SOLUTION- IAT2

HIGHWAY ENGINEERING (15CV63)

1(a).Define camber. Discuss the factors on which the amount of camber to be provided depends. Specify the recommended ranges of camber for different types of pavement surfaces..

Ans:-

Camber or cant is the cross slope provided to raise middle of the road surface in the transverse direction to drain of rain water from road surface. The objectives of providing camber are:

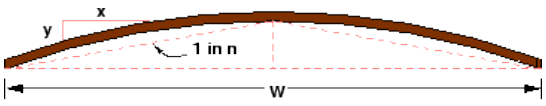
- Surface protection especially for gravel and bituminous roads
- Sub-grade protection by proper drainage
- Quick drying of pavement which in turn increases safety

The required camber of a pavement depends on:

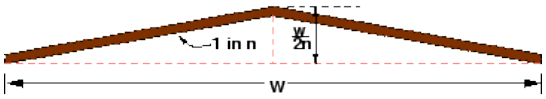
i) The type of pavement surface ii) The amount of rainfall

Too steep slope is undesirable for it will erode the surface. Camber is measured in 1 in n or n% (Eg. 1 in 50 or 2%) and the value depends on the type of pavement surface. The values suggested by IRC for various categories of pavement is given in Table below .The common types of camber are parabolic, straight, or combination of them .

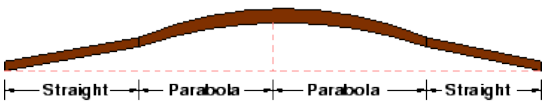
Surface type	Heavy rain	Light rain
Concrete/Bituminous	2 %	1.7 %
Gravel/WBM	3 %	2.5 %
Earthen	4 %	3.0 %



a. Parabolic camber $y=2x^2/nw$



b. Straight line camber



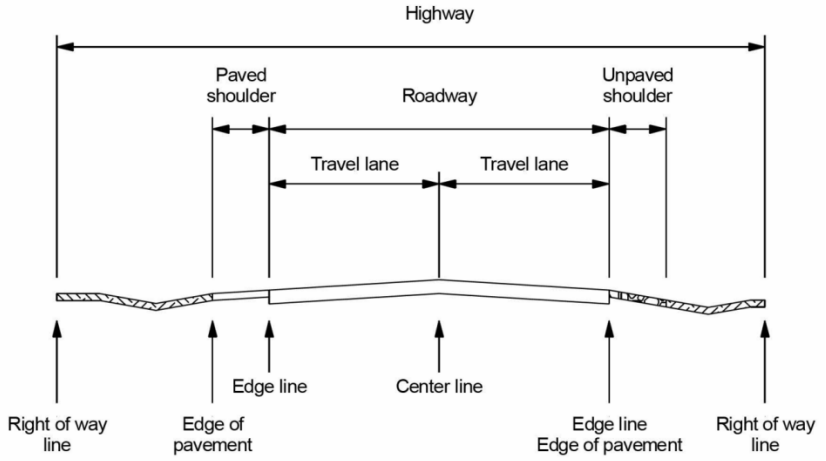
c. Combination of straight and parabolic camber

1(b). Write short notes on (a) Shoulder (b)ESWL .

Ans:-

Shoulders: Shoulders are provided along the road edge and is intended for accommodation of stopped vehicles, serve as an emergency lane for vehicles and provide lateral support for base

and surface courses. It is desirable to have a width of 4.6 m for the shoulders. A minimum width of 2.5 m is recommended for 2-lane rural highways in India.



A highway shoulder serves several functions:

1. It serves as a lateral support to the highway pavement.
2. It provides a means of protecting the highway surface from the intrusion of water, one of the great destroyers of our highways.
3. It serves as a safety feature by providing refuge room off the highway pavement surface for disabled vehicles and in emergencies for vehicles to avoid head on collisions by oncoming vehicles out of control.
4. It provides a partial storage area for snow which we must remove from the pavement to provide the traveling public with an acceptable pavement at all times.

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 ESWL is given by:

$$\log_{10} ESWL = \log_{10} P + \frac{0.301 \log_{10}\left(\frac{z}{d/2}\right)}{\log_{10}\left(\frac{2S}{d/2}\right)}$$

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, and z is the desired depth.

