KIIT POLYTECHNIC

LECTURE NOTES

ON

HIGHWAY ENGINEERING

Compiled by

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CHAPTER-1

Introduction

History of highway engineering

The history of highway engineering gives us an idea about the roads of ancient times. Roads in Rome were constructed in a large scale and it radiated in many directions helping them in military operations. Thus, they are considered to be pioneers in road construction. In this section we will see in detail about Ancient roads, Roman roads, British roads, French roads etc.

Ancient Roads

The first mode of transport was by foot. These human pathways would have been developed for specific purposes leading to camp sites, food, streams for drinking water etc. The next major mode of transport was the use of animals for transporting both men and materials. Since these loaded animals required more horizontal and vertical clearances than the walking man, track ways emerged. The invention of wheel in Mesopotamian civilization led to the development of animal drawn vehicles. Then it became necessary that the road surface should be capable of carrying greater loads. Thus roads with harder surfaces emerged. These have led to the development of foot-paths. After the invention of wheel, animal drawn vehicles were developed and the need for hard surface road emerged. The earliest authentic record of road was found from Assyrian empire constructed about 1900 BC.

Roman roads

The earliest large scale road construction is attributed to Romans who constructed an extensive system of roads radiating in many directions from Rome. They were a remarkable achievement and provided travel times across

Europe, Asia minor, and north Africa. Romans recognized that the fundamentals of good road construction were to provide good drainage, good material and good workmanship. Their roads were very durable, and some are still existing. Roman roads were always constructed on a firm - formed subgrade strengthened where necessary with wooden piles. The roads were bordered on both sides by longitudinal drains. The next step was the construction of the agger. This was a raised formation up to a 1 meter high and 15 m wide and was constructed with materials excavated during the side drain construction. This was then topped with a sand leveling course. The agger contributed greatly to moisture control in the pavement. The pavement structure on the top of the agger varied greatly. In the case of heavy traffic, a surface course of large 250 mm thick hexagonal flag stones were provided.

French roads

The next major development in the road construction occurred during the regime of Napoleon. The significant contributions were given by Tresaguet in 1764 and a typical cross section of this road is given in Figure 2:2. He developed a cheaper method of construction than the lavish and locally unsuccessful revival of Roman practice. The pavement used 200 mm pieces of quarried stone of a more compact form and shaped such that they had at least one flat side which was placed on a compact formation. Smaller pieces of broken stones were then compacted into the spaces between larger stones to provide a level surface. Finally the running layer was made with a layer of 25 mm sized broken stone. All this structure was placed in a trench in order to keep the running surface level with the surrounding country side. This created major drainage problems which were counteracted by making the surface as impervious as possible, cambering the surface and providing deep side ditches. He gave much importance for drainage. He also enunciated the necessity for continuous organized maintenance, instead of intermittent repairs if the roads were to be kept usable all times. For this he divided the roads between villages into sections of such length that an entire road could be covered by maintenance men living nearby.

British roads

The British government also gave importance to road construction. The British engineer John Macadam introduced what can be considered as the first scientific road construction method. Stone size was an important element of Macadam recipe. By empirical observation of many roads,he came to realize that 250 mm layers of well compacted broken angular stone would provide the same strength and stiffness and a better running surface than an expensive pavement founded on large stone blocks. Thus, he introduced an economical method of road construction.

The mechanical interlock between the individual stone pieces provided strength and stiffness to the course. But the inter particle friction abraded the sharp interlocking faces and partly destroy the effectiveness of the course. This effect was overcome by introducing good quality interstitial finer material to produce a well-graded mix. Such mixes also proved less permeable and easier to compact.

Modern roads

The modern roads by and large follow Macadam's construction method. Use of bituminous concrete and cement concrete are the most important developments. Various advanced and cost-effective construction technologies are used. Development of new equipment help in the faster construction of roads. Many easily and locally available materials are tested in the laboratories and then implemented on roads for making economical and durable pavements.

Scope of transportation system has developed very largely. Population of the country is increasing day by day. The life style of people began to change. The need for travel to various places at faster speeds also increased. This increasing demand led to the emergence of other modes of transportation like railways and travel by air. While the above development in public transport sector was taking place, the development in private transport was at a much faster rate mainly because of its advantages like accessibility, privacy, flexibility, convenience and comfort. This led to the increase in vehicular traffic especially in private transport network.

This has led to the emergence of transportation planning and demand management.

Highway planning in India

Excavations in the sites of Indus valley, Mohenjo-Daro and Harappan civilizations revealed the existence of planned roads in India as old as 2500-3500 BC. The Mauryan kings also built very good roads. Ancient books like Arthashastra written by Kautilya, a great administrator of the Mauryan times, contained rules for regulating traffic, depths of roads for various purposes, and punishments for obstructing traffic.

During the time of Mughal period, roads in India were greatly improved. Roads linking North-West and the Eastern areas through gangetic plains were built during this time.

After the fall of the Mughals and at the beginning of British rule, many existing roads were improved. The construction of Grand-Trunk road connecting North and South is a major contribution of the British. However, the focus was later shifted to railways, except for feeder roads to important stations.

National highways

They are main highways running through the length and breadth of India connecting major ports, foreign highways, capitals of large states and large industrial and tourist centers including roads required for strategic movements.

It was recommended by Jayakar committee that the National highways should be the frame on which the entire road communication should be based.

All the national highways are assigned the respective numbers.

For e.g. the highway connecting Delhi-Ambala-Amritsar is denoted as NH-1 (Delhi-Amritsar), where as a bifurcation of this highway beyond Fullundar to Srinagar and Uri is denoted as NH-1_A.

They are constructed and maintained by CPWD.

The total length of National highway in the country is 58,112 Kms, and constitute about 2% of total road networks of India and carry 40% of total traffic.

State highways

They are the arterial roads of a state, connecting up with the national highways of adjacent states, district head quarters and important cities within the state

They also serve as main arteries to and from district roads. Total length of all SH in the country is 1,37,119 Kms.

Major district roads

Important roads with in a district serving areas of production and markets , connecting those with each other or with the major highways.

India has a total of 4,70,000 kms of MDR.

Other district roads

Roads serving rural areas of production and providing them with outlet to market centers or other important roads like MDR or SH.

Village roads

They are roads connecting villages or group of villages with each other or to the nearest road of a higher category like ODR or MDR.

Modern developments

The first World war period and that immediately following it found a rapid growth in motor transport. So need for better roads became a necessity. For that, the Government of India appointed a committee called Road development Committee with Mr.M.R. Jayakar as the chairman. This committee came to be known as Jayakar committee.

Jayakar Committee

In 1927 Jayakar committee for Indian road development was appointed. The major recommendations and the resulting implementations were:

• Committee found that the road development of the country has become beyond the capacity of local governments and suggested that Central government should take the proper charge considering it as a matter of national interest.

• They gave more stress on long term planning programme, for a period of 20 years (hence called twenty year plan) that is to formulate plans and implement those plans with in the next 20 years.

• One of the recommendations was the holding of periodic road conferences to discuss about road construc- tion and development. This paved the way for the establishment of a semi-official technical body called Indian Road Congress (IRC) in 1934

• The committee suggested imposition of additional taxation on motor transport which includes duty on motor spirit, vehicle taxation, license fees for vehicles plying for hire. This led to the introduction of a development fund called Central road fund in 1929. This fund was intended for road development.

• A dedicated research organization should be constituted to carry out research and development work.

This resulted in the formation of Central Road Research Institute (CRRI) in 1950.

Nagpur road congress 1943

The second World War saw a rapid growth in road traffic and this led to the deterioration in the condition of roads. To discuss about improving the condition of roads, the government convened a conference of chief engineers of provinces at Nagpur in 1943. The result of the conference is famous as the Nagpur plan.

• A twenty year development programme for the period (1943-1963) was finalized. It was the first attempt to prepare a co-ordinated road development programme in a planned manner.

• The roads were divided into four classes:

– National highways which would pass through states, and places having national importance for strategic, administrative and other purposes.

– State highways which would be the other main roads of a state.

– District roads which would take traffic from the main roads to the interior of the district . According to the importance, some are considered as major district roads and the remaining as other district roads.

– Village roads which would link the villages to the road system.

• The committee planned to construct 2 lakh kms of road across the country within 20 years.

• They recommended the construction of star and grid pattern of roads throughout the country.

• One of the objective was that the road length should be increased so as to give a road density of 16kms per 100 sq.km

Bombay road congress 1961

The length of roads envisaged under the Nagpur plan was achieved by the end of it, but the road system was deficient in many respects. The changed economic, industrial and agricultural conditions in the country warranted a review of the Nagpur plan. Accordingly a 20-year plan was drafted by the Roads wing of Government of India, which is popularly known as the Bombay plan. The highlights of the plan were:

• It was the second 20 year road plan (1961-1981)

• The total road length targeted to construct was about 10 lakhs.

• Rural roads were given specific attention. Scientific methods of construction was proposed for the rural roads. The necessary technical advice to the Panchayaths should be given by State PWD’s.

• They suggested that the length of the road should be increased so as to give a road density of 32kms/100 sq.km

• The construction of 1600 km of expressways was also then included in the plan.

Lucknow road congress 1984

This plan has been prepared keeping in view the growth pattern envisaged in various fields by the turn of the century. Some of the salient features of this plan are as given below:

• This was the third 20 year road plan (1981-2001). It is also called Lucknow road plan.

• It aimed at constructing a road length of 12 lakh kilometres by the year 1981 resulting in a road density of 82kms/100 sq.km

• The plan has set the target length of NH to be completed by the end of seventh, eighth and ninth five year plan periods.

• It aims at improving the transportation facilities in villages, towns etc. such that no part of country is farther than 50 km from NH.

• One of the goals contained in the plan was that expressways should be constructed on major traffic corridors to provide speedy travel.

• Energy conservation, environmental quality of roads and road safety measures were also given due importance in this plan.

CHAPTER-2

Road Geometrics

Pavement surface characteristics

For safe and comfortable driving four aspects of the pavement surface are important; the friction between the wheels and the pavement surface, smoothness of the road surface, the light reflection characteristics of the top of pavement surface, and drainage to water.

Friction

Friction between the wheel and the pavement surface is a crucial factor in the design of horizontal curves and thus the safe operating speed. Further, it also affects the acceleration and deceleration ability of vehicles. Lack of adequate friction can cause skidding or slipping of vehicles.

Skidding happens when the path travelled along the road surface is more than the circumferential movement of the wheels due to friction

• Slip occurs when the wheel revolves more than the corresponding longitudinal movement along the road. Various factors that affect friction are:

• Type of the pavement (like bituminous, concrete, or gravel),

• Condition of the pavement (dry or wet, hot or cold, etc),

• Condition of the tyre (new or old), and

• Speed and load of the vehicle.

The frictional force that develops between the wheel and the pavement is the load acting multiplied by a factor called the coefficient of friction and denoted as f. The choice of the value of f is a very complicated issue since it depends on many variables. IRC suggests the coefficient of longitudinal friction as 0.35-0.4 depending on the speed and coefficient of lateral friction as 0.15. The former is useful in sight distance calculation and the latter in horizontal curve design.

Unevenness

• White roads have good visibility at night, but caused glare during day time.

• Black roads have no glare during day, but has poor visibility at night

• Concrete roads have better visibility and less glare

It is always desirable to have an even surface, but it is seldom possible to have such a one. Even if a road is constructed with high quality pavers, it is possible to develop unevenness due to pavement failures. Unevenness affects the vehicle operating cost, speed, riding comfort, safety, fuel consumption and wear and tear of tyres.

Unevenness index is a measure of unevenness which is the cumulative measure of vertical undulations of the pavement surface recorded per unit horizontal length of the road. An unevenness index value less than 1500 mm/km is considered as good, a value less than 2500 mm.km is satisfactory up to speed of 100 kmph and values greater than 3200 mm/km is considered as uncomfortable even for 55 kmph.

Light reflection

It is necessary that the road surface should be visible at night and reflection of light is the factor that answers it.

- White roads have good visibility at night, but caused glare during day time.
- Black roads has no glare during day, but has poor visibility at night
- Concrete roads has better visibility and less glare

The pavement surface should be absolutely impermeable to prevent seepage of water into the pavement layers. Further, both the geometry and texture of pavement surface should help in draining out the water from the surface in less time.

Camber

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

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

Too steep slope is undesirable for it will erode the surface. Camber is measured in *1 in n* or *n%* (Eg. 1 in 50 or 2%) and the value depends on the type of pavement surface.

Width of carriage way

Width of the carriage way or the width of the pavement depends on the width of the traffic lane and number of lanes. Width of a traffic lane depends on the width of the vehicle and the clearance. Side clearance improves operating speed and safety. The maximum permissible width of a vehicle is 2.44 and the desirable side clearance for single lane traffic is 0.68 m. This requires minimum of lane width of 3.75 m for a single lane road.
However, the side clearance required is about 0.53 m, on either side and 1.06 m in the centre. Therefore, a two lane road require minimum of 3.5 meter for each lane. The desirable carriage way width recommended by IRC

Kerbs

Kerbs indicate the boundary between the carriage way and the shoulder or islands or footpaths.
• Low or mountable kerbs : This type of kerbs are provided such that they encourage the traffic to remain in the through traffic lanes and also allow the driver to enter the shoulder area with little difficulty. The height of this kerb is about 10 cm above the pavement edge with a slope which allows the vehicle to climb easily. This is usually provided at medians and channelization schemes and also helps in longitudinal drainage.

• Semi-barrier type kerbs : When the pedestrian traffic is high, these kerbs are provided. Their height is 15 cm above the pavement edge. This type of kerb prevents encroachment of parking vehicles, but at acute emergency it is possible to drive over this kerb with some difficulty.

• Barrier type kerbs : They are designed to discourage vehicles from leaving the pavement. They are provided when there is considerable amount of pedestrian traffic. They are placed at a height of 20 cm above the pavement edge with a steep batter.

Road margins

The portion of the road beyond the carriageway and on the roadway can be generally called road margin. Various elements that form the road margins are given below.

Shoulders

Shoulders are provided along the road edge and is intended for accommodation of stopped vehicles, serve as an emergency lane for vehicles and provide lateral support for base and surface courses. The shoulder should be strong enough to bear the weight of a fully loaded truck even in wet conditions. The shoulder width should be adequate for giving working space around a stopped vehicle. It is desirable to have a width of 4.6 m for the shoulders. A minimum width of 2.5 m is recommended for 2-lane rural highways in India.

Parking lanes

Parking lanes are provided in urban lanes for side parking. Parallel parking is preferred because it is safe for the vehicles moving on the road. The parking lane should have a minimum of 3.0 m width in the case of parallel parking.

Bus-bays

Bus bays are provided by recessing the kerbs for bus stops. They are provided so that they do not obstruct the movement of vehicles in the carriage way. They should be at least 75 meters away from the intersection so that the traffic near the intersections is not affected by the bus-bay.

Service roads

Service roads or frontage roads give access to access controlled highways like freeways and expressways. They run parallel to the highway and will be usually isolated by a separator and access to the highway will be provided only at selected points. These roads are provided to avoid congestion in the expressways and also the speed of the traffic in those lanes is not reduced.

Cycle track

Cycle tracks are provided in urban areas when the volume of cycle traffic is high Minimum width of 2 meter is required, which may be increased by 1 meter for every additional track.

Footpath

Footpaths are exclusive right of way to pedestrians, especially in urban areas. They are provided for the safety of the pedestrians when both the pedestrian traffic and vehicular traffic is high. Minimum width is 1.5 meter and may be increased based on the traffic. The footpath should be either as smooth as the pavement or more smoother than that to induce the pedestrian to use the footpath.

Guard rails

They are provided at the edge of the shoulder usually when the road is on an embankment. They serve to prevent the vehicles from running off the embankment, especially when the height of the fill exceeds 3 m. Various designs of guard rails are there. Guard stones painted in alternate black and white are usually used. They also give better visibility of curves at night under headlights of vehicles.

Width of formation

Width of formation or roadway width is the sum of the widths of pavements or carriage way including separators and shoulders. This does not include the extra land in formation/cutting.

