KIIT POLYTECHNIC

LECTURE NOTES

ON

HIGHWAY ENGINEERING

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CHAPTER-1

Introduction To Transportation Engineering

History of highway engineering

The history of highway enginnering 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. To provide adequate strength to carry the wheels, the new ways tended to follow the sunny drier side of a path. 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. Traces of such hard roads were obtained from various ancient civilization dated as old as 3500 BC. 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 bylongitudinal 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 equipments 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. Thus road space available was becoming insufficient to meet the growing demand of traffic and congestion started. In addition, chances for accidents also increased. This has led to the increased attention towards control of vehicles so that the transport infrastructure was optimally used. Various control measures like traffic signals, providing roundabouts and medians, limiting the speed of vehicle at specific zones etc. were implemented.

With the advancement of better roads and efficient control, more and more investments were made in the road sector especially after the World wars. These were large projects requiring large investment. For optimal utilization of funds, one should know the travel pattern and travel behavior. This has led to the emergence of transportation planning and demand management.

Highway planning in India

Excavations in the sites of Indus valley, Mohenjo-dero 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 impor- tance in this plan.

CHAPTER-2

Cross Sectional Elements

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 affect the acceleration and deceleration ability of vehicles. Lack of adequate friction can cause skidding or slipping of vehicles.

Skidding happens when the path traveled 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 has no glare during day, but has poor visibility at night

• Concrete roads has 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 affect 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.

Drainage

- 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 require 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 center. 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 intersiection.

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.

There is a term called *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 atleast 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 traveled during the reaction time t and is given by vt, where v is the velocity in $m/sec2$. Braking distance is the distance traveled 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. If F is the maximum frictional force developed and the braking distance is l, then work done against friction in stopping the vehicle is $Fl = f\ Wl$ where W is the total weight 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.

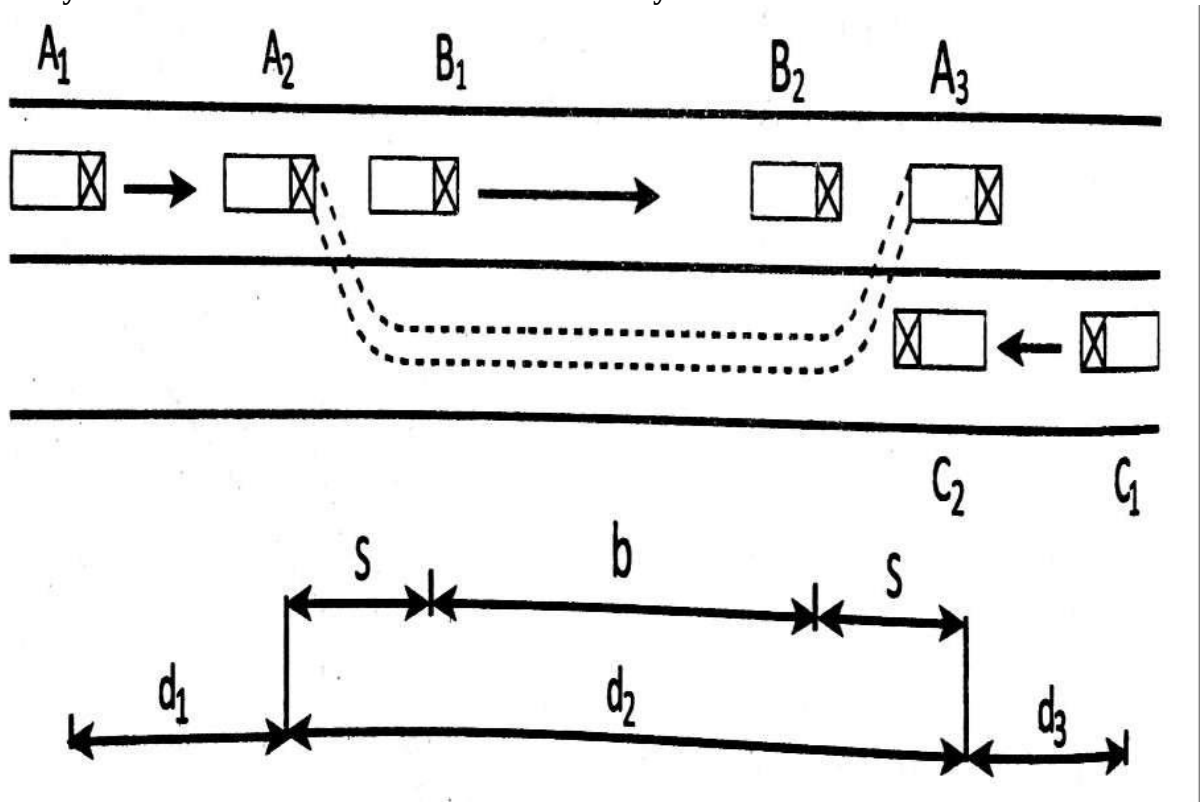
The factors that affect the OSD are:

• 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:

