CE 6504 HIGHWAY ENGINEERING

UNIT I

HIGHWAY PLANNING & ALIGNMENT

## Significance of highway planning

Transportation contributes to the economic, industrial, social & cultural development of any country. It is vital for the economic development of any region since every commodity produced whether it is food, clothing, industrial products or medicines need Transport @ all stages from Production to distribution. The adequancy of transportation system of a country indicates it's economic & social development.

## Mode of Transportation

i) Roadways
ii) Railways
iii) waterways
iv) Airways

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* The transportation by air is fastest among the 4 modes. It also provide more comfort apart from saving time.

* Transportation by water is slowest. It need min energy to haul unit load through unit distance. It is possible b/w ports on searoute or along the river or canals where inland Transportation facilities are availabl.

* Road Transport can provide door to door service only by road Transport. This mode has also the max. Flexibility for travel with reference to route, direction, time & speed of Travel.

## Scope of highway Engg.

The road pavements are generally constructed on small

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embankments, slightly above the general ground level wherever possible. In order to avoid the difficult drainage & maintenance problems

Scope of Highway Engg.

| Phases | Details |
|---|---|
| Development Planning & location | Historical background, Basis for planning, Master plan, Engg surveys & highway alignment. |
| Design, geometrics & structures | Road design, Rigid & Flexible Pavements, Design Factors, thickness design, Overlay design, Design of drainage system. |
| Traffic performance & its control | Traffic Study analysis, Need for new & road links Traffic regulation control, Intersection design, their controls with signs. |

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## Necessity of Highway Planning:

1) To plan a road network for efficient & safe traffic operation, but @ min. cost. The cost of construction, maintenance & renewal of pavement layers & the vehicle operation cost are to be given due to consideration.

2) To arrive @ the road system and the length of different categories of roads which could provide max. utility & could be constructed within the available resources during the plan period under consideration

3) To fixup datewise priorities for development of road link based on utility as the main criteria for phasing the road development programme.

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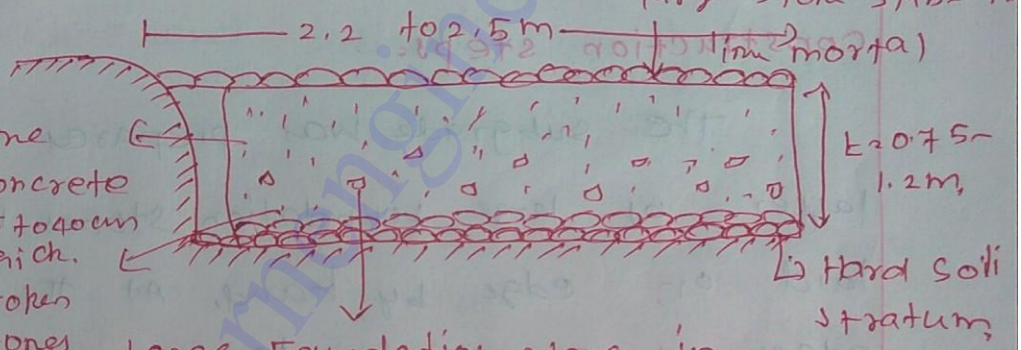
# Historical development of road construction.

## Roman roads:

During the period which many roads were built of stone blocks of considerable thickness, The appian way was built in 312 B.C extend over 580 km which illustrate the road building techniques used by Romans




They were built straight regardless of straightness

They were built after the soft soil was removed and hard stratum was reached.

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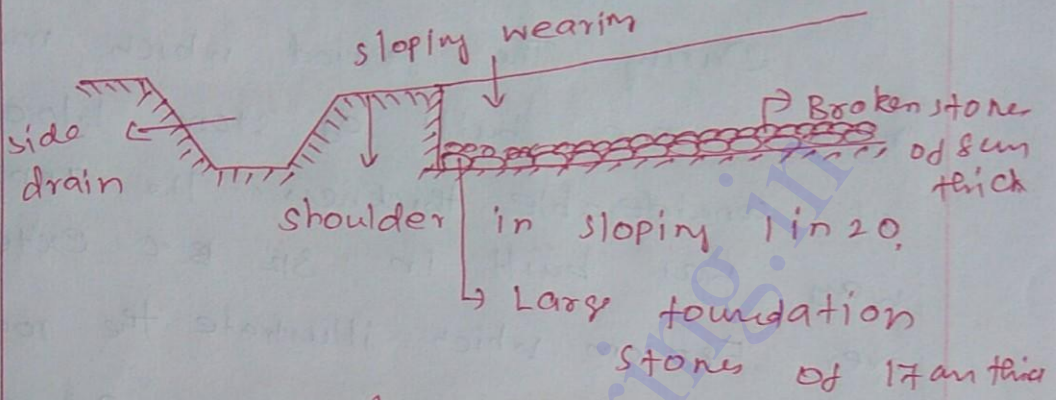
## Tresaguet construction

The thickness of construction may in the order of 30cm.




c/s.

### Construction steps:

The subgrade was prepared and a layer of large foundation stones were laid on edge by hand. At the two edges of pavements, large stones were embedded edge wise to serve as submerged kerb stones.

corners are filled with smaller stones. They were thickness of 8cm.

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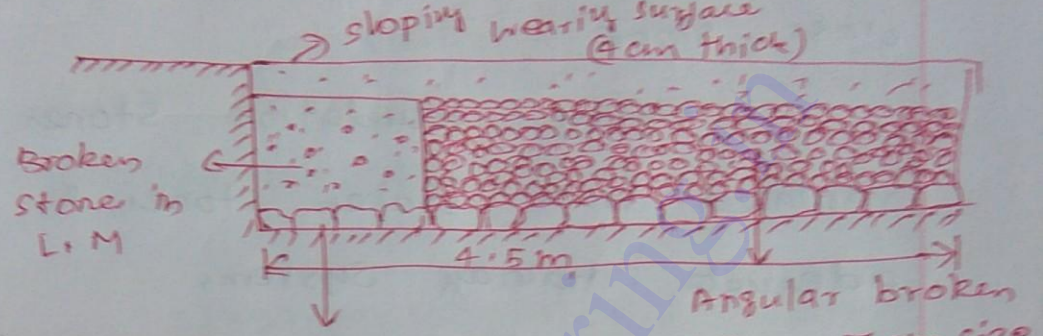
## Telford construction;

In this, heavy foundation stones used above the soil subgrade inorder to keep the road foundation firm.




* A level subgrade was prepared to design width of about 9m.
* Large Foundation stones of th 17 to 22 cm were laid with hand & with their largest face down so as to be laid in a stable position.
* The interstices are filled with smaller stone.
* The central portion was covered with 2 layers of angular section

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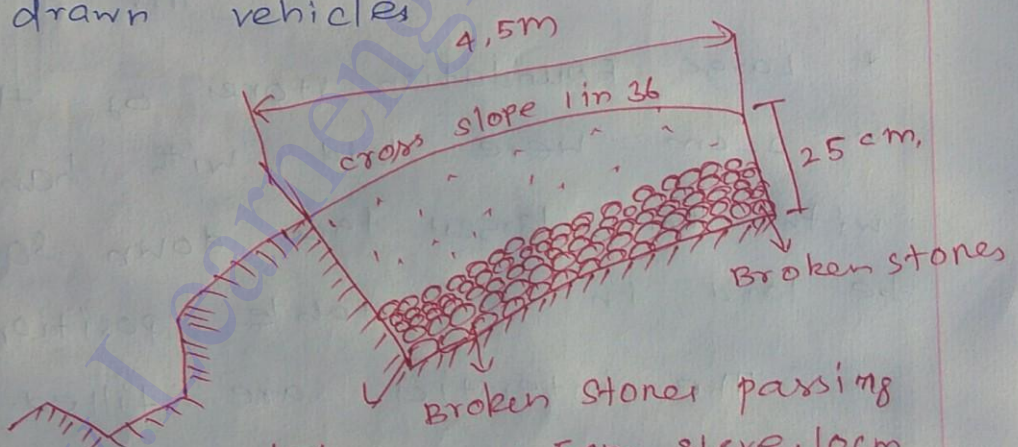
## Macadam construction:

The importance of subgrade drainage and compaction was realized subgrades were prepared with suff. cross slope

Heavy foundation stones were replaced with broken stones & with adequate drainage systems,

The thickness of 25 cm,

The size of broken stones based on the stability under animal drawn vehicles

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## History of road development in India:

Ancient period,

↓

Mughal period

↓

British period

↓

Jayakar committee

↓

IRC

↓

CRRI

## Recommendations of Jayakar committee

1) The road development in the country should be considered as a national interest as this has become beyond the capacity of State govts and local bodies

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classification of highways.

Based on

1) weather
2) Type of carriage way
3) Traffic volume
4) Load
5) Location

i) weather

a) All weather roads
b) Fair weather roads

All weather roads -

Negotiable during all weather except @ major river crossings where interruption to traffic is permissible upto a certain extent.

Fair weather roads -

Traffic may be interrupted during the monsoon season @ causeways where streams may be overflow

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Fair weather roads:

Traffic may be interrupted during the monsoon season @ causeways where streams may be over.

ii) carriageway

a) Paved roads:

If they are provided with a hard pavement course which should be atleast a water bound macadam layer.

b) Unpaved roads;

If they are not provided with a hard pavement course of atleast a WBM layer. Thus earth roads may be called uppared roads

iii) Based on pavement surfacing.

a) Surface Roads;

Provided with a block topped bituminous or cement concrete surfacing.

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b) Unsurfaced roads:

Not provided with cement concrete surfacing

iv) Traffic Volume:

a) heavy
b) Medium
c) Light traffic

} Based on vehicles per day

v) Load Transport or Tonnage:

class I
class II
:
etc

class A
class B
:
etc.,

} Tonnes per day.

vi) Location and function

a) National highways:

connecting major ports, foreign highway; capitals of states, large industrials, tourist centres.

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NH 1 - Delhi - Ambala - Amristar
NH 3 - Bombay - Agra
NH 49 - Madurai - Rameshwaram

b) State highways:

connecting national highways of adjacent state, districts & Important cities within the state.

c) Major District Roads:

Roads within district servicing areas of production & Markets and connecting those with each other or with main highways of district

d) other District Roads:

It serves rural areas of production with market centre, taluk & main roads

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(F) Village Roads:

connecting villages or groups of villages with each other to the nearest road of a higher category.

Urban roads:

i) Arterial roads - streets primarily for through traffic or continuous route

ii) Sub arterial roads - same as A.R, but they have lower level of Traffic mobility than above roads.

iii) collector streets - Provide access to arterial streets they collect & distribute traffic from & to local streets.

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## Highway alignment:

The position or the layout of the central line of highway on the ground is called alignment

Hzl Alignment:

Includes the st. path, the hzl deviations & curves.

Vtl Alignment:

changes in gradient & vtl curves are covered under alignment

### Requirements

i) short: It is desirable to have a short alignment b/w two stations

ii) Easy: It is easy to construct & maintain the road with min. problems Easy for vehicles & easy gradients

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iii) Safe; It should be safe enough for construction, Maintanance.

iv) Economical,

The total cost including initial cost, maintenance cost & vehicle operation cost is lowest

Utility of road;

↳ utility value unit length of road.