Right of way

Right of way (ROW) or land width is the width of land acquired for the road, along its alignment. It should be adequate to accommodate all the cross-sectional elements of the highway and may reasonably provide for future development. To prevent ribbon development along highways, control lines and building lines may be provided. Control line is a line which represents the nearest limits of future uncontrolled building activity in relation to a road. Building line represents a line on either side of the road, between which and the road no building activity is permitted at all. The right of way width is governed by:

• Width of formation: It depends on the category of the highway and width of roadway and road margins.

• Height of embankment or depth of cutting: It is governed by the topography and the vertical alignment.

• Side slopes of embankment or cutting: It depends on the height of the slope, soil type etc.

• Drainage system and their size which depends on rainfall, topography etc.

• Sight distance considerations : On curves etc. there is restriction to the visibility on the inner side of the curve due to the presence of some obstructions like building structures etc.

• Reserve land for future widening: Some land has to be acquired in advance anticipating future developments like widening of the road.

Sight distance

Overview

The safe and efficient operation of vehicles on the road depends very much on the visibility of the road ahead of the driver. Thus the geometric design of the road should be done such that any obstruction on the road length could be visible to the driver from some distance ahead . This distance is said to be the sight distance.

Types of sight distance

Sight distance available from a point is the actual distance along the road surface, over which a driver from a specified height above the carriage way has visibility of stationary or moving objects. Three sight distance situations are considered for design:

- Stopping sight distance (SSD) or the absolute minimum sight distance
- Intermediate sight distance (ISD) is defined as twice SSD
- Overtaking sight distance (OSD) for safe overtaking operation
- Head light sight distance is the distance visible to a driver during night driving under the illumination of head lights
- Safe sight distance to enter into an intersection.

The most important consideration in all these is that at all times the driver traveling at the design speed of the highway must have sufficient carriageway distance within his line of vision

to allow him to stop his vehicle before colliding with a slowly moving or stationary object appearing suddenly in his own traffic lane.
The computation of sight distance depends on:

• *Reaction time of the driver*
Reaction time of a driver is the time taken from the instant the object is visible to the driver to the instant when the brakes are applied. The total reaction time may be split up into four components based on PIEV theory. In practice, all these times are usually combined into a total perception-reaction time suitable for design purposes as well as for easy measurement. Many of the studies shows that drivers require about 1.5 to 2 secs under normal conditions. However, taking into consideration the variability of driver characteristics, a higher value is normally used in design. For example, IRC suggests a reaction time of 2.5 secs.

• *Efficiency of brakes*
The speed of the vehicle very much affects the sight distance. Higher the speed, more time will be required to stop the vehicle. Hence it is evident that, as the speed increases, sight distance also increases.
The efficiency of the brakes depends upon the age of the vehicle, vehicle characteristics etc. If the brake efficiency is 100%, the vehicle will stop the moment the brakes are applied. But practically, it is not possible to achieve 100% brake efficiency. Therefore the sight distance required will be more when the efficiency of brakes are less. Also for safe geometric design, we assume that the vehicles have only 50% brake efficiency.
• *Frictional resistance between the tyre and the road*
The frictional resistance between the tyre and road plays an important role to bring the vehicle to stop. When the frictional resistance is more, the vehicles stop immediately. Thus sight required will be less. No separate provision for brake efficiency is provided while computing the sight distance. This is taken into account along with the factor of longitudinal friction. IRC has specified the value of longitudinal friction in between 0.35 to 0.4.
• *Gradient of the road*
Gradient of the road also affects the sight distance. While climbing up a gradient, the vehicle can stop immediately. Therefore, sight distance required is less. While descending a gradient, gravity also comes into action and more time will be required to stop the vehicle. Sight distance required will be more in this case.

Stopping sight distance
Stopping sight distance (SSD) is the minimum sight distance available on a highway at any spot having sufficient length to enable the driver to stop a vehicle traveling at design speed, safely without collision with any other obstruction.
Safe stopping distance and is one of the important measures in traffic engineering.
It is the distance a vehicle travels from the point at which a situation is first perceived to the time the deceleration is complete. Drivers must have adequate time if they are to suddenly respond to a situation. Thus, in highway design, sight distance at least equal to the safe stopping distance should be provided.
The stopping sight distance is the sum of lag distance and the braking distance.

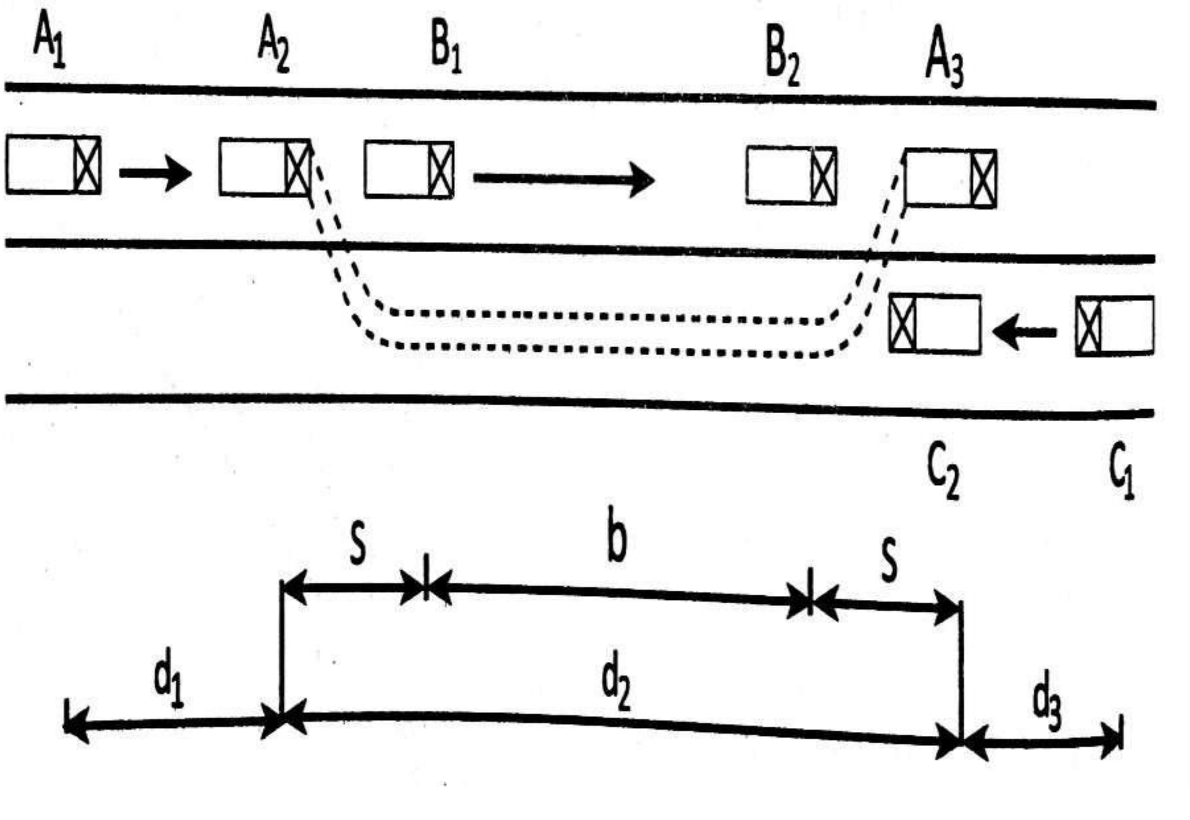
- Lag distance is the distance the vehicle travelled during the reaction time *t* and is given by *vt*, where *v* is the velocity in *m/sec*2.
- Braking distance is the distance travelled by the vehicle during braking operation. For a level road this is obtained by equating the work done in stopping the vehicle and the kinetic energy of the vehicle.

Overtaking sight distance

The overtaking sight distance is the minimum distance open to the vision of the driver of a vehicle intending to overtake the slow vehicle ahead safely against the traffic in the opposite direction. The overtaking sight distance or passing sight distance is measured along the center line of the road over which a driver with his eye level 1.2 m above the road surface can see the top of an object 1.2 m above the road surface.

The factors that affect the OSD are:
• Velocities of the overtaking vehicle, overtaken vehicle and of the vehicle coming in the opposite direction.
• Spacing between vehicles, which in-turn depends on the speed
• Skill and reaction time of the driver
• Rate of acceleration of overtaking vehicle
• Gradient of the road

Analysis of OSD on a two lane road with two way traffic:



From A1 to A2, the distance ‘d1’ (m) travelled by overtaking vehicle A at reduced speed ‘vb’ (m/s) during reaction time ‘t’ (sec),
d1= vb X t
• IRC suggest reaction time t of driver as 2 sec ,
d1= 2vb
• From A2 to A3, vehicle A starts accelerating, shift to adjoining lane, overtakes vehicle B, and shift back to its original lane during overtaking time ‘T’ (sec) and travel distance ‘d2’ (m).
From A2 to A3, the distance ‘d2’ (m) is further split into three parts viz;
d2= (s+b+s)
d2= (b+2s)

• The minimum spacing ‘s’ (m)between vehicles depends on their speed and is given by empirical formula,
$s=(0.7vb + 6)$
• The distance covered by the slow vehicle B travelling at a speed of ‘vb’ (m/s) in time ‘T’ (sec) is,
$b= vb \times T$

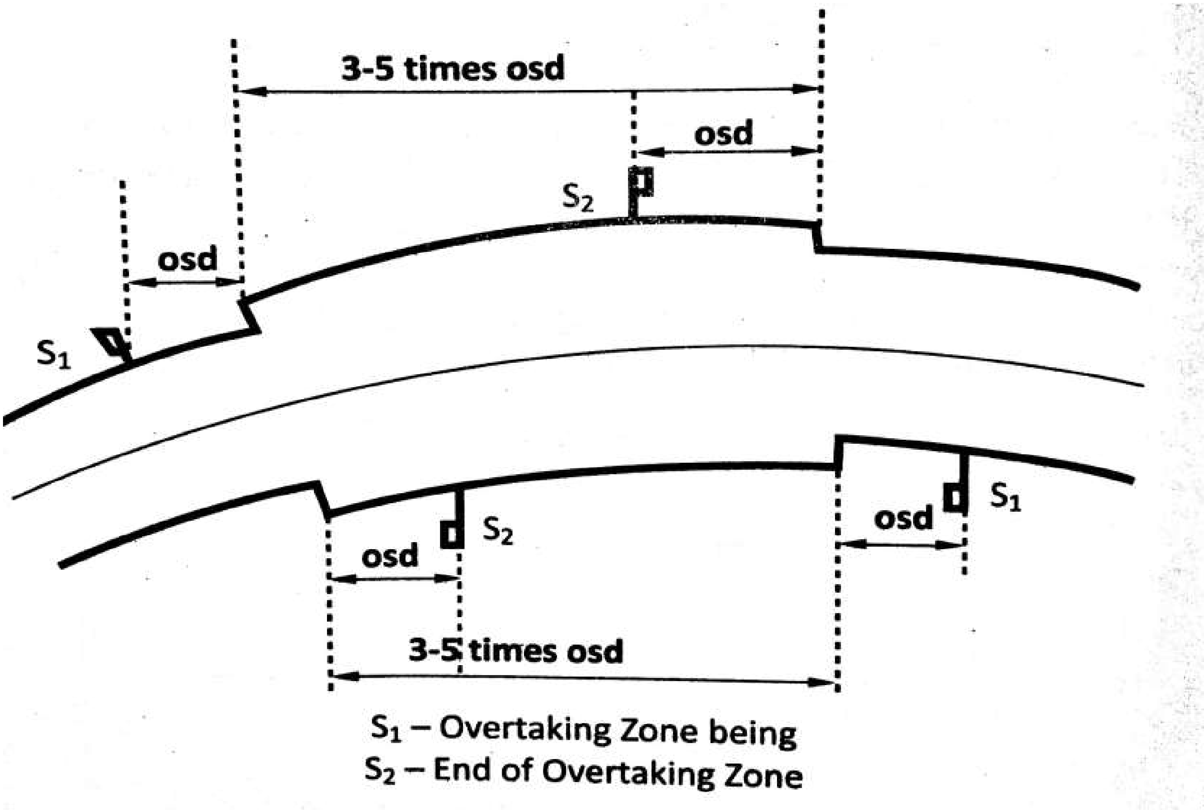
The overtaking time ‘T’ (sec) is calculated as;
$d2=(b+2s)=(vbT+aT2/2)$
$b=vb T$, $2s=aT2/2$
• From C1 to C2, distance travelled by vehicle C moving at design speed ‘v’ (m/s) during time ‘T’ (sec) is given by,
$d3=v \times T$

Thus overtaking sight distance (OSD) is,
$OSD=(d1+d2+d3)$
$OSD= (vb \times t) + (vb \times T +2s) +(v \times T)$
• If speed is in kmph,
$OSD= (0.28Vb \times t)+(0.28Vb \times T+2s)+(0.28V \times T)$
• In case speed of overtaken vehicle is not given it is assumed 16 kmph less than design speed of the highway.

where,
s=spacing of vehicles
t=reaction time of driver = 2sec
v =design speed in m/sec
V= design speed in kmph
vb=initial speed of overtaking vehicle in m/sec
Vb=initial speed of overtaking vehicle in
Kmph
A=average acceleration in kmph/sec
a=average acceleration in m/sec2

Overtaking zones

Overtaking zones are provided when OSD cannot be provided throughout the length of the highway. These are zones dedicated for overtaking operation, marked with wide roads. The desirable length of overtaking zones is 5 time OSD and the minimum is three times OSD Overtaking opportunity for vehicles moving at design speed should be given at frequent intervals as possible.



Sight distance at intersections

At intersections where two or more roads meet, visibility should be provided for the drivers approaching the intersection from either sides. They should be able to perceive a hazard and stop the vehicle if required. Stopping sight distance for each road can be computed from the design speed. The sight distance should be provided such that the drivers on either side should be able to see each other.

Design of sight distance at intersections may be used on three possible conditions:

• Enabling approaching vehicle to change the speed
• Enabling approaching vehicle to stop
• Enabling stopped vehicle to cross a main road

Design of Horizontal Alignment:

Various design elements to be considered in the horizontal alignment are :

- Design speed
- Horizontal curve
- Super elevation
- Type and length of transition curves
- Widening of pavement on curves
- Set-back distance

Horizontal curve

A horizontal highway curve is a curve in plan to provide change in direction to the central line of a road.

• When a vehicle traverses a horizontal curve, the centrifugal force acts horizontally outwards through the centre of gravity of the vehicle.

• The centrifugal force is given by the equation: $P = Wv^2/gR$

The presence of horizontal curve imparts centrifugal force which is reactive force acting outward on a vehicle negotiating it. Centrifugal force depends on speed and radius of the horizontal curve and is counteracted to a certain extent by transverse friction between the tyre and pavement surface. On a curved road, this force tends to cause the vehicle to overrun or to slide outward from the centre of road curvature. For proper design of the curve, an understanding of the forces acting on a vehicle taking a horizontal curve is necessary.

where,

P=centrifugal force in kg

W=Weight of the vehicle in kg

R=radius of the circular curve in m

v=speed of the vehicle in m/s

g=acceleration due to gravity=9.8 m/s2

P/W is known as the centrifugal ratio or the impact factor. The centrifugal ratio is thus equal to v^2/gR.

- The centrifugal force acting on a vehicle negotiating a horizontal curve has two effects:

i. Tendency to overturn the vehicle outwards about the outer wheels

ii. Tendency to skid the vehicle laterally, outwards

Super elevation (e):

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

The Super elevation 'e' is expressed as the ratio of the height of outer edge with respect to the horizontal width.

