Highway construction
Contents

- Equipments used in Highway Construction
- Construction of
  - Earth Roads
  - Gravel Roads
  - Water Bound Macadam Roads
  - Bituminous Pavements
  - Cement Concrete Pavements
Equipment used in highway construction

- Earth moving equipment
- Aggregate spreader
- Rollers
- Road brooms
- Sprayers or binder distributors
- Paver finisher
Earth moving equipment

- *Tractor* or *crawler* is the basic equipment used for earth moving activities, to which *various attachments* may be fixed for specific purposes.

**Bulldozer:**

- Movable steel blade is attached to the front of a tractor
- Used for clearing the way along the construction line and also for moving earth
Earth moving equipment

**Loader**: bucket is used for picking up, transporting, and depositing soil.
Aggregate spreaders

- Truck – mounted spreaders
Rollers

- Preferred for compacting all types of soils except for rocky soils
- Disadvantage:
  - Sometimes compaction not satisfactory due to large contact area – low pressure
  - Weaker aggregates crushes

- Preferred for compacting coarse grained soils
- Depending upon the type of material pneumatic-tyred roller compact faster and with fewer passes than a smooth wheeled roller
Rollers

- **Sheepfoot rollers**: Protrusions on its drum which penetrate into the soft soil and compact it by kneading and tamping.

- **Vibratory rollers**: Vibratory motion (1 or 2 mm) along the vertical direction is induced along with the rolling operation. Preferable for granular materials for better compaction due to vibratory effect.
Paver finisher
Types of highway construction

- Earth road and gravel roads
- Water bound macadam roads (WBM)
- Bituminous or black top roads
- Cement concrete roads or white top roads
Earth roads

Construction of earth roads:

- Cheapest type
- Soil available at site and near-by borrow pits
- Steep camber between 1 in 20 to 1 in 33

Specifications

<table>
<thead>
<tr>
<th></th>
<th>Base course</th>
<th>Wearing courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay content</td>
<td>&lt; 5 percent</td>
<td>10 – 18 percent</td>
</tr>
<tr>
<td>Silt content</td>
<td>9-32 percent</td>
<td>5 -15 percent</td>
</tr>
<tr>
<td>Sand content</td>
<td>60 – 80 percent</td>
<td>65 – 80 percent</td>
</tr>
<tr>
<td>Liquid limit</td>
<td>&lt; 35 percent</td>
<td>&lt; 35 percent</td>
</tr>
<tr>
<td>Plasticity index</td>
<td>&lt; 6 percent</td>
<td>40 to 10 percent</td>
</tr>
</tbody>
</table>
Earth road – Construction procedure

- Material
- Location
- Preparation of subgrade
- Pavement construction
- Opening to traffic
Earth road – Construction procedure

- **Material**
  - Soil survey is carried out and suitable *borrow pits* are located within economic haulage distances.

- **Location**
  - The *centre lines and road edges* are marked on the ground along the alignment, by driving wooden pegs.

- **Preparation of subgrade**
  - Clearing site
  - Excavation and construction of fills to bring the road to the *desired grades*
  - Shaping of subgrade
Earth road – Construction procedure

- Pavement construction:
  - Bringing moisture content to OMC and rolling by selecting suitable roller based on soil type.

- Opening to traffic:
  - Allowed to dry out for few days before opening to traffic.
Gravel roads

- Superior to earth roads
- Camber may be between 1 in 25 and 1 in 30
- Can cater about 100 T of pneumatic tyred vehicle or 60 T of iron tyred vehicles per day per lane

- Types:
  - Feather edge type
  - Trench type
TRENCH TYPE

FEATHER EDGE TYPE
Gravel roads - Construction

- Material
- Location
- Preparation of subgrade
- Pavement construction
- Opening to traffic
WBM Roads

- Pavement base course made of *crushed or broken aggregate* mechanically interlocked by rolling and *the voids filled with screening and binding material* with the assistance of *water*.

- May be used as a sub-base, base course or surfacing course.

- Thickness ranges from 10.0 cm to 7.5 cm depending on the size and gradation of the aggregates used.