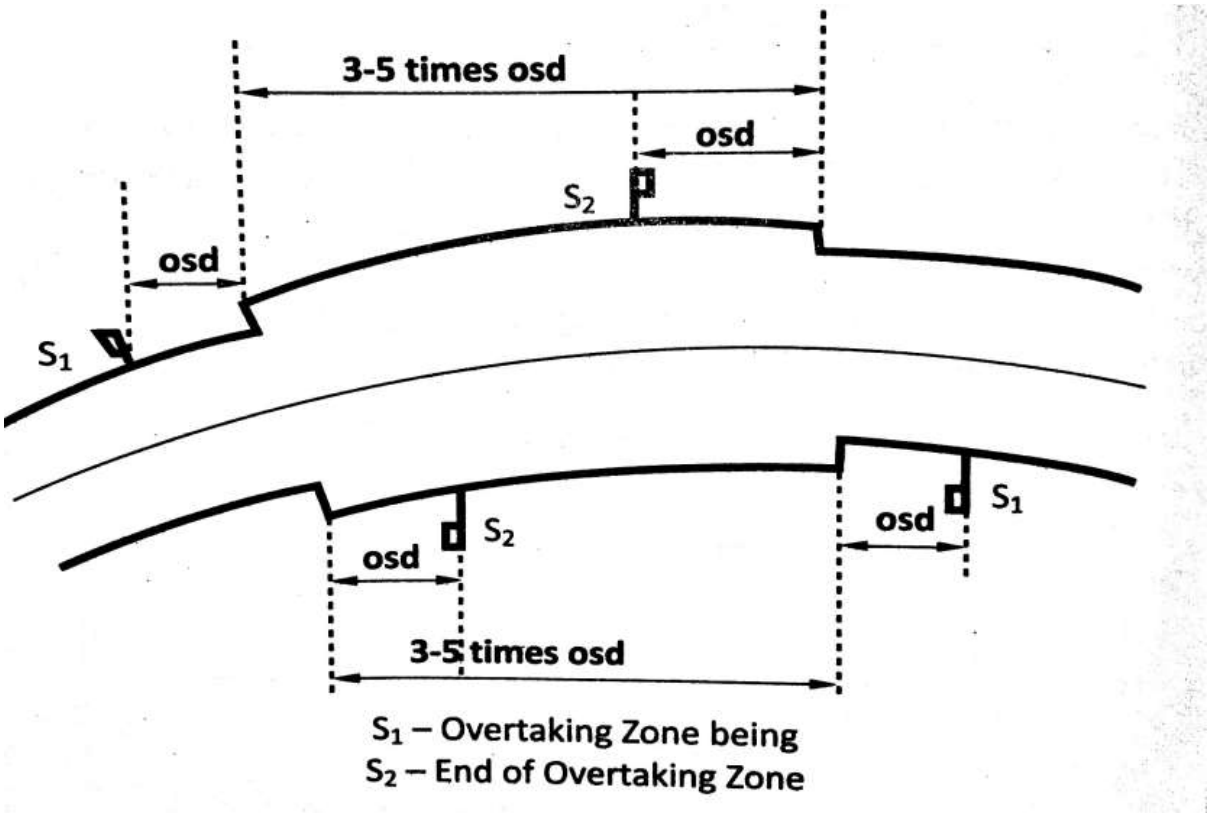


From A1 to A2, the distance ‘d1’ (m) travelled by overtaking vehicle A at reduced speed ‘vb’ (m/s) during reaction time ‘t’ (sec),
d1= vb X t
• IRC suggest reaction time t of driver as 2 sec ,
d1= 2vb
• From A2 to A3, vehicle A starts accelerating, shift to adjoining lane, overtakes vehicle B, and shift 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 X 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 X T
Thus overtaking sight distance (OSD) is,
OSD=(d1+d2+d3)
OSD= (vb X t) + (vb X T +2s) +(v X T)
• If speed is in kmph,
OSD= (0.28Vb X t)+(0.28Vb X T+2s)+(0.28V X 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 :

a. Design speed
b. Horizontal curve
c. Super elevation
d. Type and length of transition curves
e. Widening of pavement on curves
f. 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.

