UNIT -III

Pavement Design

1.0 Introduction

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 subgrade. 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.

1.1 Requirements of a pavement An ideal pavement should meet the following requirements:

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

1.2 Factors affecting pavement design

[A] Traffic and loading

Traffic is the most important factor in the pavement design. The key factors include contact pressure, wheel load, axle configuration, moving loads, load, and load repetitions.

[1] Contact pressure: The tyre pressure is an important factor, as it determine the contact area and the contact pressure between the wheel and the pavement surface. Even though the shape of the contact area is elliptical, for sake of simplicity in analysis, a circular area is often considered.

[2] Wheel load: The next important factor is the wheel load which determines the depth of the pavement required to ensure that the subgrade soil is not failed. Wheel configuration affect the stress distribution and deflection within a pavement. Many commercial vehicles have dual rear wheels which ensure that the contact pressure is within the limits. The normal practice is to convert dual wheel into an equivalent single wheel load so that the analysis is made simpler

[3] Axle configuration: The load carrying capacity of the commercial vehicle is further enhanced by the introduction of multiple axles.

[4] Moving loads: The damage to the pavement is much higher if the vehicle is moving at creep speed. Many studies show that when the speed is increased from 2 km/hr to 24 km/hr, the stresses and deflection reduced by 40 per cent.

[5] Repetition of Loads: The influence of traffic on pavement not only depend on the magnitude of the wheel load, but also on the frequency of the load applications. Each load application causes some deformation and the total deformation is the summation of all these. Although the pavement deformation due to single axle load is very small, the cumulative effect of number of load repetition is significant. Therefore, modern design is based on total number of standard axle load (usually 80 kN single axle).

[B] Environmental factors

Environmental factors affect the performance of the pavement materials and cause various damages. Environmental factors that affect pavement are of two types, temperature and precipitation and they are discussed below:

[1] Temperature :- The effect of temperature on asphalt pavements is different from that of concrete pavements. Temperature affects the resilient modulus of asphalt layers, while it induces curling of concrete slab. In rigid pavements, due to difference in temperatures of top and bottom of slab, temperature stresses or frictional stresses are developed. While in flexible pavement, dynamic modulus of asphaltic concrete varies with temperature. Frost heave causes differential settlements and pavement roughness. Most detrimental effect of frost penetration occurs during the spring break up period when the ice melts and subgrade is a saturated condition.

[**2] Precipitation**:- The precipitation from rain and snow affects the quantity of surface water infiltrating into the subgrade and the depth of ground water table. Poor drainage may bring lack of shear strength, pumping, loss of support, etc.

2.0 Flexible pavements

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

- The wheel load acting on the pavement will be distributed to a wider area, and the stress decreases with the depth. Taking advantage of this stress distribution characteristic, flexible pavements normally has many layers.

- The design of flexible pavement uses the concept of layered system. Based on this, flexible pavement may be constructed in a number of layers and the top layer has to be of best quality to sustain maximum compressive stress, in addition to wear and tear.

- The lower layers will experience lesser magnitude of stress and low quality material can be used. Flexible pavements are constructed using bituminous materials.
- These can be either in the form of surface treatments (such as bituminous surface treatments generally found on low volume roads) or, asphalt concrete surface courses (generally used on high volume roads such as national highways).
- Flexible pavement layers reflect the deformation of the lower layers on to the surface layer (e.g., if there is any undulation in sub-grade then it will be transferred to the surface layer).
- In the case of flexible pavement, the design is based on overall performance of flexible pavement, and the stresses produced should be kept well below the allowable stresses of each pavement layer

2.1 Typical layers of a flexible pavement

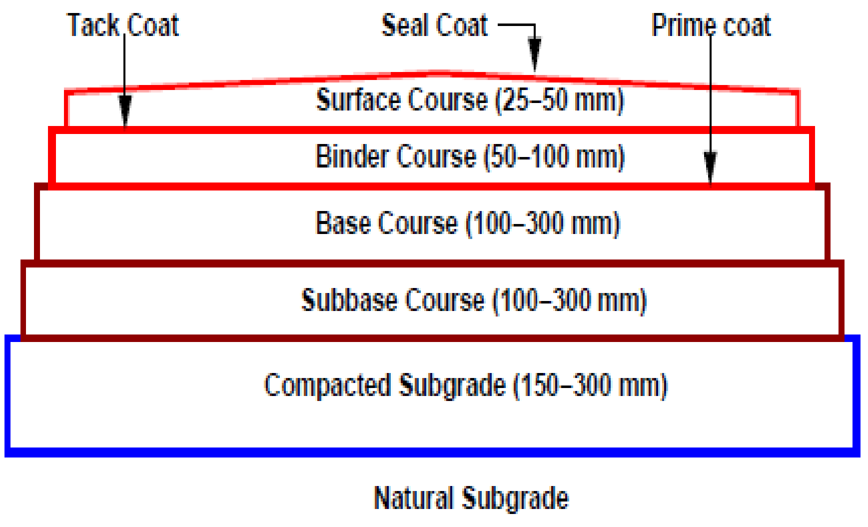


Figure 19:2: Typical cross section of a flexible pavement

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

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

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

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

Surface course: Surface course is the layer directly in contact with tra_c 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:

1. 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,
2. It must be tough to resist the distortion under traffic and provide a smooth and skid- resistant riding surface,
3. 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.