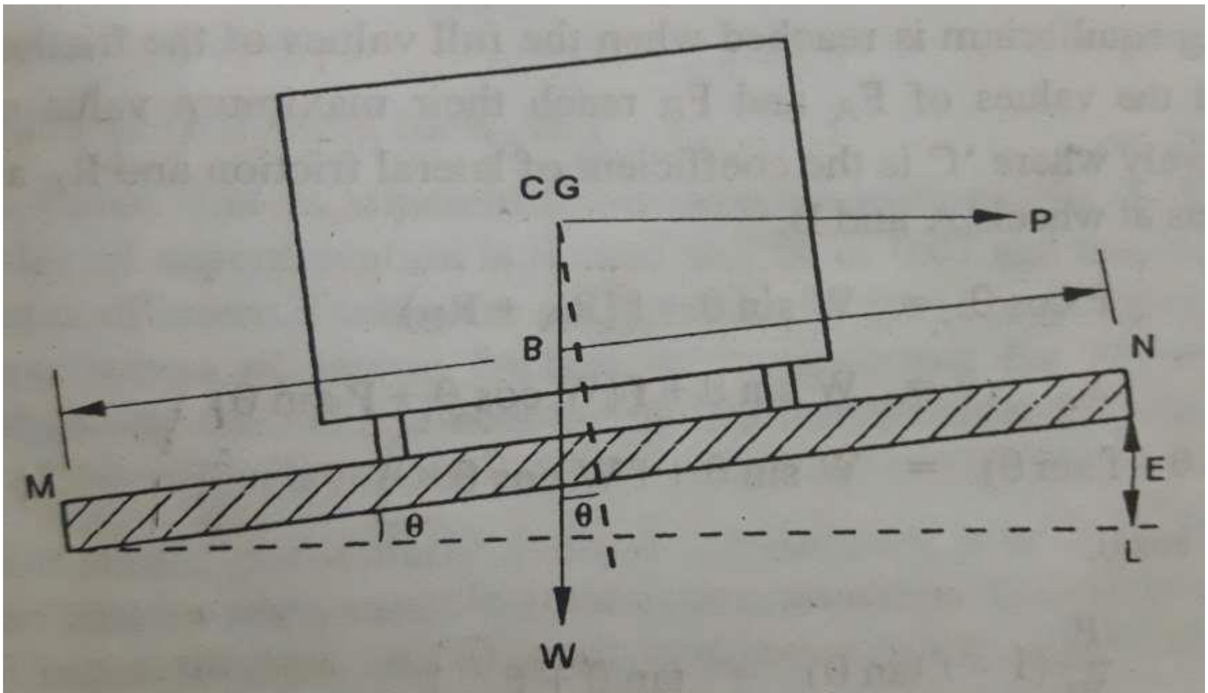
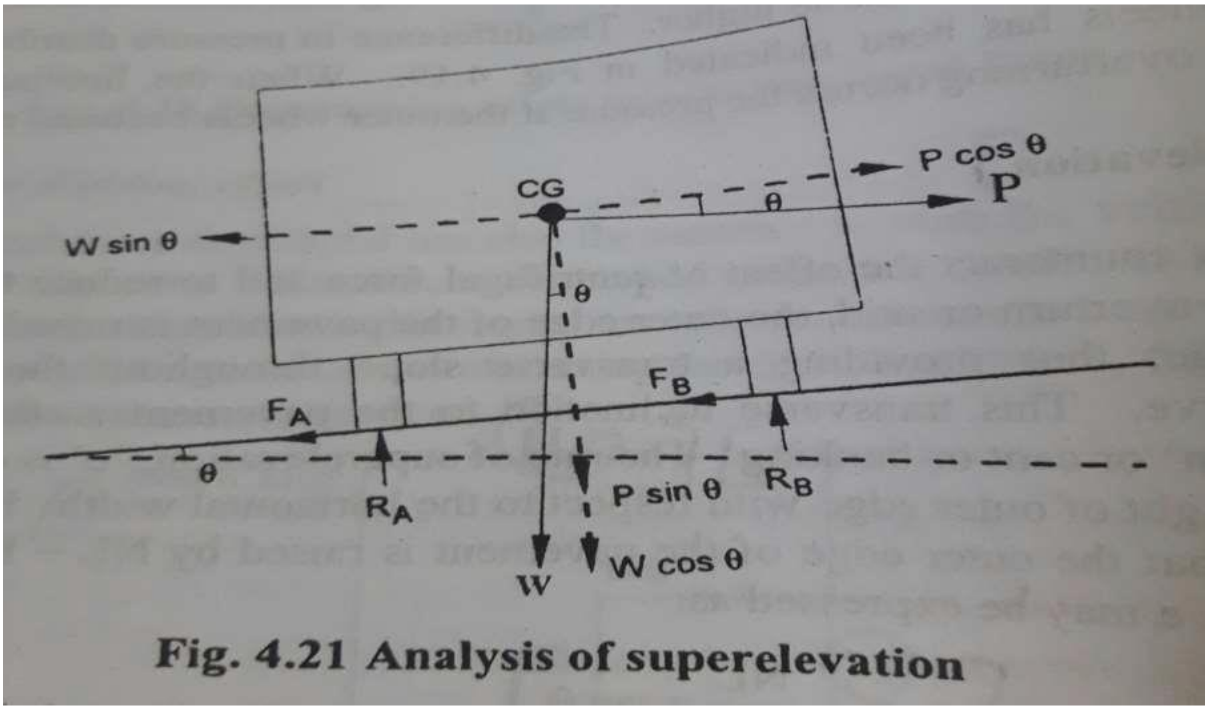


Fig. 4.20 Superelevated pavement section

Analysis of Superelevation:



For equilibrium condition,

P cosθ=W sinθ+FA+FB
P cosθ=W sinθ+ f.RA + f.RB
P cosθ=W sinθ+f(RA+RB)
P cosθ=W sinθ+f(W cos θ+P sin θ)
P(cosθ – f sinθ)=W sinθ+f Wcosθ
Dividing by Wcosθ, P/W(1- f tanθ)=tanθ+f
Centrifugal ratio =P/W= tanθ+f /(1-f tanθ)
The value of coefficient of lateral friction 'f' is taken as 0.15 and tanθ i.e. super elevation seldom exceeds 7-10%.
Therefore, Centrifugal ratio =P/W = tanθ+f
P/W = e + f ……(i)
but P/W = v^2/gR ……(ii)
Therefore, the general equation for the design of super elevation is given by,
e + f = v^2/gR
If 'V' speed of the vehicle is in kmph,
e + f = $V^2/127R$

where,
e=rate of Superelevation=tanΘ
f = design value of lateral friction
coefficient = 0.15
v = speed of the vehicle, m/sec
R = radius of the horizontal curve, m
g = acceleration due to gravity = 9.81 m/sec^2

Maximum Superelevation

• Indian Roads Congress (IRC) had fixed the maximum limit of Superelevation in plan and rolling terrains and is snow bound areas as 7.0 %.

• On hill roads not bound by snow a maximum Superelevation upto10% is recommended.

• On urban road stretches with frequent intersections, it may be necessary to limit the maximum Superelevation to 4.0 %.

Minimum Superelevation

• From drainage consideration it is necessary to have a minimum cross slope to drain off the surface water. If the calculated superelevation is equal to or less than the camber of the road surface, then the minimum superelevation to be provided on horizontal curve may be limited to the camber of the surface.

Steps For Superelevation Design

Step-I: The superelevation for 75 percent of design speed is calculated, neglecting the friction.

$e = (0.75v)^2/gR$ …..if ‘v’ is in m/sec

$e = (V)^2/225R$ …..if ‘V’ is in kmph

Step-II: If the calculated value of ‘e’ is less than 7% or 0.07 the value so obtained is provided. If the value of ‘e’ exceeds 7% or 0.07 then provides maximum superelevation equal to 7% or 0.07 and proceed with step-III or IV.

Step-III: Check the coefficient of friction developed for the maximum value of e =0.07 at the full value of design speed.

$f = v^2/gR - 0.07$ …..if ‘v’ is in m/sec

$f = V^2/127R - 0.07$ …..if ‘V’ is in kmph

If the value of ‘f’ thus calculated is less than 0.15,
the super elevation of 0.07 is safe for the design speed. If not, calculate the restricted speed as given in Step -IV.

Step-IV: The allowable speed at the curve is calculated by considering the design coefficient of lateral friction and the maximum superelevation.

$e + f = 0.07+0.15 = v_a^2/gR = V_a^2/127R$

$e + f = 0.22 = v_a^2/gR = V_a^2/127R$

If the allowed speed, as calculated above is higher than the design speed, then the design is adequate and provides a superelevation of ‘e’ equal to 0.07.

If the allowable speed is less than the design speed, the speed is limited to the allowed speed calculated above and appropriate warning sign and speed limit regulation sign are installed to restrict and regulate the speed.

Radius of Horizontal Curve:

$e + f = v^2/gR = V^2/127R$

• If maxm. allowable superelevation rate has been fixed as 7% and lateral friction f is 0.15 then,

$0.07 + 0.15 = v^2/gR = V^2/127R$

$0.22 = v^2/gR = V^2/127R$

• If design speed is decided ruling and minimum
radius is calculated as,

$R_{ruling} = v^2/g(e + f) = V^2/127(e + f)$

$R_{min} = v'^2/g(e + f) = V'^2/127(e + f)$

where, e=rate of Superelevation and f = design value of lateral friction coefficient
= 0.15

v or V= design speed of the vehicle, m/sec or kmph

v’ or V’= minimum design speed of the vehicle, m/sec or kmph

g = acceleration due to gravity = 9.81 m/sec²

Widening of pavement on horizontal curves:
On horizontal curves, especially when they are
Less than 300m radii, it is common to widen the pavement slightly more than the normal width.
• Widening is needed for the following reasons:
a. An automobile has a rigid wheel base and only the front wheels can be turned, when this vehicle takes a turn to negotiate a horizontal curve, the rear wheel do not follow the same path as that of the front wheels. This phenomenon is called off tracking.
b. While two vehicle cross or overtake at horizontal curve there is psychological tendency to maintain a greater clearance between the vehicle for safety.
c. For greater visibility at curve, the driver have tendency not to follow the central path of the lane, but to use the outer side at the beginning of the curve.
d. At higher speed superelevation and lateral friction cannot counteract centrifugal force and skidding may occur of extra widening on horizontal curves:
The extra widening of pavement on horizontal curves is divided into two parts:
a. Mechanical widening/Off tracking
b. Psychological widening

Objects of providing transition curve:
A transition curve which is introduced between straight and a circular curve will help in:
a. Gradually introducing centrifugal force.
b. Gradually introducing designed superelevation.
c. Gradually introducing extra widening.
d. To enable the driver turn steering gradually for his own comfort and safety.
Vertical Alignment:
• The vertical alignment is the elevation or profile of the centre line of the road.
• The vertical alignment consists of grades and vertical curves.
• The vertical alignment of a highway influences:
i. Vehicle speed
ii. Acceleration and deceleration
iii. Sight distance
iv. Vehicle operation cost
v. Comfort while travelling at high speeds

Gradients:
• Gradient is the rate of rise or fall along the length of road with respect to the horizontal.
• It is expressed as a ratio of 1 in n or also as percentage such as n%.

Types Of Gradients:
• Gradients are divided into four categories:
a. Ruling gradient
b. Limiting gradient
c. Exceptional gradient
d. Minimum gradient

a. Ruling gradient:
• Ruling gradient is the maximum gradient within which the designer attempts to design the vertical profile of a road.
• Ruling gradient is also known as 'Design gradient'.
• For selection of ruling gradient factors such as type of terrain, length of the grade, speed, pulling power of vehicle etc are considered.

b. Limiting gradient:
• Steeper than ruling gradient. In hilly roads, it may be frequently necessary to exceed ruling gradient and adopt limiting gradient, it depends on
a. Topography
b. Cost in constructing the road
c. Exceptional gradient:
• Exceptional gradient are very steeper gradients given at unavoidable situations.
• They should be limited for short stretches not exceeding about 100 m at a stretch.

d. Minimum gradient:
• This is important only at locations where surface drainage is important.
• Camber will take care of the lateral drainage.
• But the longitudinal drainage along the side drains require some slope for smooth flow of water.
• Therefore minimum gradient is provided for drainage purpose and it depends on the rainfall, type of soil and other site conditions.
•A minimum of 1in500 may be sufficient for concrete drain and 1in 200 or 1 in 100 for open soil drains.

Grade Compensation:
• When sharp horizontal curve is to be introduced on a road which has already maximum permissible gradient, then gradient should be decreased to compensate for loss of tractive efforts due to curve.
• This reduction in gradient at horizontal curve is called grade compensation.
Grade compensation, % = 30+R/R
IRC gave the following specification for the grade compensation:
1.Grade compensation is not required for grades flatter than 4% because the loss of tractive force is negligible.
2.The maximum grade compensation is limited to 75/R%.
Compensated gradient = ruling gradient –grade compensation

CHAPTER-3

Road Materials

Difference types of road materials in use: soil, aggregates, and binders

A wide variety of materials are used in the construction of roads these are soils (naturally occurring or processed), aggregates (fine aggregates or coarse aggregates obtained from rocks), binders like lime, bituminous materials, and cement, and miscellaneous materials used as admixtures for improved performance of roads under heavy loads and traffic.

1. Soil:

Soil constitutes the primary material for the foundation, subgrade, or even the pavement (for low-cost roads with low traffic in rural areas). When the highway is constructed on an embankment at the desired level, soil constitutes the primary embankment material; further, since all structures have to ultimately rest on and transmit loads to 'mother earth', soil and rock also serve as foundation materials.

Need for Soil Classification:

Soil deposits in nature are never homogenous in character; wide variations are observed in their properties and behaviour. Soils that exhibit similar average properties may be grouped as a class. Classification of soil is necessary to obtain an appropriate and fairly accurate idea of the properties and behaviour of a soil type.

(a) Textural classification
(b) PRA system of classification (Group index method)
(c) Unified soil classification System
(d) Indian Standard Soil classification system

2. Stone Aggregates:

Stone aggregate, or mineral aggregate, as it is called, is the most important component of the materials used in the construction of roads. These aggregates are derived from rocks, which are formed by the cementation of minerals by the forces of nature.

Stone aggregates are invariably derived by breaking the naturally occurring rocks to the required sizes. They are used for granular bases, sub-bases, as part of bituminous mixes and cement concrete; they are also the primary component of a relatively cheaper road, called water-bound macadam.

Desirable Properties of Sand Aggregates:

The following properties are desirable in soil aggregates used the construction of roads:

(i) Strength:

It is the resistance to crushing which the aggregates used in road construction, especially in the top layers and wearing course, have to withstand the stresses due to wheel loads of the traffic in addition to wear and tear.

(ii) Hardness:

It is the resistance to abrasion of the aggregate at the surface. The constant rubbing or abrading action between the tyres of moving vehicles and the exposed aggregate at the road surface should be resisted adequately.

(iii) Toughness:
This is the resistance to impact due to moving traffic. Heavily loaded trucks and other vehicles cause heavy impact loads on the road surface while moving at high speeds, and while accelerating and decelerating. Even steel-typed vehicles, though moving slow, cause heavy impact on the aggregates exposed at the surface. Hence, resistance to such impact forces is a desirable quality.

(iv) Durability:
It is the resistance to the process of disintegration due to the weathering action of the forces of nature. The property by virtue of which the aggregate withstands weathering is called soundness. This is also a desirable property.

(v) Cementation:
It is the ability of the aggregate to form its own binding material under traffic, providing resistance to lateral displacement. Limestone and laterite are examples of stones with good cementing quality. This becomes important in the case of water-bound macadam roads.

(vi) Appropriate Shape:
Aggregates maybe either rounded, cubical, angular, flaky, or elongated. Each shape is appropriate for a certain use. Too flaky and too elongated aggregates have less strength and durability; so they are not preferred in road construction.
Rounded aggregates are good for cement concrete because of the workability such aggregates provide. Cubical or angular aggregates have good interlocking properties; since flexible pavements derive their stability due to interlocking, such aggregates are the preferred type for construction. Thus, the appropriate shape for a particular use is also a desirable property.

(vii) Adhesion with Bitumen:
The aggregates used in bituminous pavements should have less affinity to water than to bitumen; otherwise, the bituminous coating on the surface of the aggregate will get stripped off in the presence of water. So, hydrophobic characteristic is a desirable property for aggregates to be used in the construction of bituminous roads.

(viii) Attrition:
This is mutual rubbing of aggregates under traffic; adequate resistance to attrition is a desirable property.

(ix) Texture:
This is a measure of the degree of fineness or smoothness of the surface of the aggregate.
Gravels from river beds are fairly smooth; as a rule, fine grained rock is highly resistant to wear and is preferred for surface courses.