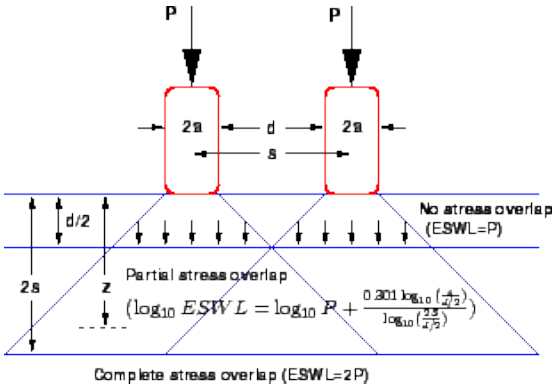
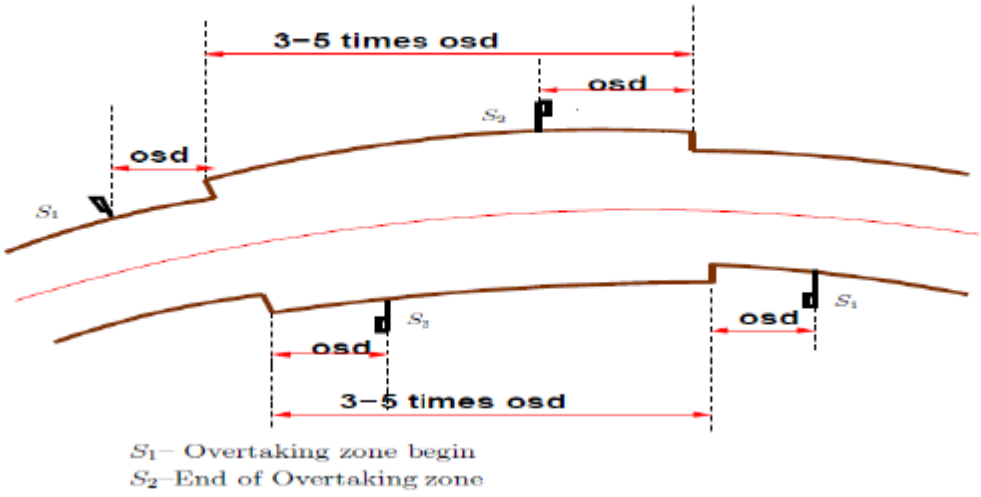


Figure: ESWL-Equal stress concept

1(C). The speeds of overtaking and overtaken vehicles are 100 kmph and 84 kmph respectively. If the acceleration of overtaking vehicle is 3.6 kmPH/SEC. Calculate the safe OSD. Draw a neat sketch of overtaking zone, indicating the necessary data.

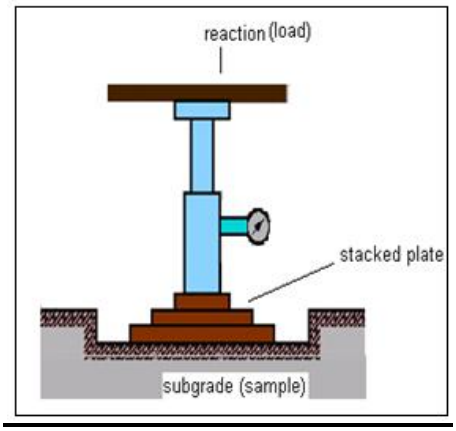
Ans:-



OSD for 2 way traffic= d1 +d2+d3
V= 100 Kmph =27.77 m/s ; v_b = 84/3.6 = 23.33 m/s ; A= 3.6 kmph/s ; t= 2 s
d1 = v_b *t = 46.66 m
d2 = v_b *T + 2S
S = 0.7*v_b + 6 = 22.331 m
T=Sq,rt((14.4*S)/A) = 9.45 s
d2 = 220.47 + 44.662 = 265.132 m
d3 = v *T = 262.426 m
OSD for 2 way traffic= d1 +d2+ d3 = 574.22 m.
OSD for 1 way traffic= d1 +d2 = 311.792 m.

2(a). Explain the step by step procedure to determine the modulus of subgrade reaction and to make corrections for variation in plate size.