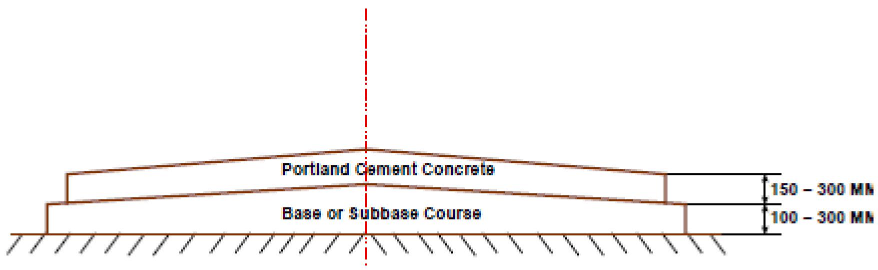
Base course : The base course is the layer of material immediately beneath the surface of binder course and it provides additional load distribution and contributes to the sub-surface drainage It may be composed of crushed stone, crushed slag, and other untreated or stabilized materials.

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.

3.0 Rigid pavements

1. Rigid pavements have sufficient flexural strength to transmit the wheel load stresses to a wider area below.
2. A typical cross section of the rigid pavement is shown in Figure . 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.
3. 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
4. In rigid pavement, load is distributed by the slab action



Typical Cross section of Rigid pavement

Sr. No.	Flexible Pavement	Rigid Pavement
1.	Deformation in the sub grade is transferred to the upper layers	Deformation in the subgrade is not transferred to subsequent layers
2.	Design is based on load distributing characteristics of the component layers	Design is based on flexural strength or slab action
3.	Have low flexural strength	Have high flexural strength
4.	Load is transferred by grain to grain contact	No such phenomenon of grain to grain load transfer exists
5.	Have low completion cost but repairing cost is high	Have low repairing cost but completion cost is high
6.	Have low life span (High Maintenance Cost)	Life span is more as compare to flexible (Low Maintenance Cost)
7.	Surfacing cannot be laid directly on the sub grade but a sub base is needed	Surfacing can be directly laid on the sub grade
8..	No thermal stresses are induced as the pavement have the ability to contract and expand freely that why expansion joints are not needed	Thermal stresses are more vulnerable to be induced as the ability to contract and expand is very less in concrete that why expansion joints are needed
9.	Strength of the road is highly dependent on the strength of the sub grade	Strength of the road is less dependent on the strength of the sub grade
10.	Rolling of the surfacing is needed	Rolling of the surfacing in not needed
11	Road can be used for traffic within 24 hours	Road cannot be used until 14 days of curing
12.	Force of friction is less Deformation in the sub grade is not transferred to the upper layers.	Force of friction is high
13.	Damaged by Oils and Certain Chemicals	No Damage by Oils and Greases

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4.0 Relative stiffness of slab to sub-grade

A certain degree of resistance to slab defection is offered by the sub-grade. The sub-grade deformation is same as the slab defection. Hence the slab defection is direct measurement of the magnitude of the sub-grade pressure. This pressure deformation characteristics of rigid pavement lead Westergaard to the define the term radius of relative stiffness l in cm is given by the equation

$$l = \sqrt[4]{\frac{Eh^3}{12K(1-\mu^2)}}$$

where

E - modulus of elasticity of cement concrete in kg/cm^2
u - Poisson's ratio of concrete(0.15),
h - slab thickness in cm and
K- the modulus of sub-grade reaction.

4.1 Critical load positions

The pavement slab has finite length and width, either the character or the intensity of maximum stress induced by the application of a given traffic load is dependent on the location of the load on the pavement surface. There are three typical locations namely the interior, edge and corner, where differing conditions of slab continuity exist. These locations are termed as critical load positions.

4.1.1 Equivalent radius of resisting section

When the interior point is loaded, only a small area of the pavement is resisting the bending moment of the plate. Westergaard gives a relation for equivalent radius of the resisting section in cm in the equation

$$b = \begin{cases} \sqrt{1.6a^2 + h^2} - 0.675\ h & \text{if a} < 1.724 \text{ h} \\ a & \text{otherwise} \end{cases}$$

where

a - radius of the wheel load distribution in cm and
h - slab thickness in cm.