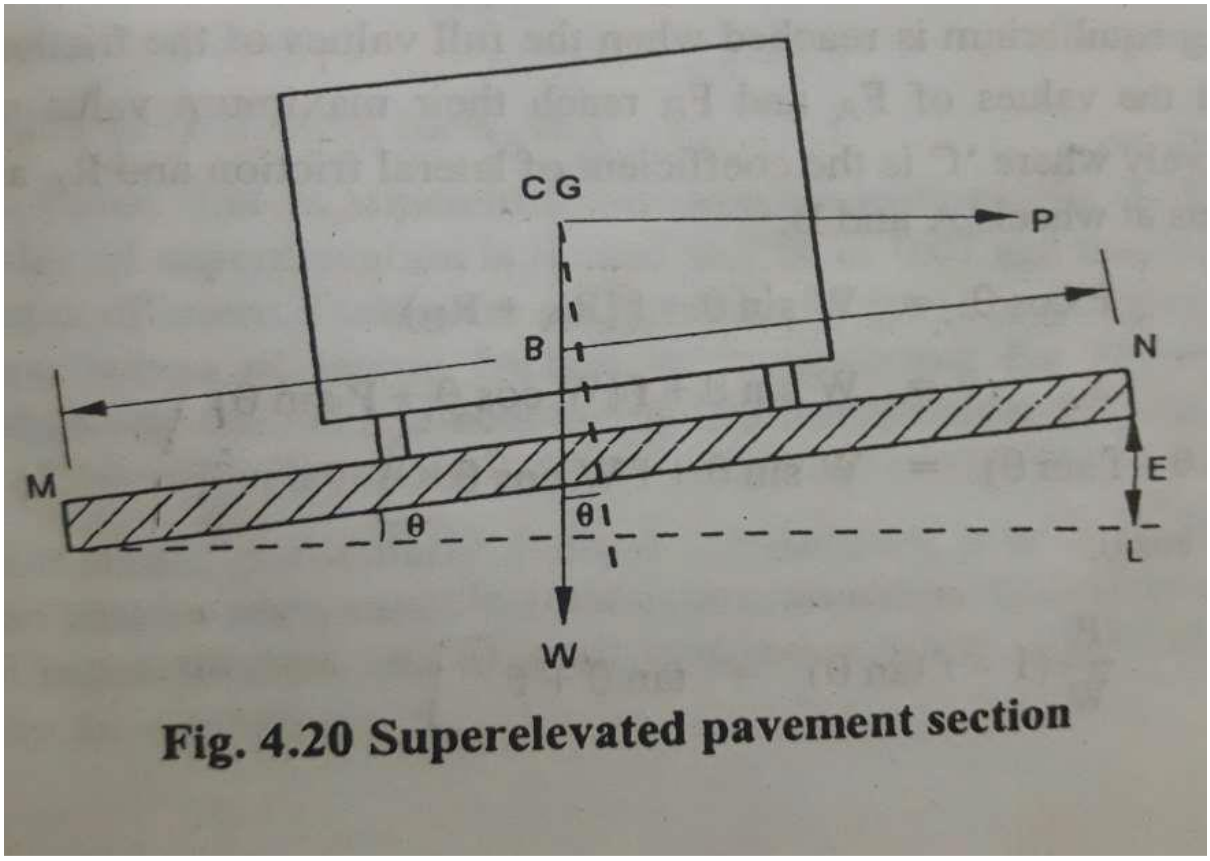


Fig. 4.20 Superelevated pavement section

Analysis of Superelevation:

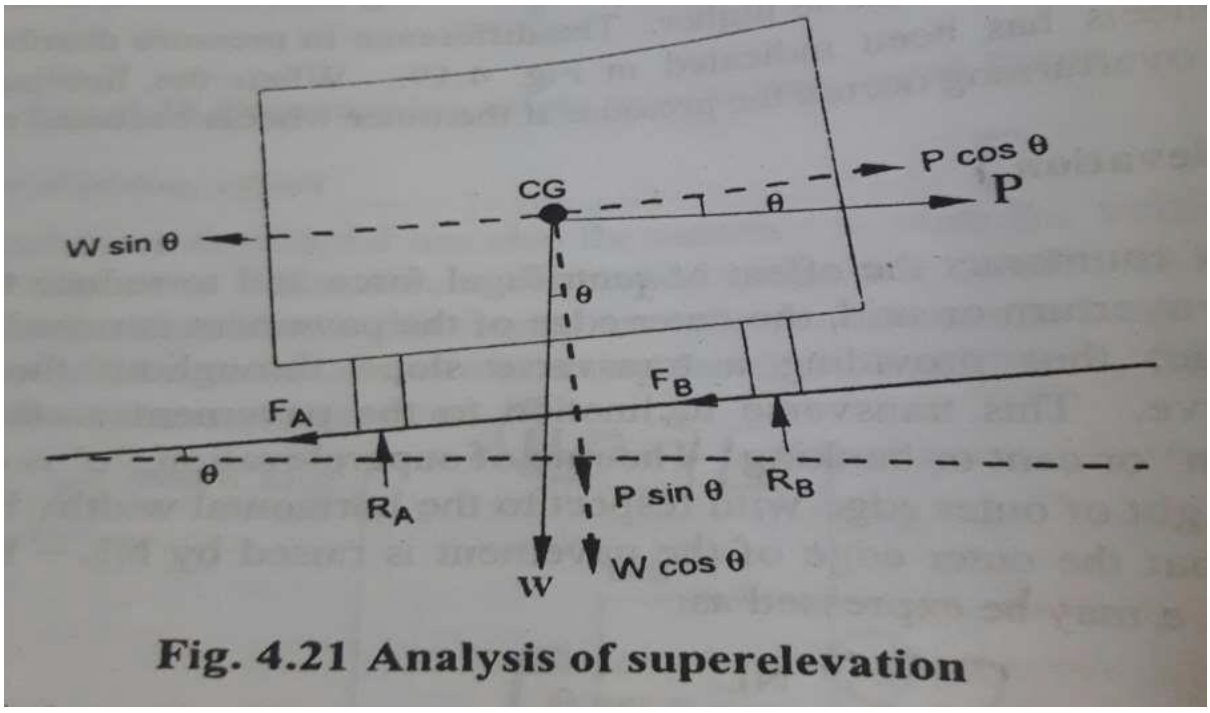


Fig. 4.21 Analysis of superelevation

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 cosө=W sinө+f(W cos ө+P sin ө)
P(cosө – f sinө)=W sinө+f Wcosө
Dividing by Wcosө,
P/W(1- f tanө)=tanө+f
Centrifugal ratio =P/W= tanө+f /(1-f tanө)
• The value of coefficient of lateral friction 'f' is taken as 0.15 and tanө i.e. super elevation seldom exceeds 7-10%.
• Therefore,
Centrifugal ratio =P/W = tanө+f
P/W = e + f ……i
but P/W = v²⁄gR ……ii
• Therefore, the general equation for the design of super elevation is given by,
e + f = v²⁄gR
• If 'V' speed of the vehicle is in kmph,
e + f = V²⁄127R
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/sec²

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 =v²⁄ gR - 0.07 …..if 'v' is in m/sec
f =V²⁄127R - 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.
$e + f = 0.07 + 0.15 = va^2 / gR = Va^2 / 127R$
$e + f = 0.22 = va^2 / gR = Va^2 / 127R$
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
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 = ruling – grade
gradient gradient 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

Overview

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.