Factors controlling alignment.

a) obligatory points.

b) Traffic

c) Design

d) Economics

e) consideration

In hill roads

stability

Drainage

Geo. standards

Resisting lengths

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Engineering Survey:

Stages:

a) Map study
b) Reconnaisance
c) Preliminary survey
d) Final location & detailed survey

Map study:

a) Alignment avoiding valleys, ponds or lakes

b) When the road has to cross a row of hills possibility of crossing through mountain pass

c) Approx. location of bridge site for crossing rivers, avoid bend of river, if any

d) When a road is to connect b/w 2 stations one of the top & other on foot of hill.

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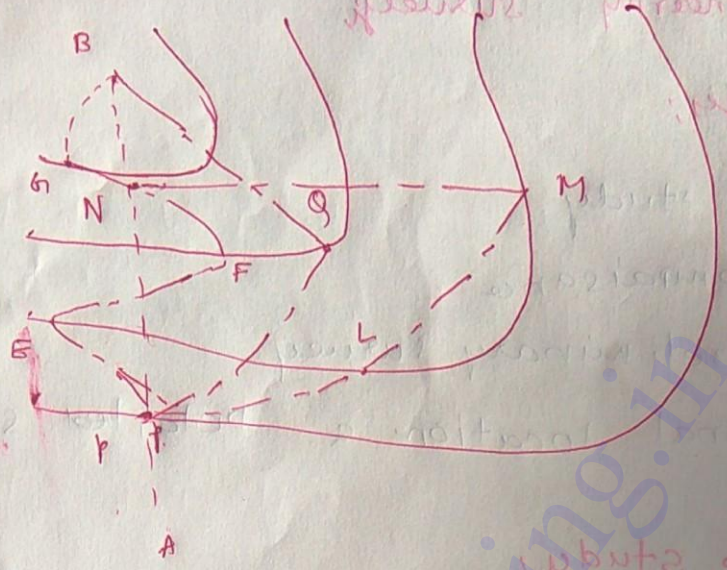


AB - Shortest route

APQB - Steeper gradient

APLMNB - Flatter "

APEFGB - Flatter Gradient

2) Reconnaisance Survey:

1) Valleys, Ponds, lakes, marshy lands, ridge, hills along the route which are not available.

2) Approx. values of gradient

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iii) No of drainage system, Max. Flood level & natural ground water level

iv) soil type along routes

v) Sources of construction material.

iii) Preliminary survey:

1) To survey alternate alignments proposed after the reconnaisance & collect all physical information & details of topography

2) compare different proposals

3) To estimate qty. of earthwork materials, cost of alternate Proposals

Methods:

A) Conventional approach

2) Modern ~~Road~~ Rapid approach

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Procedure for conventional methods

1. primary Traverse
2. Topographical Features
3. Levelling work
4. Drainage studies
5. soil survey
6. Material survey
7. Traffic survey
8. Determination of final centre line

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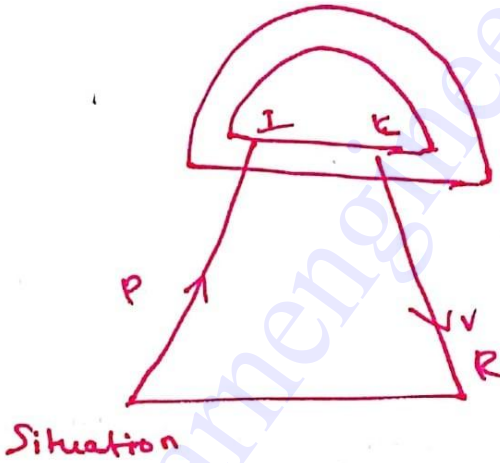
It is the time to understand the situation.

**Emotion :**

It is the time elapsed sensation & distribution such as fear, anger etc.

**Volition :**

It is the time required to take final action.




Based on PIEv theory, following are designed.

* Speed of the vehicle
* Functional resistance
* Break efficiency.

**Analysis of stopping sight distance :**

The distance travelled by the vehicle during the total reaction time is "Lag Distance".

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| Design speed (kmph) | 20-30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|
| Co-efficient of friction | 0.4 | 0.35 | 0.37 | 0.36 | 0.36 | 0.35 | 0.35 | 0.35 |

Pbm: Calculate the sabe stopping sight distance. Design Speed is 50 kmph.

i) Two way trabbic on two lane road.

ii) Two way trabbic on siggle lane road.

Soh:

SSSD = lag distance + Break distance.

$= Vt + V^2/2gf$.

Where V – Design speed

t – time

g – gravity

f – co-efficient of friction

t – 2.55 (from IRC code)

$SSSD = \left(50 \times \frac{1000}{3600} \times 2.5\right) + \left(\frac{50 \times 1000}{3600}\right)^2 = 67.49 m$

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Pbm 2 Calculate the minimum sight distance required to avoid a head on collision of two cars approaching from the opposite sides at 90km/hr other 60kmph Assume a reaction time of 2.5s, co-efficient of friction 0.7. Break efficiency of 50%.

Soln:

Speed of the vehicle $= \frac{90 \times 1000}{3600} = 25 m/s.$

$= \frac{60 \times 1000}{3600} = 16.67 m/s.$

co. efficient of friction $= 0.7 \times 50\% = 0.35$

$SSD = Vt + V^2/2gf.$

for 90kmph

$= (25 \times 2.5) + (25^2/2 \times 9.81 \times 0.35) = 153.515 m.$

for 60kmph $= (16.67 \times 2.5) + (16.67^2/2 \times 9.81 \times 0.35) = 82.142 m.$

Minimum sight distance $= 153.515 + 82.142$

$= 235.66 m.$

Incase of gradient surface. $SSD = Vt + V^2/2g(f \pm \eta\%)$

Where $\eta$ = Inclined or declined the breaking distance increases.

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Calculate the stopping sight distance on a highway at a declined gradient of 2% for the design speed 80kmph. Assume other data as IRC Recommendation

Soln:

$$V = 80 \times \frac{1000}{3600} = 22.22 \text{ m/s}$$

$$SSD = V_t + \frac{V^2}{2g(f - n\%)}$$

$$= 22.25 \times 2.5 + \left(\frac{22.22^2}{2 \times 9.81 (0.35 - 2\%)}\right)$$

$$= 131.806 \text{ m}$$

$\therefore SSD = 131.806 \text{ m}$.

Over taking Sight Distance : (OSD):

It may not be possible to provide facility for overtaking slow vehicles throughout length of road. In such cases should be made possible to frequent distance, interval, for overtaking slow vehicles.

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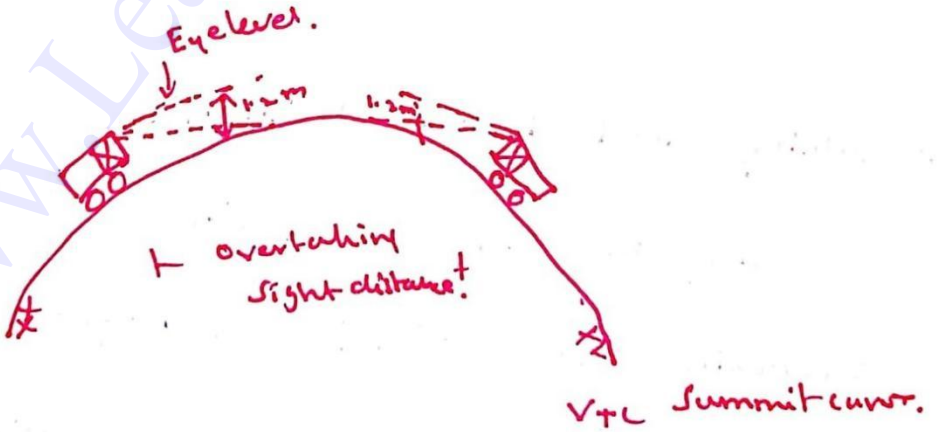
## Minimum overtaking sight Distance (OSD) or Safe passing sight Distance:

The minimum distance open to the vision of driver of a vehicle intending to overtake slow vehicles ahead with safety against the traffic of opposite direction is known as OSD.

The overtaking sight distance (OSD) is the difference measured along the centre of road. which a driver with his eyelevel 1.2m above the road. Surface can see the top of an objects 1.2m above the road surface.

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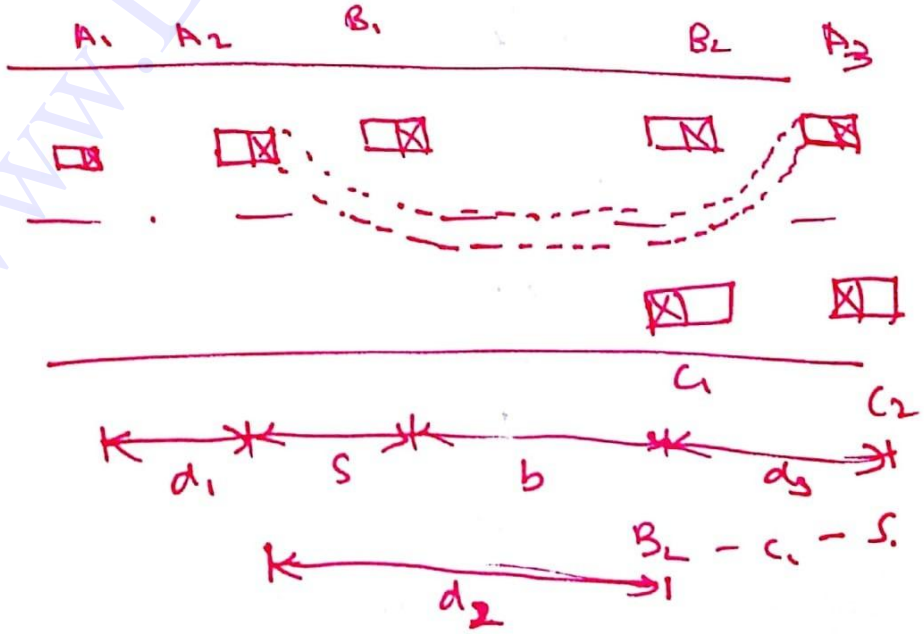
Some of the important factors on which the minimum overtaking sight distance required for the safe overtaking manoeuvre depends.

a) Speed of i) Overtaking Distance
ii) Overtaken Vehicle
iii) The vehicle coming from opposite direction, if any.

Analysis of overtaking sight Distance :

Let vehicle A travelling at design speed, another slow vehicle B, is comes from the opposite direction.

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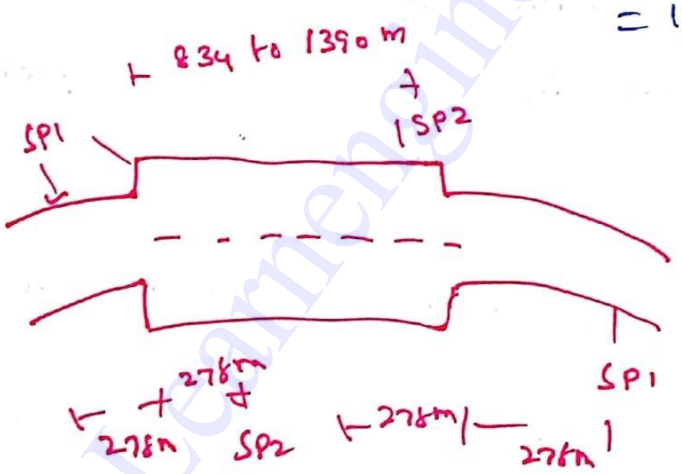
$d_3 = V.T = 14.4 \times 7.47 = 144.9 m.$

$OSD = d_1 + d_2 + d_3 = 277.6 \simeq 278 m.$

b. Minimum length of overtaking zone $= 3(OSD)$
$= 3 \times 278$
$= 834 m.$

c) Desirable length of overtaking zone $= 5(OSD)$
$= 5(278)$
$= 1390 m.$




SP1 - Sign Post 'overtaking Zone ahead'

SP2 - Sign post "End of overtaking zone"

Prbm 5 Calculate the safe overtaking sight distance for a design speed of 96kmph. Assume all the other data suitably.

