UNIT -8: CEMENT CONCRETE PAVEMENTS
Specifications and method of cement concrete pavement construction (PQC Importance of providing DLC as sub-base and polythene thin layer between PQC and sub-base); Quality control tests; Construction of various types of joints. 8 Hours

The rigid characteristic of the pavement are associated with rigidity or flexural strength or slab action so the load is distributed over a wide area of subgrade soil. Rigid pavement is laid in slabs with steel reinforcement.

1. The rigid pavements are made of cement concrete either plan, reinforced or prestressed concrete.

2. Critical condition of stress in the rigid pavement is the maximum flexural stress occurring in the slab due to wheel load and the temperature changes.

3. Rigid pavement is designed and analyzed by using the elastic theory.

Advantages of Rigid Pavement

1. Rigid lasts much, much longer i.e 30+ years compared to 5-10 years of flexible pavements.
2. In the long run it is about half the cost to install and maintain. But the initial costs are somewhat high.
3. Rigid pavement has the ability to bridge small imperfections in the subgrade.
5. High efficiency in terms of functionality
## Comparison of Flexible and Rigid Pavement

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

Rigid pavements normally use Portland cement concrete as the prime structural element. Depending on conditions, engineers may design the pavement slab with plain, lightly reinforced, continuously reinforced, prestressed, or fibrous concrete. The concrete slab usually lies on a compacted granular or treated subbase, which is supported, in turn, by a compacted subgrade. The subbase provides uniform stable support and may provide subsurface drainage. The concrete slab has considerable flexural strength and spreads the applied loads over a large area. Figure 1 illustrates a typical rigid pavement structure. Rigid pavements have a high degree of rigidity. Figure 2 show how this rigidity and the resulting beam action enable rigid pavements to distribute loads over large areas of the subgrade. Better pavement performance requires that support for the concrete slab be uniform. Rigid pavement strength is most economically built into the concrete slab itself with optimum use of low-cost materials under the slab.

Fig 1: Typical rigid pavement structure
a) **Concrete Slab (Surface Layer).** The concrete slab provides structural support to the aircraft, provides a skid-resistant surface, and prevents the infiltration of excess surface water into the subbase.

b) **Subbase.** The subbase provides uniform stable support for the pavement slab. The subbase also serves to control frost action, provide subsurface drainage, control swelling of subgrade soils, provide a stable construction platform for rigid pavement construction, and prevent mud pumping of fine-grained soils. Rigid pavements generally require a minimum subbase thickness of 4 inches (100 mm).
c) **Stabilized Subbase.** All new rigid pavements designed to accommodate aircraft weighing 100,000 pounds (45,000 kg) or more must have a stabilized subbase. The structural benefit imparted to a pavement section by a stabilized subbase is reflected in the modulus of subgrade reaction assigned to the foundation.

d) **Frost Protection Layer.** In areas where freezing temperatures occur and where frost-susceptible soil with a high ground water table exists, engineers must consider frost action when designing pavements. Frost action includes both frost heave and loss of subgrade support during the frost-melt period. Frost heave may cause a portion of the pavement to rise because of the nonuniform formation of ice crystals in a frost-susceptible material (see Figure 3). Thawing of the frozen soil and ice crystals may cause pavement damage under loads. The frost protection layer functions as a barrier against frost action and frost penetration into the lower frost-susceptible layers.

![Fig 3: Formation of ice crystals in frost-susceptible soil](image)

e) **Subgrade.** The subgrade is the compacted soil layer that forms the foundation of the pavement system. Subgrade soils are subjected to lower stresses than the surface and subbase courses. These stresses decrease with depth, and the controlling subgrade stress is usually at the top of the subgrade unless unusual conditions exist. Unusual conditions, such as a layered subgrade or sharply varying water content or densities, may change the locations of the controlling stress. The soils investigation should check for these conditions. The pavement above
the subgrade must be capable of reducing stresses imposed on the subgrade to values that are low enough to prevent excessive distortion or displacement of the subgrade soil layer.

Since subgrade soils vary considerably, the interrelationship of texture, density, moisture content, and strength of subgrade material is complex. The ability of a particular soil to resist shear and deformation will vary with its density and moisture content. In this regard, the soil profile of the subgrade requires careful examination. The soil profile is the vertical arrangement of layers of soils, each of which may possess different properties and conditions.

Soil conditions are related to the ground water level, presence of water-bearing strata, and the properties of the soil, including soil density, particle size, moisture content, and frost penetration. Since the subgrade soil supports the pavement and the loads imposed on the pavement surface, it is critical to examine soil conditions to determine their effect on grading and paving operations and the need for underdrains.

**JOINTS IN RIGID PAVEMENT**

Provisions of joints are necessitated due to:

1) Expansion, contraction and warping of concrete slabs resulting from temperature and moisture changes;

2) Facilitate a break in the construction at the end of day’s work or for any unexpected interruption to work progress; and

3) Construction of pavements in lanes of convenient width.