3. Bituminous Materials:
Bitumen was used as a bonding and water-proofing agent thousands of years ago. However, the use of bitumen for road-making picked up only in the nineteenth century. As the quest for fuels like petroleum to run automobiles grew and the distillation of crude oil emerged as a major refining industry, the residues known as bitumen and tar found increasing use in constructing bituminous surfaces, which provided superior riding surface.

Important Properties of Bitumen:

- Predominantly hydrocarbons, with small quantities of sulphur, nitrogen and metals.
- Mostly (up to 99.9%) soluble in carbon disulphide (CS2), and insoluble in water.
- Softens on heating and gets hardened on cooling.
- Highly impermeable to water.
- Chemically inert and unaffected by most acids, alkalis and salts.
- No specific boiling point, melting point or freezing point; a form of 'softening point' is used in their characterisation.
- Although generally hydrophobic (water repellent), they may be made hydrophilic (water liking) by the addition of a small quantity of surface-active agent.
- Most bitumens are colloidal in nature.

Desirable Properties of Bitumen as a Road Material:

- Workability – Bitumen should be fluid enough at the time of mixing so that the aggregates are fully coated by the binder. Fluidity is achieved either by heating or by cutting back with a thin flux or by emulsifying the bitumen.
- Durability – There should be little change in viscosity within the usual range of temperatures in the locality.
- Volatile constituents in bitumen should not be lost excessively at higher temperatures to ensure durability.
- It should have enough ductility to avoid brittleness and cracking.
- Strength and adhesion – The bitumen should have good affinity to the aggregates and should not be stripped off in the continued presence of water.
- Cost-effectiveness.

A few more terms relating to bitumen/asphalt are:

Straight-Run Bitumen: Bitumen derived from the refining of petroleum for which the viscosity has not been adjusted by blending with flux oil or bysoftening with any cut-back oil or by any other treatment. It generally has high viscosity.

Asphalt Cement:

A binder consisting of bitumen, or a mixture of lake asphalt and bitumen or flux oils, specially prepared as per prescribed quality and consistency for direct use in paving, usually in the hot condition.

Oxidised or Blown Bitumen:

Bitumen obtained by further treatment of straight-run bitumen by running it, while hot, into a vertical column and blowing air through it. In this process, it attains a rubbery consistency with a higher softening point than before.

Cut-Back Bitumen:

Asphalt/bitumen dissolved in naphtha or kerosene to lower the viscosity and increase the workability.

Emulsified Bitumen:

A mixture in which asphalt cement, in a finely dispersed state, is suspended in chemically treated water.

Liquid Bitumen:

Include cut-backs in naphtha and kerosene, as also emulsified asphalts.

Cut-Back Bitumen:

Cut-back bitumen is one, the viscosity of which is reduced by adding a volatile diluent. Penetration grade bitumens require to be heated to a specified temperature to lower its viscosity before it is applied on a road to facilitate coating the pre-heated aggregate. To obviate the need for heating the aggregate, cut-backs come in handy. Upon application, the volatiles slowly evaporate, and leave behind the original bituminous binder.

There are three types of cut-backs based on the diluent (dilutant or solvent) used:

1. Rapid-curing (RC) cutback – Bitumen blended with gasoline or naphtha, (highly volatile, low viscosity)
2. Medium-curing (MC) cutback – Bitumen blended with kerosene or coal tar creosote oil (medium viscosity)
3. Slow-curing (SC) cutback – Bitumen blended with gas oil (low viscosity, highly viscous)

Bitumen Emulsions:

A bitumen emulsion is obtained by blending bitumen with water and an additive called an emulsifier. The emulsified suspension contains dispersed minute particles of bitumen (that is, oil in water). In a bituminous emulsion, bitumen is the ‘dispersed’ phase (minutely subdivided particles), while water is the ‘continuous’ phase in which it is not soluble. The amount of bitumen to be mixed with water may range from 40 to 70% depending upon the intended use of the suspension.

Bitumen emulsions, like cutback bitumens, are also classified into three types based on their setting times:

1. Rapid-setting emulsions (RS)
2. Medium-setting emulsions (MS)
3. Slow-setting emulsions (SS)

Setting, in this context, means separation of the emulsion. When the water in the emulsion evaporates, the minute bitumen particles in the emulsion coat the surface of the aggregates; curing takes place, by which the compacted layer of the emulsion-aggregate mix hardens and attains strength. Therefore, rapid-setting emulsion sets and cures in a relatively quick manner. “IS: 3117-2004: Anionic bitumen emulsions” covers anionic emulsions, while “IS: 8887- 2004: Cationic bitumen emulsions” covers cationic emulsions.

Tar:

Tar is a black or brown to black, viscous, non-crystalline material having binding property. This is, therefore, the other category of bituminous materials.

Tar is obtained from the destructive distillation of organic materials such as coal, petroleum, oil, wood and peat, in the absence of air at about 1000°C. It is completely soluble in carbon tetrachloride (CCl_4). It contains more volatile constituents than bitumen and is therefore more susceptible to change in temperature. Generally, tar is used for surface dressing on the wearing course since it has good adhesion in damp conditions.

Some more terms relating to tar are:

i. Coal tar – Tar produced by the destructive distillation of bituminous coal.

ii. Coke-oven tar – A variety of coal tar obtained as a by-product from the destructive distillation of coal in the production of coke.

iii. Oil-gas tar – A petroleum tar produced by cracking oils at high temperature in the production of oil-gas.

iv. Water-gas tar – A petroleum tar produced by cracking oils at high temperature in the production of carburetted water-gas.

v. Refined tar – Produced from crude tar by distillation to remove water and to produce a residue of desired consistency.

vi. Road tar – A tar refined in quality and consistency for use in paving of roads.

vii. Pitch – Black or dark brown solid cementitious residue which gradually liquefies when heated and which is produced by distilling off the volatile constituents from tar.

Specifications for Road Tars:

Indian Standards classify road tars for paving purposes into five grades — RT1, RT2, RT3, RT4, and RT5, meant for specific purposes.

Low Temperature Tar:

The coal-tar produced in the manufacture of coking coal requires carbonation at high temperatures above 1000°C. In view of the increasing demand for road tars in recent years, a new technology known as low temperature carbonisation has come into vogue.

In this, the carbonisation of coal is carried out in the temperature range of 600°-750°C in a smokeless fuel process. The crude tar thus produced is successfully used for making road tars; these are known as low temperature tars.

Bitumen versus Tar:

A comparison of bitumen and tar is given below:

I. Aggregates coated with tar exhibit lower stripping action than those coated with bitumen.

II. Tar is more susceptible to temperature than bitumen. It becomes liquid at relatively lower temperature.

III. Tar is not easily dissolved in petroleum solvents; so it can be preferred for paving parking areas, where oils might drip from vehicles.

IV. Since more setting time is required for tar, it may be processed at a mixing plant and carried to the construction site.

V. In view of the higher free carbon content, tar is more brittle than bitumen.

VI. As tars have more phenol content, they can get more easily oxidised than bitumen.

VII. At higher temperatures, tar may be more easily affected than bitumen.

VIII. As more time is required for tar to set, tar-paved roads need to be closed to traffic for a longer time.

The tests used to evaluate the strength properties of soils may be broadly divided into three groups:

- Shear tests
- Bearing tests
- Penetration tests

Shear tests are usually carried out on relatively small soil samples in the laboratory. In order to find out the strength properties of soil, a number of representative samples from different locations are tested. Some of the commonly known shear tests are direct shear test, triaxial compression test, and unconfined compression test.

Bearing tests are loading tests carried out on sub grade soils in-situ with a load bearing area. The results of the bearing tests are influenced by variations in the soil properties within the stressed soil mass underneath and hence the overall stability of the part of the soil mass stressed could be studied.

Penetration tests may be considered as small scale bearing tests in which the size of the loaded area is relatively much smaller and ratio of the penetration to the size of the loaded area is much greater than the ratios in bearing tests. The penetration tests are carried out in the field or in the laboratory.

California Bearing Ratio: methods of finding CBR valued in the laboratory and at site and their significance

California Bearing Ratio Test

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

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

CHAPTER-4

Road Pavements

A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub-grade. Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements. This chapter gives an overview of pavement types, layers, and their functions, and pavement failures. Improper design of pavements leads to early failure of pavements affecting the riding quality.

Purpose of a Road Pavement

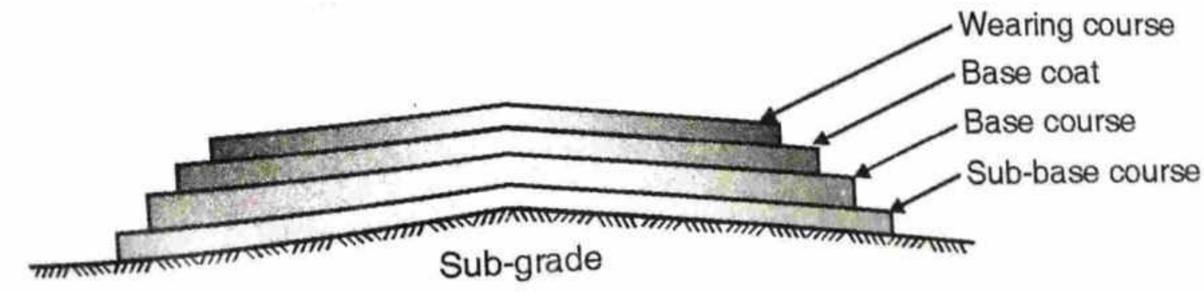
- The main purpose is to carry heavy wheel loads of vehicular traffic.
- To distribute the vehicular load over a large area of the underlying sub-grade soil.
- Generally to provide a smooth road pavement surface.
- To prevent ill effects of weathering agencies on sub-grade soil.

Requirements of a pavement

- An ideal pavement should meet the following requirements:
- Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil,
- Structurally strong to withstand all types of stresses imposed upon it,
- Adequate coefficient of friction to prevent skidding of vehicles,
- Smooth surface to provide comfort to road users even at high speed,
- Produce least noise from moving vehicles,
- Dust proof surface so that traffic safety is not impaired by reducing visibility,
- Impervious surface, so that sub-grade soil is well protected, and
- Long design life with low maintenance cost.

Component Parts of Road Pavement Structure

- Sub-grade or Formation
- Sub-base
- Base Course or Foundation Course
- Base Coat or Intermediate Course
- Wearing Course



1. Sub-grade :

Definition : The finished and compacted earthwork on which a road pavement rests is called as sub-grade or formation.

Functions of Sub-grade:

To provide support to the pavements.

Sub-grade carries entire load of pavement including the traffic.

2. Sub-base :

Definition : A layer of granular material provided in between the sub-grade and the base course in a road pavement is called sub-base.

Functions of Sub-base :

It improves the bearing capacity of sub-grade.

It improves drainage and keep check on capillary rise of subsoil water.

3. Base Course :

Definition : A layer of boulders or bricks provided in double layer over the sub-base or immediately over the sub-grade in the absence of sub-base in a pavement is called base course.

Functions of Base Course:

To withstand high shearing stresses develop due to the impact of traffic on the wearing course.

To act as foundation to the pavement, which transfers load over the pavement surface to the sub-base and sub-grade lying underneath.

4. Base Coat :

Definition : The layer of hard stones provided in between the base course and the wearing course in a road pavement is called base coat or bearing course or intermediate coat.

Functions of Base Coat :

Generally to transmit the load over the large area of the base course.

To act as layer of transmission material.

5. Wearing Course :

The top most layer of pavement directly exposed to traffic is called as wearing course or surfacing.

Functions of Wearing Course :

The main function of wearing course is to provide impervious layers so that entry of water to the base course can be prevented.

Moreover the entire traffic load is safely distributed over the base course.

It acts as impervious layer, thus avoids the entry of water to the base course.

Types of Road Pavement

The pavements can be classified based on the structural performance into two, flexible pavements and rigid pavements. In flexible pavements, wheel loads are transferred by grain-to-grain contact of the aggregate through the granular structure. The flexible pavement, having less flexural strength, acts like a flexible sheet (e.g. bituminous road). On the contrary, in rigid pavements, wheel loads are transferred to sub-grade soil by flexural strength of the pavement and the pavement acts like a rigid plate (e.g. cement concrete roads). In addition to these, composite pavements are also available. A thin layer of flexible pavement over rigid pavement is an ideal pavement with most desirable characteristics. However, such pavements are rarely used in new construction because of high cost and complex analysis required.

1. **Flexible Pavement**
2. **Rigid Pavement**

Flexible pavements

Flexible pavements will transmit wheel load stresses to the lower layers by grain-to-grain transfer through the points of contact in the granular structure

The wheel load acting on the pavement will be distributed to a wider area, and the stress decreases with the depth. Taking advantage of this stress distribution characteristic, flexible pavements normally has many layers. Hence, the design of flexible pavement uses the concept of layered system. Based on this, flexible pavement may be constructed in a number of layers and the top layer has to be of best quality to sustain maximum compressive stress, in addition to wear and tear. The lower layers will experience lesser magnitude of stress and low quality material can be used. Flexible pavements are constructed using bituminous materials. These can be either in the form of surface treatments (such as bituminous surface treatments generally found on low volume roads) or, asphalt concrete surface courses (generally used on high volume roads such as national highways). Flexible pavement layers reflect the deformation of the lower layers on to the surface layer (e.g., if there is any undulation in sub-grade then it will be transferred to the surface layer). In the case of flexible pavement, the design is based on overall performance of flexible pavement, and the stresses produced should be kept well below the allowable stresses of each pavement layer.

Types of Flexible Pavements

The following types of construction have been used in flexible pavement:

- Conventional layered flexible pavement,

- Full - depth asphalt pavement, and
- Contained rock asphalt mat (CRAM).

Conventional flexible pavements are layered systems with high quality expensive materials are placed in the top where stresses are high, and low quality cheap materials are placed in lower layers.

Full - depth asphalt pavements are constructed by placing bituminous layers directly on the soil sub-grade. This is more suitable when there is high traffic and local materials are not available.

Contained rock asphalt mats are constructed by placing dense/open graded aggregate layers in between two asphalt layers. Modified dense graded asphalt concrete is placed above the sub-grade will significantly reduce the vertical compressive strain on soil sub-grade and protect from surface water.

Typical layers of a flexible pavement

Typical layers of a conventional flexible pavement includes seal coat, surface course, tack coat, binder course, prime coat, base course, sub-base course, compacted sub-grade, and natural sub-grade .

Seal Coat:

Seal coat is a thin surface treatment used to water-proof the surface and to provide skid resistance.

Tack Coat:

Tack coat is a very light application of asphalt, usually asphalt emulsion diluted with water. It provides proper bonding between two layer of binder course and must be thin, uniformly cover the entire surface, and set very fast.

Prime Coat:

Prime coat is an application of low viscous cutback bitumen to an absorbent surface like granular bases on which binder layer is placed. It provides bonding between two layers. Unlike tack coat, prime coat penetrates into the layer below, plugs the voids, and forms a water tight surface.

Surface course

Surface course is the layer directly in contact with traffic loads and generally contains superior quality materials. They are usually constructed with dense graded asphalt concrete(AC). The functions and requirements of this layer are:

It provides characteristics such as friction, smoothness, drainage, etc. Also it will prevent the entrance of excessive quantities of surface water into the underlying base, sub-base and sub-grade,

It must be tough to resist the distortion under traffic and provide a smooth and skid- resistant riding surface,

It must be water proof to protect the entire base and sub-grade from the weakening effect of water.

Binder course

This layer provides the bulk of the asphalt concrete structure. It's chief purpose is to distribute load to the base course The binder course generally consists of aggregates having less asphalt and doesn't require quality as high as the surface course, so replacing a part of the surface course by the binder course results in more economical design.

Base course

The base course is the layer of material immediately beneath the surface of binder course and it provides additional load distribution and contributes to the sub-surface drainage It may be composed of crushed stone, crushed slag, and other untreated or stabilized materials.

Sub-Base course

The sub-base course is the layer of material beneath the base course and the primary functions are to provide structural support, improve drainage, and reduce the intrusion of fines from the sub-grade in the pavement structure If the base course is open graded, then the sub-base course with more fines can serve as a filler between sub-grade and the base course A sub-base course is not always needed or used. For example, a pavement constructed over a high quality, stiff sub-grade may not need the additional features offered by a sub-base course. In such situations, sub-base course may not be provided.