$OSD = d_1 + d_2$ for one way traffic

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If $V_B$ is not given then $V_B = (V - 16)$ km/hr $= (V - 4.5)$ m/s

Minimum length of overtaking zone = 3 × OSD

Desirable length of overtaking zone = 5 × OSD.

Pbm 4 : The speed of overtaking & overtaken vehicles are 70 & 40 kmph. respectively. on a two way traffic road. If the acceleration of overtaking vehicle is 0.99 m/s². a) calculate safe overtaking sight Distance.

b) Mention the min. length of overtaking zone.

c) Draw Overtaking zone & show position of the sign

Soln :

a) Overtaking sight distance for two way traffic. $= d_1 + d_2 = d$

Assume the design speed as the speed of overtaking

Vehicle A, $V = 70$ kmph. $= 70/3.6 = 19.4$ m/s.

$$V_b = 40/3.6 = 11.1 \text{ m/s.}$$

$$d_1 = V_b \times t \text{ (adopt } t = 2s) = 11.1 \times 2 = 22.2 \text{ m.}$$

$$d_2 = V_B \cdot T + 2s.$$

$$s = (0.7V_b + b) = (0.7 \times 11.1 + 6) = 13.8 \text{ m}$$

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... by overtaking vehicle A during the reaction time 't' sec of the driver from position $A_1$ to $A_2$.

$d_2$ is the distance travelled by vehicle A from $A_2$ to $A_3$ during the actual overtaking operation in time 'T' sec.

$d_3$ is the distance travelled by on-coming vehicle 'C' from $C_1$ to $C_2$ during the overtaking operation of 'A'.

Steps:

$$d_1 = V_b \cdot t$$

$$s = (0.7\, V_b + b)$$

$$d_2 = b + 2s$$

$$b = V_b \times T$$

$$T = \sqrt{4s/a}$$

$$d_3 = V \times T$$

$$OSD = (d_1 + d_2 + d_3)$$

Where

$V_b$ - Overtaken vehicle with uniform speed.

b

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Assume $V_b = V - 16 = 80$ kmph.

$d_1 = 0.28 V_b t = 0.28 \times 80 \times 2 = 44.8$ m.

$d_2 = 0.28 V_B T + 2s$

$s = (0.2 V_b + b) = 0.2 \times 80 + 6 = 22$ m.

$T = \sqrt{\frac{14.45}{A}}$

$A = 2.5$ kmph/sec from 4.2 table.

$T = \sqrt{\frac{14.4 \times 22}{2.5}} = 11.33$

$d_2 = 0.28 \times 80 \times 11.3 + 2 \times 22 = 297$ m

$d_3 = 0.28 VT = 0.28 \times 96 \times 11.3 = 303.7$ m.

OSD on one way traffic road $= d_1 + d_2 = 342$ m

OSD on two way traffic road $= d_1 + d_2 + d_3 = 646$ m.

## Design of Horizontal Alignment

Various design factors to be considered in the horizontal alignment are design speed, radius of curve, length of curve, super elevation and widening of pavement on curve.

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Improper design of horizontal alignment, road would necessitate speed changes, increasing operation cost & higher accident rate.

## Design Speed:

It depends on the class of road, terrain,

- Plain terrain
- Rolling terrain
- Steep terrain
- Mountainous terrain

For eg. The design speed for the national & state highways of our country passing through a plain terrain is 100kmph & through rolling terrain.

## Horizontal curve:

It is a curve in plain to provide changes in direction to the centre-line of road. Vehicle traverse the horizontal curve centrifugal force act horizontally, outwards through the c.g of the vehicle.

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to given radium beyond which super elevation is not required in table 4.9 S.K khanna.

## Design of Super elevation:

For the practical consideration, it is suggested that the S.E should be provided to fully counteract the centrifugal force due to 75% of design speed.

S/1: S.E for 75% design speed $e = \frac{75}{100} \times \frac{V^2}{127R}$

S/2: If e value exceeds 0.07 that the max. super elevation is equal to 0.07 practised with S3 & S4

S/3: Check the co-efficient of friction for values $e = 0.07$

$$e + f = \frac{V^2}{127R}$$
$$0.07$$

$$f = \frac{V^2}{127R} - 0.07$$

If this $f$ is $< 0.15$ it is safe.

If not, then calculate allowable speed.

S/4: The allowable speed at curve, then

$$0.07 + 0.15 = \frac{V^2}{127R}$$

$$V = \sqrt{27.94R}$$

Pbm 1: The design speed of a highway is 80kmph. Where is a hzl curve of radius 200m. Calculate the super elevation

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V - Speed ; g = Gravity.

Problem b The radius of the hzl curve is 100m, The design speed is 50kmph. Design co-efficient of friction is 0.15. Calculate. i) Super elevation required in lateral friction ii) Find co. eff. of friction if no super elevation provided iii) Calculate Super elevation if the pressure on inner & outer should be equal.

Soln:

$$e+f = \frac{V^2}{127R} \qquad R = 100\ m\ ;\ V = 50\times\frac{10}{36}$$

$$e = \frac{V^2}{127R} - f = \frac{\left(\frac{50\times10}{36}\right)^2}{127\times100} = 0.15$$

$$= 1 : 21.4$$

ii) Without Super elevation:

$$0+f = V^2/gR$$

$$f = 0.197$$

iii) friction is zero

$$e+0 = V^2/gR = 0.197 = 1 \text{ in } 5$$

It is impossible without Super elevation.

Maximum Super elevation:

As per IRC, in plain & rolling terrain & in snow bounded area 7%. taking such mix traffic & hill road 10%.

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$V = 80 \times \frac{16}{36} =$

$R = 200m$

$e = 0.75 \times \frac{V^2}{127R} = 0.18 > 0.07$

$e = 0.07$

$f = \frac{V^2}{127R} - 0.07 = 0.1$

$0.07 + 0.15 = \frac{V^2}{127R}$

$V = 74.75$ kmph.

Max. speed to drive is 74.75 kmph. It is safe.

## Widening of Pavement :

On hel curve, when they are not in very large radius, it is common to widen the pavement fo the following reason.

i) During the turning of vehicle, rear wheel doesn't follow the same path of the front wheel. This is called as Tracking.

ii) For greater visibility.

iii) During high speed, when super elevation is develop are not able to counteract CF force, slidding occur.

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W = Wt of vehicle

V = Speed of vehicle

g - gravity of vehicle

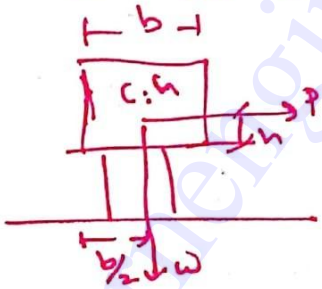
R - Radius of curve.

It has two effects.

i) overturning effect

ii) Skidding effect

To avoid the overturning and lateral skidding on a hzl curve, the centrifugal ratio (P/W) should always less than b/2h and f is co-efficient of friction.




**Super elevation:**

In order to counteract the effect of centrifugal force and to reduce the tendency of the vehicle to skid (or) overturn the outeredge of the pavement is raised.

w.r.t the inner edge the inclination to the pavement surface is known as superelevation.

$$e+f = \frac{V^2}{127R} \text{ kmph}$$

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UNIT III

# DESIGN OF HIGHWAY PAVEMENTS

Obje

Design Principles - Pavement components and their role - Design practice for flexible and rigid pavements (IRC Methods only) - Embankments.

Objectives :

In order to provide a stable and even surface for the traffic, the roadway is provided with a suitably designed and constructed pavement structure.

Thus a pavement consist of a few layers of pavement material is constructed over a prepared soil - sub grade to serve as a carriage way.

The pavement carries a wheel loads and transfer the load stressed through a wider area on the soil subgrade below. Thus the stresses transferred to sub grade soil through the pavement layers are considerably lower than Contact pressure or compressive stresses under the wheel load on pavement surface.

The reduction in the wheel load stress due to the pavement depends both on its thickness and characteristics of pavement

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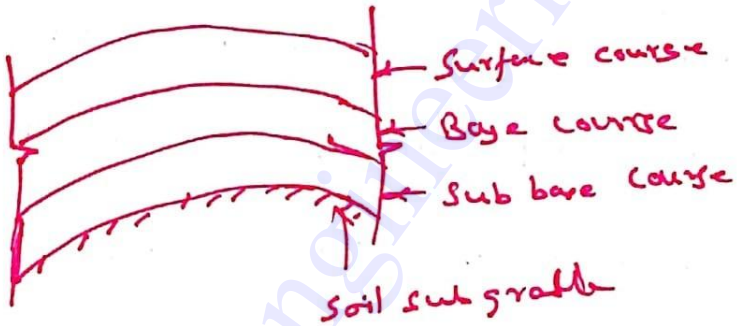
the elastic deformation of pavement within the permissible limits so that the pavement can sustain a large number of repeated load applications during the design life.

## Type of Pavement Structure :

i. Flexible pavements
ii. Rigid pavements.

## Flexible Pavements :




Design of flexible pavement is based on the principle that the wheel loads of vehicle are dissipated to the natural soil through successive layers of granular material

The intensity of load decreases with depth as the area of dissipation is increased. Hence the layer quality of material is placed at top.

The strength of the subgrade decides the thick of flexible pavements.

WBM roads, stabilised roads, earth roads, gravel roads, etc consist of layers of road making materials composed to form an ' under flexible pavement

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## Components of Pavement: Subgrade:

### Subgrade:

It is defined as the supporting structure on which the pavement surface and its special undercourses rest.

Main function is to provide sufficient support to the pavement.

Subgrade should posses sufficient stability under adverse climate & loading conditions.

### Sub base:

Economy is the prime factor to be considered in the design of Subbase course. It is generally recommend to use locally available material for Sub-base.

The main purpose is to permit the construction of pavement at low cost.

Objective:

i. To add to the structural support for the over laying layers (ie) base & surface courses.

ii) To improve drainage.

iii) To reduce frost heave in cold weather conditions.

### Base course:

It is provided under the wearing course or pavement. They have to satisfy the following requirements.

i) Thickness should be adequate to distribute the heavy wheel load pressure gradually to the subgrade through a Sub base.

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ii) Should have ... sufficient structural stability so as to resist the vertical pressures & shear stresses due to moving vehicles.

iii) Should have enough resistance to weatherity

iv) Should be compacted well to have sufficient density

## Wearing or Surface course:

This course comes into contact with the wheels of vehicles.

The main purpose is to resist the pressure exerted by the tyres and to be smooth, so that the vehicles will have large mileage & less wear & tear for tyres.