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.

There are various types of joints in concrete pavement, e.g. contraction joint, construction joint, expansion joint and warping joint. The functions of these joints are as follows:
Contraction joint: Contraction joints are provided along the transverse direction to take care of the contraction of concrete slab due to its natural shrinkage.

Construction joint: Construction joints are provided whenever the construction work stops temporarily. The joint direction could be either along the transverse or longitudinal direction.

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.

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

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**Quality Requirements for Joint Construction**

1) All foreign material in the joints should be removed first. The manual cleaning of the joints is done with a raker followed by coir brushing. The fine particles are removed with the help of air compressor. After the joints have been cleaned, primer is used.
The primer has very low viscosity and penetrates in the pores of the concrete. This is followed by joint filler and finally sealing compound is used. The primer used earlier helps to improve bond between sealing compound and concrete.

2) The joints should be sealed flush with the adjacent pavement surface on either side in summer and should be filled to a depth of 3-4 mm below the surface in winter so that they may become flush on expanding during hot weather.

3) Dowel bars are required for the transverse joints to

- Transfer part load across the adjacent slab
- Stresses becoming critical
- Assist in the event of loss of sub grade support at the location of joint

4) Dowel bars are generally mild steel round bars embedded and bonded into concrete on one side of the joint and the other half length deliberately prevented from bonding with concrete on that side. A recess is provided at the sliding end for free movement of slab when used in the expansion joints.

5) The dowel bar should be supported on cradles/dowel chairs in pre-fabricated joint assemblies positioned prior to the construction of the slabs or mechanically inserted with vibration into the plastic concrete by method which ensures correct placement of the bars besides full re-compaction of the concrete around the dowel bars.

6) Dowel bars should be positioned at mid depth of the slab, and centered equally about intended lines of the joint. They should be aligned parallel to the finished surface of the slab and to the center line of the carriageway and to each other.

7) Dowel bars should be covered by a thin plastic sheath for at least two-thirds of the length from one end for dowel bars in contraction joints or half the length plus 50 mm for expansion joints. The sheath shall be tough, durable and of and average thickness not greater than 1.25 mm. The sheathed bar shall comply with the specified pullout tests.
Expansion Joints

8) For expansion joints, a closely fitting cap 100 mm long consisting of waterproofed cardboard or an approved synthetic material, like, PVC or GI pipe should be placed over the sheathed end of each dowel bar. An expansion space at least equal in length to the thickness of the joint filler board should be formed between the end of the cap and the end of the dowel bar by using compressible sponge to block the entry of cement slurry between dowel and cap. It may be taped.

9) Tie bars are provided to prevent adjacent slabs from separating, particularly on curves or at fills. The tie bars are not meant to add structural capacity of the slabs and are designed to withstand only tensile stresses.

10) Tie bars in longitudinal joints should be deformed steel bars of strength 415 Mpa complying with IS: 1786.
11) Tie bars projecting across the longitudinal joint shall be protected from corrosion for 75 mm on each side of the joint by a protective coating of bituminous paint.

12) Tie bars in longitudinal joints shall be made up into rigid assemblies with adequate supports and fixings to remain firmly in position during the construction of the slab. Alternatively, tie bars at longitudinal joints may be mechanically or manually inserted into the plastic concrete from above by vibration using a method which ensures correct placement of the bars and re-compaction of the concrete around the tie bars.

13) Tie bars shall be positioned to remain within the middle third of the slab depth approximately parallel to the surface and perpendicular to the line of joint with a minimum cover of 30 mm below the joint groove.

**Specification of Materials**

For concrete slabs cement, coarse aggregates, fine aggregates and water are required. If reinforcement is provided, steel wire fabric are used & for construction of joints, joint filler & sealer are used.

1. **Cement** – Ordinary Portland cement is used. In case of urgency rapid hardening cement is used.

2. **Coarse Aggregates** – The max size should not exceed 1/4th slab thickness. The gradation may range from 50 – 4.75 or 40 – 4.75. The aggregates should be free from iron, purities, cola, mica, clay, alkali, etc., For Physical properties desire limits are –
   a) Aggregate Crushing Value : 30% Max
   b) Aggregate Impact Value : 30% Max
   c) Los Angeles abrasion Value : 30% Max
   d) Soundness for sodium sulphate : 12% Max

3. **Fine aggregates** – Natural sands, crushed stones etc., are used.