4.1.2 Wheel load stresses - Westergaard's stress equation

The cement concrete slab is assumed to be homogeneous and to have uniform elastic properties with vertical sub-grade reaction being proportional to the defection. Westergaard developed relationships for the stress at interior, edge and corner regions, denoted as σ_i, σ_e, σ_c in kg/cm^2 respectively and given by the equation

$$\sigma_i = \frac{0.316\ P}{h^2}\left[4\ \log_{10}\left(\frac{l}{b}\right) + 1.069\right]$$

$$\sigma_e = \frac{0.572\ P}{h^2}\left[4\ \log_{10}\left(\frac{l}{b}\right) + 0.359\right]$$

$$\sigma_c = \frac{3\ P}{h^2}\left[1 - \left(\frac{a\sqrt{2}}{l}\right)^{0.6}\right]$$

where

h - slab thickness in cm,

P - wheel load in kg,

a - radius of the wheel load distribution in cm,

l - radius of the relative stiffness in cm and

b - radius of the resisting section in cm

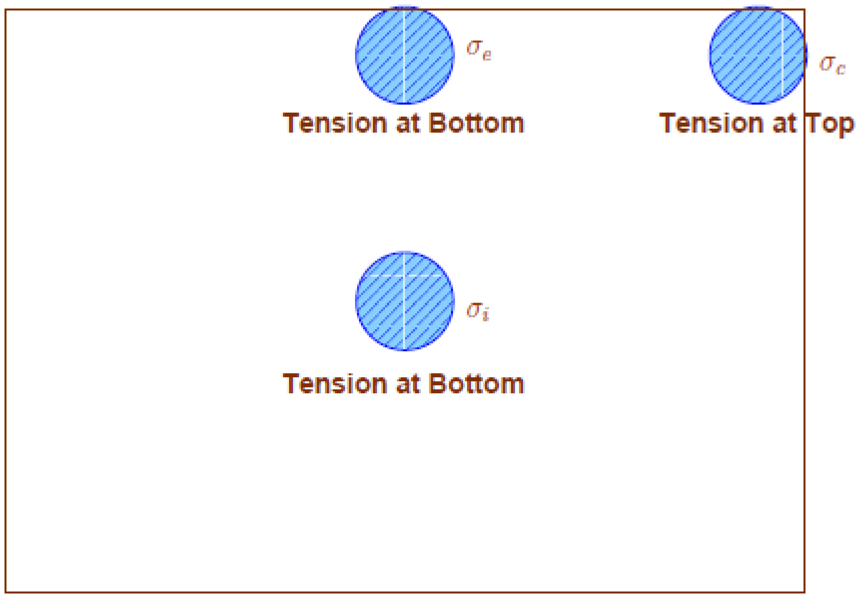


Figure : Critical stress locations

4.2 Temperature stresses

Temperature stresses are developed in cement concrete pavement due to variation in slab temperature. This is caused by (i) daily variation resulting in a temperature gradient across the thickness of the slab and (ii) seasonal variation resulting in overall change in the slab temperature. The former results in warping stresses and the later in frictional stresses.

4.2.1 Warping stress

1. During the day the top of the pavement slab get heated under the sunlight when the bottom of the slab still remain relatively colder.
2. The maximum difference in temperature between the top and bottom of the pavement slab may occur at some period after the mid-noon.
3. This causes the slab or bend as the warping is resisted by the self weight of the slab
4. Warping stresses are developed late in the evening, the bottom of the slab get heated up due to heat transfer from the top and atmospheric temperature falls, the top of the slab becomes colder resulting warping of the slab in the opposite direction and there is a reversal in warping stresses at the different region of the slab
5. Thus the daily variation in temperature causes warping stresses in reverse direction of at the corner, edge and interior regions of the slab
6. The warping stress at the interior, edge and corner regions, denoted as _ σ_{t_i}, σ_{t_e}, σ_{t_c} in kg/cm^2 respectively and given by the equation

$$\sigma_{t_i} = \frac{E\epsilon t}{2}\left(\frac{C_x + \mu C_y}{1-\mu^2}\right)$$

$$\sigma_{t_e} = \mathrm{Max}\left(\frac{C_x E\epsilon t}{2}, \frac{C_y E\epsilon t}{2}\right)$$

$$\sigma_{t_c} = \frac{E\epsilon t}{3(1-\mu)}\sqrt{\frac{a}{l}}$$

where

E - modulus of elasticity of concrete in kg/cm^2 ,
e -thermal coefficient of concrete per ^{o}C
t - temperature difference between the top and bottom of the slab,
Cx and Cy - coefficient based on $\frac{Lx}{l}$ in the desired direction and $\frac{Ly}{l}$ right angle to the desired direction,
U - Poisson's ration (0.15),
a - radius of the contact area and
l - radius of the relative stiffness.

