavement in the stresses in the pavement layers due to moving wheel load in comparison to the static loads of the same magnitude. But on uneven pavements, the effects of impact increases with the speed.

Subgrade:

The properties of the soil subgrade and its support to the pavement layers above are important in deciding the thickness requirement of flexible pavements. All other design factors being the same, a subgrade with lower stability requires the thicker pavement to protect it from the traffic loads during the design life. For example, the total thickness of flexible pavement over a subgrade soil with a lower CBR value will be higher than that over another soil with higher CBR value. The variations in stability and volume of the subgrade soil with moisture changes are to be studied, as these properties are dependent on the characteristics of subgrade soil. Therefore the lowest stability value of the subgrade soil at the highest possible moisture content at the site is to be considered during the design. This points out the importance of effective drainage in order ror maintain the subgrade soil in relatively dry condition.

Climatic factors

Among the climatic factors, rainfall effects the moisture conditions in the subgrade and the pavement layers. The daily and seasonal variations in temperature has significant effect in the design and performance of bituminous pavement layers of flexible pavements; at high pavement temperatures, the bituminous binders as well as the mixes become softer whereas at very low temperatures, they become stiffer resulting in vast changes in fatigue characteristics under repeated application of the wheel loads. Where freezing temperatures are prevalent during winter, the possibility of frost action in the subgrade and the damaging effects should be considered itself. Roads passing thorough locations with adverse climatic conditions will need higher thickness of flexible pavement structure.

The climatic variations cause the following major effects on the road pavements:

i)Variation in moisture condition

ii)Frost action

iii)Variation in temperature

Variation in moisture content:

Considerable variations in the moisture condition of subgrade soil is likely during the year, depending on the climatic conditions, soil type, ground water level and its variations, drainage

conditions, type of pavement and shoulders. The surface water during the rains may enter the subgrade either through the pavement edges or through the pavement itself, if it is porous. The subgrade moisture variations depend on fluctuations of ground water table. The moisture movement in the subgrade is also caused by the capillary action and vapour movement. However, high moisture variations can be controlled by providing suitable surface and sub-surface drainage systems.

Frost action:

Frost action refers to the adverse effects due to Frost heave, first melting or thaw and the alternate cycles of freezing and thawing. The frost action in general includes all the effects associated with freezing temperature on pavement performance.

The held water in subgrade soil forms ice crystals at some spots if the freezing temperatures continue for a certain period. These ice crystals grow further in size if there is a continuous supply of water due to capillary action depressed temperature continuous. This results in rising of portion of the pavement structure known as Frost heave. If the Frost heave causes uniform rising of pavement structure, the subgrade support is not adversely affected at this stage. however, non-uniform heaving may cause damages.

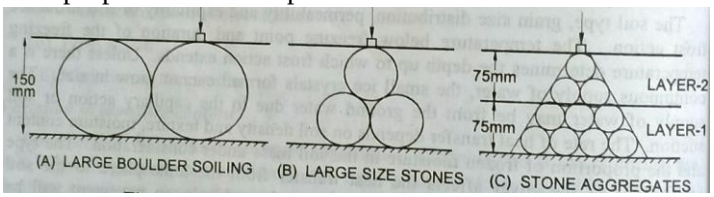
Variation in temperature:

Wide variation in temperature due to climatic changes main cause damaging effects in pavements. bituminous binders and mixes of the flexible pavement surface Course become soft during hot weather and brittle in very cold weather. these affect the performance and life of the pavement. These problems can be sorted out by proper choice of the type and grade of bituminous Binder. 2M

Pavement component materials:

The soil subgrade plays the most important role as this has to ultimately support all the pavement layers laid above along with the anticipated traffic load the stress distribution characteristics through the granular payment component layers depend on the characteristics of the materials used in these layers. the type of aggregates used, their shape factors and gradation play an important role in load dispersion characteristics of the granular base and sub-base courses. the thickness requirement of the flexible pavement structure will also depend upon the load dispersion characteristics of the payment layer materials.