Requirements of a pavement

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

Types of pavements

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.

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

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 (Figure 2).

Seal Coat:

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

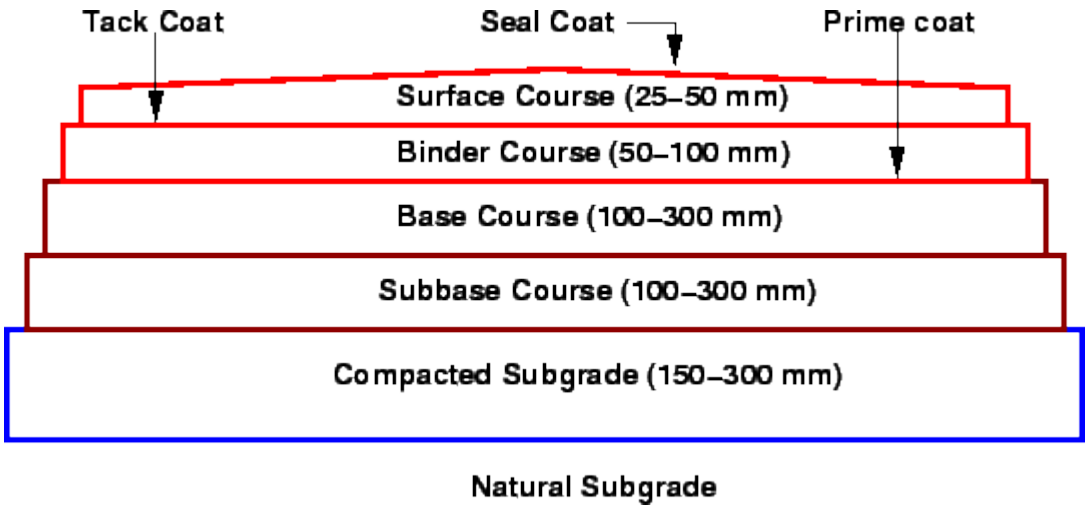
Tack Coat:

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.

Figure 1: Typical cross section of a flexible pavement



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.

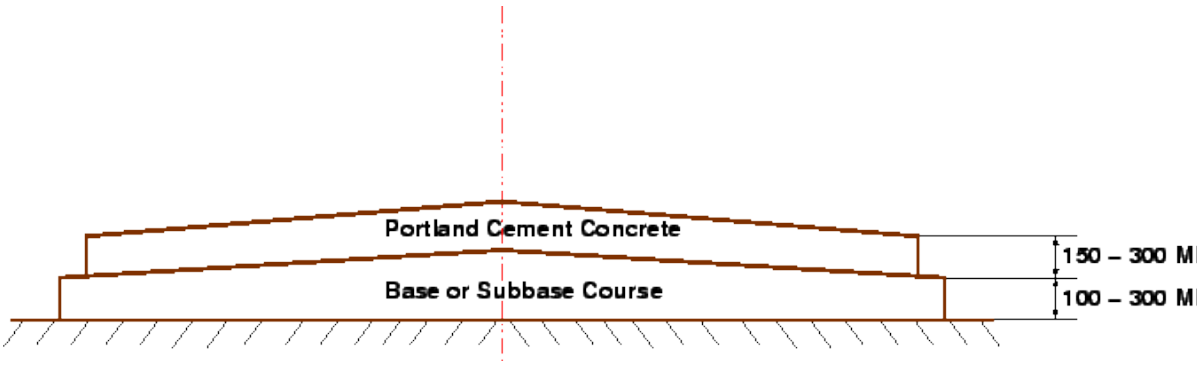
Failure of flexible pavements

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.

Figure2: Typical Cross section of Rigid pavement



In rigid pavement, load is distributed by the slab action, and the pavement behaves like an elastic plate resting on a viscous medium

Types of Rigid Pavements

Rigid pavements can be classified into four types:

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

Jointed Plain Concrete Pavement:

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:

Complete elimination of joints are achieved by reinforcement.

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.

Highway Pavement Stabilization:

Highway pavement stabilization techniques enhance pavement strength and longevity. These techniques involve modifying the soil's physical and chemical properties to improve its load-bearing capacity and resistance to deformation. soils are stabilized for road construction in most parts of the world for the following one or more

Objectives of Soil Stabilization:

Improve the strength (stability and bearing capacity) for subgrade, subbase, base, and

low-cost road surfaces,

Improve the volume stability – undesirable properties such as swelling, shrinkage,

high plasticity characteristics, and difficulty in compaction, etc. caused by change in

moisture,

Improve durability – increase the resistance to erosion, weathering or traffic, and

Improve high permeability, poor workability, dust nuisance, frost susceptibility, etc.

Common stabilization methods include mechanical stabilization, cement stabilization, lime stabilization, and bitumen stabilization.

Types of Highway Pavement Stabilization:

Mechanical Stabilization:

This method involves improving soil properties by physically mixing and compacting different materials, such as aggregates, to achieve a desired strength and density.

Mechanical stabilization is an improvement of an available material by blending it with one or more materials in order to improve the particle size distribution and plasticity characteristics.

Typical materials used for mechanical stabilization include river deposited sand, natural gravel, silty sands, sand clays, silt clays, crushed run quarry products and waste quarry products, volcanic cinders and scoria, poorly graded laterites and beach sands, etc. Materials produced by blending have properties similar to conventional unbounded materials and can be evaluated by ordinary methods.