4.2.2 Frictional stresses

1. During the summer season as the mean temperature of the slab increases, the concrete pavement expands towards the expansion joint.
2. Due to the frictional resistance at the interface which depend upon the self weight of the slab and coefficient of the friction at the interface
3. Similarly during the winter season , the slab contract causing the tensile stress at the bottom due to the frictional resistance again opposing the movement of the slab as it tend to expand.
4. Thus the frictional stresses are developed due to seasonal variation in temperature

The frictional stress σ_f in kg/cm^2 is given by the equation

$$\sigma_f = \frac{WLf}{2 \times 10^4}$$

where

W - unit weight of concrete in kg/cm^2

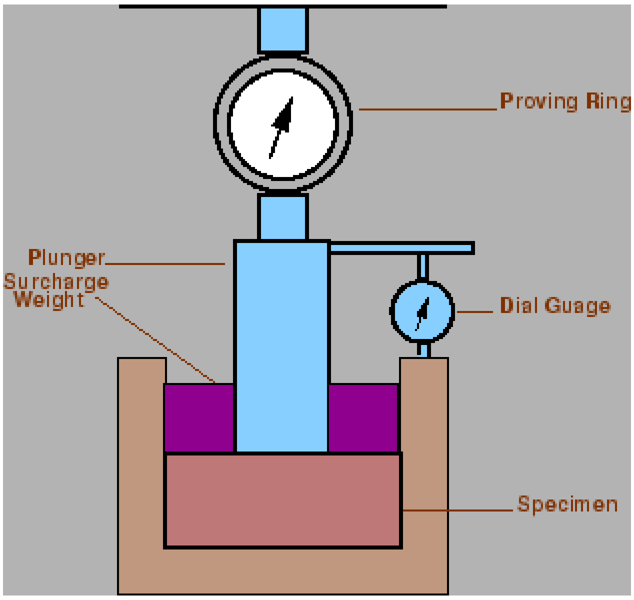
f - coefficient of sub grade friction (1.5) and

L - length of the slab

4.3 CALIFORNIA BEARING RATIO METHOD

It is the **ratio of force per unit area** required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the **corresponding penetration** of a standard material. The California Bearing Ratio Test (CBR Test) is a penetration test developed by *California State Highway Department (U.S.A.)* for evaluating the bearing capacity of subgrade soil for design of flexible pavement.

Tests are carried out on natural or compacted soils in water soaked or un-soaked conditions and the results so obtained are compared with the curves of standard test to have an idea of the soil strength of the subgrade soil.



TEST PROCEDURE

1. Normally 3 specimens each of about 7 kg must be compacted so that their compacted densities range from 95% to 100% generally with 10, 30 and 65 blows.
2. Weigh of empty mould
3. Add water to the first specimen (compact it in five layer by giving 10 blows per layer)
4. After compaction, remove the collar and level the surface.
5. Take sample for determination of moisture content.
6. Weight of mould + compacted specimen.
7. Place the mold in the soaking tank for four days (ignore this step in case of unsoaked CBR.
8. Take other samples and apply different blows and repeat the whole process.
9. After four days, measure the swell reading and find %age swell.
10. Remove the mould from the tank and allow water to drain.
11. Then place the specimen under the penetration piston and place surcharge load of 10lb.
12. Apply the load and note the penetration load values.
13. Draw the graphs between the penetration (in) and penetration load (in) and find the value of CBR**.**

USES AND SIGNIFICANCE of California Bearing Ratio Test:

1. The CBR test is one of the most commonly used methods to evaluate the strength of a sub grade soil, sub base, and base course material for design of thickness for highways .

2. The california bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.
3. This instruction sheet covers the laboratory method for the determination of C.B.R. of undisturbed and remoulded /compacted soil specimens, both in soaked as well as unsoaked state.

4.4 CBR METHOD – I R C RECOMMENDATIONS

Some of the important points recommended by IRC for the CBR method of design **(IRC:37 – 1970)** are given below:

1. The CBR tests should be performed on remoulded soils in the laboratory. In – Site tests are not recommended for design purpose. The specimens should be prepared by static compaction where ever possible and other wise by dynamic compaction. The standard test procedure should be strictly adhered to.
2. For the design of new roads the sub grade soil sample should be compacted at OMC to proctor density whenever suitable compaction equipment is available to achieve this density in the fields; otherwise the soil sample may be compacted to the dry density expected to be achieved in the field. In the case of existing roads, the sample should be compacted to field density of sub graded soil (at OMC or at a field moisture content.)
3. In new constructions the CBR test samples may be soaked in water for four days period before testing. However in areas with arid climate or when the annual rain fall is less than 50 cm and the water table is too deep to affect the sub grade adversely and when thick and impermeable bituminous surfacing is provided, it is not necessary to soak the soil specimen before carrying out the CBR test. Wherever possible the most adverse moisture condition of the sub grade should be determined from the field study.
4. At least three samples should be tested on each 1 type of soil at the same density and moisture content. If the maximum variation in CBR valves of the three specimens exceeds the specified limits, the design CBR should

be the average of atleast six samples (The specified limits of maximum variation in CBR are 3 for CBR values up to 10,5 for values 10 to 30 and 10 for values 30 to 60%)

