Undulate – विरलना

Values of Level of Service B, C, D and E ~~fails to~~ decrease with increase in the traffic vol. or vol. to capacity ratio as well as the operating speed of faster vehicles and their opportunities to overtake decreases.

:: Transportation Engineering – II

Section – A
Unit – I

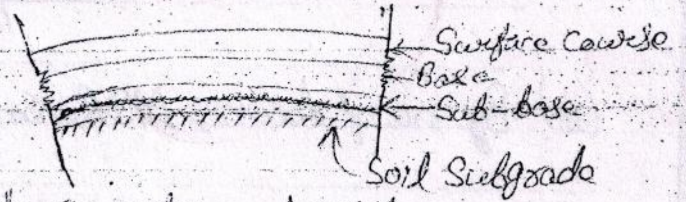
☒ Types of Pavement Structure :–

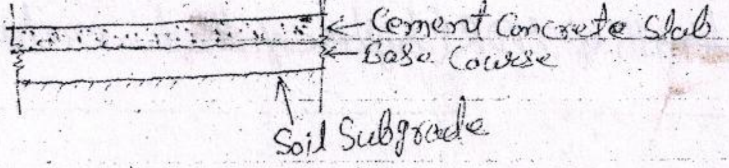
(i) Flexible Pavements; and (ii) Rigid Pavements

(i) Flexible Pavements :→

- These are those, which on the whole have low or negligible flexural strength and are rather flexible in their structural action under the loads.
- If the lower layer of the pavement or soil subgrade is ~~undul~~ undulated, the flexible pavement surface also get undulated (hinged).
- A typical flexible pavement consists of four components:

(i) Soil Subgrade (ii) Sub-base course (iii) base course (iv) Surface Course





8) The area of a certain district in India is 13400 km²; and 12 towns as per 1981 census. Determine the lengths of different catagories of roads to be provided in this district by the year 2011.

Ans :→

(i) Length of NH, Km = Total ~~length~~ area of the Country/50

$= 13400/50 = 168$ Km

(ii) Length of SH,

(a) By area, SH Km = Total length of the country/25

$= 536$ Km

(b) By area and no. of towns, SH, Km =

(62.5 X No. of towns) − (area of the state/50)

$= (62.5 \times 12) - \frac{13400}{50} = 482$ Km

Adopt length of SH (higher of two criteria) = 536 km

(iii) Length of MDR in the district

(a) By area, MDR, Km = Total area of the Country/12.5

$= \frac{13400}{12.5} = 1072$ Km

(b) By no. of towns, MDR, Km = 90 X No. of towns

$= 90 \times 12 = 1080$ Km

Provide length of MDR (higher of the two criteria) = 1080 Km

(iv) Total length of all categories of road may be assumed to provide an overall density of road length equal to 82 km per 100 km² area by the year 2001.

$$NH + SH + MDR + ODR + VR = 13400 \times \frac{82}{100} = 10988 \text{ km}$$

$$\text{Length of } NH + SH + MDR = 268 + 536 + 1080 = 1844 \text{ km}$$

∴ Total length of rural roads consisting of ODR + VR

$$= 10988 - 1844 = 9104 \text{ km}$$

(i) Primary system of NH = 268 km

(ii) Secondary system consisting of SH = 536 km and MDR = 1080, total length = 1616 km

(iii) Tertiary system of rural roads consisting of ODR and VR = 9104 km

(iv) Total length of road = 10988 km

* Cement concrete Pavement construction ⇒

Cement concrete pavement may be constructed with three different patterns :-

(i) Cement grouted layer
(ii) Rolled Concrete layer
(iii) Cement Concrete slab

(i) In cement grouted layer, mixing of aggregates is done and aggregate mix is prepared with the minimum aggregate size 18 to 25 mm. This mix is laid on the prepared subgrade or base course and is dry rolled. The loose thickness is compacted to provide 80% of the realled thickness. Grouting is prepared by mixing cement course sand and water. The proportion of cement to sand should be 1: 1½ to 1: 2½. The preparted groute is then laid on the surface and is allowed to seep through aggregate matrix

(ii) Rolled Concrete layer, concrete is prepared with the help of cement, sand, water and cement. The prepared mix is laid on the surface subgrade or base course. The loose thichness is compacted to provide

20% more than rolled thickness. Tandem rollers are recommended. The rolling Operation is done befor the final setting time. Curing is done with conventional method.

Both cement grouted layer and concrete rolled concrete layer are done only in case of base course.