- To prolong life, bituminous surfacing course will be laid over the WBM layer.
Specifications - Material

- Coarse aggregates:

<table>
<thead>
<tr>
<th>Property</th>
<th>Requirements for pavement layer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sub-base</td>
</tr>
<tr>
<td>(i) Los Angeles abrasion value</td>
<td>60</td>
</tr>
<tr>
<td>(maximum value, percent)</td>
<td></td>
</tr>
<tr>
<td>(ii) Aggregate impact value</td>
<td>50</td>
</tr>
<tr>
<td>(maximum value, percent)</td>
<td></td>
</tr>
<tr>
<td>(iii) Flakiness index</td>
<td>-</td>
</tr>
<tr>
<td>(maximum value, percent)</td>
<td></td>
</tr>
</tbody>
</table>
Specifications - Material

- Size and grading requirements of coarse aggregates:

<table>
<thead>
<tr>
<th>Grading No.</th>
<th>Size range, mm</th>
<th>Sieve size, mm</th>
<th>Percent passing the sieve, by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>90 to 40</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td></td>
<td>65 – 85</td>
</tr>
<tr>
<td></td>
<td>63</td>
<td></td>
<td>25 – 60</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td></td>
<td>0 – 15</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td></td>
<td>0 – 5</td>
</tr>
<tr>
<td>2</td>
<td>63 to 40</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>63</td>
<td></td>
<td>90 – 100</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td></td>
<td>30 – 70</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td></td>
<td>0 – 15</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td></td>
<td>0 – 5</td>
</tr>
<tr>
<td>3</td>
<td>50 to 20</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>63</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td></td>
<td>95 – 100</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td></td>
<td>35 – 70</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td></td>
<td>0 – 10</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td></td>
<td>0 – 5</td>
</tr>
</tbody>
</table>
**Screenings**: Aggregates of smaller size generally of the same material as the coarse aggregates.

<table>
<thead>
<tr>
<th>Classification grading</th>
<th>Size of screenings (mm)</th>
<th>Sieve size, (mm)</th>
<th>Percent passing the sieve, by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>12.5</td>
<td>12.5</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.0</td>
<td>90 – 100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.75</td>
<td>10 – 30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15</td>
<td>0 – 8</td>
</tr>
<tr>
<td>B</td>
<td>10.0</td>
<td>10.0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.75</td>
<td>85 – 100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15</td>
<td>10 – 30</td>
</tr>
</tbody>
</table>
Binding Material

- Fine grained material is used
- Kankar nodules or lime stone dust may also be used if locally available
- If surface course the P.I should be from 4 – 9 percent
- If base or subbase course the P.I should be less than 6 percent
Construction procedure

a. Preparation of foundation for receiving the WBM course
b. Provision of lateral confinement
c. Spreading of coarse aggregates
d. Rolling
e. Applications of screenings
f. Sprinkling and grouting
g. Application of binding material
h. Setting and drying
Bituminous pavements

- Commonly used in developing countries like India
- Commonly adopted as wearing course
- Stage wise construction is possible
- Excessive binder content over the optimum value for a given mix is detrimental
- Control of proper viscosity is essential
Types of bituminous construction

1. **Interface treatments** like prime coat and tack coat
2. **Surface dressing** and seal coat
3. **Grouted** or penetration type constructions:
   - Penetration Macadam
   - Built – up Spray grout
4. **Premix methods**
   - Bituminous bound macadam
   - Carpet
   - Bituminous concrete
   - Sheet asphalt or rolled asphalt
   - Mastic asphalt
Types of bituminous construction

Based on Construction techniques:

- **Hot mix**: Bitumen or Tar
- **Cold mix**: Cut back bitumen or bitumen emulsion

Based on the gradation, the premix constructions are classified

- Open graded
- Dense graded
Interface treatments

- Laying a thin layer of bituminous binder over the existing pavement layer is called interface treatment.
- Is necessary to provide the necessary bond between the old and new layers.