5. The top 50-cm of sub grad should be compacted at least up to 95 to 100 percent of proctor density.
6. An estimate of the traffic to be carried by the road pavement at the end of expected life should be made keeping in view the existing traffic and probable growth in traffic due to change in the land use. Pavements of major roads should be designed at least for 10days life period and the following formula may be used in such cases for traffic prediction.

$$A = P(1+r)^{(n+10)}.$$

Where

A = Number of heavy vehicles per day for design (laden Weight>3 tonnes)
P = number of heavy vehicles per day at least count
r = annual rate of increase of heavy vehicles.
n = number of years between the last count and the year of completion of construction.

7. The value of P in the formula should be the seven day average of heavy vehicles found from 24 hour counts. If a reliable value of growth factor r is not available, a value of 7.5% may be assumed for roads in rural areas.
8. The traffic for the design is considered in units of heavy vehicles (of laden weight exceeding 3 tons) per day in both directions and are divided into seven categories A to G. The suitable design curve should be chosen from the table given in the design chart (fig). The design thickness is considered for single axle loads upto 8,200 kg and random axle loads upto 14,500 kg. For higher axle loads the thickness values should be further increased. (This is improvement over earlier mentioned values of 8160 kg and 4080 kg)
9. When sub-base course materials contain substantial proportion of aggregates of size above 20 mm, the CBR value of these materials would not be valid for the design of subsequent layers above them. This layers

of wearing course such as surface dressing or open graded premixed carpet up to 2.5 cm thickness should not be counted towards the total thickness of pavement as they do not increase the structural capacity as the pavement.

4.5 Joint in rigid pavement

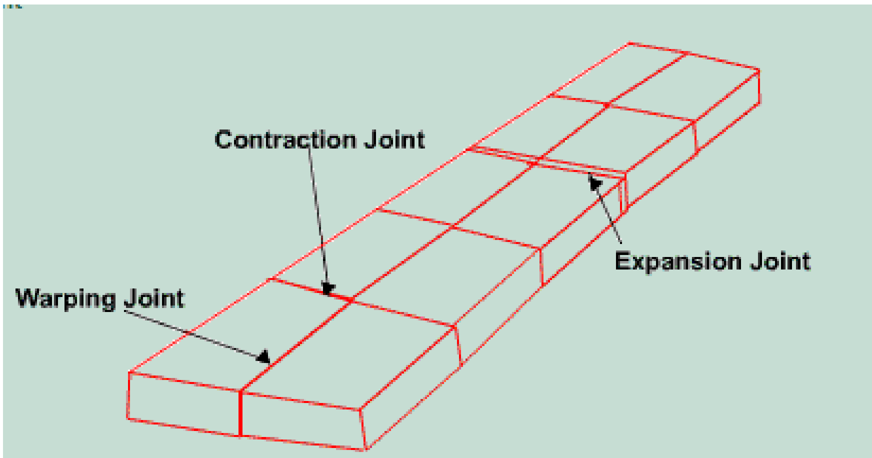


Figure: Location of joints in concrete pavement

1. Joints are the discontinuities in the concrete pavement slab, and help to release stresses due to temperature variation, subgrade moisture variation, shrinkage of concrete etc.
2. There are various types of joints in concrete pavement, e.g. contraction joint, construction joint, expansion joint and warping joint. Fig. 3 schematically shows position of various joints. The functions of these joints are as follows:

i. **Contraction joint:** Contraction joints are provided along the transverse direction to take care of the contraction of concrete slab due to its natural shrinkage.

ii. **Expansion joint:** Expansion joints are provided along the transverse direction to allow movement (expansion/ contraction) of the concrete slab due to temperature and subgrade moisture variation.

iii. **Warping joint:** Warping joints are provided along the longitudinal direction to prevent warping of the concrete slab due to temperature and subgrade moisture variation.

3. These discontinuities (joints) could be extended to the full or partial depth of the slab. Sometimes iron bars are provided across the joints,
4. The iron bars along the longitudinal joints are called **tie bars** and along the transverse joints are called **dowel bars**.