The concept of pressure distribution through granular layers by grain to grain contact to the lower layers is illustrated in the following figures. A layer of granular sub base course pavement of thickness 150 mm is shown in figure below illustrates the full depth of this layer consisting of large Boulder stones of single size. is obvious that the stress does not get spread through a larger area indicating that this layer does not serve the purpose of load dispersion to a larger area below the magnitude of compressive stress applied on the top of the stone is practically passed on to the subgrade through the same area. Therefore, this layer consisting of single layer of large boulders stones does not serve the purpose of load dispersion.



Drainage and environmental factors:

Pavement performance and pavement deterioration very much depend on the pavement drainage. Effective payment drainage is one of the most important factors to be taken into account at the design and construction stages of the road pavements. The performance and service life of flexible pavement structure very much depend on the drainage characteristics of road at each location.

The local and environmental factors including the relative level of the subgrade with respect to adjoining land, type of land use, on either side of road, height of the embankment and its Foundation details Dept of cutting if any Dept of subsurface water table etc. affect the drainage characteristics and performance of the pavement. if the adjoining land on one or both sides of the road are cultivated and are irrigated, the moisture content of the fill and subgrade soils will remain High resulting in adverse payment performance, unless suitable measures are taken initially at the planning,design and construction stages. 2M

b) Write various equations to calculate wheel load stresses in cement concrete pavement according to Westerguard and explain various terms involved. 6M

Sol:

Relative stiffness of slab to sub-grade:

$$l = \sqrt[4]{\frac{Eh^3}{12K(1-\mu^2)}}$$

Where l = radius of relative stiffness

E = modulus of elasticity of cement concrete in kg/cm2 ($3x10^5$)

μ = Poisson's ratio for concrete = 0.15

h = Slab thickness, cm

K = Sub-grade modulus or modulus of sub-grade reaction, kg/cm^3

Equivalent radius of resisting section:

When the interior point is loaded, only a small area of the pavement is resisting the bending moment of the plate.

Westergaard's gives a relation for equivalent radius of the resisting section in cm by a equation as follows

$$b = \begin{cases} \sqrt{1.6a^2 + h^2} - 0.675\ h & \text{if a} < 1.724\ \text{h} \\ a & \text{otherwise} \end{cases}$$

Where

a = the radius of the wheel load distribution in cm and

h = the slab thickness in cm. 3M

Wheel load stresses - Westergaard's stress equations

$$\sigma_i = \frac{0.316\ P}{h^2}\left[4\ \log_{10}\left(\frac{l}{b}\right) + 1.069\right]$$

$$\sigma_e = \frac{0.572\ P}{h^2}\left[4\ \log_{10}\left(\frac{l}{b}\right) + 0.359\right]$$

$$\sigma_c = \frac{3\ P}{h^2}\left[1 - \left(\frac{a\sqrt{2}}{l}\right)^{0.6}\right]$$

where h is the slab thickness in cm, P is the wheel load in kg,

a is the radius of the wheel load distribution in cm,

b is the radius of the resisting section in cm and

l the radius of the relative stiffness in cm 3M

UNIT III

6. a) Explain various steps involved in the construction of Water bound Macadam Pavements. 6M

Sol:

Construction procedure of WBM Roads:

(i) Preparation of Foundation for receiving the WBM course

- The foundation for receiving the new layer of WBM may be either the subgrade or sub-base or base course.
- This foundation layer is prepared to the required grade and camber and the dust and either loose materials are cleaned.
- On existing road surfaces, the depressions and pot-holes are filled and the corrugations are removed by scarifying and reshaping the surface to the required grade and camber as necessary.

(ii) Provision of Lateral Confinement

- Lateral confinement is to be provided before starting WBM construction.
- This may be done by constructing the shoulders to advance, to a thickness equal to that of the compacted WBM layer and by trimming the inner sides vertically.