Types:

1. **Prime coat**:
   - Is the first application of Low viscosity liquid bituminous material over an existing porous surface like the WBM base course.
   - Object is to plug in the capillary voids of the porous surface.
2. **Tack coat**: High viscosity liquid bituminous material over an existing pavement surface which is relatively impervious like an existing bituminous surface or a cement concrete pavement or a pervious surface like the WBM *which has been already been treated by a prime coat*
Bituminous Surface dressing

- Is provided over an existing pavement to serve as thin wearing coat.
- **Single coat** surface dressing: Single application of bituminous binder
- **Two coat** bituminous surface dressing
- Bituminous surface dressing with pre-coated aggregates if better adhesion required
Bituminous Surface dressing

Seal Coat :

- Generally seal coat is premixed sand bitumen.
- The seal coat is a very thin surface treatment or a single coat surface dressing which is applied over an existing black top surface which is worn out.
- Usually recommended as a top coat over certain bituminous pavements which are not impervious, such as open graded bituminous constructions like premixed carpet and grouted Macadam.
Specifications:
Work is to be done only in dry and clear weather when the atmospheric temp is above 16 degree C.
Bitumen grades between 80/100 and 180/200 are frequently used.
Tar or cut back may also be used.

### Binder Quantity for Surface Dressing

<table>
<thead>
<tr>
<th>Base course Type</th>
<th>Binder requirement kg per 10 m² area</th>
<th>First or Single coat</th>
<th>Second coat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bitumen</td>
<td>Tar</td>
<td>Cutback</td>
</tr>
<tr>
<td>(i) WBM</td>
<td>17 to 19.5</td>
<td>17 to 22</td>
<td>19 to 22</td>
</tr>
<tr>
<td>(ii) Renewal of black top to surfacing</td>
<td>10 to 12</td>
<td>10 to 17</td>
<td>10 to 12</td>
</tr>
</tbody>
</table>

### Aggregate type should conform to the following requirements:
- Los Angeles abrasion value: 35 percent max.
- Aggregate impact value: 30 percent max.
- Flakiness index: 25 percent max.
- Water absorption: 1 percent max.
- Stripping at 40°C after 24 hours immersion (CRRI test): 25 percent max.

The recommended size of chippings and quality required are given below:

<table>
<thead>
<tr>
<th>Sieve size, mm</th>
<th>Quantity in m³ for 10 m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Passing</td>
</tr>
<tr>
<td>First coat, 12 mm thick</td>
<td>18</td>
</tr>
<tr>
<td>Second coat or renewal coat, 9 mm thick</td>
<td>12</td>
</tr>
</tbody>
</table>
Bituminous Surface dressing

Construction steps:

- Preparation of the existing surface
- Application of the binder
- Application of the stone chippings
- Rolling of first or final coat
- Application of binder and stone chippings for second coat
- Rolling of second coat
- Finishing and opening to traffic
Grouted or penetration type constructions

a. Penetration Macadam:

- Used as base or binder course
- Hot bituminous binder of relatively high viscosity is sprayed

Depending upon quantity of bitumen spread:

a. Full grout: in case of heavy rain fall
b. Semi-grout: in case of moderate rain fall
Specifications of Materials

IRC recommends to use any grade of bitumen from 80/100, 60/70 and 30/40. Tars, RT-4 and RT-5 could also be used. The quantity of bitumen required depends on the desired degree of penetration of binder into the compacted aggregate layer.

The physical requirements of stone aggregates are specified by the following values:

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Angeles abrasion value</td>
<td>40 percent max.</td>
</tr>
<tr>
<td>Aggregate impact value</td>
<td>30 percent max.</td>
</tr>
<tr>
<td>Flakiness index</td>
<td>25 percent max.</td>
</tr>
<tr>
<td>Stripping at 40°C after 24 hours immersion (CRRI test)</td>
<td>25 percent max.</td>
</tr>
<tr>
<td>Loss with sodium sulphate, 5 cycles</td>
<td>12 percent max.</td>
</tr>
</tbody>
</table>
### Gradings of Coarse Aggregates for Penetration macadam

<table>
<thead>
<tr>
<th>Percent passing sieve size, mm</th>
<th>Compacted thickness, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>-</td>
</tr>
<tr>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>38</td>
<td>-</td>
</tr>
<tr>
<td>25</td>
<td>35-70</td>
</tr>
<tr>
<td>19</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>0-15</td>
</tr>
<tr>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>4.75</td>
<td>-</td>
</tr>
<tr>
<td>2.36</td>
<td>0-5</td>
</tr>
</tbody>
</table>

### Table 8.3 Key Aggregates for Penetration Macadam

<table>
<thead>
<tr>
<th>Percent passing sieve size, mm</th>
<th>Compacted thickness, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>-</td>
</tr>
<tr>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>19</td>
<td>100</td>
</tr>
<tr>
<td>12</td>
<td>35-70</td>
</tr>
<tr>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>4.75</td>
<td>0-15</td>
</tr>
<tr>
<td>2.36</td>
<td>0-15</td>
</tr>
</tbody>
</table>

The coarse aggregates required for 50 mm compacted thickness is 0.06 m$^2$ per 10 m$^3$ area and for 75 mm compacted thickness is 0.90 m$^3$ per 10 m$^3$.