The principal properties affecting the stability of compacted base or sub-base materials are internal friction and cohesion. Internal friction is chiefly dependent on the characteristics of the coarser soil

particles, i.e. gravel, sand and silt sizes. The cohesion, shrinkage, swelling and compressibility are mainly associated with the quantity and nature of the clay fraction as indicated by plastic properties.

Cement Stabilization:

Cement is added to the soil and mixed thoroughly, creating a hardened matrix that increases the soil's strength and reduces its susceptibility to moisture damage.

Cement is an effective stabilizing agent applicable to a wide range of soils and situations. It has two important effects on soil behaviours:

• Reduces the moisture susceptibility of soils – cement binds the particles greatly and reduces moisture induced volume change (shrinkage and swell) and it also improve strength stability under variable moisture, and

• Develop inter-particle bonds in granular materials – increased tensile strength and elastic modulus.

Soil properties progressively change with increasing cement contents. For practical reasons, two

categories of cement stabilised materials have been identified.

Cement modified materials – cement is used to reduce plasticity, volume-change, etc, and the inter-particle bonds are not significantly developed. Such materials are evaluated in the same manner as conventional unbound flexible pavement materials.

Cement bound materials – cement is used to sufficiently enhance modulus and tensile strength.

Cement bound materials have practical application in stiffening the pavement.

Lime Stabilization:

Lime is added to the soil to reduce plasticity and increase strength through cation exchange and pozzolanic reactions. Lime is not effective with cohesionless or low cohesion materials without the addition of secondary (pozzolanic-fine materials which react with lime to form cementitious compounds) additives. The cementitious products resulting from cement and lime stabilization are with comparable behaviour and may follow fairly similar evaluation, design, and construction considerations. The significant difference in the nature and rate of cementitious reactions, however, is a basis for the choice between cement and lime. The reaction between soil and lime are complex and still not completely understood. Basically four different factors are involved in the soil-lime reaction which are: cation exchange, flocculation, pozzolanic reaction, and carbonation. Cation exchange is an immediate reaction and unlike pozzolanic reaction, it is not significantly dependent on temperature in which cations such as sodium and hydrogen are replaced by calcium ions for which the clay mineral has a greater affinity. It has been shown that the thickness of the water layer around the clay particles decrease substantially as the result of cation exchanges. This condition in turn promotes the development of flocculent

structures. This means that plasticity, shrinkage and swelling and other normal clay – water interactions are distinctly inhibited. The effects of lime on the plasticity properties of soils are primarily due to cation exchange reactions. An immediate reduction in plasticity results in an immediate increase in shear strength. The effect of lime on clay minerals of high cation exchange capacity, such as montmorillonite clays, is therefore more apparent than it is on clay minerals of low cation exchange capacity such as koalinite clays.

The strength of lime stabilized materials is dependent on the amount of lime, the curing time, curing temperature and compaction. In addition, the quality of water, type of stabilizing lime, and uniformity of mixing are important factors affecting the quality of production as they are in cement stabilization. Although lime modifies or bonds soil as in cement stabilization, the tendency to form bound products is less with lime than it is with cement. Lime has more tendencies to produce granular materials and consequently its major applications are in the modification of clays, plastic sands, and plastic gravels.

Bitumen Stabilization:

Bitumen (asphalt) is used to bind soil particles together, improving the soil's resistance to water and enhancing its load-carrying capacity. Bituminous stabilization is used with non-cohesive granular materials – where the bitumen adds cohesive strength; and with cohesive materials – where the bitumen "waterproofs" the soil thus reducing loss of strength with increase in moisture content. Both effects take place partly from the formation of bitumen film around the soil particles which bonds them together and prevents the absorption of water, and partly from simple blocking of the pores, preventing water from entering the soil mass. Because more care is necessary in bituminous stabilization to achieve satisfactory mixing, its use has not been as widespread as cement and lime stabilizations.

Depending on the particle size distribution and physical properties of the available soil materials and the function of the stabilising bitumen, there are four types of

soil-bitumen mixtures in highway engineering:

1. Soil-bitumen: this is a mixture of cohesive soil and bitumen for waterproofing purposes. The maximum grain size should preferably not greater than one-third of the compacted layer. The best result has been obtained with soils that fall within the grain size limits. The bitumen requirements commonly range from 4-7% of the dry weight of the soil.

2. Sand bitumen: sands such as beach, river, pit, or existing roadway sand may be stabilized with bitumen if they are substantially free from vegetable matter, lumps or balls of clay or adherent films of clay. Some times it may require admixture of filler material to meet mechanical stability requirements.

It is recommended that the sand contain less than 12 % of 0.075 mm. however, in the case of windblown sands up to 25 % finer than 0.075 mm may be allowed provided that the portion of the sand passing the No. 40 sieve has a field moisture less than 20 % and linear shrinkage less than 5 %. The required amount of bitumen content ranges from 4-10 %, the optimum should be determined by compaction, strength, and water resistance testing and should not exceed the pore space of the compacted mineral mix.

CHAPTER -5

Hill Road

A hill road may be defined as the one which passes through a terrain with a cross slope of 25% or more. There may be sections along hill roads with the cross slope less than 25%, especially when the road follows a river route. Even then these sections are also referred to as hill roads. Hence, to establish a hill road overall terrain must be taken into account.