4. **Proportioning of Concrete** – It is proportioned so as to obtain a minimum modulus of rupture of 40Kg/cm² on field or to develop minimum compressive strength of 280 Kg/cm² at 28 days.
Construction method

a) Preparation of subgrade and sub base –
1. No soft pots are present in subgrade or sub base.
2. It should extent at least 30cm on either side of width to be connected.
3. Subgrade is properly drained; minimum modulus of subgrade reaction is $5.54 \text{Kg/Cm}^2$.
4. The layers should be kept moist when cement concrete is placed.
5. Water proof paper may also be used when CC is laid directly.

b) Placing of Forms –
1. The steel or wooden forms are used.
2. The steel forms are M.S. Channel sections and their depts. Is equal to thickness of pavement and length atleast 3m except on curves $< 45\text{m radius}$.
3. Wooden forms are dressed on side, these have minimum base width of 100n for slab thickness or 20cm.
4. The forms are jointed neatly and are set with exactness to the required grade and alignment.

c) Batching of Material & Mixing –
1. The proportioned mixture is placed into holper in weigh batching plant.
2. All batching of material is done on the basis of one or more whole bags of cement, wt of one bag is 50 kg or unit wt of cement is taken as $1440\text{Kg/m}^3$.
3. The mixing of concrete is done in batch mixer. So that uniform distribution, uniform is color and homogenous mix is obtained.
4. The batch of cement, fine aggregate and coarse aggregate is led together into the mixer. Water for mixing is introduced into the drum within fifteen seconds of mixing.

d) Transportation & Placing of Concrete –
1. The cement concrete is mixed in quantities required for immediate use.
2. It should be seen that no segregation of materials results while transporting.
3. Spreading is done uniformly; certain amount of redistribution is done with shovels.
e) Compaction & Finishing –
1. The surface of pavement is compacted either by means of power driven finishing machine or by vibrating hand screed.
2. Areas where width of slab is small, hand consolidation and finishing is adopted.
3. The concrete is further compacted by longitudinal float. It is help parallel to carriage way and passed gradually from one site to other.
4. The slab surface is tested for its grade and level with straight edge.
5. Just before the concrete becomes hard, the surface is belted with two ply canvas belt.
6. Broom finish is given with fibre broom brush and it is done perpendicular to centerline of pavement.
7. Before concrete develop initial set, the edges of slab are carefully finished with an edging tool.

f) Curing of cement concrete –
1. Initial curing – The surface of pavement is entirely covered with burlap cotton or jute mats prior to placing it is saturated with water and wet side is placed on pavement.
2. Final curing – Curing with wet soil exposed edges of slabs are banked with soil berm. A blanket of sandy soil free from stones is placed. The soils is thoroughly kept saturated with water for 14 days.

In impervious membrane method, use of impervious membrane which does not impart a slippery surface to the pavement is used. Liquid is applied under pressure with a spray nozzle to cover the entire surface with a uniform film. It hardness within 30 minutes after its application. The liquid applied immediately after surface finishing. When the concrete attains the required strength or after 28 days of curing the concrete road is opened to traffic.
Quality Control Tests:

A) Quality control tests for materials used –

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<tr>
<td>1</td>
<td>Cement</td>
<td>Physical &amp; Chemical Tests</td>
</tr>
<tr>
<td></td>
<td></td>
<td>One for each source of supply and occasionally</td>
</tr>
<tr>
<td>2</td>
<td>Coarse aggregates &amp; fine aggregates</td>
<td>(i) Gradation (ii) Deleterious constituents</td>
</tr>
<tr>
<td></td>
<td></td>
<td>One test for every day work of each fraction of coarse aggregate and fine aggregate.</td>
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B) Quality control tests for levels, alignment and texture –

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<tbody>
<tr>
<td>1</td>
<td>Level Tolerance</td>
<td>+5mm</td>
</tr>
<tr>
<td>2</td>
<td>Width of pavement &amp; position of paving edges</td>
<td>-6mm +10mm</td>
</tr>
<tr>
<td>3</td>
<td>Alignment of joints, widths, depths of dowel grooves</td>
<td>To be checked @ one joint per 400m length</td>
</tr>
<tr>
<td>4</td>
<td>Surface regularity both transversely</td>
<td>Once a day or one day’s work</td>
</tr>
<tr>
<td>5</td>
<td>Alignment of dowel bars and tie bars</td>
<td>To be checked in trail length.</td>
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</tbody>
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Difference between Tie bars and Dowel bars in concrete carriageway:

Tie bars are deformed rebars or connectors used for holding faces of rigid slabs in contact to maintain aggregate interlock. Tie bars are not load transferring device. For instance, tie bars are used in longitudinal joints in concrete pavement.

Dowel bars are smooth round bars which mainly serve as load transfer device across concrete joints. They are placed across transverse joints of concrete pavement to allow movement to take place. Where movement is purposely designed for longitudinal joints, dowel bars can be adopted.
1. Mention the specifications and method of cement concrete pavement construction.
2. Compare flexible and rigid pavements.
3. List the quality checks on cement concrete pavement, carried out both laboratory and on the field.
4. Explain the various types of joints used in cement concrete road. Why are they provided?
5. Explain the necessity of providing i) Explain joint ii) Longitudinal joint.

**TEXT BOOKS:**


**REFERENCES BOOKS:**

2. RRL, DSIR, ‘Soil Mechanics for Road Engineers’, HMSO Publication.
3. Relevant IRC codes and MoRT & H specifications.