4.5.1Design of joints

[A] Expansion joints

1. The purpose of the expansion joint is to allow the expansion of the pavement due to rise in temperature with respect to construction temperature. The design consideration

- Provided along the longitudinal direction,
- design involves finding the joint spacing for a given expansion joint thickness (say 2.5 cm specified by IRC) subjected to some maximum spacing (say 140 as per IRC)

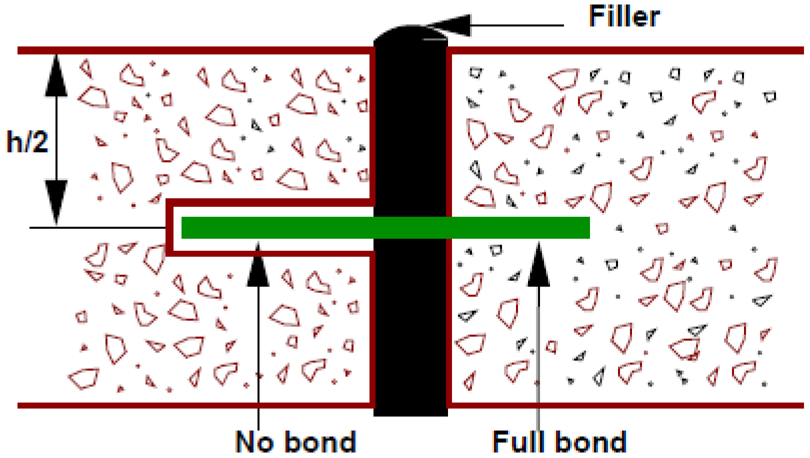


Figure: Expansion joint

[B]Contraction joints

The purpose of the contraction joint is to allow the contraction of the slab due to fall in slab temperature below the construction temperature. The design considerations are:

- The movement is restricted by the sub-grade friction
- Design involves the length of the slab given by:

$$L_c = \frac{2 \times 10^4 S_c}{W.f}$$

where,

Sc - allowable stress in tension in cement concrete ,

W- unit weight of the concrete and

f - coefficient of sub-grade friction which can be taken as 1.5.

Steel reinforcements can be use, however with a maximum spacing of 4.5 m as per IRC.

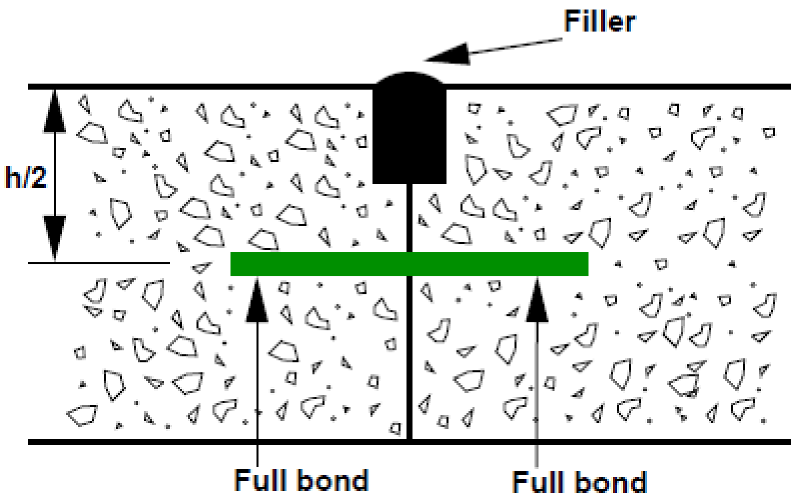


Figure : Contraction joint

Dowel bars ;-The purpose of the dowel bar is to effectively transfer the load between two concrete slabs and to keep the two slabs in same height. The dowel bars are provided in the direction of the traffic (longitudinal).

Construction Procedure of Earth roads

The construction of the earth road may be divided into the following step

[A] Materials: The soil survey is carried out and suitable borrow pits are located within the economical haulage distance. The borrow pits are usually selected outsides the land width. The trees, roots and other organic matter including top soil are removed before excavating earth for construction.

[B] Location: The centre line and earth road are marked on the ground along the alignment by driving the wooden pegs. Reference peg also also driven to help in the following vertical desire profile of the road during construction. The spacing of the reference peg depend upon the estimated length of a road construction per day.

[C] Preparation of subgrade: The various operation are involved in the preparation of subgrade are as follow

- **Clearing site:-** the site clearance may be carried out manually using appliance like hand shovel. Mechanical equipment like dozer, scraper may also be used for this purpose

- **Excavating and construction of fill to bring the road to a desire grade:-** excavation of cost and construction of fill to bring the road profile to the desire grade may also be done either manually or using excavation.

- **Shaping of subgrade:-** The subgrade should be graded to the desire camber and longitudinal profile and to the desire depth depending on the thickness of pavement construction. It is desirable to compact the subgrade before placing the pavement layer.

[D] Pavement Construction: The borrowed soil (more than one soil type mixed with to the desire proportion, if necessary) is dumped on the prepared subgrade. The field moisture content is checked and additional water is added. The soil is mixed, spread and roller in layers such that the compacted thickness of each layer does not exceed the 10 cm. the type of roller is compacter is decided based on soil type.

[E] Opening to The Traffic: The compacted earth road is allow to dry out for few days before opening to traffic.