Sub-grade

The top soil or sub-grade is a layer of natural soil prepared to receive the stresses from the layers above. It is essential that at no time soil sub-grade is overstressed. It should be compacted to the desirable density, near the optimum moisture content.

Failure of flexible pavements

The major flexible pavement failures are fatigue cracking, rutting, and thermal cracking. The fatigue cracking of flexible pavement is due to horizontal tensile strain at the bottom of the asphaltic concrete. The failure criterion relates allowable number of load repetitions to tensile strain and this relation can be determined in the laboratory fatigue test on asphaltic concrete specimens. Rutting occurs only on flexible pavements as indicated by permanent deformation or rut depth along wheel load path. Two design methods have been used to control rutting: one to limit the vertical compressive strain on the top of subgrade and other to limit rutting to a tolerable amount (12 mm normally). Thermal cracking includes both low-temperature cracking and thermal fatigue cracking.

Rigid pavements

Rigid pavements have sufficient flexural strength to transmit the wheel load stresses to a wider area below. A typical cross section of the rigid pavement is shown in Figure 3. Compared to flexible pavement, rigid pavements are placed either directly on the prepared sub-grade or on a single layer of granular or stabilized material. Since there is only one layer of material between the concrete and the sub-grade, this layer can be called as base or sub-base course.

In rigid pavement, load is distributed by the slab action, and the pavement behaves like an elastic plate resting on a viscous medium (Figure 4). Rigid pavements are constructed by Portland cement concrete (PCC) and should be analyzed by plate theory instead of layer theory, assuming an elastic plate resting on viscous foundation. Plate theory is a simplified version of layer theory that assumes the concrete slab as a medium thick plate which is plane before loading and to remain plane after loading. Bending of the slab due to wheel load and temperature variation and the resulting tensile and flexural stress.

Types of Rigid Pavements

Rigid pavements can be classified into four types:

1. Jointed plain concrete pavement (JPCP),
2. Jointed reinforced concrete pavement (JRCP),
3. Continuous reinforced concrete pavement (CRCP), and
4. Pre-stressed concrete pavement (PCP).

Jointed Plain Concrete Pavement:

These are plain cement concrete pavements constructed with closely spaced contraction joints. Dowel bars or aggregate interlocks are normally used for load transfer across joints. They normally has a joint spacing of 5 to 10m.

Jointed Reinforced Concrete Pavement:

Although reinforcements do not improve the structural capacity significantly, they can drastically increase the joint spacing to 10 to 30m. Dowel bars are required for load transfer. Reinforcements help to keep the slab together even after cracks.

Continuous Reinforced Concrete Pavement:

Continuously reinforced concrete pavements (CRCP) is a type of concrete pavement that does not require any transverse contraction joints. Transverse cracks are expected in the slab, usually at intervals of 1.5 - 6 ft (0.5 - 1.8 m). CRCP is designed with enough embedded reinforcing steel (approximately 0.6-0.7% by cross-sectional area) so that cracks are held together tightly. Determining an appropriate spacing between the cracks is part of the design process for this type of pavement.

Pre-stressed concrete pavement (PCP)

Complete elimination of joints is achieved by reinforcement.

Difference between Flexible Pavements and Rigid Pavements

Sl. No.	Flexible Pavement	Rigid Pavement
1	It consists of a series of layers with the highest quality materials at or near the surface of pavement.	It consists of one layer Portland cement concrete slab or relatively high flexural strength.
2	It reflects the deformations of subgrade and subsequent layers on the surface.	It is able to bridge over localized failures and area of inadequate support.
3	Its stability depends upon the aggregate interlock, particle friction and cohesion.	Its structural strength is provided by the pavement slab itself by its beam action.

4	Pavement design is greatly influenced by the subgrade strength.	Flexural strength of concrete is a major factor for design.
5	It functions by a way of load distribution through the component layers	It distributes load over a wide area of subgrade because of its rigidity and high modulus of elasticity.
6	Temperature variations due to change in atmospheric conditions do not produce stresses in flexible pavements.	Temperature changes induce heavy stresses in rigid pavements
7	Flexible pavements have self-healing properties due to heavier wheel loads are recoverable due to some extent.	Any excessive deformations occurring due to heavier wheel loads are not recoverable, i.e. settlements are permanent.

Failure criteria of rigid pavements

Traditionally fatigue cracking has been considered as the major, or only criterion for rigid pavement design. The allowable number of load repetitions to cause fatigue cracking depends on the stress ratio between flexural tensile stress and concrete modulus of rupture. Of late, pumping is identified as an important failure criterion. Pumping is the ejection of soil slurry through the joints and cracks of cement concrete pavement, caused during the downward movement of slab under the heavy wheel loads. Other major types of distress in rigid pavements include faulting, spalling, and deterioration.

Types of Failures in Rigid Pavements

The different types of distresses responsible for failures in rigid pavements are:

1. Joint Spalling
2. Faulting
3. Polished Aggregate
4. Shrinkage Cracking
5. Pumping
6. Punch out
7. Linear Cracking
8. Durability Cracking
9. Corner Break

Joint Spalling in Rigid Pavements

Excessive compressive stress causes deterioration in the joints, called as the spalling. This may be related to joint infiltration or the growth of pavement, that are caused by the reactive aggregates. Poor quality concrete or construction technique will also result in joint spalling. Small edges to large spalls in the back of the slab and down to the joints can be observed. Main causes of joint spalling in rigid pavements are:

Joints subjected to excessive stress due to high traffic or by infiltration of any incompressible materials

The joint that are constructed with weak concrete joint that is accumulated with water that results in rapid freezing and thawing

Main causes of joint spalling in rigid pavements are:

- Joints subjected to excessive stress due to high traffic or by infiltration of any incompressible materials
- The joint that are constructed with weak concrete
- Joint that is accumulated with water that results in rapid freezing and thawing

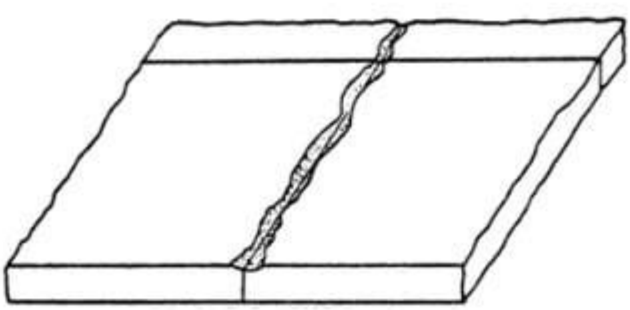


Fig.1: Joint Spalling in Rigid Pavement Slabs

Faulting in Rigid Pavements

The difference in elevation between the joints is called as faulting. The main causes of failures in rigid pavements due to faulting are:

Settlement of the pavement that is caused due to soft foundation

The pumping or the erosion of material under the pavement, resulting in voids under the pavement slab causing settlement

The temperature changes and moisture changes that cause curling of the slab edges.

Fig.2: Faulting with difference in elevations found between the joints

Polished Aggregate in Rigid Pavements

The repeated traffic application leads to this distress. These are the failures in rigid pavements caused when the aggregates above the cement paste in the case of PCC is very small or the aggregates are not rough or when they are angular in shape, that it cannot provide sufficient skid resistance for the vehicles. The polishing degree should be specified before the construction is carried out. This study is included in the condition survey, where it is mentioned as a defect.

Fig: Polished Aggregates

Shrinkage Cracking in Rigid Pavements

These are hairline cracks that are less than 2m in length. They do not cross the entire slab. The setting and curing process of the concrete slab results in such cracks. These are caused due to higher evaporation of water due to higher temperature cracks. Improper curing can also create shrinkage cracks in rigid pavements.Shrinkage Cracking in Rigid Pavements

Fig: Shrinkage Cracking in Pavements

Pumping Effects

The expulsion of water from the under a layer of the pavement is called as pumping. This distress is caused due to the active vehicle loads coming over the pavement in a repetitive manner. This will result in the fine materials present in the sub base to move along with water and get expelled out with the water. Larger voids are created under the pavement due to repeated expulsion. The stains on the pavement or on the shoulder surface are the method through which this type of failure of rigid pavement is evidenced. Pumping can be avoided by the prevention of water accumulation at the pavement sub-base interface. This can be achieved by reducing the deflection to a minimum value and by the provision of a strong well-constructed sub-base. The constructed sub-base must have a sufficient drainage facility so that the subgrade below is not saturated. Modern pavement construction makes use of underground drainage system that is the best solution for pumping distress.

Fig: Pumping Effect

Corner Breaks in Rigid Pavements

These are the failures in rigid pavements that is caused due to pumping in excessive rate. When the pumping completely remove the underlying support that no more support exists below to taken the vehicle load, the corner cracks are created. The repair method is either full slab replacement or the repair for the full depth must be carried out.

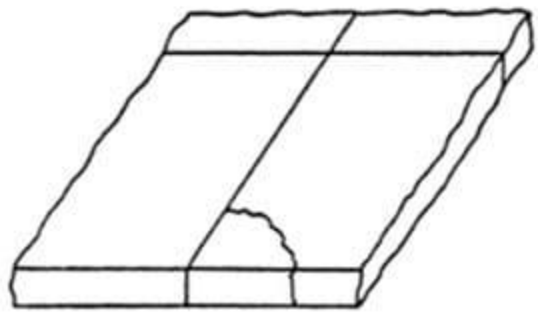


Fig: Corner Break Failures in Rigid Pavement

Punch-out in Rigid Pavements

A localized area of concrete slab that is broken into pieces will be named as punch out distress. This distress can take any shape or form. These are mainly defined by joints and cracks. The joints and cracks will mainly keep 1.5m width. The main reason behind punch outs is heavy repeated loads, the slab thickness inadequacy, the foundation support loss or the construction deficiency like honeycombing.

Fig. Punch-out Failures in Rigid Pavements

Linear Cracking in Rigid Pavements

These types of failures in rigid pavements divides the slab into two or three pieces. The reason behind such failures is traffic loads at repeated levels, the curling due to thermal gradient and moisture loading repeatedly.

Fig: Linear Cracking

Durability Cracking in Rigid Pavements

The freezing and thawing action will create regular expansion and contraction which will result in the gradual breakdown of the concrete. This type of distress is patterns of cracks on the concrete surface as layers that are parallel and closer to the joints. Joints and cracks are the areas where the concrete seem to be more saturated. Here a dark deposit is found and called the 'D' cracks. This failure of rigid pavement will finally result in the complete disintegration of the whole slab.

Fig. Durability Cracking or 'D' Cracks Failure in Rigid Pavements

CHAPTER-5

Hill Roads

Definition:

The term hill road can be explained with reference to the cross slope, i.e., the slope approximately perpendicular to the centreline of the highway alignment. Thus, a road is termed as a hill road if it passes through a terrain with a cross slope of 25% or more and it is characterized by widely differing elevations, deep gorges, a number of watercourses, and steep slopes. The hill roads are also sometimes referred to as ghat roads.

IMPORTANCE OF HILL ROADS

There are possibly two modes of transport for mountainous or hilly areas, namely, roads and railways. The choice between the two should be based on the relative economics and the following factors are certainly in favour of hilly roads:

(1) Development in stages: A road of small width involving less expenditure can open out the area of immediate economic development and the improvements in the roadway system can be carried out as and when the traffic develops.

(2) Initial cost: There is no doubt that the initial cost of construction of railways is much more than that of roads in hilly areas.

(3) Length: The roads can be constructed with comparatively steeper grades which will result in the reduction of the length of road as compared to the length of the railway track required with milder slopes for rail traction for the same height.

The importance of hill roads can be imagined by understanding the following purposes which they serve:

(i) Economic development: The hilly areas are backward as far as modern civilization, culture and education are concerned and hence, they require tremendous economic development. The main activity of the people in these areas is agriculture. The lands in hills are ideally suited for a variety of crops like the apples, apricots, cherry, etc. among fruits and potatoes, ginger, etc. among the vegetables. If these paying crops are grown in place of maize and other local food-grains and economically transported outside, the economic life of the population can be considerably improved.

(ii) Forest wealth: The hilly areas contain huge forest wealth

in the form of structural and other timbers, minerals, stones, etc. and all these items form the basic valuables for developing the country as a whole and the hilly areas in particular, provided there is an efficient transportation system for carrying these valuables to the plains from where they can be processed and sent to the consumers.

(iii) Industrial development: There are certain areas of hills which are ideally suited for growing tea and jute and for bringing up silk-worms. The presence of roads can help in setting up of the industries of these products in the hilly areas.

(iv) Strategic considerations: In case of an emergency such as war, a well layout system of roads in hilly areas helps considerably for moving the army from one place to the other.

(v) Tourism: Some of the hilly areas present immense natural scenic beauty which attracts thousands of local and foreign tourists. The construction of hill roads is probably the main contributing factor for the development of tourism all along the Himalayas from Gulmarg to Darjeeling and other important hill stations of our country.

BASIC PRINCIPLES OF PLANNING OF HILL ROADS

In a broad sense, the main aim of planning a hill road is to establish the shortest, most economical and safe route between the obligatory points, and to achieve this purpose successfully, the following basic principles are to be observed in the planning of hill roads:

(1) Construction work

(2) Existing routes

(3) Intensity of traffic

(4) Master plan

(5) Natural climatic conditions

(6) Use of contours.

(1) Construction work: The construction of hill roads requires considerable period and greater funds as compared to the roads in plains because it involves items such as parapets to demarcate

the roadway boundary, rock cuttings in difficult regions, provision of erosion control measures, greater number of drainage crossings, etc. It is therefore advisable to plan the construction work in stages over a number of years in such a way that each stage of construction improves upon the previous construction stage so as to bring it upto the requirements of the developing traffic.

(2) Existing routes: The existing pedestrian and mule tracks or good animal beaten tracks present the most convenient routes for further improvements and extension and hence, it is one of the essential principles in hill road planning that maximum use should be made of such existing routes. They may however be suitably modified as the traffic requirements increase.

(3) Intensity of traffic: For the purpose of planning, the hill roads may be categorized as jeepable roads and motorable roads from the view point of intensity of traffic. These roads may then be converted into National Highways, State Highways, etc. depending upon the relative importance in the whole set up of planning. The jeepable roads are narrow in width, have comparatively sharper bends and steeper grades and they can be traversed by jeep cars only. The motorable roads can be used by the commercial vehicles in the hilly area. It may be a good policy to aim at jeepable roads first and to provide motorable roads at a later stage after studying the possibility of providing necessary standards of geometric design and construction.

(4) Master plan: It is advisable to draw a master plan for the development of the whole hilly area and work out the priorities instead of starting the work haphazardly. It may avoid the tremendous economic loss in the form of more construction and operation costs due to greater lengths covered by the haphazard planning.

(5) Natural climatic conditions: It is necessary to explore the natural climatic conditions of the hilly area before the planning of road alignment. It is observed that the sunny side of the hills above a height of about 4500 m and the shady side of the hills above a height of about 3600 m are covered with snow. Now the snow melts quickly on the sunny sides as compared to the shady sides of the hills. It is therefore advisable, as far as possible, to align the road on the sunny side of the hills. In a similar

way, the convenient slopes are available along the river valleys and it is therefore economical to carry the alignment along the river valleys, as far as possible. The hilly areas subjected to heavy winds having velocity exceeding 100 km p.h. should also be located and avoided, as far as possible.

(6) Use of contours: When a virgin hilly area is to be explored, the use of contour maps should also be made. It should always be kept in mind that whatever height has been gained should never be lost. For instances, let us say that a ridge has to be crossed to go to a valley beyond it. It is then essential to touch the most convenient lowest points on the ridge to have the minimum length of road.

ALIGNMENT OF HILL ROADS

The success and utility of a hill or ghat road depend on its proper alignment. It is, therefore, necessary to exercise great care in fixing the alignment of hill roads. A good alignment has the following features:

(i) It achieves the minimum costs of construction and maintenance.

(ii) It allows comfortable travel and the expenditures on motive power, as well as wear and tear of vehicles, are also greatly reduced.

(iii) It contains sharp curves having small radius.

(iv) It gives a stable and safe road.

(v) It grants the easiest, shortest, and most economical line of communication between the obligatory points or important centers to be connected by the hill road.

(vi) It has the gradient as easy as possible.