The quantity of key aggregates required for 50 and 75 mm compacted thickness are 0.15 and 0.18 m$^3$ per 10 m$^3$ area.
Grouted or penetration type constructions

Construction steps:

a) Preparation of existing surface
b) Spreading the coarse aggregates
c) Rolling
d) Bitumen application
e) Spreading of key aggregates
f) Seal coat
g) Finishing
h) Opening to traffic
Built-up spray grout

- Consists of two layer composite construction of compacted crushed aggregates with application of bituminous binder after each layer for bonding and finished with key aggregates at the top
- Total compacted thickness is 75 mm
- For strengthening of existing bituminous pavements

Specifications of materials:

- Bitumen grades 80/100 to 30/40 or road tar RT-4 and RT -5 may be used as binder
- Other specifications are almost similar to the penetration macadam
Built-up spray grout

Construction steps:

a) Preparation of the existing base
b) Tack coat
c) Spreading first layer
d) Rolling
e) Application of binder
f) Spreading of second layer of coarse aggregates
g) Rolling
h) Second application of binder
i) Application of key aggregates
j) Surface finish
k) Opening to traffic
Premix methods

- The aggregates and the bituminous binder are mixed thoroughly before spreading and compacting.
  
- Each particle of aggregate is coated with binder.

Classification:
- Open graded
- Semi dense mixes
- Dense mixes
Premix methods

- Bituminous Macadam (BM)
- Bituminous concrete (BC)
- Bituminous premixed carpet
- Sheet asphalt
- Mastic asphalt
Cement concrete pavement construction
Construction of cement concrete pavements

1. Construction of pavement slabs
2. Construction of joints
Construction of pavement slabs
Construction of pavement slabs

a. Cement grouted layer
b. Rolled concrete layer

c. Cement concrete slab

Base / Sub base
Cement grouted layer

- Open graded aggregate mix with minimum size of aggregates as 18 to 25 mm is rolled
- Grout made of coarse sand, cement and water is prepared
- The proportion of cement to sand is taken as 1:1½ to 1:2½
- Grout is applied on the surface and is allowed to seep through the aggregate matrix.
Rolled concrete layer

- Lean mix of aggregate, sand, cement and water is prepared and laid on the prepared subgrade or subbase course
- Rolling
- Curing
Cement concrete slab

a. Alternative bay method
b. Continuous bay method
Cement concrete slab - Specifications

**Cement**: ordinary Portland cement

**Coarse aggregate**: Max size of coarse aggregate should not exceed ¼ of the slab thickness

Desirable limits:

Aggregate impact value: 30 percent max

Losangeles abrasion value: 30 percent max

**Fine aggregate**: Natural sands

**Proportion of concrete**:

Minimum modulus of rupture 40 kg / Sq cm after 28 days curing

Minimum compressive strength 280 kg / Sq cm after 28 days curing
Plants and Equipment

- Concrete mixer
- Batching device
- Wheel borrow
- Vibrating screed
- Internal vibrators
- Float
- Straight edge
- Belt
- Fibre brush
- Edging tool
- Other small tools
Plants and Equipment

- **Wheel borrow:**
  - wheel borrow with two wheels are used to transport concrete for short distances from the mixer

- **Vibrating screed:**

- **Internal vibrators:**
  - To ensure compaction and to avoid any tendency of honey-combing at the edges of the slab

- **Float:** For smoothing the concrete

- **Straight edge:** To check finished pavement surface in longitudinal direction
Plants and Equipment

- **Belt**
  - Canvas belts are used for finishing the pavement surface before the concrete hardens.

- **Fibre Brush**
  - Used to make broom marks across the pavement surface and to make it skid resistance.