(iii) Spreading Of Coarse Aggregates

- The coarse aggregates are spaced uniformly to proper profile to even thickness upon the prepared foundation and checked by templates.
- The WBM course is normally constructed to compacted thickness of 7.5 cm except in the case of WBM sub-base course using coarse aggregate grading no.1 which is of 10cm compacted thickness. 2M

(iv) Rolling

- After spreading the coarse aggregates properly, compaction is done by a three wheeled power roller of capacity 6 to 10 tonnes or alternatively by an vibratory roller ; the weight of the roller depends on the type of coarse aggregates.
- Rolling is started from the edges, the roller being run forward and backward until the edges are compacted.
- The run of the roller is then gradually shifted towards the centre line of the road, uniformly overlapping each preceding rear wheel track by one half width.
- This process is repeated by rolling from either edge towards the centre line until adequate compaction is achieved.

(v) Application of Screenings

- After the coarse aggregates are rolled adequately, the dry screenings are applied gradually over the surface to fill the interstices in three or more applications.
- Dry rolling is continued as the screenings are being spread and brooming carried out.

(vi) Sprinkling and Grouting

- After the application of screenings, the surface is sprinkled with water, swept and rolled.
- Wet screenings are swept into the voids using hand brooms.
- Additional screenings are applied and rolled till the coarse aggregates are well bonded and firmly set. 2M

(vii) Application Of Bonding Material

- After the application of screening and rolling, binding material is applied at a uniform and slow rate at two or more successive thin layers.
- After each application of binding material, the surface is copiously(abundantly) sprinkled with water and wet slurry swept with brooms to fill the voids.
- This is followed by rolling with a 6 to 10 tonnes roller and water is applied to the wheels to wash down the binding materials that sticks to the roller.
- When crushable type screenings like moorum or gravel are used, there is no need to apply binding materials, except in the surfacing course.

viii) Setting and drying

- After final compaction, the WBM course is allowed to set over-night.
- On the next day the hungry spots are located and are filled with screenings or binding material, lightly sprinkled with water if necessary and rolled.
- No traffic is allowed till the WBM layer sets and dries out.
- In the case of WBM base course, the layer is allowed to dry completely without permitting traffic to ply over the WBM layer taking proper care not to damage the layer. 2M

b) Explain various failures of Cement concrete pavements with neat sketch. 6M

Sol:

some of the common types of distresses and failures in improperly laid old cement concrete pavements in India are:

Mud pumping: Mud pumping is the process of mud or soil slurry being ejected out through the joints and edges of CC pavements during the movement of heavy vehicles. Fine soil particles suspended in water in the form of mud gets ejected out through the joints, cracks and edges of cement concrete pavements under the heavy wheel loads during or just after the rainy season. The development of mud pumping in CC pavements and consequent failure process is explained below.

The heavy wheel loads cause the weak CC pavement slab to deflect or move downwards repeated pavement deflections due to heavy vehicle movement lead to permanent deformation of the subgrade. Thus a little gap is formed between the bottom of CC slab and the subgrade excess water present in the subgrade could stagnate in this gap. Further pavement deflections under heavy wheel loads causes the fine soil particles to be churned and ejected out in the form of mud through the joints are the pavement edge, resulting in loss of soil particles and consequently gab under the pavement increases further at a rapid rate.

The above process is called 'mud pumping' in CC pavements which leads to progressive loss of subgrade support at these locations and finally the CC pavement develops structural cracks and breaks down at these locations. The main factors which could initiate the mud pumping process are:

1. The CC pavement structure is weak resulting in high deflection of the pavement slab under the heavy wheel loads.

2. The CC pavement is laid directly on the subgrade soil containing substantial proportion of silt and clay.

3. Ineffective pavement drainage resulting in excess water content in the subgrade soil or stagnation

of water in the space gab under pavement slab.