Construction Procedure of Gravel Roads

Gravel roads are considered superior to the earth road as they carry heavier traffic

[A] Materials:- Hard variety of crushed stone or gravel is used. Softer varieties of stones may also be used.

[B] Location: The centre line and earth road are marked on the ground along the alignment by driving the wooden pegs. Reference peg also also driven to help in the following vertical desire profile of the road during construction. The spacing of the reference peg depend upon the estimated length of a road construction per day.

[C] Preparation of subgrade: Site is clear fill and cut are completed. Trench is formed to the desire depth of construction the width of the trench is made equal to that carriage way. The trench is brought to desire grade and is compacted.

[D] Pavement Construction: Crushed gravel aggregates are placed carefully in the trench so as to avoid segregation. Aggregates are spread with greater thickness at Centre and less towards the edge so as to obtained the desire camber. The layer is rolling using smooth wheeled roller starting from the edge and proceeding towards the Centre. Some quantity of water may also be sprayed and rolling is done so that the compaction is effective.

[E] Opening to the traffic: A few day after the final rolling and drying out the road is open to the traffic.

Construction Procedure of water bound macadam (WBM) Roads.

Construction of water bound macadam road involves the following 6 basic steps as given below.

1. Preparation of sub-grade
2. Preparation of sub-base
3. Preparation of base
4. Preparation of wearing course
5. Preparation of shoulders
6. Opening to traffic

STEP – 1 (CONSTRUCTION OF SUB-GRADE)

Sub-grade act as a cushion for other layers i.e. In order to achieve durable road sub-grade should be strong. Sub-grade is provided by digging up the sub-soil and the level of the sub-grade is decided by subtracting the total thickness of the pavement from the finished level of the road pavement. The sub-grade is thoroughly compacted by rollers weighing 8 tonnes by sprinkling water one night before. Low spots which develop during rolling must be made up and brought to the grades as required. In rocky regions the sub-grades are not rolled whereas in region of clay soils, a layer to natural sand, moorum or gravel, is provided over sub-grade and is duly packed.

Sub grade preparation

STEP – 2 CONSTRUCTION OF SUB-BASE

On a well compacted sub-grade, spread 10 to 20 cm size boulders or broken stones, or over burnt bricks in layers of 15 cm thickness and total width of the sub-base to be kept 60 cm wider than pavement width, projecting 30 cm on each side. The sub-base should be compacted by a roller to provide an even surface.

Roller Compaction

STEP – 3 CONSTRUCTION OF BASE

On the prepared sub-base or directly on the sub-grade, as the case may be, the specified materials of the base course is spread and proper grade, thickness and cross sections maintained as per design shown on the supplied drawings.

STEP – 4 PREPARATION OF WEARING COURSE

This course may be laid in one or two layers according to the total designed thickness and the thickness of each layer should not exceed 10 cm. this component being very important, the following steps may be taken systematically.

1. Check the defective portions/patches of the newly laid base course i.e. soling and rectify them
2. Provide either bricks on end edging or earthen kerbs strong enough to prevent the new road material from spreading outward and also to retain water used in consolidation of the wearing course.
3. Spread the road metal evenly over the prepared base to the specified thickness and hand pack them so that the finished surface is brought to the required camber.
4. Spread the coarse aggregate over the surface and roll it dry with a suitable roller till interlocking of the aggregate is achieved with sufficient void space. The rolling is started from the edges and gradually shifted towards the centre.
5. After dry rolling, spread the screening materials (stones upto 12 mm size) with uniform rate so that voids of coarse aggregates get filled properly. This is achieved by dry rolling. till the voids of the coarse aggregates are filled.
6. After spreading the screening material, sprinkle sufficient quantity of water, sweep the surface and roll it with roller again.
7. Now apply the binding material in two to three thick layers at a slow and uniform rate. Each layer of binding material is rolled after adding sufficient water. The slurry is swept in with brooms to fill the void properly. The moving wheel of the roller should be cleaned with water. Continue the operations of spreading of binder, sprinkling of water, sweeping with brooms and rolling till the voids get filled and slurry forms a wave before the moving wheel of the roller.
8. After proper compacting allow it to dry over night. Spread a layer of sand or earth, about 6 mm thick and roll the surface again after sprinkling water lightly.
9. The surface may be allowed for 7 to 10 days of curing.

Spreading binder material

STEP – 5 CONSTRUCTION OF SHOULDERS

While curing the pavement surface, prepare the shoulders by filling earth to the specified cross slope and compact them properly by rolling or by tamping. Width and thickness of the shoulder should be as per specification.

Construction of shoulders

STEP – 6 OPENING TO TRAFFIC

After properly drying, the road pavement may now be opened to traffic, ensuring that the traffic is distributed uniformly over the full width of the pavement.

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Construction Procedure of Wet Mix Macadam Roads. (WMM)

Wet mix macadam :- it is road mix materials consisting of crushed rocked or slag usually mixed with control amount of water sufficient for adequate compaction.