Ans:-



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

A compressive stress is applied to the pavement layer through plates of large size and deflections are measured for various stress values. Prepare the test site and remove the loose material so that 75 cm diameter plate rests horizontally in full contact with the soil sub-grade. Place the plate accurately and then apply a seating load equivalent to a pressure of 0.07 kg/cm 2 and release it after few seconds. The settlement dial readings are adjusted to zero for zero load. A load is applied by means of the jack, sufficient to cause an average settlement of about 0.25 mm. When there is no perceptible increase in settlement or when the rate of settlement is less than 0.025 mm per minute, the load dial reading and the settlement dial readings are noted. The average of the three or four settlement dial readings is taken as the average settlement of the plate corresponding to the applied load. The load is increased till the average settlement increased to a further amount of about 0.25 mm and the load and the average settlement readings are noted as before. The procedure is repeated until the settlement is about 1.75 mm. A graph is plotted with the mean settlement (mm) on x axis and load (kN/m ^{2}) on y-axis. The pressure p corresponding to a settlement of 1.25 mm is obtained from the graph. The modulus of sub-grade reaction K is calculated from the relation

$$K = P/0.00125 \text{ kN/m}^2/\text{m or kN/m}^3$$

2(b). List the test on bitumen.

Ans:- The following tests are usually conducted to evaluate different properties of bituminous materials.

1. *Penetration test*
2. *Ductility test*
3. *Softening point test*
4. *Specific gravity test*
5. *Viscosity test*
6. *Flash and Fire point test*

7. *Float test*
8. *Water content test*
9. *Loss on heating test*
10. *Spot test*
11. *Solubility test*

2(C). A NH passing through a flat terrain has a horizontal curve of radius equal to the ruling minimum radius. If the design speed is 80 Kmph calculate the (i) design super elevation (ii) extra widening, and (iii) length of transition curve by making suitable assumptions.

Ans:- Given: Radius of curve, R = 360 m, Design speed, V = 80 kmph.
Assuming: Length of wheel base(l) = 6.0 m , Pavement width, W= 10.5 m, rate of introduction of super elevation = 1 in 100.

(i) **Super elevation rate**, **e**

From practical considerations of mixed traffic conditions, super elevation to fully counteract centrifugal force should be designed with 75% of design speed**.**

$E=V^2/225R=80^2/225*360 =0.08$

As this value is greater than 0.07, it is not safe for the design speed. Therefore provide a super elevation rate, e = 0.07.

Transverse skid resistance, $f = (V^2/ 127R) -0.07 = 0.06$.

Since f < 0.15, super elevation of 0.07 is safe for the design speed.

ii) Extra widening of pavement: $We=nl^2/2r + V/9.5\sqrt{r}$

N=3 as the pavement width is 10.5m, Wheel base=6m

$We = 3 \times 6^2/2 \times 360 + 80 / 9.5\sqrt{229.06}$

$=0.15 + 0.4438= 0.235$ m

iii) Length of transition curve, Ls

a) By rate of change of centrifugal acceleration

Allowable rate of change of centrifugal acceleration C is

$C=80/75 + v = 80 / 75 +80 = 0.516$ m/sec^3

$Ls=0.0215\ V^3 / CR= 0.0215 \times 80^3/0.516 \times 229.06= 93.13$ m

b) By rate of introduction of super elevation E

Total super elevation E = B x e

Total pavement width including extra widening on curve

B = W + We=10.5 + 0.235=10.735 m

E= 10.735 x 0.07 = 0.7515m

Ls = (0.7515/2)* 100 = 37.57 m.

c) IRC formula

$Ls=2.7V^2/R = 2.7 \times 80^2 /229.06 =75.43$ m.

Adopting highest of the above three values, length of transition curve Ls = 93.13 m.

3(a). Explain (i) Ruling gradient ii) Limiting gradient iii) Minimum gradient iv) Grade compensation on curve.

Ans:- Ruling gradient :-The ruling gradient or the design gradient is the maximum gradient with which the designer attempts to design the vertical profile of the road. This depends on the terrain, length of the grade, speed, pulling power of the vehicle and the presence of the horizontal curve. In flatter terrain, it may be possible to provide at gradients, but in hilly terrain it is not

economical and sometimes not possible also. IRC has recommended some values for ruling gradient for different types of terrain.

Limiting gradient :-This gradient is adopted when the ruling gradient results in enormous increase in cost of construction. On rolling terrain and hilly terrain it may be frequently necessary to adopt limiting gradient. But the length of the limiting gradient stretches should be limited and must be sandwiched by either straight roads or easier grades.