The hilly regions generally have extremes of climatic conditions, difficult and hazardous terrains, topography and vast high altitude areas. The region is sparsely populated and basic infrastructural facilities available in plain terrain are absent. Hence, a strong stable and feasible road must be present in hilly areas for overall development of other sectors as well.

Design and Construction Problems

Design and Construction of roads in hills and mountain are more complex than in plain terrain. It is due to several factors associated in the region.

They are:

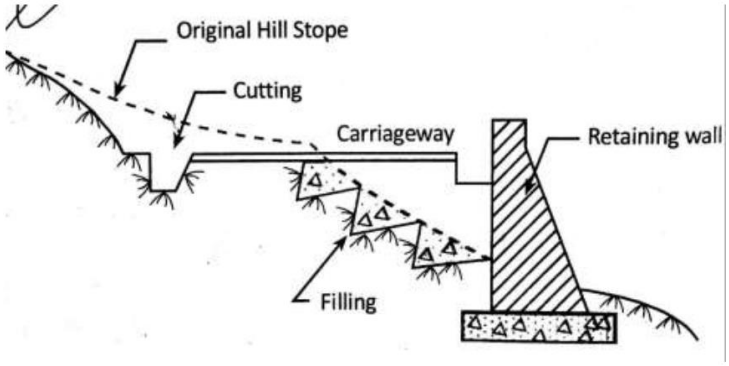
- A hilly or mountainous area is characterized by highly broken relief with vastly differing elevations and steep slopes, deep gorges etc. which may unnecessarily increase road length.
- The geological condition varies from place to place.
- Hill slopes stable before construction may not be as stable due to increased human activities.
- There may be variation in hydro-geological conditions which may easily be overlooked during design and construction
- Due to highly broken relief construction of special structures should be done at different places. This increases the cost of the construction.

Typical Cross Sections of Hill Road

The cross section of a road in a hilly terrain is determined by the original ground slope of the site, the slope of the road formation, width of roadway, side drain size, and shape and so on. Various types of road cross-section are:

1. Cut and fill
2. Bench type
3. Box cutting
4. Embankment with retaining walls
5. Semi bridge
6. Semi tunnel
7. Platforms

Typical Cross Sections of Hill Road



Retaining structures

A retaining structure is usually a wall constructed for supporting vertical or nearly vertical earth bank. Retaining walls are constructed on the valley side on the cut hill side to prevent the the slide towards the roadway. Situations where construction of retaining walls is required:

- Places where the valley side surface gets saturated in the monsoons and is likely to result in slip taking a part of the the road with it.
- Places where undercutting by a stream or other water course causes damage to the valley side and the road.
- In valley point where water flows over the road
- To achieve roadway width, where cutting into the the hill is not economical or has to be restricted due to other reasons.

HAIR-PIN CURVES

- The curve in a hill road which changes its direction through an angle of 180 degree or so, down the hill on the same side is known as hair-pin curve.
- This curve is so called because it conforms to the shape of a hair-pin.
- The bend so formed at the hair-pincurve in a hill road is known as hair-pin bend.
- This type of curve should be located on a hill side having the minimum slope and maximum stability. It must also be safe from view point of land slides and ground water.
- Hair-pin bends with long arms and farther spacing are always preferred.
- They reduce construction problems and expensive protective works. Hair-pin curves or bends of serpentine nature are difficult to negotiate and should, therefore, be avoided as far as possible.

CHAPTER -6

Road Drainage

Introduction and Importance of Highway Drainage System

Road drainage refers to the systems and techniques used to remove excess water from roadways and surrounding areas. This is crucial for maintaining road stability, preventing damage from water infiltration, and ensuring safety for all road users. Effective drainage systems prevent flooding, ponding, and seepage, while also preserving the underlying road structure and preventing damage from hazardous surface water.

• Bearing capacity of soil foundation gets decreased when the moisture content in its get increased and is lowest when the same gets saturated.

• Water standing on the carriageway is danger to high speed traffic.

Highway Drainage may be defined as the process of interception and removal of water from over, under and vicinity of the road surface.

Destruction of highways by water:

• Softening the road surface constructed of soil or sand-clay or gravel or water bound macadam.

• Erosion of side slopes forming gullies, erosion of side drains, etc.

• Softening the subgrade soil and decreasing its bearing power.

• Chances of landslides and slips.

Ways of Protecting above effects:

• Interception and diversion of the surface water which would otherwise flow across the road or along it and cause erosion.

• Interception and rapid removal of seepage of subsurface water.

• Proper soil treatment

• Change of the water course

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.

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.

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.

Aqueduct

Aqueduct is an open or closed conduit sufficiently above the roadway to drain water across the road with the provision of pillar supports on either side of the road. These structures can be advantageously used in hill roads where culverts are not feasible.

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 low- lying areas during rainy seasons which becomes very harmful to the pavement and the subgrade especially when the subgrade is made of fine- grained 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 center 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

Road maintenance aims to preserve roads in their original constructed condition, ensuring safety and efficient travel. It involves regular upkeep, addressing issues like potholes, debris, and damaged signs. Preventive, corrective, and emergency maintenance are key, with drainage and pavement care crucial for road longevity.

Importance of Road Maintenance:

- Preserves Road Condition: Keeps roads in their original constructed state, preventing rapid deterioration.
- Improves Safety: Addresses hazards like potholes and damaged signs, reducing accidents.
- Reduces Operating Costs: Proper maintenance can lower vehicle operating costs and repair expenses.
- Extends Road Lifespan: Regular maintenance can significantly extend the lifespan of road infrastructure.