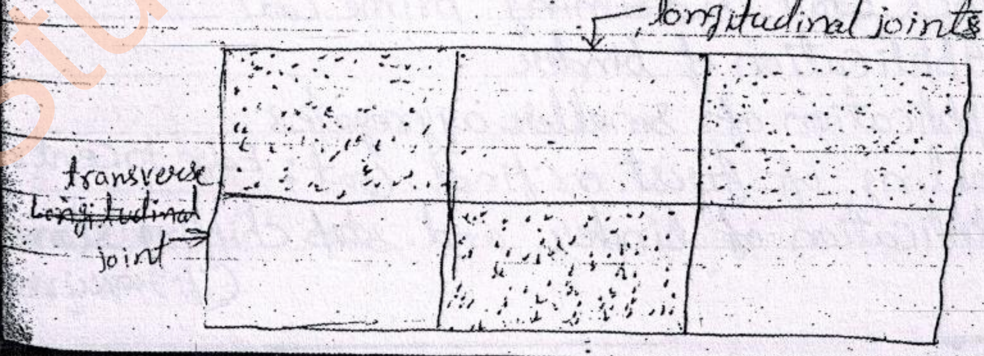
(iii) <u>Cement Concrete Slab</u> :→

This is done by two methods

(a) alternate bay method

(b) Continuous bay method

Alternate bay method is adopted where more traffic doesn't exist. It is not best method because in this method is done in a number of steps like constructing a bay or a slab in alternate succession leaving the next or intermediate bay to follow up after a gap of one week.



Drawbacks:→

(i) Large number of transverse joints are to be provided. This will result in increase of cost and unsmoothness riding surface.

(ii) During rains, water collects on the subgrades.

(iii) Construction is sprayed to full width of the road and hence traffic problems occurs.

* Bituminous Construction:→

(i) Surface ~~dessi~~ dressing
(ii) Grouted or penetration mecadam
(iii) Built-up spray grout
(iv) Bitumen bound mecadam
(v) Bituminous carpet
(vi) Bituminous concrete

Bituminous

(i) Surface dressing:–

(a) Preparation of existing surface
(b) Tack coat or ~~priming~~ prime coat
(c) Application of binder
(d) Application of smaller aggregates
(e) Rolling of first or final coat: Edge to centre
(f) Application of binder and ~~stop~~ chipping stones (if required)

—

(g) Rolling of second (if required) :- tandem roller wt. 10 tonnes
(h) Finishing and opening to traffic

(ii) Grouted or Penetration Mecadam :→
(a) Preparting of existing surface, (a') Tack coat (Prime)
(b) Spreading the coarse aggregates :-
50 mm thickness = $0.60 m^3$ per $10 m^2$
75 mm thickness = $0.90 m^3$ per $10 m^2$
(c) Rolling :- Overlap recommended 30 cm
(d) Bitumen/binder application :-
50 kg per $10 m^2$ — 50 mm thickness
68 kg per $10 m^2$ — 75 mm thickness
(e) Spreading of key aggregates :
$0.15 m^3$ per $10 m^2$ — 50 mm thickness
$0.18 m^3$ per $10 m^2$ — 75 mm thickness
(f) Seal or final coat :- if another surface is not reqd.
(g) Finishing :- By checking cross profile with template and longitudinal profile by straight edge.
(h) Opening to traffic :- After 24 hours.

Same steps are adopted for all other bituminous construction.
But decrease, coarse aggregate and key aggregates size, bitumen/binder

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* Tar :→

Tar is the viscous liquid obtained when natural organic material such as wood and coal carbonized distilled in the absence of air. Based on the material from which tar is derived, it is reffered to as wood tar or coal tar. Latter it is more widely used for road work because it is superior.

Three stages for the production of road tar are:-

(i) Carbonization of coal to produce crude tar
(ii) Refining or distillation of crude tar
(iii) Blending of distillation residue with distillate oil fraction to give the desired road tar.

There are five grades of roads tars are:
RT-1, RT-2, RT-3, RT-4 and RT-5, based on their viscosity and other properties.

RT-1 is the lowest viscosity and is used for surface painting under exceptionally cold weather as this has very low viscosity.

RT-2 is recommended for standard surface painting under normal Indian Climatic Conditions.

RT-3 may be used for surface painting, renewal coats.

RT-4 is generally used for premixing tar macadam in base course.

- For grouting purposes RT-5 may be adopted, which has the highest viscosity among the road tars.