It serves as water-resistant membrane not allowing the surface water getting into the bay & not allowing the capillary water to pass through the wearing course.

Bituminous materials – Surfacing in a flexible pavements

Cement concrete layer act as wearing surface.

## Overlays:

If the pavement surface is deteriorated due to age or otherwise or it is intended to increase the traffic or allow heavy vehicles, it is necessary to strengthen the pavement surface.

Strengthening is done by providing additional thickness of pavement in one or more layers over the existing pavement.

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Rigid

The design of rigid pavement is based on the strength of the structural slab which tends to distribute the load over a wide area of soil.

The pavement slab is of portland cement concrete which has high rigidity resists the deformation of surface.

## Semi - Rigid pavement:

Cement grouted, lean cement concrete, soil cement pavement etc may fall under this group.

## Design factors:

The various factors to be considered for the design of pavements are given below.

i) Design wheel load
ii. Subgrade soil
iii. Climatic factors
iv. Pavement component materials
v. Environmental factors.
vi. Special factors in the design of different type of pavements

## Design of wheel load:

Thickness of pavement depends on the design of wheel load only.

Higher Wheel load => Need Thickness pavement.

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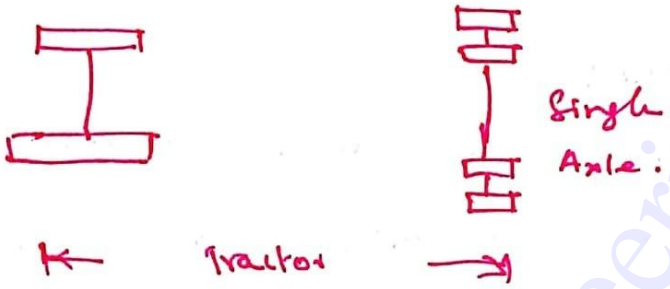
Various wheel load factors are

i. Maximum wheel load
ii. Contact pressure
iii) Dual or multiple wheel loads & ESWL
iv. Repertation of loads.

## Maximum wheel load




For highways, the maximum legal axle load as specified by IRC is 8170 kg with a max. equivalent single wheel load of 4085 kg.

Total load ~ Influences Tk of pavement.

Type pressures ~ Influences quality & surface (wearing course)

The eqn for VH stress computation under a UDL circular load based on Boussinesq's theory is given by.

$$\sigma_z = p\left[1 - \frac{z^3}{(a^2+z^2)^{3/2}}\right]$$

Where

$\sigma_z$ = VH stress at depth z

p → Surface pressure

z

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e pressure.

and less than unity for tyre pressure lighter than $7 kg/cm^2$.

R.F depends on the degree of of tension developed in the walls of tyres.

## Equivalent single wheel load:

To maintain the maximum wheel load within the specified limit and to carry greated load it is necessary to provic dual wheel assembly to the rear axles of the road vehicles

In doing, so the effect on the pavement through a dual wheel assembly is obviously not equal to 2 times the load on any one wheel. In other words, "The pressu at a certain depth, below the pavement surface cann't be obtained numerically adding the pressure caused by one wheel. The effect is in b/w the single load & two times the load carried by any one wheel.

In order to simplify, the analysis, the load dispersion is assumed to be at an angle of 45°. Let d be clear gap b/w two loads.

S be spacing b/w centres of wheels

a be radius of circular contact area of each wheel.

Then $\boxed{S = d + 2a}$

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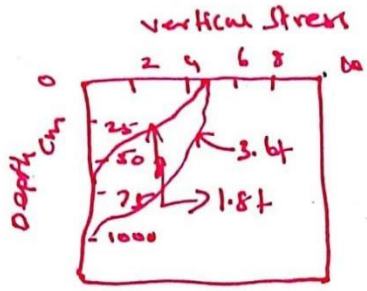
## Contact Pressure :




Influence of tyre pressure is pre-dominatly in the upper layers.

Tyre pressure of high magnitudes therefor demand high quality of materials in upper layers in pavements.

Sample :

The stresses on the pavement surface, under the steel tyred wheels of bullock carts are very high.

This demands use of very strong & hard aggregate for the wearing surface of the pavement.

Generally the wheel load is assumed to be distributed over a circular area.

Important terms are
- Tyre pressure
- Inflation pressure
- Contact pressure

Contact Pressure = load on wheel / Contact area or Area of Imprint

The ratio of the contact pressure to tyre pressure is defined as **Rigidity factor.**

Value of R.F is 1.0 for an avg tyre pressure of 7 kg/cm².

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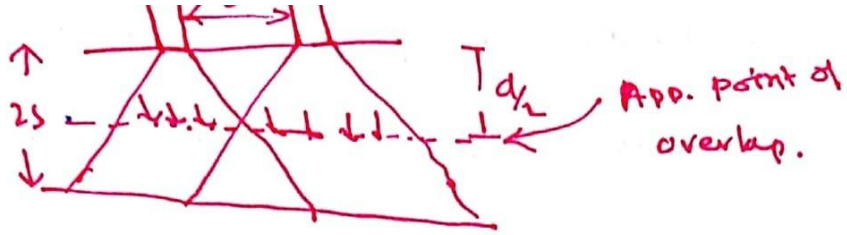


Stress overlap due to Dual wheels.

Upto the depth of $d/2$ each wheel load 'P' acts independently abd after this point, the stresses included due to each load begins to overlap. At depth 2s, and above the stresses induced are due to effect of both wheels as the area of overlap is considerable.

So, the total stresses due to dual wheels at any depth greater than 2s is considered to be equivalent to a single wheel load of magnitude 2P.

**Pbm:** Calculate ESWL of a dual wheel assembly carrying 2044 kg each for pavement thickness of 15, 20, 25 cms. Centre-Centre tyre spacing = 27cm and Distance b/w the walls of tyres is 11cm.

Soln:

here $P = 2044$ kg

$2P = 4088$ kg

$d = 11$ cm

$s = 27$ cm.

~~here P = 2044~~ x & y points are plotted on a log-graph

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Y has co-ordinates (24, 25) = (4088, 54)

| Pavement Thickness (cm) | ESWL (kg) |
|---|---|
| 15 | 2760 |
| 20 | 3000 |
| 25 | 3230. |

## Repition of loads

The deformation of pavement or subgrade due to a single application of wheel load may be small. But due to repeated application of load there would be increased magnitude of plastic and elastic deformations.

Equivalent load factors are employed to convert daily traffic count for each category of wheel load for design purposes.

## Strength characteristics of pavement layers.

1. California Bearing Ratio (CBR) value
2. Elastic module.

## California Bearing Ratio :

The strength values so obtained for the materials tested are of relative significance and do not provide as absolute measure. These are design methods which employ the CBR strength value of materials used differently

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Depending upon, the design methods, the elastic modulus of different pavement materials are evaluated

Determined by i) Plate bearing test
ii) Triaxial compression test

The elastic module values of the following are determined by plate bearing tests.

1. Sub grade modulus.
2. Elastic moduli of base course & sub base course materials.

The max. VH deflection $\Delta$ at the surface and the centre of a flexible plate is given by.

Boussinesq's eqn. $$\Delta = \frac{1.5\, p\, a}{E \cdot S}$$

here p - Uniform pressure on the flexible loaded plate of radius a.

Es - Modulus of elasticity of soil.

for rigid plates $$\Delta = \frac{1.8\, Pa}{Es}$$

Burmister's Analysis

$$\Delta = 1.5 \frac{Pa}{E \cdot S} \cdot F_2 \quad \text{(for flexible plates)}$$

$$\Delta = 1.8 \frac{Pa}{Es} \cdot F_2 \quad \text{(For rigid plate)}$$

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i. Variation in moisture condition

ii. Frost action

iii. Variation in temperature.

Variation in moisture condition:

→ Pavement performace is very much affected, because of variation in stability and the volume of sub grade soil.

The surface water during rains may enter the sub grade either through pavement edges or through the pavement itself.

As moisture content of subgrade below the centre is often different from that at pavement edges, there can be differential rise or fall of pavement edges w.r. Centre due to swelling & shrinkage of subgrade soil.

It leads to considerable damages to the pavements and will also be progressive & culative.

Frost action:

It refers to adverse effective due to frost heave, frost melting or thaw & alternate cycles of freezing and thawing

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The freezing and thawing which occur alternatively due to variation in weather causes undulations & considerable damages to the pavement. Hence the overall effects due to frost heave, frost melting and alternative freeze-thaw cycles is called frost action.

Depends on factors such as:

i) Frost susceptile soil.
ii) Depressed temp. below freezing point
iii) Supply of water.
iv) Cover

## Capillary cut-off:

Way to reduce the adverse effects of frost action on pavements by stabilization

## Variation in temperature:

Temperature stresses of high magnitude are induced in cement concrete pavement due to daily variation in temp. & consequent warping of pavement

Bituminous pavement becomes soft in hot weather and brittle in very cold weather.

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# Design of Flexible pavements :

3 Approaches

- Empirical method
  - Group index mtd.
  - CBR mtd
  - Stabilometer
  - Mc leod method
- Semi-Empirical mtd
  - Burmister mtd
  - Triaxial mtd.
- Theoritical mtd.

## IRC Recommendations - CBR Test.

1. Performed in laboratory only
2. Compaction done by proctor compaction test
3. Top 50cm of sub grade should be compacted atleast upto 95% to 100% of proctor density.
4. $A = P(1+r)^{n+10}$.

Where P → No. of heavy vehicle/day. at last count

A → No of heavy vehicles per/ day.

r → Annual rate of increase of heavy vehicles

n → No of years b/w last count & year of completion of action.

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Pbm: 3 The CBR value of sub grade soil is 5%. Calculate the total Ht of pavement using.

i) Design curve developed by California State Hw dept.

ii) Design chart recommended by IRC

iii) Use US Corps of Engineers.

Assume 4100 kg wheel load for medium light traffic of 200 commercial vehicles per day for design.

Type pressure - 6kg/cm².

Soln:

i) Using design Chart of California State highway Dept, the pavement Ht for 4100 kg wheel load and CBR = 5% = 35

ii) Using design chart recommended by IRC for 200 commercial vehicles per day and using curve D and for CBR values = 5%.

The thickness = 5cm.

(ii) Using Design formula:

$$t = \sqrt{P}\left[\frac{1.75}{CBR} - \frac{1}{p\pi}\right]^{1/2}$$

$P = 4100\ kg$

$p = 6\ kg/cm^2$.

$$t = \sqrt{4100}\left[\frac{1.75}{5} - \frac{1}{6\pi}\right]^{1/2} = 35.5\ cm.$$

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## Design Procedure:

In this design method, it is required to provide, a pavement section, which satisfies

1. Resistance value of subgrade, (R-value)
2. Expansion Pressure.
3. Exudation pressure.

## Design steps:

1. The pavement thickness values required as per the R-values of sub-grade soil at different moisture content are calculated (Say $T_{r1}$, $T_{r2}$ ...) Here, pavement may first be assumed to consists of single base course layer of known c-value $C_g$.

2. Pavement thickness fulfilling both R-values and expansion pressure are found by dividing the expansion pressure by avg. density of pavement which may assumed as about 2.1 g/cm³. The pavement th value (Say $t_{e1}$, ...) as per expansion pressure at different moisture contents are calculated.