Types of Road Maintenance:

Routine Maintenance:

Ongoing, regular activities like patching potholes, clearing debris, replacing damaged signs, and cleaning drainage systems.

Periodic Maintenance:

Performed at regular intervals to address wear and tear, including surface dressing, slurry sealing, and regravelling.

Emergency Maintenance:

Immediate actions to address sudden road closures or damage from accidents or natural disasters.

1. Routine Maintenance:

- Pothole patching: Repairing small holes in the road surface to prevent further damage.
- Street sweeping: Removing debris, leaves, and litter from the road surface.
- Signage and markings: Maintaining clear and visible road signs and markings.
- Crack sealing: Filling small cracks in the pavement to prevent water infiltration and further damage.
- Edge repairs: Addressing minor damage to the edges of the road.

- Shoulder maintenance: Maintaining the shoulders of the road, including vegetation control.
- Drainage maintenance: Ensuring proper drainage to prevent water damage to the road.
- Bridge maintenance: Inspecting and performing minor repairs on bridges.

2. Periodic Maintenance:

- Resurfacing: Applying a new layer of asphalt or concrete to restore the road surface.
- Rehabilitation: Addressing more extensive damage to the road structure.
- Reconstruction: Replacing the entire road structure.
- Seal coating: Applying a protective layer to the road surface to extend its life.
- Crack sealing (more extensive): Addressing larger cracks and preventing water damage.

3. Emergency/Special Maintenance:

- Debris removal: Clearing fallen trees, accident debris, or other obstructions from the road.
- Accident damage repairs: Addressing damage caused by accidents.
- Flooding repairs: Addressing damage caused by flooding.
- Snow and ice control: Applying salt or sand to roads to improve traction in winter conditions.
- Emergency bridge repairs: Addressing urgent repairs to bridges.
- Clearing blocked drains: Ensuring proper drainage to prevent road damage.

Road Failure:

Highway failures refer to the deterioration of pavement or structural components of a road, leading to issues like cracks, potholes, rutting, and other forms of damage. These failures can be caused by factors like heavy traffic, poor construction, inadequate maintenance, and environmental conditions like extreme temperatures or heavy rainfall. Effective maintenance strategies, including crack sealing, patching, and resurfacing, are crucial for addressing these issues and ensuring road safety and longevity.

Types of Highway Failures:

Cracking: This includes fatigue cracking (caused by repeated traffic loads), longitudinal cracking (running along the length of the road), and transverse cracking (perpendicular to the road).

Surface Deformation: This includes rutting (depressions along wheel paths), shoving (where the pavement layer is pushed or displaced), and depressions (sinking of the pavement).

Disintegration: This involves the breakdown of the pavement surface, including ravelling (loss of aggregate particles) and potholes.

Other Issues: These can include water bleeding (water rising to the surface), corrugation (wavy or rippled surface), and edge cracking.

Causes of Highway Failures:

Traffic Loads: Heavy vehicles and high traffic volume can cause excessive stress on the pavement, leading to cracking and deformation.

Construction Defects: Poor construction practices, inadequate compaction, and the use of substandard materials can weaken the pavement structure.

Environmental Factors: Temperature variations, rainfall, and freeze-thaw cycles can cause the pavement to expand, contract, and crack.

Lack of Maintenance: Inadequate or delayed maintenance can allow minor issues to escalate into major problems.

Subgrade Problems: Weak or unstable subgrade soil can lead to settlement and pavement failure.

Maintenance Strategies:

Preventive Maintenance: This includes activities like crack sealing, patching, and surface treatments to address minor issues before they become serious.

Rehabilitation: This involves more extensive measures like resurfacing or overlays to restore the pavement's structural integrity.

Reconstruction: In cases of severe damage, complete reconstruction of the pavement may be necessary.

CHAPTER -8

Construction Equipments

The common types of construction equipments to be discussed in this chapter are:

- Earth excavation equipments
- Hauling equipments
- Dozing equipments
- Compaction equipments
- Grading equipments
- Trenchers
- Scrapers
- Tunneling and rock drilling equipment
- Lifting equipments
- Concrete mixing equipments
- Truck mixers
- Pumping and de- watering equipment
- Concrete vibrating equipments
- Asphalt drum mix plants

Earth Excavators

Excavators are heavy equipment consisting of a boom, bucket and cab on a rotating platform known as the control room. The house sits atop an under carriage with tracks or wheels. All movement and functions of the excavator are accomplished through the use of hydraulic fluid, be it with rams or motors.

Types of excavator:

- Compact excavator
- Crawler excavator
- Wheeled excavators
- Dragline excavator
- Power shovel

Compact Excavator

A compact or mini excavator is tracked or wheeled vehicle with an approximate operating weight from 0.7 to 7.5 tons. It generally includes a standard backfill blade and features independent boom swing. Hydraulic Excavators are somewhat different from other construction equipment in that all movement and functions of the machine are accomplished through the transfer of hydraulic fluid. The compact excavator's work group and blade are activated by hydraulic fluid acting upon hydraulic cylinders. The excavator's slew (rotation) and travel functions are also activated by hydraulic fluid powering hydraulic motors.

Crawler Excavator

a) Mini-Crawler Excavator

With a wide range of available sizes and features like Power Tech engines, zero-tail-swing, offset boom, multiple attachments and ultra comfortable operator stations, there's excavator to fit every job. Hydraulic management system, which helps by balancing hydraulic pressure and flow and sensing when extra power is needed without draining other systems.

b) Heavy Crawler Excavator

Crawler excavator gets the job done with muscle, control and peerless productivity. Efficient, cool-running engines and enhanced hydraulics make these the most-reliable and hardest-working excavators yet. Climb into one of these best-in-class cabs and unleash a mighty workhorse to tackle toughest jobs.