The CC pavement slab deflects more under heavy wheel loads if the slab thickness is not adequate with respect to the applied load; the deflection will be more when the heavy load is near the edges or that transverse joints. If CC pavement is laid directly over the subgrade soil containing substantial proportion of silt and clay the increasing permanent deformation is at a faster rate due to repeated load applications. During rainy season the surface water infiltrates through joints, cracks and pavement edges into soil subgrade as shown in the figure below.

Due to repeated applications of heavy wheel loads and consequent deflections of CC slab some space or gap is developed underneath the pavement slabs particularly near the joints and pavement edges. The surface water that infiltrates into the subgrade stagnates in the space gap under the CC pavement. Subsequent movement of heavy wheel loads and consequent pavement deflection causes the water to churn the soil fines, forming soil slurry or mud which is ejected out through the joints and pavement edge as shown in the figure below.

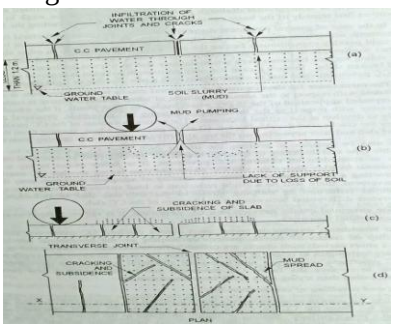


Fig. Failure of CC Pavement due to mud pumping

When more and more mud is ejected out there is a substantial loss in find graded soil from subgrade rapid increase in the gap under the pavement slab and loss of subgrade support resulting in development of structural cracks in the slab and breaking up of the payment as shown in figure. The pavement cracking due to mud pumping is generally a progressive type of failure in rigid pavements.

Development of structural cracks in CC pavement:

Structural cracks are formed near the edge and corner regions of the CC pavement slabs due to combined wheel load and working stresses in the slab. The formation of structural cracks in CC pavements is viewed seriously and needs immediate attention as these indicate possible beginning of pavement failure. First the cause of the failure should be investigated. If the value is confined to one or a few slabs only at a particular location and in general there are no structural cracks in other slabs, the failure maybe localised one due to some weak spot in the subgrade or due to localised settlement of embankment or underground drainage problem. The maintenance work in such a case involves first remedy of the basic cause of the failure and then recasting the failed slabs.

The main cause for the development of structural cracks in CC pavements is inadequate thickness with respect to the actual magnitude of wheel loads payment is sustaining and the repeated application of heavy wheel loads. In other words, if the wheel loads are excessive with respect to the thickness of existing CC pavement, structural cracks are likely to develop at the critical locations. The critical locations of the CC pavement slab where the cracks start developing are:

1. At the pavement edges starting from the bottom of the slab and later appearing on the top also
2. Near the corners starting from the top.

It may be possible to prolong the life of such weak CC pavements by laying a suitable type and thickness of overlay, before the development of structural cracks. In order to strengthen an existing CC pavement it is rather easier to lay a suitable bituminous overlay above the old CC payment than laying another CC overlay. By constructing a dense graded bituminous overlay of adequate thickness over the week CC pavement there will be a slight reduction in load stresses; however there will be substantial reduction in warping stress in the CC slab due to reduction in the temperature differential between top and bottom of the CC slab.

Once structural cracks develop in a CC pavement, it is rather difficult to resort to simple remedial measures.

If a bituminous overlay is constructed over a cracked CC payment there is a possibility of cracks of similar pattern developing on bituminous overlay also within a short period; such cracks are called reflection cracks as shown in the figure below.