3. Pavement thickness fulfilling both R-values & expansion Pressure is found by plotting Tr values against corresponding Te values. From above ① & ② to the same scale, and by drawing 45° line.

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4. The exudation pressure of sub-grade soil found at various compactive moisture contents are plotted against pavement thickness found from (1) above based on corresponding R values. The pavement thickness corresponding to an exudation pressure of 21 kg/cm². is obtained from this graph.

5. Pavement thickness as per california design method is the higher the values determined in 3 & 4 above

6. The thickness of the pavement length are decided & equivalent values of base course thickness replaced calculated using co-hesiometer values of materials.

## Design of Rigid Pavements:

Wesier guard's modulus of subgrade reaction:

$$k = \frac{P}{\Delta}$$

$$i.e = \frac{P}{0.125} \text{ kg/cm}^3.$$

Relative stiffness of slab to subgrade.

$$l = \left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4}$$

here $l$ = ratio of relative stiffness

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h - thickness of slab.

k - Subgrade modulus kg/cm³.

Prob 4 Compute radius of relative stiffness of 15cm th Cement concrete slab from following data.

$$l = \left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4}$$

$\mu = 0.13$

$E = 2,10,000 kg/cm^2$.

$k \rightarrow 3 kg/cm^3$

$7.5 kg/cm^3$.

i) For $k = 3 kg/cm^3$.

$$l = \left[\frac{210000 \times 15^3}{12 \times 3(1-0.15^2)}\right]^{1/4}$$

$= 67.0$ cm.

ii) For $k = 7.5 kg/cm^3$

$$l = \left(\frac{210000 \times 15^3}{12 \times 3(1-0.15^2)}\right)^{1/4}$$

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Spacing of Expansion Joint.

$$l_c = \frac{\delta'}{100\,c(T_2 - T_1)}$$

$\delta'$ = Max. expansion in slab

$T_1$ & $T_2$ → Temprature.

$c$ → Spacing b/w contraction Joints, m.

$h$ → Slab tk.

$f$ → Co-efficient of friction (max. ≈ 1.5)

$w$ → Unit wt of cement conc. kg/m³ (2400 kg/m³)

$f_c$ → Allowable stress in tension in cement concrete kg/cm². (0.5 kg/cm²)

Spacing of Joints when $A_s$ provided.

$$l_c \rightarrow \frac{200\, S_s\, A_s}{b\, h\, W_f}$$

Where $A_s$ - Total area of steel, cm².

$b$ - Slab width

$h$ - Slab thickness

$S_s$ - Allowable Tensile stress in steel, kg/cm².

1400.

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Design of Dowel bars :

$$L_d = 5d \left[ \frac{F_f}{F_b} \times \frac{L_d + 1.5\delta}{L_d + 8.8\delta} \right]^{1/2}$$

$F_f$ = Permissible flextural stress in dowel bar kg/cm²

$F_b$ → Permissible bearing stress in Concrete kg/cm².

Pbm 5 Width of expansion joint gap is 2.5cm in a cement Concrete pavement. Laying temp. 10°c, max Slab temp in summer 54°c. Calculate Spacing b/w expansion Joint. Assume $\epsilon = 10 \times 10^{-6}$ per °c.

Soln :

$$\delta' = \frac{2.5}{2} = 1.25 \text{ cm}.$$

$$T_2 - T_1 = 54 - 10 = 44^\circ c.$$

$$\therefore L_e = \frac{\delta'}{100 \epsilon (T_2 - T_1)} = \frac{1.25}{100 \times 10 \times 10^{-6} \times 44} = 28.5 \text{ m}.$$

$$L_e = 28.5 \text{ m}.$$

Pbm 6 Determine Spacing b/w contraction Joints, for 3.5m Slab width having thk of 20cm & $f = 1.5$

1) For plain cement conc. $S_c = 0.8 \text{ kg/cm}^2$.

2. For Rcc 1.0 cm dia bar @ 0.3m Spacing.

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Soln.:

i) For PCC

$$L_c = \frac{2S_c}{\omega_f} \times 10^4$$

$$= \frac{2 \times 0.8 \times 10^4}{2400 \times 1.5} = 4.4\,m.$$

ii) For RCC

$$A_s = \frac{3.5 \times \pi \times 1.0^2}{0.3 \times 4} = 9.16\,cm^2.$$

$$L_c = \frac{200 \times S_c A_s}{b_h \omega_f}$$

$$= \frac{200 \times 1200 \times 9.16}{3.5 \times 20 \times 2400 \times 1.5}$$

$$= 8.72\,m$$

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# HIGHWAY CONSTRUCTION MATERIALS & PRACTICE

## HIGHWAY MATERIALS (CONSTRUCTION)

Sub-Grade materials

Coarse aggregates

Fine Aggregates.

Bitumen, Tar

Concrete Road.

## Properties of Road Aggregates

Strength

Hardness

Toughness

Durability

Shape of Aggregate

Adhesion with bitumen.

**Strength:**

Aggregate Should be capable of with-standing high stresses in addition to wear & tear.

**Hardness:**

Aggregate Should be hard enough to resist wear due to abrasive action of traffic.

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### Toughness

Aggregate should be able to resist impact produced by heavily loaded steel tyred vehicles.

### Durability

Stone used in the pavement construction should be durable and should resist disintegration due to action of weather.

### Shape of Aggregate

Too flaky and too much elongated aggregate should be avoided as far as possible in road construction.

### Adhesion with bitumen

Aggregates used in bituminous pavements should have less affinity with water, when compared with bituminous materials.

## Tests for Road Aggregates

- Crushing Test.
- Abrasion Test
- Impact Test
- Soundness Test
- Shape Test.
- Specific Gravity & Water absorption Test.
- Bitumen adhesion Test.

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# Crushing Test

## Theory & Scope

- This is one of the major mechanical properties required in a road Stone.
- The test evaluates the ability of aggregates used in road Construction, to withstand the stresses induced by moving vehicles in the form of crushing.
- With this the aggregates should be also provide sufficient resistance to crushing under the roller during Construction and under rigid tyre rims of heavily loaded animal drawn vehicles.
- The aggregate Crushing Value provides a relative measure of resistance to crushing under a gradually applied Compressive load.
- To achieve a high quality of pavement aggregate possesing low aggregate crushing value should be preferred.
- The aggregate crushing Value of coarse aggregates used for cement Concrete pavement at Surface Should not exceed 30%. and aggregates used for Concrete other than for wearing surfaces, shall n't exceed 45% as specified by Indian Standard (IS) and Indian Road Congress (IRC).

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## Compaction Equipment Detail

1. A steel cylinder of internal dia 15.2 cm (steel cylinder with open ends)
2. A square base plate, plunger having a piston dia of 15 cm
3. A cylindrical measure of internal dia of 11.5 & ht 18 cms.
4. Steel tamping rod having dia of 1.6 cm length 45 to 60 cms
5. Balance of capacity 3 kg with accuracy upto 1 gms
6. Compression Testing Machine capable of applying load of 40 tonnes at a loading rate of 4 tonnes per minute.
7. Aggregate in surface-dry condition, before testing & passing 12.5 mm sieve & retained on 10 mm sieve is selected.
8. Tamped 25 times;
9. 2.36 mm IS sieve.
10. Aggregate Crushing Value $= 100 \times \frac{W_2}{W_1}$ %

where, $W_1$ → wt of dry aggregate passing 12.5 mm IS sieve & retained on 10 mm sieve.

$W_2$ → wt of crushed material passing 2.36 mm sieve.

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## Abrasion Test

### Theory & Scope

→ Abrasion is a measure of resistance to wear or hardness.

→ It's an essential property for road aggregates especially when used in wearing Course.

→ Due to the movements of traffic, the road Stones used in the Surfacing Course are subjected to wearing actions at the top.

→ When traffic moves on the road the soil particle (sand) which comes blw the wheel & road Surface cause abrasion on the road stone.

Abrasion Test on aggregate may be Carried out by following Tests:

* Los Angeles abrasion Test
* Deval Abrasion Test
* Dorry Abrasion Test.

### Los Angeles Abrasion Test:

* The principle of los Angles abrasion test is find the percentage wear due to relative rubbing action blw aggregates & steel balls.
* Used as abrasive charge pounding action of these balls also exist while Conducting Test.



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## Construction Equipment Detail

1. Sample & Abrasion Charge (6 Spheres, 48 mm dia) in testing machine.
2. 390 - 445 gms used.
3. 5 - 10 kg Sample used ($W_1$)
4. 500 - 1000 revolutions @ 20 - 33 rpm.
5. Retained on 1.7mm Sieve, washed & dried.

Let the original weight of aggregate $= W_1$ g.

Wt of aggregate retained on 1.70 mm Is Sieve after the test $= W_2$ g.

Loss in weight due to wear $= (W_1 - W_2)$ g.

Loss Angles Abrasion Value % = Percentage wear

$$= (W_1 - W_2) / W_1 \times 100.$$

## Deval Abraion Test

This test is similar to los Angles Abrasion Test. Only the difference is abrasion Test machine.

'American Society for Testing Materials'.

Maximum Allowable los Angeles Abrasion Value of Aggregates in Different type of Pavement layers as per IRC:

- For Sub-base Course a value of 60%
- For base Course such as WBM, Bituminous Macadam.
- Built-up Spray grout base Course & etc.. value of 50%

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→ For Surface Course such as WBM, BM, Bituminous Penetration Macadam, Built-up Spray grout binder Course etc., a Value of 40%.

→ If aggregates are used in Surface Course as Bituminous Carpet, Bituminous Surface dressing, Single or two Coats, Cement Concrete Surface Coarse etc., a value of 35%.

→ Deval Abrasion test was devised to test rock fragments. It also been Standardised by ISI as a test for abrasion of Coarse aggregates.

→ In this test also both abrasion & impact take Place due to the steel balls used as abrasive Charge.

## Construction Equipment Detail

* It Consists of one or more hollow Cast iron cylinders Closed at one end & provided with iron Cover at the other end ~~& provided with iron cover at the oth~~ Capable of fitting tightly.
* The inside dia of cylinder is 20cm, Length is 34cm.
* The cylinders are mounted on a Shaft at an angle of 30° with the axis of rotation.
* Total weight 2500g is placed.
* 10,000 revolutions @ 30-33 rpm
* Retained on 1.7 mm Sieve, washed & dryed.



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Let the original wt of Sample be $W_1$ g.
Wt of material retained on 1.70mm IS Sieve after the abrasion Test $W_2$ g.

∴ Percentage wear or Deval Abrasion Value % $= \left(\frac{W_1 - W_2}{W_2}\right) 100$

## Deval Attrition Test

→ When the test is carried out by deval machine without using abrasive charges, the test is know as Deval attrition Test.

→ However, this test is n't Commonly carried out.

## Dorry Abrasion Test

Initially, it is used for testing the resistance to abrasion of cylindrical stone specimen on a rotating metal disc in presence of Sand used as abrading agent. Now, it is modified to find the abrasion Value of aggregates.

## Construction Equipment Detail:

* It consists of a flat circular iron disc of 60 cm dia, which is rotated in a hxl plane @ 28 - 30 rpm.
* Two rectangular trays are kept 26cm from the centre of disc hold the aggregate Sample in a specified manner.
* Abrasive Sand is fed through the funnel as the disc is subjected to 500 revolutions.