- **Edging tool**
  - Used for rounding the transverse edges at expansion joints and the longitudinal joints.
Construction steps

I. Preparation of subgrade and subbase
II. Placing of forms
III. Batching of material and mixing
IV. Transporting and placing of concrete
V. Compaction and finishing
VI. Floating and straight edging
VII. Belting, brooming and edging
VIII. Curing of cement concrete
Compaction and finishing

- The surface of pavement is compacted either by means of a power-driven finishing machine or by a vibrating hand screed.

- For areas where the width of the slab is very small as at the corner of road junction, etc., hand consolidation and finishing may be adopted.
  - Concrete as soon as placed, is struck off uniformly and screeded to the crown and cross-section of the pavement to conform the grade.
Floating and straight edging

- The concrete is further compacted by means of the longitudinal float.
- The longitudinal float is held parallel to CW CL and passed gradually from one side of the pavement to the other.
- After longitudinal floating is done and the excess water gets disappeared, the slab surface is tested for its grade and level with straight edge.
Construction steps

- Belting, brooming and edging
  - Just before the concrete becomes hard, the surface is belted with a two-ply canvas belt. The short strokes are applied transversely to the CW.
  - After belting, the pavement is given a broom finish with fibre broom brush.
  - Before the concrete develops initial set, the edges of the slab are carefully finished with an edging tool.
Construction of Joints
Introduction

Types of joints:

1) Transverse joints
   a. Expansion joint
   b. Contraction joint
   c. Construction joint

2) Longitudinal joints
Joints

Location of Joints

CONTRACTION JOINT

SLAB LENGTH

DOWEL BARS

LONGITUDINAL JOINT

TIE BARS

EXPANSION JOINT

SLAB WIDTH
Transverse joints

a. Expansion joints:

- To allow for expansion of the slabs due to rise in slab temperature above the construction temp of the cement concrete
- Also permit the contraction of the slabs
- Provided at an interval of 50 to 60 m for smooth interface laid in winter and 90 to 120 m for smooth interface laid in summer.
Expansion Joint with Dowel Bar

- Steel Dowel Bar
- Filler
- Sealer
- Bitumen Coating
- Metal Cap Partly Filled with Cotton

Dimensions:
- 22 cm
- 30 cm
- Approx. 7.5 cm
- Approx. 2.5 cm
Contraction Joints

➢ To permit the contraction of the slabs
➢ Spaced closer than the expansion joints
➢ Load transference at the joints is provided through the physical interlocking by the aggregates projecting out at the joint faces
➢ Spacing of contraction joints in unreinforced CC slabs is 4.5m and in reinforced slab of thickness 20 cm is 14 m
➢ For added safety dowel bar will be used
Longitudinal joints

- When the width of the road is more than 4.5 m
- Provided to prevent the longitudinal cracking in the cement concrete pavements
- Tie bars are provided to hold the adjacent slabs together
Arrangement of joints

The joints in transverse direction are placed as follows:

- Staggered arrangement: sympathetic cracks
- Uniform arrangement: recommended
- Skew arrangement: try to avoid, at some typical layout at intersections
Arrangement of joints
Joint filler and sealer

- Joints allow the infiltration of water for which mud pumping occurs at the subgrade soil.
- Due to entrance of stone grit the effective joint width gets reduced and faults like spalling of joint edges takes place.
- Hence the joint spaces are first filled with compressible filler materials and the top of the joints are sealed using a sealer.
Joint filler and sealer

**Joint Filler:**

- Should possess the following properties:
  a. Compressibility
  b. Elasticity
  c. Durability

**Type of joint filler:**

- Soft wood
- Impregnated fibre board
- Cork or cork bound with bitumen
During Summer

During Winter
Joint sealer

- Sealing compounds possess the following properties:
  a. Adhesion to cement concrete edges
  b. Extensibility without fracture
  c. Resistance to ingress of grit
  d. Durability
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pour point</td>
<td>180°C max.</td>
</tr>
<tr>
<td>Softening point</td>
<td>75°C min.</td>
</tr>
<tr>
<td>Increase in softening point after heating to 20°C above pour point for 3hrs</td>
<td>5°C max.</td>
</tr>
<tr>
<td>Penetration value</td>
<td>15 to 50</td>
</tr>
<tr>
<td>Extensibility</td>
<td>6 mm max.</td>
</tr>
<tr>
<td>Resistance to girt penetration (on impact test at 35°C in tenths of mm)</td>
<td>20 max.</td>
</tr>
</tbody>
</table>