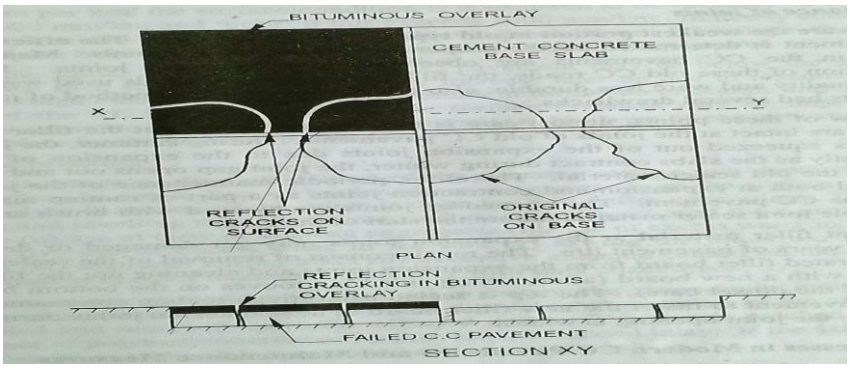


Fig. Cracked CC Pavement and reflection cracks on bituminous overlay

There are techniques to retard or delay reflection cracking; however if strengthening of the CC payment is delayed and extensive structural cracks have developed, it is desirable to remove the failed CC pavement and to reconstruct a new pavement structure, rather than trying such crack retarding measures. 3M

Surface uneveness or roughness:

the surface condition of CC pavement is considered to be good if the value of uneveness index or roughness index determined using the bump integrator is less than 2200 mm per km; the surface condition is considered to be average is the value is 2200 to 3000 mm/ km and poor if this exceeds 3000 mm/km. In newly constructed CC pavement it has been possible to achieve much lower UI values than 2200 mm/km, with the help of modern construction technology and equipment.

Though the initial UI value of a new CC pavement maybe below the specified limit, on some road stretches the value maybe increase later on due to reasons such as settlement of high embankments,etc.; this results in formation of bumps and dips near the joint of CC pavements slabs. the surface eveness may be improved by diamond grinding to partial remove the bumps; a thin layer of concrete is removed from the surface by grinding process.

Scaling and ravelling:

Scaling is due to pelling of part of the concrete surface to a depth of 5 to 15 mm. Ravelling is due to loss of hardend cement mortar from the surface; raveling also takes place if sawing of the joints is done too early after concreting. the causes scaling and raveling may be summarised as:

1. segregation of concrete mix at the surface
2. use of dirty on clean aggregate
3. use of excess water in the mix at a location
4. use of excess fines in the mix
5. sawing the joints too early after concreting
6. improper curing and
7. Excessive abrasion caused on the surface by the movement of crawler mounted machinery with steel chain drive.

The areas to be repaired are marked out in rectangular shape by including extra 50 mm around the affected area. The partially disintegrated materials of the affected area chisseled up to the affected depth. The area is patched up using a suitable mix of polymer concrete or by providing a bonded inlay. If the affected depth is more than 25 mm the slab is removed and reconstructed.

Spalling of joints:

Spalling of joints occur due to cracking and breaking away part of the concrete near the joints of the CC slab. The common causes for spalling of expansion joints are:

1. Ingress of stones or grit into the gap of expansion joints
2. Failure or defects in load transfer dowel bar system or their placement at the concerned joint or
3. use of weaker concrete or improperly compacted concrete when the work is stopped at the construction joint.

If the affected width on either side of the joint is less than 20 mm and the affected length of spalled portion is less than 25% of joint length epoxy resin motor is applied. If the affected width and length exceed the above, partial depth repair is carried out.

Loss of joint sealant:

The sealent at the joints of CC pavement is subjected to various conditions and therefore suffers distress over a period of time. If there is loss of joint sealent or if the sealent has got damaged,the old sealant material is removed, the joint groove is cleaned and the joint is re-sealed using appropriate type of sealant. Polysulphide sealants are reported to perform well for 5 to 7 years; silicone sealants are reported to serve well for 10 years.

Shrinkage cracks:

Two types of shrinkage cracks are likely to develop in CC pavements:
1. Plastics shrinkage cracks and
2. Drying shrinkage cracks.