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(5)

## Impact Test

This test is designed to evaluate toughness of stone or resistance of the aggregates to fracture under repeated impacts

The aggregate impact value indicates a relative measure of resistance, of aggregate to impact, which has a different effect than the resistance to gradually increasing compressive stress.

## Equipment Details:

- Passing through 12.5mm & retained at 10mm.
- In cup in 3 layers, each layer compacted 25 times
- Weight of Sample in cup ($W_1$)
- 15 blows in impact test apparatus.
- Passing through 2.36 sieve ($W_2$)
- Impact value in % = $W_2 / (W_1 \times 100)$
- Aggregate Impact value < 30% for wearing course.
  < 35% for bituminous.

In. Macadam,

< 40% for WBM base course.

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## Soundness Test

* The most Common Soundness test involves repeatedly Submerging an aggregate Sample in a Saturated Solution of Sodium or magnesium Sulfate. This process causes salt Crystals to form in the aggregate pores, which Simulate ice-crystal formation.

## Equipment Detail.

→ Oven dry Sample and Separate it into Specific Sieve Sizes.

→ Immerse the Sample in a Saturated Solution of Sodium or magnesium Sulphate & let it remain at a Constant temp for 18 hrs.

→ Remove the Sample from the solution & dry to a Constant weight at 110 ± 5°C (230 ± 9°F)

→ Repeat this cycle five times

→ Wash the Sample to remove Salt; then dry.

→ Determine loss in weight for each specific Sieve Size Computs a weighted average percentage loss for the entire Sample.

→ The maximum loss values typically range from 10-20% for every 5 cycles.

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→ Other Soundness tests use relatively same procedure but substitute actual freezing & thawing in place of salt crystallization of procedure described previously. Cracks in Pcc resulting from poor aggregate freeze-thaw resistance are often called durability cracks.

## Standard Soundness Tests are:

* AASHTO $T_{104}$ & ASTM C 88: Soundness of aggregates by use of Sodium Sulphate or magnesium Sulphate.
* AASHTO $T_{103}$ : Soundness of Aggregates by freezing & Thawing.

## SHAPE TEST

- Flakiness Index
- Elongation Index.

The shape test give only a rough idea of the relative shape of aggregates. Flaky & elongated particles Should be avoided in pavement Construction, particularly in Surface course.

If such particles, are present in appreciable proportions, the Strength of pavement layer would be adversely affected due to possibility of breaking under loads. workability is reduced for Cement Concrete.



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## Flakiness Index

$= (X_1 + X_2 + \ldots) / (W_1 + W_2 + \ldots) \times 100$

It is the percentage by weight of particles whose least dimension (thickness) is less than (0.6 times) three-fifths of their mean dimension.

## Elongation Index

$= (Y_1 + Y_2 + \ldots) / (W_1 + W_2 + \ldots) \times 100$

It is the percentage by weight of particle whose greatest dimension (length) is greater than (1.8 times) nine fifths their mean dimension. This test is not applicable for sizes smaller than 6.3 mm.

## Water Absorption Test (Coarse Agg).

### Sample Procedure

1. Take sample of 2kg. Wash thoroughly. put in a jar. Fill with distilled water immersed atleast 5 cm (in wire basket immersed in a tank) & 25 times up & down to remove entrapped air. leave for 24 ± ½ hr at 22-32°C.
2. Drain water, Surface dry on clothes & in open air (not in sunlight) may be under fan after 10 minutes of drying (weight A).
3. Put in oven at 100 - 110°C for 24 plus ± ½ hr cool in air tight container (weigh B)



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Water absorption = $\frac{(A-B) \times 100}{B}$.

## Specific Gravity

Specific gravity of rocks vary from 2.6 to 2.9. Rock Specimen having more than 0.66 % water absorption are considered unsatisfactory unless found acceptable based on Strength tests.

## California Bearing Ratio (CBR) Test.

* This is a penetration test for evaluating Stability of soil sub-grade & other flexible pavement materials.
* CBR apparatus Consists of a mould 150 mm dia with a base plate and a collar, a loading frame with the cylindrical plunger of 50mm dia & dial gauges for measuring the expansion on soaking & the penetration value.
* The load values to cause 2.5mm & 5mm penetration is recorded. These loads are expressed as percentages of Standard load values at respective
* Deformation levels to obtain CBR value.



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CBR = Load at specimen 2.5 or 5mm / Load @ sustained Std agg. x100

* CBR test is essentially an arbitary strength test & hence can't be used to evaluate soil particles like cohesion, angle of internal friction. or shearing resistance.

* Material passing 20 mm Sieve is only used in Test. Field CBR Test, is carried out using site penetration Test.

CBR = Load or pressure at sustained by the specimen 2.5mm or 5 mm Penetration.

Load or pressure @ sustained by the standard aggregates @ Corresponding Penetration.

Normally, CBR value at 2.5mm penetration which is higher than that at 5.0mm is reported as the CBR Value of material.

## BITUMINOUS Materials.

1. Bituminous binders used in pavement Construction works including both bitumen and tar. Bitumen is a petroleum product obtained by distillation of petroleum crude where as road tar is obtained by destructive distillation of coal or wood.

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(8)

* Both bitumen & tar have Similar appearance, black - in colour though they have different characteristics.

* Bitumen is hydrocarbon material of either natural or pyrogenous origin. found in gaseous, liquid, semisolid or solid form & is Completely Soluble in Carbon. disulpide & in Carbon tetra chloride.

* When the bitumen Contains Some inert material or minerals, it is Sometimes called asphalt. Asphalt is found as deposit in the form of natural asphalt or rock asphalt.

* The grades of bitumen used for pavement Construction work of roads & airfields calling paving grades & those used for water proofing of structures & industrial floor called industrial Grades.

* Available bitumen in India is categoried as

A-type : Paving Bitumen from Assam petroleum Designated as A35, A90, etc.,

S-Type : Paving Bitumen from other sources Designated as S35, S90, etc.,



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## Requirements of Bitumen

The general problems while using bitumen in paving mixes are:

* Mixing
* Attainment of desired stability of mix.
* To maintain the stability under adverse weather conditions
* To maintain sufficient flexibility & thus avoid cracking of bituminous surface.
* To have sufficient adhesion with the aggregates in the mix in presence of water.

## Available Test:

1. Penetration Test
2. Ductility Test
3. Viscosity Test.
4. Float Test
5. Specific Gravity Test.
6. Softening Point Test.
7. Flash & Fire Point Test.
8. Solubility Test.
9. Spot test
10. Loss on heating Test.



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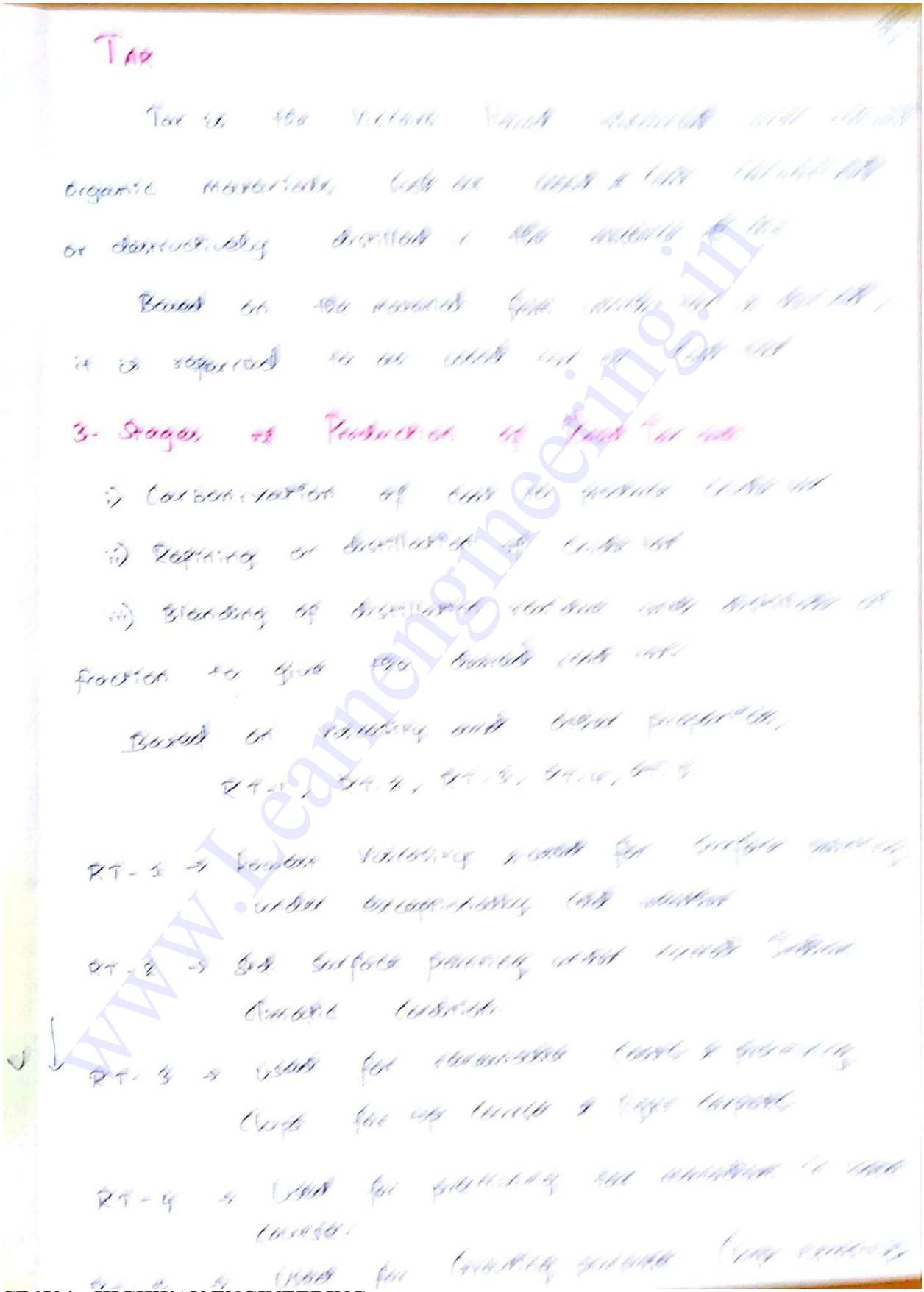



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# Comparision of Tar & Bitumen

- Bitumen & Tar have black to dark brown colour.
- But bitumen is a petroleum product, whereas tar is produced by the destructive distillation of coal or wood.
- The chemical constituents of bitumen & tar are quite different.
- Bitumen is soluble in carbon-di-sulphide & in carbon tetrachloride, but tar is soluble only in toluene.
- Tar is more temperature susceptible, resulting in a great variation in viscosity with temp Bitumen has less Temp. susceptible
- The free carbon content is more in tar as seen from the solubility test.

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## Construction Methods.

The highway types are classified as

→ Earth road & Gravel roads.

→ Soil stabilized roads

→ Water Bound Macadam (WBM) road.

→ Bituminous or black-Top roads.

→ Cement Concrete roads.

## Construction of Water Bound Macadam Road.

1. Preparation of foundation for receiving the WBM or Course.
2. Spreading of Coarse Aggregates
3. Compaction (Rolling)
4. Application of Screening
5. Sprinkling & Growing
6. Application of Binding Material.
7. Setting & Drying.