Minimum gradient :-This is important only at locations where surface drainage is important. Camber will take care of the lateral drainage. But the longitudinal drainage along the side drains requires some slope for smooth flow of water. Therefore minimum gradient is provided for drainage purpose and it depends on the rain fall, type of soil and other site conditions. A minimum of 1 in 500 may be sufficient for concrete drain and 1 in 200 for open soil drains are found to give satisfactory performance

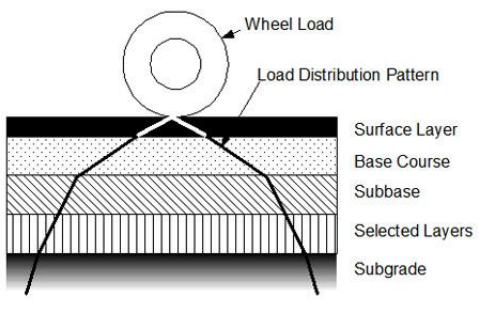
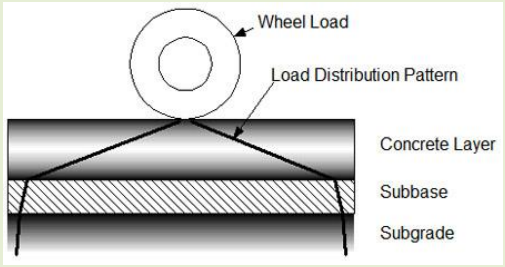
Grade compensation on curve:- While a vehicle is negotiating a horizontal curve, if there is a gradient also, then there will be increased resistance to traction due to both curve and the gradient. In such cases, the total resistance should not exceed the resistance due to gradient specified. So if a curve need to be introduced in a portion which has got the maximum permissible gradient, then some compensation should be provided so as to decrease the gradient for overcoming the tractive loss due to curve. Thus grade compensation can be defined as the reduction in gradient at the horizontal curve because of the additional tractive force required due to curve resistance ($T - T\cos\alpha$), which is intended to offset the extra tractive force involved at the curve. IRC gave the following specification for the grade compensation:

1. Grade compensation is not required for grades flatter than 4% because the loss of tractive force is negligible.
2. Grade compensation is 30+R R %, where R is the radius of the horizontal curve in meters.
3. The maximum grade compensation is limited to 75 R %.

3(b). Compare between flexible and rigid pavement.

Ans:-

	Flexible Pavement	Rigid Pavement
1.	It consists of 4 component layers with the highest quality materials at or near the surface of pavement.	It consists of 3 component layers
2.	It reflects the deformations of subgrade and subsequent layers on the surface.	It is able to bridge over localized failures and area of inadequate support.
3.	Possess low flexural strength	Possess high flexural strength
4.	Pavement design is greatly influenced by the subgrade strength.	Minimum imperfections or weak spots below the slab is taken care by the slab itself.

5.	Design is based on CBR value	Design is based on modulus of subgrade reaction.
6.	Design life is around 10-20 yrs.	Design life is around 30-40 yrs.
7.	Causes more hazardous environment due to heating of bitumen	No negative environmental effects
8.	Black in colour and hence need more lighting	Grey in colour; causes glare effect.
9.		

3(c). The load penetration values of CBR tests conducted on a soil specimen is given below. Determine the CBR value of the soil if 100 division of the load dial represents 190 Kg load in the calibration chart of the proving ring.

Penetration of the plunger, mm	0	0.5	1.0	1.5	2	2.5	3	4	5	7.5	10	12.5
Load dial readings, divisions	0	0.5	1.5	2.5	6	13	20	30	38	50	58	63

Ans:-

Solution

The penetration values are plotted against the load dial reading as shown in Fi 6.11. (Instead, the load dial readings may also be converted either to load values in k or load per unit area of cross section of the plunger in kg/cm^2 and plotted on the ' axis.)

Specimen no.2

As the curve has an initial concavity, correction is required. A tangent is drawn from the steepest portion of the curve - 2 to intersect the X-axis, which is taken as the corrected origin for this specimen. The penetration values are measured from this corrected origin, as shown in Fig. 6.11.

$$\text{CBR value at 2.5 mm penetration} = \frac{32.0 \times 190 \times 100}{100 \times 1370} = 4.4\ \%$$

$$\text{CBR value at 5.0 mm penetration} = \frac{46.5 \times 190}{2055} = 4.3\ \%$$

$$\text{CBR value of Specimen no.2} = 4.4\ \%$$