Plastic shrinkage cracks develop on CC pavement surface due to rapid drying of fresh concrete caused by wind blowing at high speeds. These cracks are formed perpendicular to the direction of wind they are about 0.3 to 0.6 m in length and extend upto a depth of 20 to 30 mm. Formation of such shrinkage cracks can be prevented by taking suitable measures for curing of concrete. These cracks are not viewed seriously as they do not pose any functional or structural problem; however the cracks maybe sealed using epoxy resin of low viscosity.

Drying shrinkage cracks develop due to overall shrinking of CC mix during the initial curing period which is restrained by the interface friction between the bottom of the CC slab and the supporting layer or the seperation membrane. These shrinkage cracks start developing from the bottom of the slab and progress upwards. Random development of such shrinkage cracks may be prevented by properly designing the spacing of the contraction joints and carrying out the joint cutting within the recommended period after laying the concrete. These cracks may not always pose major structural or functional problems, unless the crack width increases due to combined effect of heavy traffic and other and environmental factors. Once the cracks appear on the top surface of CC slab, it is desirable resort to full depth repair to prevent deterioration.

Loss of surface texture:

Loss of surface texture results in smoothening of the CC pavement surface which may become slippery under wet conditions. The probable causes for loss of surface texture are:
1.Poor texturing during construction
2. Abrasion of the surface due to wear and tear caused by heavy traffic movements and under wet conditions or when the surface is covered by sand particles
3. Movement of construction traffic before the concrete gains strength
4. Road streches with frequent braking or turning moments of fast vehicles and
5. Use of non durable materials in the concrete.

The surface texture may be measured in terms of:
1. Mean texture depth by sand patch method or
2. Frictional resistance or skid number using appropriate friction testing machine such as 'British pendulum tester'.

The surface texture and the desired skid resistance maybe restored by 'diamond grinding' or groove cutting of the polished surface. Grooves of 2.0 to 4.0 mm width and 1.5 mm depth are cut at about 5.0 to 6.0 mm intervals in transverse or longitudinal direction using gang-mounted diamond saw blades.

Maintenance of joints:

Joints are the weakest portion in old types of cc pavements the efficiency of the CC payment is determined by the proper functioning of the joints. Majority of the failures in the CC pavements are observed at or near the joints. During the construction of these old CC roads the filler and sealer materials used where much inferior quality and where less durable; also the old construction method of joints in CC pavements had several drawbacks.

In view of these points utmost care is to be taken to see that the filler and sealer materials are intact at the joints of old CC pavements. During summer the joint filler material is squeezed out of the expansion joints due to the expansion of the slabs; subsequently as the slabs contract during winter the joint gap opens out and cracks are formed in the old Sealer material. Therefore periodic maintenance of the joint filler is essential both at expansion and contraction joints as a part of routine maintenance work of the CC pavement. The opened up joints are cleaned with brush and refilled with suitable joint filler material before the start of the rains.

The joint filler material at the expansion joints may get damaged or deteriorated after a few years of pavement life. The repair consists of removal of the filler material and deteriorated filler Board from the Expansion joints and cleaning up; the filler board is replaced with new board. The top is sealed using fresh sealing compound. It will be more convenient to insert the new filler board at the Expansion joints during winter season when the joint opening is widest.

(OR)

7. a) Explain in detail various precautions to be taken while drainage is provided in water logged areas. 6M

Sol: When the subgrade is subjected to soaking condition due to high subsoil water and capillary rise, the area is considered as waterlogged.