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# Construction of Bituminous Pavements

Types of bituminous Construction Techniqua

i) Interface treatments like prime coat & tack coat

ii) Surface dressing & seal coat.

iii) Grouted or penetration type Construction.

* The surface of the existing pavement layer is to be cleaned to removed dust & dirt and a thin layer of bituminous binder is to be sprayed before the construction of any type of bituminous layer over this surface.

* This treatment with bituminous material is called interface treatment which is necessary to provide the necessary bond blw the old & new layers.

* The interface treatment may either be a prime coat or a tack coat & in sortie cases, the prime coat followed by a tack coat.

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# Highway Drainage

It is the process of removing & controlling excess surface & sub-soil water within the right of way. This includes interception & diversion of water from the road surface & sub-grade.

## Requirements of Highway Drainage System

1. The surface water from the carriageway & shoulder should effectively be drained off without allowing it to percolate to sub-grade.
2. The surface water from the adjoining land should be prevented from entering roadway.
3. Side-drain should have sufficient capacity & longitudinal slope to carry away all the surface water collected.
4. Flow of surface water across the road & shoulders & along slopes shouldn't cause formation of cross cuts or erosion.

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5. Seepage & other Sources of under-grd water should be drained off by the sub-surface drainage system.

6. Highest level of grd W.T should be kept well below the level of sub-grade, atleast 1.2m.

7. In water-logged area, Special precautions should be taken, especially if detrimental salts are present or if flooding is likely to occur.

## Recent Advances in Building Materials

Plastics in building industry have been used for different purposes such as wall tiles, floor Coverings, roofing, heat insulation, Plumping Units, Wall panels, doors, etc.,

## Applications of Plastics in building Industry

1. Phenolic resins or glue bonded paper laminates - For making resin-bonded plywood & corrugated sheets for resin.



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2. Asbestos filled with phenolic resins
   - For moulding W.C cistern - light in weight & corrosion proof.

3. Urea formaldehyde Plastics
   - For stoppers of wash basins & baths, cistern valves, handles, towel rails, etc.,

4. Poly vinyl polymers or plastics
   - For polyvinyl tiles used as wall tiles, cemented on wood, tile bricks, etc.,

5. Poly Vinyl Chloride & acetate type
   - For floor, sheeting.

6. Acrylics resins.
   - For specialized glazing, paneling & components of built in fitments

7. Veneered plastic boards
   - For doors for use in hospitals, public buildings, bathrooms & lavatories

8. Phenolic resins - Asbestos plywood.
   - For fire resistance doors & partitions walls.



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## Geo Polymer

It posses excellant mechanical properties, doesn't dissolve in acidic solutions & doesn't generate any deterious alkali- aggregate reaction even in the presence of high alkalinity.

Applications:

1. Marine Structures
2. Railway sleepers
3. sewer Pipes.

Geopolymer Concrete is a concrete, made without using portland Cement & such it is environmentally friendly & energy efficient Construction material with an enormous potential in many infa structural applications

The limited test results show that geopolymer Concrete undergoes very little drying shrinkage & moderately low creep & possesses excellant resistance to sulphate attack.

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## Basalt Fibres

It is manufactured by melting naturally occurring pure basalt rock.

It is abundantly available, environmentally safe, non-toxic, non-corrosive, non-magnetic, possess high heat stability & insulating characterstics.

It is in amorphous state exhibit higher chemical stability than glass-fibres.

→ Satisfactory workability can be maintained with the addition of basalt fibres upto 0.5% by volume. A higher % of fibres could be used without causing any balling or segregation.

→ Compared to the Control Concrete, there was considerable increase to the toughness & impact strength for the basalt fibre Concrete.

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UNIT V

# EVALUATION AND MAINTENANCE OF PAVEMENTS:

## 1) Highway Maintenance:

Preserving and keeping each type of road way, roadside structures as nearly as possible in its original condition as constructed or as subsequently improved and the operation of highway facilities and services to provide satisfactory and safe transportation is called Maintenance of highways. It includes both physical maintenance activities such as sealing, Patching and traffic service activities.

Highway Maintenance is essential inorder to

* Preserve the road in its originally constructed condition.
* protect adjacent resources & user safety.
* Provide efficient, convenient travel along the route.

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## Types of highway Maintenance:

Under the type of routine Maintenance following works are carried out

1. Maintenance of side drains as clearing of silt & maintain proper slope.
2. Maintain of shoulders & subgrade
3. Periodic Maintenance
4. Special Repairs - strengthening of Pavement structure or overlay construction, widening of roads etc.,

## Factors affecting road Maintenance:

The following factors affect the maintenance of Pavements.

* Increase in the intensity of Traffic.
* Inadequate thickness of Pavements
* Effect on number of lanes.

## Functions of Highway Maintenance:

* Shoulder care becomes a serious Problem where narrow lanes force heavy vehicle to travel with one set of wheels.

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* Improper designed drainage facilities mean erosion or deposition of material & costly cleaning operation or other corrective Measures.

* In Snowy country, improper location extremely low fills and narrow cuts leave no room for snow storage, creating extreme difficult snow removal problems.

The various maintenance function include

1) Surface Maintenance
2) Roadside & Drainage Maintenance.
3) Shoulder & approach Maintenance.
4) Snow & ice control.
5) Bridge Maintenance.
6) Traffic service.

Surface Maintenance roads:

Pavement Maintenance & rehabilitation Programs, restore riding quality & maintain the structural integrity of the pavement over its full design life.

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* For maintenance of gravel roads, blading & occasional resurfacing is required.

* For surface treatment of low type bituminous surface in maintenance of roads. Patching, seal coating or possible loosening oiling, remixing & relaying are involved.

* Use same material and methods for road surface Maintenance as far as possible.

Roadside and highway Drainage Maintenance:

* If there is dry grass fire hazard burning, plowing must be done.

* When back slope is covered with bush, trimming must be done to increase the sight distance & clearance of road.

* Picking up litter, thrown or blown along roadside or wayside area a routine work.

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## Shoulders:

* Shoulders must be moved and occasionally bladed down to the level of the road so that water is not trapped in the traveled way. Grass must be kept in good condition

* Shoulders protected by bituminous blankets or surface treatments same as for road way surface.

## Snow & Ice control:

Ice forming on the roadway reduces co.efficient of friction b/w tires & surface which makes vehicle control almost impossible. In highway maintenance we can apply abrasive to heavily traveled roadway & street. Suitable Materials that can be used are clean & sharp sand, cinders & washed stone screening.

## Bridge Maintenance:

* Exposed steel work must be cleared by sand blasting flame or other means followed by painting.

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* Deck joint may extrude or become filled with dirt so that cleaning & resealing is necessary.

* Out of control vehicle, causing damage to guard rail, must be repaired & strengthened.

* Remedial measures to correct serious scour around & under piers & abutments.

Traffic Service:

Include Stripping, sign repair & maintenance

Distress in flexible & Rigid Pavements.

Surface Distress:

It is any indication of poor or unfavourable pavement performance or signs of impending Failure. Surface distress is related to roughness. Broadly classified into three groups.

* Fracture
* Distortion
* Disintegration

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Flexible Pavement distress: (4)

1) Alligator (Fatigue) cracking:

Description:

A series of interconnected cracks caused by fatigue failure of the hot mix asphalt surface under repeated traffic loading. As magnitude of load becomes more, longitudinal cracks formed & connect forming many sided sharp angled pieces that develop into a pattern of an alligator or crocodile.

Problem:

Roughness, indicator of structural Failure, cracks allow moisture infiltration into the base & subgrade results in potholes & Pavement disintegration.

Causes:

* Decrease in Pavement load supporting characteristics.
* Loss of base, subbase or subgrade support from poor drainage.
* Inadequate structural design & poor construction.

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Repair:

Small, localized Failure cracking indicative of loss of subgrade support. Remove the cracked pavement area then dig the out & replace the area of Poor subgrade & improve the drainage of the area if necessary. Patch over the repaired subgrade.

2) Bleeding:

Description:

A film of asphalt binder on the Pavement surface. It usually creates a shiny, glass like reflecting surface that can become sticky when dry & slippery when wet.

Problem: Loss of skid resistance when wet, unsightly.

causes:

* Excessively asphalt binder in the HMA.
* Excessive application of asphalt binder during BST application
* Low HMA air void content.

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Repair:

Minor bleeding can often be corrected by applying coarse sand to blot up the excess asphalt binder.

Major bleeding can be corrected by cutting of excess asphalt with a motor grader or removing it with a heater planner. If the resulting surface is excessively rough, resurfacing may be necessary.

3. Block cracking:

Description:

Pavement & distress in Flexible & Rigid Pavement

Introduction,

The maintenance operations involve the assessment of road condition, diagnosis of the problem and adopting the most appropriate maintenance. Even if the highways are well designed, constructed, they may require maintenance, the extent of which will depend on several factors including the Pavement type.

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## General causes of pavement Failures.

1. Defects in the quality of materials used.
2. Defects in construction method & quality control during construction
3. Inadequate surface or sub-surface drainage in the locality resulting in the stagnation of water in the subgrade or in any of the pavement layers.
4. Increase in the magnitude of wheel loads & no. of load repetitions due to increase in traffic volumes.
5. settlement of foundation of embankment of the fill material itself.
6. Environmental Factors including heavy rainfall, soil erosion, high water table, snow fall, Frost action etc.,

## 7. Pavement Failures:

### Failure in Cement concrete pavement:

Failure of cement concrete pavements are recognized by the formation of structural cracking. The Failures are mainly due to

i) Deficiency of Pavement Materials.
ii) Structural inadequacy of the pavement system.

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## Deficiency of Pavement Material:

Following are the chief causes of which would rise to the different defects or) Failures of C.C pavement.

i) soft aggregates ii) Poor workmanship in joint construction iii) Poor joint Filler & sealer material iv) Poor surface finish v) Improper & Insufficient curing.

The various defects that creep in due to the above are

a) Disintegration of cement concrete.
b) Formation of cracking
c) Poor riding surface.
d) spalling of joints
e) Formation of shrinkage cracks.
f) Slippery surface.
g) Ingress of surface water & further progressive Failures.

## Structural inadequacy of Pavement

Inadequate subgrade support pavement thickness would be a major cause of developing structural cracking pavements.

Types of failure which develops.

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i) Inadequate pavement thickness

ii) Inadequate sub-grade support & poor subgrade soil

iii) Incorrect spacing of joints.

Above leads to the following failures.

i) cracking of slab corners.

ii) " " Pavement longitudinally

iii) Settlement of slabs.

iv) Widening of joints.

v) Mud pumping.

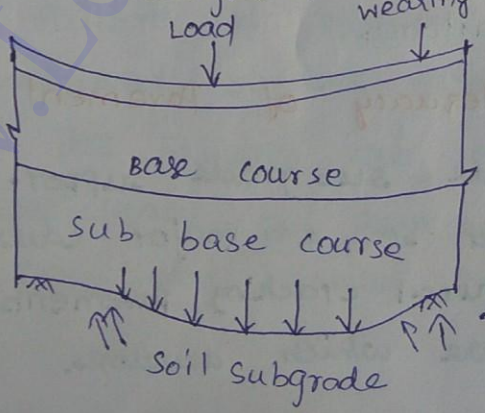
Failure in Flexible Pavement.

i) Failures in subgrade.

ii) Failures in base course

iii) Failures in wearing course.