* Bitumen:→

Crude petroleum obtained from different places are quite different in their Composition.

Bitumen is the viscous liquid obtained distillation of crude petroleum.

Three stages for the production of road bitumen are:-

(i) Carbonization of coal to produce crude petroleum

(ii) Refining or distillation of crude petroleum

(iii) Blending of distillation residue with distillate oil fraction to give the desired road bitumen.

Requirement of bitumen:-

(a) mixing

(b) to provide stability to mixing

(c) to maintain stability under ~~transverse~~ adverse weather conditions

(d) to maintain sufficient flexibility

(e) to avoid cracking of bituminous surface

(f) to have sufficient adhesion with the aggregates in the mix in presence of water

* **Adzing**:→ Adzing of sleepers is the process of cutting wooden sleepers to provide inward slope of 1 in 20 at rail seat

* **Tilting**:→ Tilting of rails is the art of placing the rails of a track at an inward slope of 1 in 20.

Remainings of Flexible Pavements

- The flexible pavement layers transmit the vertical or compressive stresses to the lower layers by grain to grain transfer through the points of contact in the granular structure.
- A well compacted granular structure consisting of strong graded agg. can transfer the compressive stresses through a wider area and thus forms a good flexible pavement layer.
- Bituminous Concrete is one of the ~~most~~ best flexible pavement layer material.
- The flexible pavement may be constructed in a no. of layers and the top layer has to be the strongest as the highest compressive stresses are to be sustained by this layer, in addition to the wear & tear due to traffic.
- The lowest layer is the prepared surface consisting of the local soil itself, called the subgrade.
- Each of the flexible pavement layers above the subgrade, viz. sub-base, base course and the surface course may consist of one or more no. of layers of the same or slightly different materials and specifications.

⊠ Rigid Pavements :→

- These are those which possess note worthy flexural strength or flexural rigidity.
- The stresses are not transferred from grain to grain to the lower layer as in the case of flexible pavement layers.
- The rigid pavements are made of portland cement concrete – either plain, reinforced or prestressed conc.
- The cement concrete pavement slab can very well serve as a wearing surface as well as effective base course.
- Providing a good base or sub-base course layer under the cement concrete slab, increases the pavement life and therefore works out more economical.

⊠ Functions of Pavement Components :→

(1) ~~Subgra~~ Soil Subgrade and its evaluation :-

- It is a layer of natural soil prepared to receive the layers of pavement material placed over it.
- The loads on the pavement are ultimately received by the soil subgrade for dispersion to the earth mass.
- It is essential that at no time, the soil subgrade is overstressed. It means that the pressure transmitted on the top of the subgrade is within the allowable limit, not to cause excessive stress condition or to deform the same beyond the elastic limit.

- It is desirable that atleast top 50 cm layer of the subgrade soil is well compacted under controlled conditions of optimum moisture content and max. dry density.
- The common strength tests for the evaluation of soil subgrade are:
  - ⇒ California bearing ratio test
  - ⇒ California Resistance value test
  - ⇒ Triaxial Compression test
  - ⇒ Plate bearing test

2) Sub-base and Base Courses and their evaluation:→

- These layers are made of broken stones bound or unbound aggregate.
- Smaller size graded agg. or soil agg. mixes or soft agg. is better to use due to interlocking property, so do not sink in the weak subgrade soil when wet.
- When the subgrade consists of fine grained soil and when the pavement carries heavy wheel loads, there is a tendency for these boulder stones or bricks to penetrate into the wet soil resulting uneven pavement surface.
- Base course and sub-base courses are used under flexible pavement primilarly to improve the load supporting capacity by distributing the load through a finite thickness.
- They have main function to provide a stress transmitting medium to spread the surface wheel loads to prevent shear and consolidation deformations.

Plate bearing, CBR or Stabilometer test are ...

3) Wearing Course and its evaluation:→

- The purpose of the wearing course is to give a smooth riding surface that is dense.
- It resists pressure exerted by tyres and take up wear and tear due to traffic.
- It also offers a water tight layer against the surface water infiltration.
- In flexible pavement normally a bitumenous surfacing is used as a wearing course.
- In rigid pavement, the cement concrete acts like a base course as well as wearing course.
- There is no test for evaluating the structural ability stability of the wearing course.
- Plate bearing test & Bankelman Beam tests are also sometimes made use of for evaluating the wearing course and the pavement as a whole.