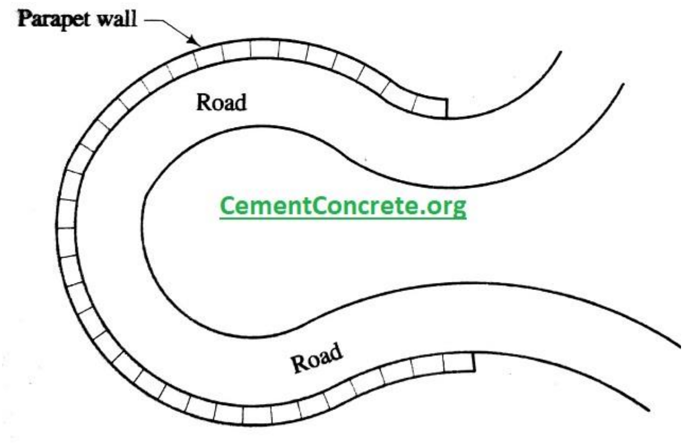


Fig.1. Hairpin Bend used for Hill road

In general, it can be stated that the best and most convenient alignment will be the one having the minimum of cutting and filling; and a minimum of walling and bridging. In many cases, the alignment of the hill road contains two types of sharp curves known as hairpin bends and corner bends. Fig. 1 shows the hairpin bend and fig. 2 shows the corner bend.

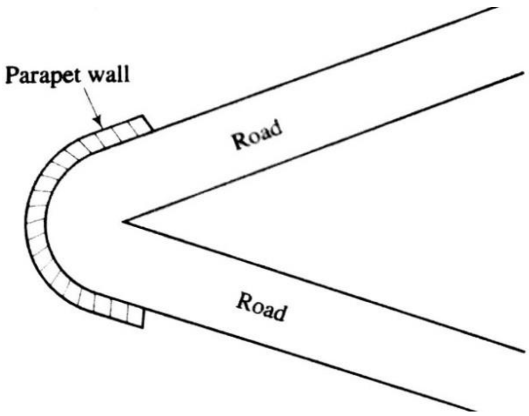


Fig.2. Corner bend used in Hill road design

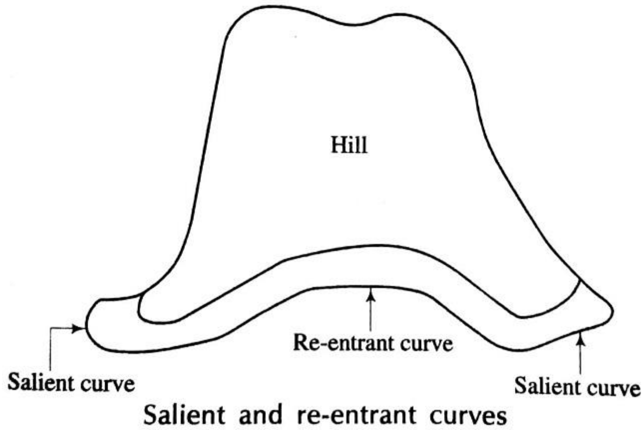


Fig.3. Salient and re-entrant curve used in hill road design

If the side of hill contains ridges and valleys, it will have to be provided with salient and re-entrant curves. A salient curve is a convex curve with its convexity on the outer edge of the road at the ridge of hillside. A re-entrant curve is a concave curve at the valley of the hillside. Fig. 3 shows the salient and re-entrant curves. Due to these ridges and valleys, the visibility on a hill road is less and the traffic has to be very careful while negotiating the salient and re-entrant curves in succession. Otherwise, there are chances of fatal accidents to occur at these points. To improve the visibility at a salient curve, some portions of the hill may even be cut down.

PROTECTIVE WORKS FOR HILL ROADS

In order to give stability and a sense of safety to the hill roads, the following three types of protective works are provided:

(1) Retaining walls

(2) Breast walls

(3) Parapet walls.

Retaining walls:

The formation of a hill road is generally prepared by the excavation of the hill and the material which is excavated is dumped or stacked along the cut portion. The retaining wall is constructed on the valley side of the roadway to prevent the sliding of backfilling as shown in fig.5. Thus the main function of a retaining wall for hill roads is to retain the back filling and it is provided at the following places:

at all re-entrant curves;

at places where the hill section is partly in cutting and partly in embankment; and

at places where the road crosses drainage.

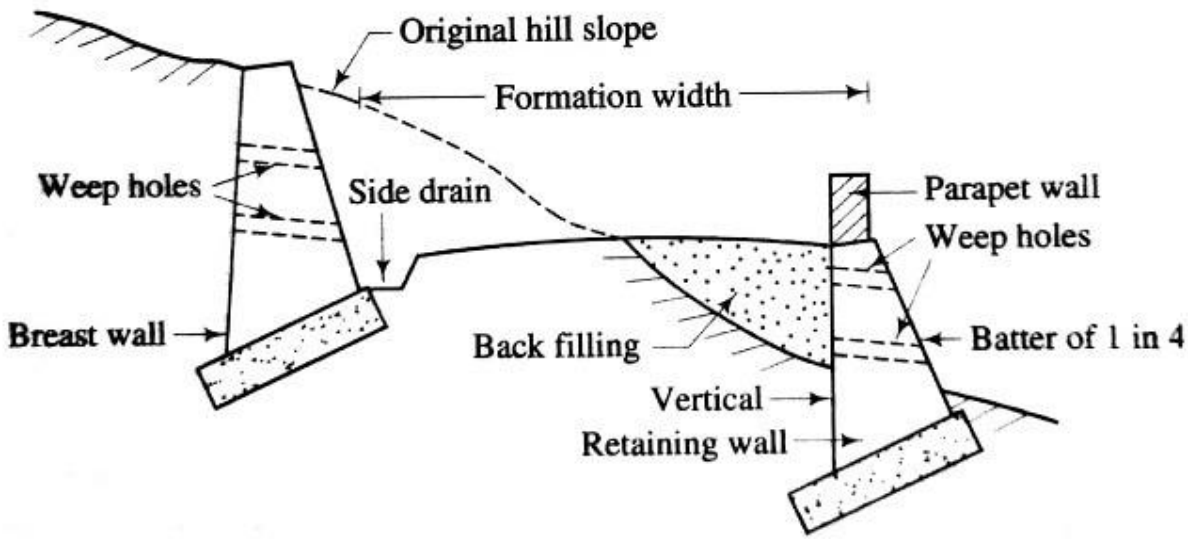


Fig.5. Retaining wall and breast wall for protective works for hill road

Where stones are economically and easily available, it is customary to construct the retaining walls in dry stone masonry as it permits easy drainage of seeping water. The design of retaining walls is based on rules-of-thumb and the performances of similar existing retaining walls. The minimum width of 600 mm is kept at the top. The rear side is kept vertical. The front side is provided with a batter of 1 in 4. If the height of the retaining wall exceeds 6 m or so, the bands of coursed rubble masonry in cement mortar at vertical and horizontal intervals of about 3 m are constructed to grant additional stability to the wall.

To facilitate the drainage of the water behind the retaining wall, suitable weep holes at vertical height of 1 m and horizontal spacing of 1.2 m are provided with slope outwards.

Breast walls:

The cut portion of hill is to be prevented from sliding and the wall which is constructed for this purpose is known as breast wall. See fig. 5. The breast walls are provided with a front batter of 1 in 2 and a back batter of 1 in 3. The back batter may be provided either in one straight batter or in the form of projections. If the height of the wall is less than 2 m, the entire section is made in random rubble stone masonry. If the height of wall exceeds 2 m, the top portion of 2 m height alone is made in random rubble masonry and the remaining portion is constructed in cement mortar of proportion (1:6).

The weep holes, as in case of retaining walls, are provided with slope outwards and sometimes, the vertical gutters connecting the weep holes to the side drain are provided.

Parapet walls:

The parapet walls are usually provided all along the valley side of the road except where the hill slope is very gentle. They are constructed immediately above the retaining wall, as shown in fig.5 and they prevent the wheels of the vehicles from coming on the retaining wall. It is to be noted that the construction of a parapet wall merely gives a sense of security to the driver and the passengers and it is very rare unless constructed in stone masonry with cement mortar that they act as protecting structures in the event of an accident.

The parapet walls are usually of wall type with uniform thickness of 600 mm and height of 600 mm above the berm level. They can also be constructed of R.C.C. posts of 150 mm x 150 mm section with 1 m height above ground level and 450 mm below ground level and spaced at 1 m centre to centre. In case of hard rocky stratum, the parapet walls may be replaced by the railing of cast-iron.

DRAINAGE IN HILL ROADS

The rain falls very heavily on the hills and as the slopes of hills are quite steep, the water reaches the roadside very quickly and creates drainage problems. The water thus collected should be disposed-off in a proper way through the well-planned and designed drainage system.

(1) Sub-surface drainage:

The seepage flow of water on hills creates problems during and after monsoons. The level of seepage water may be at, above, or below the road level depending upon several factors such as depth of hard stratum and its inclination, the quantity of underground flow of water, etc. The seepage flow also causes the weakening of the roadbed and the pavement and it also causes problems of slope stability. It is, therefore, necessary to control the seepage flow by adopting the suitable method of the sub-surface drainage system.

(2) Surface drainage:

For carrying the surface water, the side drains are provided only on the hill side of the road, as shown in fig. 5. There is limitation in the formation width of road and hence, these drains are constructed of such a shape that the vehicles could utilize the space of side drains in case of an emergency for crossing or parking. The side drains are usually of the following three types:

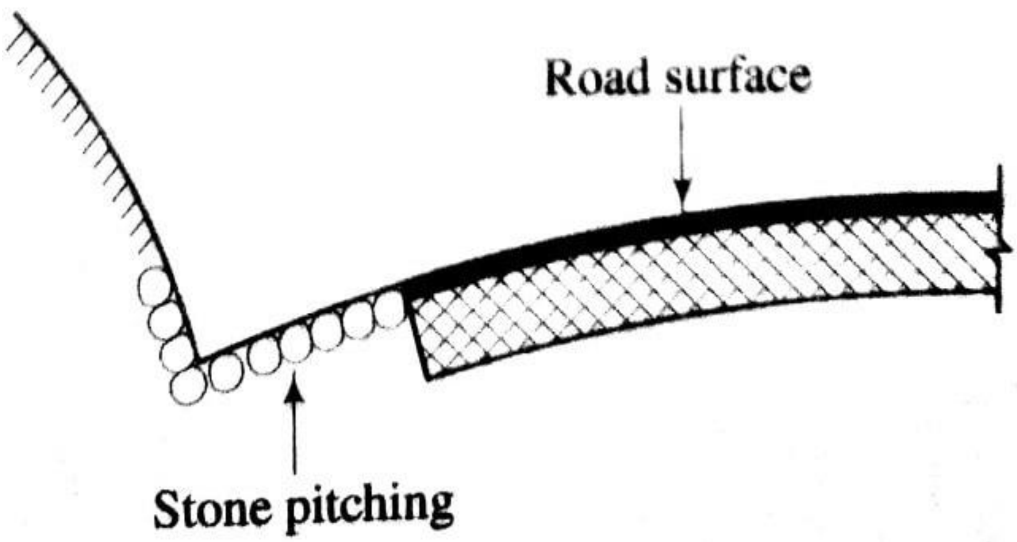


Fig.6. Angle side drain for hill road drainage works

angle side drains as shown in fig. 6;

kerb and channel side drain as shown in fig. 7; and

saucer side drain as shown in fig. 8.

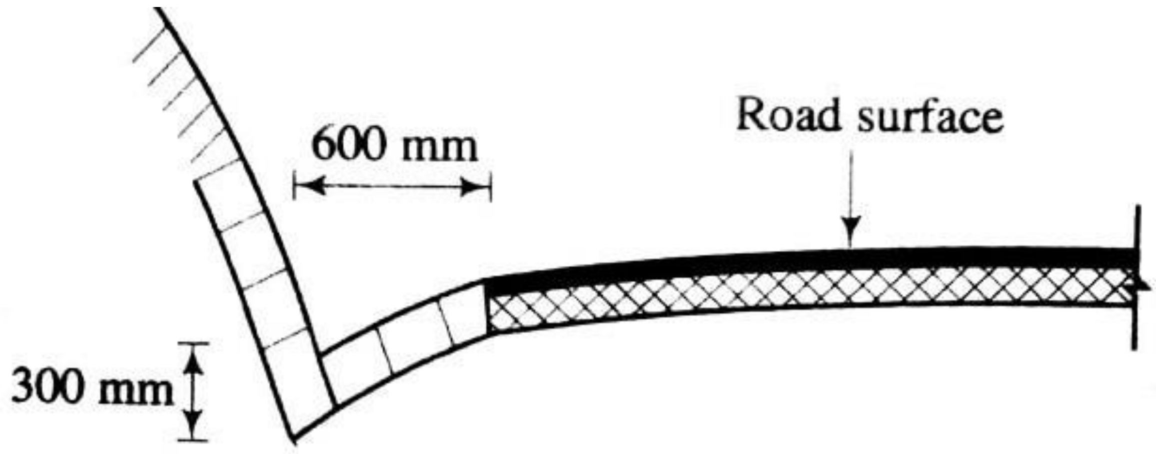


Fig.7. Kerb and channel side drain

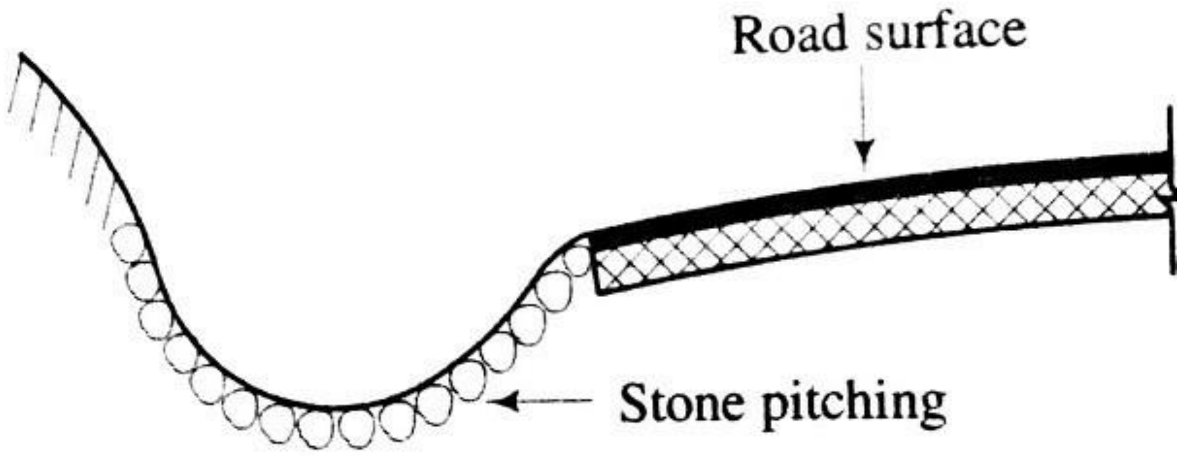


Fig.8. saucer side drain

In order to prevent the side drains from overloading and thereby causing the road surface flooding, the following two measures are taken:

provision of catch water drain or intercepting ditch above the side drain; and

suitable cross-drainage work to divert the water through the road on downside of the hill.

Fig. 9 shows the layout plan of catch water drain, sloping drain and cross-drainage work. The water from the hill slope is intercepted and diverted through the catch water drains which are running parallel to the roadway. The catch water drains are usually provided with a gradient of 1 in 50 to 1 in 33 to avoid high water velocity and possible wash out. The water from the catch water drains is led to the cross-drainage works through the sloping drains.

catch water drain and cross-drainage work for hill side road

Fig.9. catch water drain and cross-drainage work for hill side road

The cross-drainage works are in the form of culverts, scuppers or causeways. They are constructed under the road and usually at right angle to it. For collecting the stones and debris and for preventing scour, the catch pits may be provided at the head of small cross drains. The floor level of catch pit may be kept about 300 mm below the sill of the culvert.

MAINTENANCE OF HILL ROADS

The hill roads because of their peculiar location require careful attention in their maintenance. For the purpose of convenience, the maintenance problems of the hill roads can be grouped into the following four categories:

(1) Control of avalanches

(2) Drainage structures

(3) Prevention of land slides

(4) Snow clearance.