Wheeled Excavators

Wheeled excavators easily navigate streets and hard surfaces to deliver powerful bucket forces in well-balanced, high-stability machines. Even with all that muscle outside, operators find quiet comfort inside spacious air conditioned cabs. Low effort levers deliver smooth boom and bucket

control.

Dragline Excavator

Dragline Excavation Systems are heavy equipment used in civil engineering and surface mining. In civil engineering the smaller types are used for road and port construction. The larger types are used in striping operations to move overburden above coal, and for tar sand mining. Draglines are amongst the largest mobile equipment ever built on land, and weigh in the vicinity of 2000 metric tons, though specimens weighing up to 13,000 metric tons have also been constructed.

A dragline bucket system consists of a large bucket which is suspended from a boom (a large truss like structure) with wire ropes. The bucket is maneuvered by means of a number of ropes and chains. The hoist rope, powered by large diesel or electric motors, supports the bucket and hoist coupler assembly from the boom. The dragrope is used to draw the bucket assembly horizontally. By skillful maneuver

of the hoist and the dragropes the bucket is controlled for various operations. A schematic of a large dragline bucket system is shown below.

Power Shovel

A power shovel (also stripping shovel or front shovel or electric mining shovel) is a bucket equipped machine, usually electrically powered, used for digging and loading earth or fragmented rock and for mineral extraction.

Tipper (dumper truck)

A tipper or dump truck is a truck used for transporting loose material (such as sand, gravel or dirt) for construction. A typical dump truck is equipped with a hydraulically operated open-box bed hinged at the rear, the front of which can be lifted up to allow the contents to be deposited on the ground behind the truck at the site of delivery.

Types of dump trucks

- Standard dump truck
- Articulated dump truck
- Transfer dump truck
- Truck and pup
- Semi trailer end dump truck
- Semi trailer bottom dump truck
- Double and triple trailer bottom dump truck
- Side dump truck
- Off-road dump truck

Bulldozers:

Bulldozer, which pushes earth and rocks with a blade installed at the machine's front end. Large-sized crawler dozers normally have a set of claws called a ripper that is installed at the machine's rear end and can crush a hard rock. Swamp bulldozers are equipped with an undercarriage that is configured to enable them to freely move around on a marshy land. As a fellow machine, there is a pipe- laying machine that lays down a large steel pipe in the construction of a pipeline and a dozer shovel (crawler loader) for loading.

Trenchers

Trenchers or Trenching machines are used to excavate trenches in soil. These trenches are generally used for pipeline laying, cable laying, drainage purposes etc. Trenching machines are available in two types namely chain trenchers and wheeled trenchers. Chain trenchers contain a fixed long arm around which digging chain is provided. Wheeled trenchers contain a metal wheel with digging tooth around it. To excavate hard soil layers, wheeled trenchers are more suitable. Both types of trenchers are available in tracked as well as wheeled vehicle forms.

Scrapers

The design of scrapers (tractor scrapers) allows for loading, hauling, dumping, and spreading of loose materials. Use a scraper for medium-haul earthmoving operations and for moving ripped materials and shot rock. The haul distance (zone of operation), the load volume, and the type and grade of surface traveled on are the primary factors in determining whether to use a scraper on a particular job. The optimum haul distance for the small and medium-size scrapers is 300 to 3,000 feet. There are larger scrapers that are effective up to 5,000 feet.

Hot mix plant

Hot Mix Plant or Asphalt Drum Mix Plant is equipment for producing good quality of hot mix for flexible pavement construction. The ingredients of the hot mix in required proportion are continuously fed to the rotating drum in drying & mixing zones and the discharge end of the drum delivers continuous output of the hot mix. The main ingredients of hot mix are virgin cold aggregates of different grades, asphalt (bitumen) and mineral fillers. The output capacity of this plant varies from 30 TPH to 120 TPH (Tone per hour). Asphalt drum mix plant generally consists of :

- Cold Aggregate Four Bin Feeder
- Single Deck Vibratory Screen For Oversized Material Removal
- Slinger (Cold) Conveyor
- Drying Cum Mixing Thermo drum
- Load out conveyor with Gob hopper
- Asphalt Tank
- Mineral Filler Unit
- Centralized Control Panel with Insulated Cabin
- Dryer Auto Burner
- Fuel Storage Tank
- Pollution Control Unit (Optional)

In this the cold aggregates of different grades which are stored in the multiple feeder bins are transferred in required proportion to the primary section of the rotary drum through slinger conveyor. The burner

fitted on the in feed side of the drum produce appropriate flame to remove the moisture from the aggregates and heat the dried aggregates to the desired temperature in the primary section of the drum.

The hot aggregates then travel down the secondary section where they are mixed & coated with the asphalt & filler material. The asphalt and filler material are pumped in the secondary section in predetermined proportion from asphalt tank and mineral filler unit respectively. These hot mix from the drum is then transferred to truck through load out conveyor. The heavy dust is collected by the multi cone type dust collector and the exhaust is passed through wet scrubber type pollution control unit before letting it to the atmosphere.

Asphalt Drum Mix Plants offer advantages of higher production rates, less moving parts, lower maintenance, simple to operate, lower fuel consumption & better economy