Failure in Subgrade:

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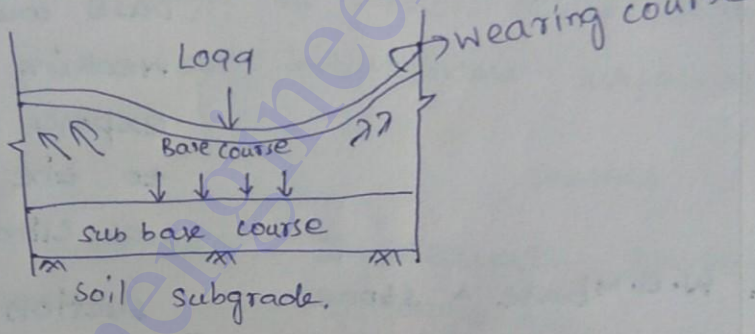
Failure causes

1) Inadequate stability - Inherent weakness of soil excessive moisture.

2) Excessive stress application - Improper compaction More no. of repetitions Loads to change in bearing of unmodulation waves & corrugations.

Failures in sub-base (or) Base - course.




1) Inadequate stability or strength.
2) Inadequate wearing course.
3) Lack of Lateral confinement for the granular base course.

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| | Failure | | causes |
|---|---|---|---|
| 1. | Loss of binding action | - | Poor mix of proportioning, inadequate thickness soft stone aggregates Loss of binding action. |
| 2. | Formation of alligator | - | Internal movement of aggregates under repeated stress applicatin |
| 3. | Loss of base course Material | - | Non provision of W.C over base course or complete wearing out the W.C exposes the base course to the damaging effects of climate variation, |
| 4. | W.B.M base & stone aggregates being left in a loose state | - | suction causes b/w the pneumatic tires & exposed base course materials. |
| 5. | Pot holes | - | Abrasion & attrition. |
| 6. | Structural Failure | - | Iron tires cause damaging effect to surface course. use of inferior materials Inadequate pavement thickness Lack of proper Mix. |

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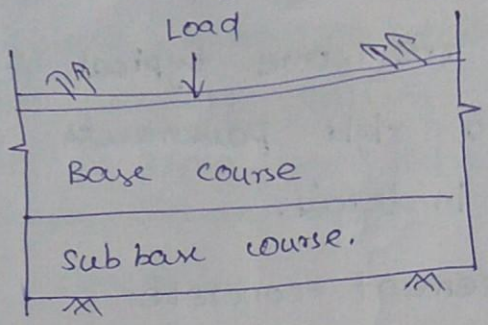
Failure in Wearing course.




observed due to Lack of mix design
Improper gradation of aggregate.
Inadequate binder content & inferior type of binder result in a poor bituminous surfacing

| Failure | causes |
|---|---|
| i) cracking of pavement surface | - Inadequate gradation of aggregates. |
| ii) Inadequate binder content | - Inadequate binder content. |
| iii) Inferior type of binder | - volatilization & oxidation of binder make the bituminous surfacing brittle. Lack of high degree of quality control. over or under estimated binder content. |

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## Rigid Pavement Failures:

Following are some typical & basic types of failures in rigid pavements which are dealt here in detail.

1) Scaling of cement concrete:

a) Scaling is observed in cement concrete pavement showing overall detereoration of concrete

b) The scaling is mostly attributed due to the deficiency in the mix or presence of some chemical impurities which damages the mix

c) Further due to excessive vibration given to mix, the cement mortar comes to the top during construction & thus with use the cement mortar gets abraded exposing the aggregate of the mix.

2) Shrinkage cracks:

a) During the curing operation of cement concrete pavements immediately after the construction, the shrinkage cracks normally develop.

b) The placement of cracks are in longitudinal as well as in transverse direction

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3) Spalling of Joint: (9)

Sometimes when preformed filler materials are placed during casting of pavement slabs, the pavement is some how delocated & filler is thus placed @ an angle.

The concreting is completed without noticing this faulty alignment of the filler material.

Thus this forms an overhang of a concrete layer on the top side & the joint later on shows excessive cracking & subsidence.

4) Warping cracks:

If the joints are not well designed to accomodate the warping of slabs @ edges this results in development of excessive stresses due to warping & the slab develops cracking @ the edges in an irregular pattern.

Hinge joints are generally provided for relieving the slabs of warping stresses.

5) Mud Pumping:

Mud Pumping is recognized when the soil slurry ejects out through the joints & cracks of cement concrete slab under

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the heavy wheel loads.

Following are the factors which cause mud pumping are

i) Extent of slab deflection
ii) Type of subgrade soil
iii) Amount of free water.

PAVEMENT MANAGEMENT SYSTEM:

i) Minimum acceptable serviceability standards for the maintenance of different categories of roads.

ii) Field surveys for the evaluation of maintenance requirements.

iii) Various Factors influencing the maintenance needs such as subgrade soil, drainage, climate, traffic, environmental condition etc.,

iv) Estimation of rate of deterioration of the Pavement under the prevailing set of conditions.

v) Type & extent of Maintenance requirements and various possible alternatives & their Economic evaluation

vi) Availability of Funds.

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vii) Maintenance cost, availability of Materials, (10) man power & Equipment.

viii) Need based allocation for optimum utilization of inputs & fixing maintenance properties.

PAVEMENT EVALUATION:

The primary objective of pavement condition evaluation is to assess & to whether & to what extent the pavement fulfills the intended requirements so that the maintenance & strengthening jobs could be planned in time.

Various approaches for pavement evaluation

i) structural evaluation of Pavements.

ii) Evaluation of Pavement surface condition.

Structural Evaluation of Pavements:

* The structural evaluation of both flexible & rigid Pavement may be carried out by plate bearing Test.

* The structural capacity of pavement maybe assessed by the load carried @ a specified deflection of the plate.

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* Measurement of transit deflection of pavement under design wheel loads serve as an index of the pavement to carry Traffic loads under prevailience condition.

* of the various equipment used for the purpose, Benkelman beam is most commonly used, as the measurements are simple & Easy.

* There are no. of other non-destructive testing Techniques for assessing the load carrying capacity of the pavements.

Evaluation of Pavement surface conditions:

⇒ The surface condition of flexible Pavement may be evaluated by the unevenness, ruts, patches & cracks.

⇒ The surface condition of rigid Pavements may be assessed by the cracks developed & by Faulty joints affecting the riding quality of Pavement.

Unevenness:

The pavement unevenness may be measured by using unevenness indicator, Profilo graph, Profilometer or roughometer.

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Bump Integrator → Integrate the unevenness of Pavement surface to a cumulative scale & that gives the unevenness index of the surface in cm/km length of road.

Present Serviceability Index (P.S.I).

This is correlated with the physical measurements such as longitudinal & transverse profile of Pavement, degree of cracking & patching etc., affecting Pavement serviceability.

Skid Resistance:

Skid resistance property of Pavement surface is essential requirement for highway safety.

The skid resistance or friction of the Pavement surface may be measured by using anyone of the devices such as the Pendulum type Friction recorded (or) the skid testing device attached to test vehicle (or) the instrument mounted dynamic skid resistance tester by another vehicle.

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skidding has been contributing to the large no. of accidents on highways.

{ 40'/. of accidents are due to the poor skid resistance.

Factors causing ⇒ water, clay, dust, dry sand, oil & grease leads to reduction in grid b/w tyre & pavement surface.

Types of skidding:

a) Straight skidding → occurs in the direction of travel when the sudden brakes are applied

b) Impending skidding → Encountered when the braking is gradual & wheel continues to revolve.

c) sideway skidding → Occurs on curves where sufficient superelevation is not provided or co. eff. of friction is inadequate.

Remedial Measure to skidding is renewal of the wearing course surface,

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## Evaluation by Benkleman Deflection Method: (12)

A well compacted pavement section or one which has been well conditioned by traffic deforms elastically under each wheel load applications that when the load moves away, there is an elastic recovery or rebound deflection of the deformed pavement surface. This is the basic principle of deflection method pavement evaluation (or) overlay Design.

### Procedure:

The stretch of road length to be evaluated is first surveyed to assess the general condition of pavement with respect to ruts, cracks or undulations.

A minimum of 10 deflection observations may be taken on each of the selected stretch of pavement. The deflection observation points may also be staggered. if necessary & taken along the wheel paths. on both the edges of pavement

After making the deflection observation point, study is carried out in following steps.

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1) The truck is driven slowly parallel to the edge is stopped such that the left side rear dual wheel is centrally placed over the first point for deflection measurement.

2) The probe end of the Benkelman beam is inserted b/w the gap of dual wheel & is placed exactly over the deflection observation point

3) When the dial gauge reading is stationary (or) when the rate of change of pavement deflection is less than 0.025 mm / minute, the initial dial gauge reading $D_0$ is noted.

4) The truck is moved forward slowly through a distance of 2.7 m from the point & stopped. The intermediate dial gauge reading $D_i$ is noted when the rate of recovery of pavement is less than 0.025mm / minute.

5) The truck is then driven forward through a further distance of 9.0 m & final dial gauge reading $D_f$ is recorded as before.

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6) The strengthening deflection dial reading $D_o$, $D_i$, $D_f$ form a set of readings @ one deflection Point under consideration. similarly, the truck is moved forward to the next deflection point, the probe of benkleman beam inserted and the procedure of noting the set of 3 deflection observation is repeated. The deflection observation is also to be continued @ all desired points.

7) Temperature @ surface is recorded periodically Tyre Pressure, Moisture content in sub grade soil determined at suitable intervals.

8) Rebound deflection value 'D' @ any point is given by one of the following Two conditions

i) If $D_i - D_f \leq 2.5$ divisions of dial gauge.

$$D = 2(D_o - D_f).$$

ii) If $D_i - D_f \geq 2.5$ divisions, correction needed for ver. movement of front legs

$$D = 2(D_o - D_f) + 2K(D_i - D_f) \text{ divisions}$$

$$K = \frac{3d - 2e}{f}.$$

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where

d ⇒ Distance b/w the bearing of beam & rear adjusting leg.

e ⇒ Distance b/w dial gauge & rear adjust leg.

f ⇒ Distance b/w the front & rear legs.

Deflection value, D with leg correction is given by

$$D = 0.02(D_o - D_f) + 0.0582(D_i - D_f) \text{ mm}$$

## STRENGTHENING OF EXISTING PAVEMENTS

Strengthening may be done by providing additional thickness of pavement of adequate thickness in one or more layers over the existing pavement, which is called overlay.

If the existing pavement have completely deteriorated, an overlay wouldn't serve the purpose and the solution would be to remove the existing damaged pavement structure & to rebuild the same.

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In Particularly damaged pavement sections, patch repair works are carried out before constructing the overlay.

The maintenance engineer should therefore the vigilent & Should take the decision in time for providing an overlays as & when needed.

Types of overlays:

The overlay combinations are divided into four categories based on the type of existing Pavement & overlay.

i) Flexible overlay over flexible pavement.
ii) cement concrete or rigid overlay over flexible pavement.
iii) Flexible overlay over cement concrete or rigid pavements
iv) cement concrete or rigid overlay over rigid pavements.

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