Each of the above category will now be briefly described.

Control of avalanches:

An avalanche indicates a large mass of loosened snow, earth, rocks, etc. which suddenly and swiftly slides down a hill. Where there are chances for an avalanche to occur, suitable remedial measures may be adopted so that minimum damage occurs to the road structures. One of such preventive measure which is commonly adopted is the construction of galleries above the road which permit the avalanche to slide over the gallery roof without inducing impact loads.

Drainage structures:

The drainage structures such as catch water drains, catch pits, side drains and culverts are to be periodically inspected and cleaned off all the debris and blockages which prevent the smooth flowing of water in such structures during rains.

As a precautionary measure, the upper slopes are planted with trees to reduce considerably scouring action of unstable ground due to rains.

Prevention of land slides:

The term land slide is used to indicate the downward and outward movement of slope-forming materials composed of natural rock soils, artificial fills or combinations thereof. The landslides move along the surface of separation by falling, sliding and flowing.

When the shear stresses exceed the shear strength of the soil, the movement in the form of land slide occurs. Hence, anything which contributes towards a decrease in shear strength of the soll or an increase in the shear stress can cause a land slide.

The decrease in shear strength of the soil takes place mainly due to the following causes:

decrease in inter-granular pressure;

formation of faults in bedding planes of strata:

hair-cracking due to alternate swelling and shrinkage of the soil structure;

increase in water content and consequent swelling and increase in pore water pressure;

seepage pressure of percolating ground water; etc.

Snow clearance:

The depth of accumulated compacted snow on the road surface in winter poses a serious problem for its early removal to restore traffic. In the case of heavily snow bound areas, it becomes difficult for the snow clearing party to locate the position of the road and other structures under the snow cover. For this purpose, the snow markers which are in the form of wooden posts with their height marked in meters are fixed before the winter starts along the road next to the parapet walls to mark the outer edge of the road.

The snow clearance is done with the help of machines and extreme care is taken to see that the top surface of the road is not damaged by the movement of such machines. The commonly used machines are motor graders, snow blasts, or wheel dozers. If the thickness of snow is more, the blasting by explosives may also be adopted. On the other hand, if the thickness of snow is less, the snow clearance can be carried out by manual labor only.

CHAPTER-6

Road Drainage

Importance of Highway Drainage:

Highway Drainage is required to mitigate the effects due to water and moisture variation that are listed below as:

• Road surface becomes soft and loses its strength.

• Road subgrade may be softened and its bearing capacity is reduced.

Variation in moisture content in expansive soil causes variation in the volume of subgrade and thus failure of road.

• Presence of moisture at freezing temperature may damage road due to frost action.

• Erosion of side slopes, side drains and formation of gullies may result if proper drainage conditions are not maintained.

• Flexible pavement's failure by formation of waves and corrugations is due to poor drainage.

• Formation of pot holes.

• Failure of rigid pavement by mud pumping.

Requirements of Highway Drainage System:

• Surface water from the carriageway and shoulder should be effectively drained off without allowing it to percolate to the subgrade.

• Surface water from the adjoining land should be prevented from entering the roadway.

• The side drain should have sufficient capacity and longitudinal slope to carry away all the surface water collected.

• Seepage and other sources of underground water should be drained off by the sub-surface drainage system.

• Highest level of ground water table should be kept well below the level of subgrade, preferably by at least 1.20m.

Components of Highway Drainage System

a) Surface Drainage System

b) Subsurface Drainage System

Surface Drainage System

A part of rainwater falling on the road surface and adjoining area, is lost by evaporation and percolation. The remaining water is known as surface water. Removal and diversion of this surface water from highway and adjoining land is known as surface drainage. The water from the pavement surface is immediately removed by providing camber and cross slope to the pavement. The camber and slope depend upon the type of the pavement and the intensity of rainfall. The road surface is made impermeable to prevent infiltration of water.

Collection of Surface Water

The surface drainage may be divided into three categories as:

a) Drainage in rural highway

There is the provision of side drains in these areas which are generally open, unlined and trapezoidal cut to suitable cross section and longitudinal slopes. Camber is applied to the pavement to drain the surface water and has to drain across the shoulders which are provided with more cross slope. Usually, drains are provided on one or both sides in embankments while drains are provided on both sides in case of roads with cutting. Open drains are dangerous in the places where space is restricted in cutting and hence covered drains are used with layers of coarse sand gravel.

b) Drains in Urban Street

In urban roads, underground longitudinal drains are provided due to the limitation of land width, the presence of foot path, dividing island and other road facilities. This is provided where there is lesser number of natural water courses and in the presence of impervious surfaces. Water is collected in the catch pits at suitable intervals and lead through underground drainage pipes.

c) Drainage in hill roads

In hill roads, there are complex drainage problems. Water flowing down the hill has to be efficiently intercepted and disposed of downhill side by constructing suitable cross drainage works. Catch water drains at the upper hill side, sloping drains and cross slopes are provided to drain out the water whereas side drains are provided only at the hill side. If hill roads are not properly drained, rockslides and slips may occur blocking the road during monsoon season. The shape of the side drains is made in such a way that vehicles can park at that space during emergency, crossing or parking.

Different types of road side drain

On the basis of the shape of drain, the road side drain may be rectangular, trapezoidal, triangular or semi-circular. The type of drain may be angle drain, saucer drain or kerb and channel drain as mentioned earlier.

Cross Drainage Structures

Cross drainage structures are those structures which are provided whenever streams have to cross the roadway facility. The water from the side drains is also often taken across these structures in order to divert the water away from the road to a water course or a valley.

Culverts

A closed conduit placed under the embankment to carry water across the roadway is termed as culverts. In NRS 2070, culverts are the bridging structures of linear waterway span less than about 6m. It is extensively used in road drainage system. In fact, more than 75% of the cross-drainage structures are culverts. A culvert is more hydraulically efficient than minor bridge and discharge through a culvert is more than a minor bridge

Functions of culverts

The functions of culvert are:

• Collection and transport of water across the road so as to not cause damage to the road bank or the stream bed by scouring.

• To provide sufficient waterway to prevent heading up of water above the road surface.

Bridge

A bridge is a structure constructed over water course to carry traffic over it. In NRS 2070, bridges are the structures having linear waterway span more than about 6m.

On the basis of construction materials

• Steel bridges

• Concrete bridges

• Timber bridges, etc.

On the basis of structural point of view

• Cantilever bridges

• Suspension bridges

• Moving bridges, etc.

Causeway

They are constructed instead of culverts on less important roads where the maximum flow of depth does not exceed 1.5m which saves the construction cost. During the flood, the water flows over the road and traffic on both sides is stopped but as soon as the flood recedes, the traffic flow is resumed.

Bed slope of the causeway in estimating the span should not generally exceed (4-5) % in order to prevent the vehicles from skidding and overturning downstream. The depth of flow in most of the period of the year should not exceed 30cm.

Inverted Siphon

The inverted siphon is a structure which lowers the invert level of the conduit to the desired level and both inlet and outlet pits are provided to receive flow from the drain and discharge water to the downstream drain respectively. . It is generally provided when the provision of culvert and aqueduct is not possible.

Sub-Surface Drainage System:

• Stability and strength of the road surface depends upon the strength of subgrade.

• With increase in moisture content the strength of the subgrade decreases.

The variation in moisture content of subgrade is caused by the free water and the ground water. Every effort is needed to reduce the moisture content to a minimum. From usual drainage system, only gravitational water can be drained by the provision of subsoil drainage.

Drainage of infiltrated water

• During rainy season and snow melting season, water will find its way to the subgrade soil through the permeable surface of the adjoining land, carriageway, shoulder, side slope and cracks.

• Removal of such infiltrated water from the subgrade may be accomplished by the arrangements shown in figures below. The control of subsurface water is classified under three headings:

1. Control of seepage flow
2. Lowering of water table
3. Control of capillary rise

Control of seepage flow

• Seepage may occur from the higher ground in hilly topography or in road cuttings where a layer of permeable soil overlies an impermeable stratum which affects the strength characteristics of the subgrade.

• The best solution to this type of problem would be to intercept the seepage water on the uphill side of the road.

• If the seepage level reaches a depth less than 60-90 cm from the road subgrade, it should be intercepted to keep seepage line at a safe depth below the road subgrade.

Lowering of water table

• The water table may rise and may come up to the pavement layers in lowlying areas during rainy seasons which become very harmful to the pavement and the subgrade especially when the subgrade is made of finegrained soils. Therefore, it becomes necessary to lower the water table safely below the pavement.

• If the underground water table is more than 1.2m below the surface of the road, it does not require any subsurface drainage but when it is less than 1.2m the best measure would be to raise the road formation.

• The water table is lowered to the desired depth by providing sub drains on either side of the road. It may be possible to lower the water table by merely constructing longitudinal drainage trenches with drain pipes and filter sand if the soil is relatively permeable.

• But if the soil is relatively less permeable, the water table lowered at the centre of the pavement or between the two longitudinal drains may not be adequate. Thus, transverse drains may have to be provided in order to effectively drain off the water and lower the water table.

• The depth to which the drains should be laid depends upon the width of the roadway, amount of water table to be lowered, type of subgrade soil and lateral distance between the trenches.

• The pipe in the drainage system should be laid such that silting and scouring do not occur.

• For maintenance of these systems, manholes and inspection chambers can be provided.

Control of capillary rise

In water logged sections, there will be possibility of rising of water to the subgrade level due to the phenomenon of capillary action which affects the strength of the subgrade. Thus, capillary cut off measures needs to be provided to free the subgrade from the excessive moisture. If the subgrade soil is of permeable type, the lowering of water table is economical but in case of retentive type of soil, drainage becomes very difficult and costly. In these cases, capillary cut offs become more economical. There are two types of capillary cut off:

1. Granular capillary cut off:

• Provision of granular material of suitable thickness between the subgrade and the highest level of subsurface water table during the construction of embankment.

• The granular capillary cut off layer's thickness should be sufficiently higher than the anticipated capillary rise within the granular layer so that the capillary water cannot rise above the cut off the layer.

• Suitable sand blanket and gravel blanket can be used for cut off.

2. Impermeable capillary cut off:

• Provision of impermeable membrane such as prefabricated bituminized surfacing is used instead of granular blanket.

• Bitumen stabilized soil, heavy duty tar felt or heavy-duty polythene envelope can also be used.

CHAPTER-7

Road Maintenance

Highway (road) maintenance is defined as preserving and keeping the serviceable conditions highway as normal as possible and practicable. The main objectives of road maintenance men are the allocation of available maintenance resources according to actual needs and priorities. If the maintenance works are not done at all or done faulty or the pavement structure inadequate for present-day and loading.

Types of Pavement Failure

Some of the types of pavement failure are:

A. Cracking:

- Cracking is one of the most common types of pavement failure. The nature of the crack itself is fast spreading.
- Cracking is usually caused due to use of improper material mix during construction and settling of the subgrade or base during operation.

Several cracking in the pavement are:

i. Alligator Cracking:

- Alligator cracking is the cracking that is associated with load and structural distresses.
- These cracks are extensively found at intersections where the vehicles are stopped for a relatively long period because these cracks start to form when the sub-grade and base compress due to the excessive imposed wheel load.

a. Alligator Cracking in Flexible Pavement

Causes of Alligator Cracking in Flexible Pavement

- Weakness in base, surface or sub-grade
- Thinning of a surface course or base course
- Poor Drainage
- Excessive vehicular loads
- Vehicle stopped for a relatively long period

Repair of Alligator Cracking in Flexible Pavement

a. Determine the primary source of the problem and the best way to repair it.

b. If a problem is seen on the surface course, the crack filler is applied.

b. If failure is due to weakening of base or sub-base course, cut the affected pavement area into rectangular or square shapes. Then patch it like a pothole.

b. Alligator Cracking in Rigid Pavement

Causes of Alligator Cracking in Rigid Pavement

a. Weakening of base

b. Poor drainage

c. Poor quality material mix or use.

Repair of Alligator Cracking in Rigid Pavement

1. Full Depth Patching:

It is a widely used method for treating alligator cracks in rigid pavements and restoring the structural stability and rideability of the pavements.

It includes the following series of steps:

a. Defining repair boundaries:

The boundary of the area to be repaired must be first defined by surveying the region.

b. Sawing old concrete:

Full-depth saw cuts facilitate the separation of damaged concrete from the adjacent concrete with minimal damage.

c. Removing old concrete:

Concrete removal can be carried out either by lift out or breakup. Lifting sawed concrete is faster, requires less labor, and also doesn't cause any significant damage to the adjacent layers.

In some cases, lifting concrete can be risky, and in such a situation, the deteriorated concrete is broken into smaller fragments and removed by backhoe or hand tools.

d. Preparing the patch area:

After removing old concrete, the area to be patched is prepared. If the area contains water, it must be pumped out and cleaned correctly.

e. Placing and Finishing new concrete:

Placing the new concrete is usually done by ready-mix trucks or other mobile batch vehicles. Concrete must be evenly distributed and spread. Using the finishing tools, the placed concrete is finished.

ii. Block Cracking:

Block cracking is another cracking seen on highway pavements that form a box-like crack on the surface.

This type of cracking is associated with the unusual expansion and contraction of concrete in the rigid pavement and due to improper mixing or aging of asphalt or poor quality asphalt in flexible pavement.

Block cracking is mainly caused by shrinkage of the asphalt or concrete and daily temperature cycling, and it is not load-associated.

i. Block Cracking in Flexible Pavement

Causes

1. Use of improper mix
2. Fine aggregates mixed with low penetration asphalt
3. Poor asphalt binder
4. Ageing of asphalt
5. Temperature cycling

Repair

The quicker this cracking is detected, the easier it becomes to repair.

The sealing method of repair can be used for cracks less than ½ inch or lesser.

In severe cracks, the deteriorated pavement must be removed and replaced by an overlay.

ii. Block Cracking in Rigid Pavement

Causes

1. Use of improper mix
2. Lack of expansion joints in the pavement
3. Temperature cycling

Repair

If the crack is less than 1/2 inch, flexible fillers can be used to fill the cracks.

If the crack is larger than 1/2 inch, the affected section of the road is removed and replaced by an overlay. Sometimes, joining of the sections with metal plates also can be done if traffic is low.

To eliminate the problem of block cracking, it is better to provide expansion joints at regular intervals.

iii. Linear Cracking:

Linear cracking is the common type of crack seen parallel to the roadway.

These are generally associated with fatigue and weak points of the pavement.

It is also known as longitudinal cracking.

Causes

1. Pavement fatigue
2. Reflective cracking
3. Poor construction of joints

Repair

It can be repaired by sealing or replacement.

For less severe cracks, sealing of the cracks may be done.

For severe cracks, replacement by an overlay may be carried out.

iv. Edge Cracking:

Edge cracking is the type of crack that is usually formed at the edge of highway pavements.

These cracks are typically associated with the ingress of water in underlying layers.

Figure: Edge Cracks

Causes

a. Lack of support at edges of pavement

b. Poor drainage condition

c. Heavy vegetation

d. Heavy traffic alongside the edge of the pavement

Repair

The initial step for repairing the edge cracks is removing the vegetations from the edges of pavement and fixing all the issues of drainage.

Sealing of cracks can be done to prevent further damage.

2. Pot Holes:

Potholes are the type of flexible pavement failure that can be seen as small depressions on the surface of the pavement and can penetrate deep up to the base course.

These are generally associated with infiltration and also results from alligator crack if not treated properly.

Generally, severe alligator cracks that are left untreated create small fragments of pavement and when vehicles ride over them results in the formation of potholes.

Figure: Pot Hole

Causes of Pot Holes

1. Pavement fatigue

2. Untreated alligator cracks

Repair of Pot Holes

The potholes can be repaired by patchwork which includes the following steps:

1. Repair for Concrete Roads

The a. Defining repair boundaries:

boundary of the area to be repaired must be first defined by surveying the region.

b. Sawing old concrete:

Using full-depth saw cuts, the damaged area is first isolated from the remaining area.

Full-depth saw cuts facilitate the separation of damaged concrete from the adjacent concrete with minimal damage.

c. Removing old concrete:

The removal of concrete can be carried out either by lift out or by the breakup.