In extreme cases there may be even flooding for prolonged periods. In addition to water-logging if the area is infested with detrimental salts like sulphates, there are additional problems for construction and maintenance of roads in such area. When the problem is one of water-logging only without flooding or presence of detrimental salts, 3M

The following methods may be adopted

- Depressing the subsurface water level by suitable drainage system.
- Raising the road level by constructing embankment.
- Providing a capillary cut off to arrest the capillary rise of water.
- Providing sufficient pavement thickness in view of the subgrade conditions. 3M

b) Discuss the importance of highway drainage. What are the requirements of good highway drainage system? 6M

Sol:

Importance of highway drainage :

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:

- Excess of moisture in soil sub grade cause lower of its stability.
- Increase in moisture cause reduction in strength of many pavements like stabilized soil and WBM.
- Waves and corrugation in flexible pavements mainly due the poor drainage.
- Sustained contact of water with bitumen it will causes stripping.
- Mud pumping is due to presence of water in sub grade.
- Due to excess of water it will increases the stress, reason that failure of earth slopes.
- Erosion of soil from top of unsurfaced roads and slopes of embankment. 3M

Requirements of good highway drainage system:

- The surface water from the carriage way and shoulder should effectively be drained off without allowing it to percolate to subgrade.
- The surface water from the adjoining land should be prevented from entering the road way.
- The Side drain should have sufficient capacity and longitudinal slope to carry away all the surface water collected.
- Flow of surface water across the road and shoulder should not cause formation of cross ruts.
- Seepage and other sources of underground water should be drained off by the sub surface drainage system.
- Highest level of ground water table should be kept well below the level of sub grade, preferably by at least 1.2m
- In water logged areas special precautions should be taken. Where the water presents salt.

3M

UNIT IV

8. a) What are the different road user characteristics which effect the road design? Briefly Explain 6M

Sol:

Road Users Characteristics:

The human element is involved in all actions of road users either as Pedestrian, Cyclist, motorists or vehicle driver. Physical, mental or emotional characteristics of human beings affect their operational ability and safety of driving. Factors affecting road user characteristics

Physical: vision, Hearing, strength and general reaction to stimuli

Vision – Acute, Peripheral and Tunnel, Glare vision, glare recovery

Acute vision is in 3^0 cone, Up to 10^0 is fairly good (but in general 20^0 in horizontal) In the vertical plane the clear vision is only 2/3rds of that in the horizontal plane. Eye movement is required to see in peripheral vision (160^0 and 110^0 in horizontal and vertical plane) As the speed increases the peripheral vision decreases. This depends on physical and mental characteristics

Glare – dark to light and light to dark

Depth judgement for judging distance and speed of vehicles or objects

Hearing – more important to pedestrians and cyclists

Strength – for parking and steering heavy vehicles

General reaction – PIEV theory

Fatigue, illness and alcohol/drugs increase reaction time, reduce alertness and affect judgment 3M

Mental: knowledge, skill, intelligence, literacy and experience

Knowledge of vehicles, traffic, driving knowledge, psychology of road users, road rules

Skill, intelligence, literacy will help of timely actions
Experience helps react spontaneously to situations
Psychological: Emotional, fear, anger, impatience, superstition etc
Emotional, fear, anger, impatience, superstition(false notion) etc
Impatience leads to dangerous actions, dis-regard to traffic rules, and not having right attitude
Non traffic events, mental worries.
Environmental: Traffic stream characteristics, facilities to the traffic, atmospheric conditions and the locality.
The traffic stream consists of mixed traffic or heavy vehicles where as the facilities to overtake for faster vehicles may be limited.
The other environmental factors of importance are the weather visibility and other atmospheric conditions. 3M

b) Write a detailed note on various uses of Traffic volume studies. 6M

Sol: Traffic volume is a measure to quantify the traffic flow. Traffic volume or traffic flow is expressed as the number of vehicles that pass across a given transverse line of the road during unit time. It is generally expressed as number of vehicles per hour or per day, per traffic lane. 2M

Uses of Traffic Volume Studies:

- True measure of relative importance of road
- Used in planning operation and control
- Analysis of traffic patterns
- Classified traffic volume useful in structural design
- Volume distribution for one way streets and other regulation
- Turning movements of traffic for intersection designs
- Pedestrian Volume for foot paths sidewalks, pedestrian signals etc