☒ Design Factors:

★ Factors to be considered in Design of Pavements:

- Pavement design consists of two parts:-

(i) mix design of materials to be used in each pavement component layer.

(ii) thickness design of the pavement and the component layers.

The various factors to be considered for this are:
(i) Wheel load design (ii) Subgrade soil
(iii) Climatic factors (iv) Pavement component materials
(v) Environmental factors
(vi) Special factors in the design of diff. types of pavements.

- The thickness design of pavement primarily depends upon the design wheel loads. Higher wheel load need thicker pavement, provided other design factors are same.

- The properties of the soil subgrade are imp. in deciding the thickness requirement of pavements. A subgrade with lower stability requires thicker pavement to protect it from traffic loads.

- Among the climatic factors, rain-fall affects the moisture conditions in the subgrade & pavement layers. The daily and seasonal variations in temp. has signifance in the design and performance of rigid pavements and bitumenous pavements.

- The stress distribution char. of the pavement component layers depend on char. of the materials used. The fatigue behaviour of these materials and their char. durability under adverse conditions of weather should also be given due consideration.

- The environmental factors such as ht of embakment and its foundations details, depths of cutting, depth of subsurface water table etc. affect the performance of the pavement.

[*] Design of Flexible Pavements

Following are the some imp. methods:-
(i) Group index (ii) California Bearing Ratio
(iii) California Resistance Ratio Value or Stabilometer
(iv) Triaxial test (V) McLeod (Vi) Burmister

Group index — Grain Size Analysis (Plastic, limit etc)
CBR — Done (with IRC guidlines)
Triaxial — done in SM

(iii) California Resistance Value or Stabilometer Method :→

- F.M. Hveem and R.M. Carmany in 1948 provided design method based on stabilometer R-value and cohesiometer C-value.
- The stabilometer consists of a cylindrical mould which can accomodate a specimen 10 cm dia. & 6.25 cm ht. resting over a rigid metal cylinder.
- The specimen is encased in the rubber membrane which acts as an inner wall of the mould.

diagram-P.No. -324

- Fluid pressure can be applied through the membrane.
- The confining fluid pressure is applied by rotating a handle and is measured by a pressure gauge.
- The vertical pressure is applied through the loading head placed on the loading machine.

The stabilometer and Cohesionmeter value are calculated by

$$S = \frac{22.2}{\frac{P_h - D_2}{P_v - P_h} + 0.222}$$

Here,

S = Relative Stability

P_v = Vertical Pressure at 28 kg/cm² or Total load of 2268 kg

P_h = Hor. pressure corresponding to $P_v = 28\,kg/cm^2$

D_2 = Displacement on Specimen

$$C = \frac{L}{W(0.2H + 0.0176H^2)}$$

Here,

C = Cohesionmeter value

L = wt. of shots in gm

W = dia. or width of specimen (cm)

H = ht. of specimen (cm)

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The stabilometer resistance R-values is determined by placing the specimen in the stabilometer and applying the lateral and vertical pressure. The R-value of soil is calculated by:

$$R = 100 - \frac{100}{\frac{2.5}{D_2}\left(\frac{P_v}{P_h} - 1\right) + 1}$$

Here,
P_v = Ver. Pres (11.2 kg/cm²)
P_h = Hor. Pressure corr to P_v = 11.2 kg/cm²
D_2 = displacement of stabilometer fluid

al

(V) McLeod Method :→

kg/cm²

- Norman W. McLeod through Canadian Department of Transport conducted extensive plate bearing tests on airfield & highway pavements & developed a design method.
- From plate load tests

$$T = K \log_{10} \frac{P}{S}$$

Here, T = thickness reqd. of gravel base (cm)
P = gross wheel load (kg)
K = Base course constant

It is found that the base course constant K depends on the loaded area.

(vi) Burmister's (Layered System) Method :→

- Donald M. Burmister developed the layered system analysis.
- Following are the assumptions:

(i) the materials, in the pavement layers are isotropic, homogenous and elastic.

(ii) the surface layer is infinite in hor. direction and finite in vertical direction.

(iii) the layers are in continuous contact; the top layer is free of shearing and normal stresses outside the loaded area.

The displacement eqns are,

For flexible Plate, $\Delta = 1.5 \frac{pa}{E_s} . F_2$.

For rigid Plate, $\Delta = 1.18 \frac{pa}{E_p} . F_2$

For Single layer, $h = 0$, & $\frac{E_s}{E_p} = 1$, $F_2 = 1$