Lifting of sawed concrete is faster, requires less labour and also doesn’t cause any significant damage to the adjacent layers.

In some cases, lifting of concrete can be risky and in such a situation the deteriorated concrete is broken into smaller fragments and removed by backhoe or hand tools.

d. Preparing the patch area:

After the removal of old concrete, the area to be patched is prepared.

If the area contains water, it must be pumped out and cleaned properly.

e. Placing and Finishing new concrete:

Placing of the new concrete is usually done by ready-mix trucks or other mobile batch vehicles.

Concrete must be evenly distributed and spread.

Using the finishing tools, the placed concrete is finished.

2. Repair for Flexible Pavements

1. Clean the area along the hole with the broom.

2. Trim it vertically to a regular geometrical shape like square or rectangle.

3. Level the bottom of the hole and remove loose aggregate and foreign materials.

4. Apply tack coat on bottom and sides of holes.

5. Now, apply the patching layer and compact it properly by taping or roller.

6. If the depth of the hole is greater than 7.5cm, Patching layer should be provided in 2 or more layers where each layer should be tamped or rolled properly.

3. Depressions:

Depression indicates the area on the surface of pavements that have a slightly lower elevation than the surrounding areas.

They become prominently visible after rainfall due to the accumulation of water.

These are also referred to as birdbath.

Causes of Depressions

1. Uneven thickness of subsequent layers

2. Unequal compaction

3. Foundation soil settlement

Repair of Depressions

In case of severe depression, the asphalt surface has to be replaced while for smaller depressions patching of the area may be done.

4. Rutting:

Rutting is a type of pavement failure that results in the formation of channelized depressions particularly in the wheel track of pavement.

Two types of rutting particularly the pavement rutting and subgrade rutting may occur.

With time, the wheel of heavy vehicles starts to compact the asphalt surface thereby forming ruts.

Causes of Rutting

1. Lateral movement or consolidation of consecutive layers under traffic load

2. Insufficient layer thickness

3. Lack of compaction

4. Improper mix

5. Moisture infiltration

Repair of Rutting

If minor rutting has occurred, the rut can simply be filled and provided with an overlay.

In case of severe rutting, the damaged area must be lifted out and replaced by a new layer.

5. Corrugation & Shoving:

Corrugations refer to the distresses that occur at regular intervals in the form of ridges and valley on the surface of the pavement.

They run along the direction of the pavement itself and are usually less than 5 feet.

Similar distresses that run perpendicular to the traffic is known as shoving.

Figure: Corrugation and Shoving

Causes of Corrugation and Shoving

1. Weak granular base

2. Excessive fine aggregate

3. Excessively rounded aggregate

4. Extensively soft asphalt

Repair of Corrugation and Shoving

It may be repaired by partial or full-depth patchwork as in case of alligator cracking.

6. Ravelling:

It is the type of pavement failure that occurs due to continuous ingress of water thereby causing degradation of the topmost asphalt layer.

As ravelling progresses, the aggregate particles separate from the surface and leave behind eroded like patches on the surface of the pavement.

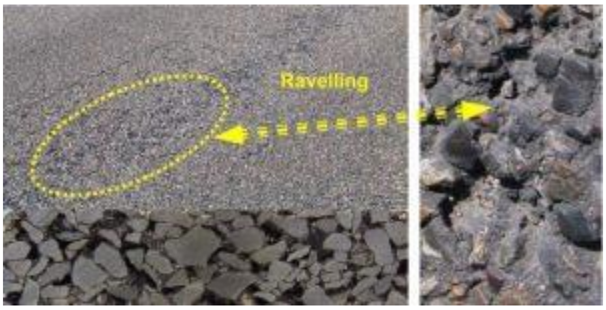


Figure: Ravelling in the pavement

Causes of Ravelling

1. Excessively porous asphalt

2. The untimely placing of asphalt

Repair of Ravelling

A thin hot-mix overlay may be provided. Sealing of the affected areas may also be effective.

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CHAPTER-8

Construction Equipment

HOT MIX PLANT - DRUM MIX PLANT

Asphalt drum mix plant is also called “Hot mix plant”. The ultimate mixer of asphalt, concrete, fine aggregates, coarse aggregates & filler material together gives final result of drum mix plant output. Primarily for road construction, cold aggregate mixer from wet mix macadam plant is allowed to spread to form base & minimum level of road. And then this hot aggregate obtained from Drum mix plant is used mainly to form final layer of road. Basically there are two different modes of working of plant.

A) Batch Type Plant

B) Continuous Type Plant

FABHIND Company provides drum mix plant of different capacities ranging from DM:-30-90 TONS. Drum mix plant consist of cold bin feeder, drying drum, dust collector, Burner, asphalt storage tank & asphalt supply system. Drum mix plant is fully computerized plant with automated control panel.

Drum Mix Plant Types

According to its structure & specifications, Drum mix plant is mainly divided into two types:

1. Mobile Drum Mix Plant

2. Stationary Drum Mix Plant

If client needs single plant for multiple site use & has filed tender of different cities then mobile plant is more reliable for those clients. If client requires plant for bigger project at single site for longer time then stationary plant is more preferable. Mobile plant is equipped with wheeled structure in single frame to impart mobility easily to the plant, while stationary plant has quite different structure as it needs to be erected using solid foundation.

Hot Mix Plant Working

Drum mix plant works on similar principle as Asphalt batch mix plant, but the main difference is drum mix plant does not have tower consisting of vibrating screen, hot bin, Pug mill mixer & hot aggregate elevator. In working mechanism of Drum mix plant, the mixer consisting of different size of aggregates & filler is allowed to dry & mixed with bitumen in drying drum. Hence both work of drying different sized aggregates & mixing them with hot bitumen is carried out in same unit i.e. drying drum, while batch mix plant is equipped with two separate units for carrying out these two activities i.e. drying drum for drying purpose & Pug mill mixture for mixing aggregate with hot bitumen. This resultant hot aggregate mixture is transferred into loading trucks to reach at site of road construction.

Drum Mix Plant Advantages

Fully automatic plant equipped with control panel for operation. Due to variation in structure it can be moved to different sites. If one needs the aggregate continuously then it can be achieved with asphalt drum mix plant-Continuous model. As all components used are of high quality, less maintenance is needed. Easy to operate & highly reliable.

Tipper

Tippers are used for the transport of all these materials in road construction (road-site to dump and burrow or plant to road-site). In dams, hydropower projects and canal work, nature of work involved is essentially removal and relocation of earth on the sites to obtain the desired profile.

BENEFITS OF TIPPER TRUCKS

Lift heavy goods with ease – saving the effort of manpower, tipper trucks do the work for you, so you don't have to break a sweat. Deposit heavy goods directly on site – thanks to the tipper feature, you can drive your materials directly to their required location and unload without having to do it yourself. Agile manoeuvrability – even with extremely heavy cargo, a tipper truck can transport and provide precise unloading. Cost-effective – hiring one tipper will cost a lot less than hiring several people to lift, carry and deposit heavy materials from one site to another. Variety of tipper options – tippers range in size, from 26 tonnes to 3.5 tonnes, and plenty of other options in between – there's a perfect sized tipper for any job.

Tractors

Tractors are generally associated with farming as farmers use them alongside machinery to perform implements like ploughing, tilling, sowing, and harrowing. In addition, a tractor is used for pushing or pulling the machinery, thereby making the farming operations more convenient.

Excavator

Excavators are intermittent types of heavy construction equipment and are widely used in the construction industry. Excavator consists of a long arm (boom), dipper, bucket, and a cab mounted on a rotating platform known as the "house" which eventually sits atop an undercarriage with tracks or wheels. It is the oldest type of machine which removes earth. The general purpose of an excavator is excavation work but other than that it is also used for different purposes like heavy lifting, digging of trenches, holes, foundations, river dredging, cutting of trees, etc.

Bulldozer

Bulldozers are very useful excavation equipment and can be used for the following tasks in construction work such as to clear the site of work, leveling the land, preparing pilot roads through mountains and hard ground, excavating the material, and hauling for a distance of about 100 meters.

In Bulldozer, most of the work is done by a sharp edge wide metal plate provided at its front. A bulldozer can be used on wet ground and in all conditions of climate.

Wheel Tractor Scrapers

Wheel tractor-scraper also sometimes called a belly scraper is a type of heavy construction equipment used for earthmoving. The front section consists of a wheeled tractor vehicle. The rear portion has a scraping arrangement consisting of a horizontal front blade, conveyor belt, and a collecting hopper (also known as the bowl).

The collecting hopper can be hydraulically lowered and raised. When the hopper is lowered, the front edge of the hopper cuts the soil and fills the hopper.

When the hopper is full it is lifted and closed with a vertical blade (known as the apron) and finally, the soil is dumped to the respective place and this whole cycle is repeated.

Motor Grader

Graders also called motor grader is a type of heavy equipment used in construction, especially used for the construction of roads.

It is used to spread loose material, level the soil surface, build earth roads, and shape subgrade. It is either self-propelled or towed by a tractor.

Drag Line Excavator

A dragline excavator is another heavy equipment used in construction commonly used for large-depth excavation and surface mining. It has a long-length boom and an excavator bucket is suspended from the top of the boom using a cable.

PAVER:

The modern system of road and building machines is a complex of high-performance machines and mechanisms, of large and small capacity and productivity. Expansion of paved roads network of use of resource-saving technologies, increasing of pace and quality of work, ensuring reliability and durability of highways have a major impact on the development of road construction machinery. Modern paver machines are used to lay asphalt on roads, bridges, parking lots and other such places. It lays the asphalt flat and provides minor compaction before it is compacted by a roller. The modern paver machines come with hydraulic loading legs which extend to allow for easy loading and transport, coupled with the ability to change widths quickly. Discussed below are the different types of pavers machines used in road construction.

Modern construction equipment for road

INTRODUCTION

Construction equipment have evolved as per changing requirements in the industry. Earlier for one job many equipment were required but now one equipment can do multiple jobs. Appropriate use of equipment contributes to completion of project on time, work speed, quality, and most importantly economy. It is not always possible for the contractor undergoing construction works to own each and every type of construction equipment required for the project due to complexity of project, shortage of skilled or efficient manpower, project involving handling of large quantity of earth materials, coping up with the time schedules, etc. However, one can purchase or hire the equipment as per suitability. If the equipment has to be used frequently and for a long duration of time then it proves to be economical to purchase the equipment. On the contrary, if the equipment has to be used occasionally and for a short duration of time, it proves to be economical to get it hired.

CLASSIFICATION OF EQUIPMENTS

Various equipment involved in construction works are-

1. Excavating Equipment

i) Power Shovel

ii) Hoe

iii) Dragline

2. Hauling Equipment

3. Earth-moving Equipment

4. Hoisting Equipment

a) Mobile Cranes

b) Tower Cranes

c) Crawler Mounted Cranes

d) Passenger Hoist

e) Builders Hoist

2. Dredging Equipment

3. Conveying Equipment

4. Compacting Equipment

5. Pumping Equipment

6. Pile Driving Equipment

7. Material Testing Equipment

8. Drilling Equipment

9. Aggregate, concrete and HMA (Hot Mix Asphalt) production Equipment.

Excavating Equipment-These equipment are commonly used for digging, excavating and placing earth materials to a distant place, to remove snow, lifting pipes, grading the ground, etc. It consists of a long bucket arm attached to a cabin where the operator operates and can rotate by 3600 This is a large piece of equipment which is used for big jobs and it runs on tracks. It can also be used with different attachments, such as a clamshell attachment to pick up dirt and debris.

Power Shovel– It is a bucket-equipped machine, usually electrically powered, used for digging, loading fragmented rock or earth and for extract ion of minerals. Main parts include the track system, cables, rack, stick, boom foot-pin, saddle block, boom, boom point sheaves, bucket and cabin.

Dragline– It is so named as its prominent operation involves dragging the bucket against the material to be dug. It consists of long light crane boom where the bucket is loosely attached to the boom through cables. They are useful for digging below its track level and effective while handling softer materials. Here the basic parts include boom, hoist cable, drag cable, hoist chain, bucket and drag chain. It has long reach and also used for excavating canals and then depositing on embankments without use of hauling units.

Hoe– It is also known as back shovel or pull shovel. It is used to excavate beneath the natural surface on which it rests. It is used for works like excavating trenches, digging pitsforbasements, and it is also used forgradingworkswhich needs precision in case of controlofdepths. Here the basic parts include boom, jackboom, boomfootdrum, boomsheave, sticksheave, bucket, bucketsheave and stick.

Dragline– It is so named as its prominent operation involves dragging the bucket against the material to be dug. It consists of long light crane boom where the bucket is loosely attached to the boom through cables. They are useful for digging below its track level and effective while handling softer materials. Here the basic parts include boom, hoist cable, drag cable, hoist chain, bucket and drag

chain. It has long reach and also used for excavating canals and then depositing on embankments without use of hauling units.

Hauling Equipment– The equipment used for transporting material are known as hauling equipment or haulers. They may be operated on railways or roadways which involve operations like carriage and disposal of earth materials, haulage of big construction equipment and transportation of building materials. It is also classified as dump trucks and dumpers.

Earth Moving Equipment-These equipment include excavators, loaders, motor graders, trenchers, backhoes and bulldozers. They are used to shift large amounts of dig foundations, landscape areas and dirt.

Hoisting Equipment– Hoisting refers to the lifting of a weight from one location to another location at a reasonable distance. These include jacks, winches, cranes and chain hoists. Crane is the only single piece machine capable of providing three-dimensional movement of a weight.

Mobile Cranes– Such type of cranes is mounted on mobile units which is either of wheel type or crawler type. Truck cranes are such having high mobility whereas the crawler mounted cranes move quite slowly. Crawler mounted cranes can move on rough terrain.

Tower Cranes– These cranes are derrick crane mounted on a steel tower. They are used for industrial and high-rise residential buildings especially for assembly of industrial plants consisting of steel structures. Such cranes resemble truss structures which are made by welding of steel bars and channel sections. Basic parts include carriage, slewing platform, jibs and tower with operator's cabin.

Crawler Mounted Cranes– These are the cranes which are placed on a set of rugged tracks that provides movement and stability for carrying heavy crane equipment. These crawler cranes are suitable for the rough surface area .Even though these cranes have no outriggers, they can operate lifts with minimal setup. Also, in addition to that they can move around easily. Crawler cranes can move around even with a heavy load.

Dredging Equipment– The choice of the dredging equipment for executing a dredging operation depends on conditions such as the weather, accessibility to the site and wave conditions, anchoring conditions, required accuracy and many more. They can dig hydraulically or mechanically. Hydraulic digging involves using of working of a water flow which is erosive in nature. It is mostly done in cohesionless soils such as silt, sand and gravel. Whereas mechanical digging by teeth or cutting edges of dredging equipment or knives is applicable to cohesive soils.

Conveying Equipment– Such equipment carry material in continuous stream with its distinct feature such as endless belt or chain. They are used for transporting material from one place to another over a structure which is stationary. They can proceed work horizontally, vertically or in inclined position. They are used in mining and construction industries.

Compacting Equipment– They can be of type such as smooth-wheel rollers, sheep-foot rollers and pneumatic type rollers. Such equipments are used to expel air from a soil mass so as to achieve a high density. Smooth-wheel rollers are suitable for gravels and sand. Pneumatic-tired rollers are suitable for clays with reasonably high moisture content. And sheepsfoot rollers are the suitable for clays with low moisture content.

Pumping Equipment– Pumping equipment are used to remove water from a volume of liquid, solid material or soil. Pumps remove liquid from a volume of liquid. They can be used for keeping water out of foundations, pits, tunnels, and other excavations and many more.

Pile Driving Equipment– Such equipment units involve lifting the piles from ground while taking in position to a specified depth. Here driving is accomplished by hammer on pile top. Equipments are so designed so as to remain economic while driving. Major pile driving equipment includes pile driving rigs and pile driving hammers.

Material Testing Equipment– It is frequently used in the quality control processes which are related with the analysis of soil, concrete, asphalt, bitumen, cement, mortar, steel, aggregates, and other materials used in construction. The mechanism in which the equipment performs analysis varies according to the material to be analysed. These testing instruments are capable of analysing the hardness, moisture content, permeability and other mechanical properties.