(OR)

9. a) Explain Webster method of signal design in detail. 6M

Sol:

It has been found from studies that the average delay and the overall delay to the vehicles at signalized intersection vary with the signal cycle length. The average delay per vehicle is high when the cycle length is very less, as a sizable proportion of vehicles may not get cleared during the first cycle and may spill over to subsequent cycles as the signal cycle time is increased, average delay per vehicle decreases up to a certain minimum value and there after that deletes starts increasing, indicating that there is an' optimum signal cycle time' corresponding to least overall delay. The optimum cycle time depends on the geometric details of the intersection and the volume of traffic approaching the intersection from all the approach roads during the design hour.

Webster method of traffic signal design is an analytical approach of determining the optimum signal cycle time, Co responding to minimum total delay to all the vehicles at the approach roads of intersection. the field work consists of determining the following two sets of values on each approach Road near the intersection:

1. The normal flow q on each approach during the design hour and
2. The Saturation flow S per unit time

The normal flow values, q_1 and q_2 on roads 1 and 2 are determined from field studies conducted during the design hour auto traffic during peak 15 minute's period. The saturation flow of vehicles is determined from careful field studies by noting the number of vehicles in the stream of compact flow during the green phases and the corresponding time intervals precisely. In the absence of data the approximate value of saturation flow is estimated assuming 160PCU per 0.3 meter width of the approach Road. 3M

Based on the selected values of normal flow, the ratio $y_1 = q_1/S_1$ and $y_2 = q_2/S_2$ are determined on approach roads 1 and 2. In case of mixed traffic, it is necessary to convert the different vehicle classes in terms of suitable PCU values at signalized intersection; in case these are not available they may be determined separately.

The normal flow of the traffic on approach roads may also be determined by conducting field studies during off-peak hours to design different sets of signal timings during other periods of the day also as required so as to provide different signals settings.

The optimum signal cycle is given by the relation:

$$Co = (1.5L+5)/(1-Y)$$

where

L= total cost time per cycle=2n+R

N = is the number of phases

R = All redtime or red Amber time

$$Y=y1+y2.$$

Here, $y_1= q_1/S_1$ and $y_2=q_2/S_2$

Then, $G_1=(y_1/Y)(Co-L)$ $G_2=(y_2/Y)(Co-L)$

Similar procedure is followed when there are more number of signal phases 3M

b) Explain various advantages and disadvantages of at grade and grade separated intersections. 6M

Sol:

Advantages of at grade intersections:

a) The construction and maintenance cost of these intersections minimum.
b) In flat or plain terrain these are desirable.

Disadvantages of at grade intersections:

a) As conflict area is more in these kinds of intersections the possibility of accidents will be more.
b) The capacity of these intersections is low which leads to traffic issues. 2M

Advantages of grade separated intersections:

a) Uninterrupted flow is possible for the crossing traffic. As the roads are separated at two levels, there is no crossing conflict thus avoiding accidents while crossing with no need to stop while crossing.

b) There is increased safety for turning traffic and by indirect interchange ramp even right turn movement is made quite easy and safe by converting into diverging to left and merging from left.

c) There is overall increase in comfort and convenience to the motorists and saving in travel time and vehicle operation cost.

d) The capacity of the grade separated intersection can practically approach the total capacity of the two cross roads.

e) Grade separation is an essential part of controlled access highway like expressway and highway.

f) It is possible to adopt grade separation for all likely angles and layout of intersecting roads.

g) Stage construction of additional ramps is possible after the grade separation structures between main roads are constructed.

Disadvantages of grade separated intersections:

a) It is very costly to provide complete grade separation and interchange facilities.

b) Where there is limited right of way like built up or urban area or where the topography is not favourable, construction of grade separation is costly, difficult and undesirable.

c) In flat or plain terrain, grade separation may introduce undesirable crests and sags in the vertical alignment. 4M

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