Construction step

- Preparation of mix
- Spreading of mix
- Compaction by vibratory roller for 200 mm and static roller for 25 mm.
- Setting and drying

a. Aggregate used are smaller size, varies between the 4.75 to 20 mm sizes and binder are mixed with mixing machine or batching plant.

b. Then they are brought to the site for overlaying and compaction.

c. The plasticity index of the binding material is kept low because it should be a sound and non plastic material.
d. If the plasticity index are more then there are the chances of the swelling and more water retention properties.

Flexible pavement failures

Flexible pavement consist of different layers such as,

- Sub-grade
- Sub-base course
- Base course and
- Surface course

If any one of the above mentioned layers becomes unstable or weak then it will result in failure of flexible pavement. Therefore it is very important to design and construct each layer with utmost care.

Different types of failure encountered in flexible pavements are as follow.

1. Alligator cracking or Map cracking (Fatigue)
2. Consolidation of pavement layers (Rutting)
3. Shear failure cracking
4. Longitudinal cracking
5. Frost heaving
6. Lack of binding to the lower course
7. Reflection cracking
8. Bleeding

1. ALLIGATOR OR MAP CRACKING (FATIGUE CRACKING)

This is a common type of failure of flexible pavements. This is also known as fatigue failure.

Followings are the primary causes of this type of failure.

- Relative movement of pavement layer material
- Repeated application of heavy wheel loads
- Swelling or shrinkage of subgrade or other layers due to moisture variation

2. CONSOLIDATION OF PAVEMENT LAYERS (RUTTING)

Formation of ruts falls in this type of failure. A rut is a depression or groove worn into a road by the travel of wheels.

This type of failure is caused due to following reasons.

- Repeated application of load along the same wheel path resulting ***longitudinal ruts***.
- Wearing of the surface course along the wheel path resulting ***shallow ruts***.

3. SHEAR FAILURE CRACKING

Shear failure causes upheaval of pavement material by forming a fracture or cracking.

Followings are the primary causes of shear failure cracking.

- Excessive wheel loading
- Low shearing resistance of pavement mixture

4. LONGITUDINAL CRACKING

This types of cracks extents to the full thickness of pavement.

The following are the primary causes of longitudinal cracking.

- Differential volume changes in subgrade soil
- Settlement of fill materials
- Sliding of side slopes

5. FROST HEAVING

Frost heaving causes upheaval of localized portion of a pavement. The extent of frost heaving depends upon the ground water table and climatic condition.

6. LACK OF BINDING WITH LOWER LAYER (POTHOLES & SLIPPAGE)

When there is lack of binding between surface course and underlying layer, some portion of surface course looses up materials creating patches and potholes. Slippage cracking is one form of this type of failure.

Lack of prime coat or tack coat in between two layers is the primary reason behind this type of failure.

7. REFLECTION CRACKING

This type of failure occurs, when bituminous surface course is laid over the existing cement concrete pavement with some cracks. This crack is reflected in the same pattern on bituminous surface.

9. BLEEDING

Excess bituminous binder occurring on the pavement surface causes bleeding. Bleeding causes a shiny, glass-like, reflective surface that may be tacky to the touch. Usually found in the wheel paths.

Rigid Pavement Failure

Following are the basic types of failure in rigid pavement are as follow:

1. Scaling of cement concrete
2. Shrinkage cracks
3. Spalling of joints
4. Warping cracks
5. Mud pumping
6. Structural cracks

1. Scaling of cement concrete

Scaling is observed in cement concrete pavement showing overall deterioration of the concrete. The scaling is mainly attributed due to the deficiency in the mix or presence of some chemical impurities which damage the mix. Further due to excess vibration given to mix, the cement mortar comes to the top during the construction and with use the cement mortar get abraded exposing the aggregate of the mix

2. Shrinkage cracks

During the curing operation of cement concrete pavement immediately of the construction, the shrinkage cracks normally develop. The placement of cracks are in longitudinal and transverse direction

3. Spalling of Joint

Sometimes pre- formed filler materials are placed during casting of pavement slabs, the pavement is some how dislocated and filler is placed at an angle. The concrete is completed without noticing this faulty alignment of the filler materials. The top side of the concrete layer and joint shows excessive cracking and subsidence.

4. Warping cracks

If the joint are not well design to accommodates the warping of the slab at the edges, this result in development of excessive stresses due to warping and slab develop the cracking at the edges in an irregular patterns. hinge joint are generally provided for relieving the slab of warping stresses.

5. Mud pumping

Mud pumping is recognized when soil slurry ejects out the joint and cracks on cement concrete pavement caused during the downward movement of the slab under the heavy wheel load. Following are the factor which causes the mud pumping

- Extend of slab deflection
- Types of subgrade soil
- Amount of free water