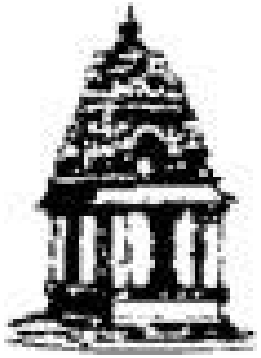


BRUHAT BANGALORE MAHANAGARA PALIKE

Office of the Chief Engineer

(Vigilance & P.P.E.D)

Supporting Layers of Pavements

- Materials, Construction and QC

By

(V &P.P.E.D Division)

Bruhat Bangalore Mahanagara Palike

Bangalore-02

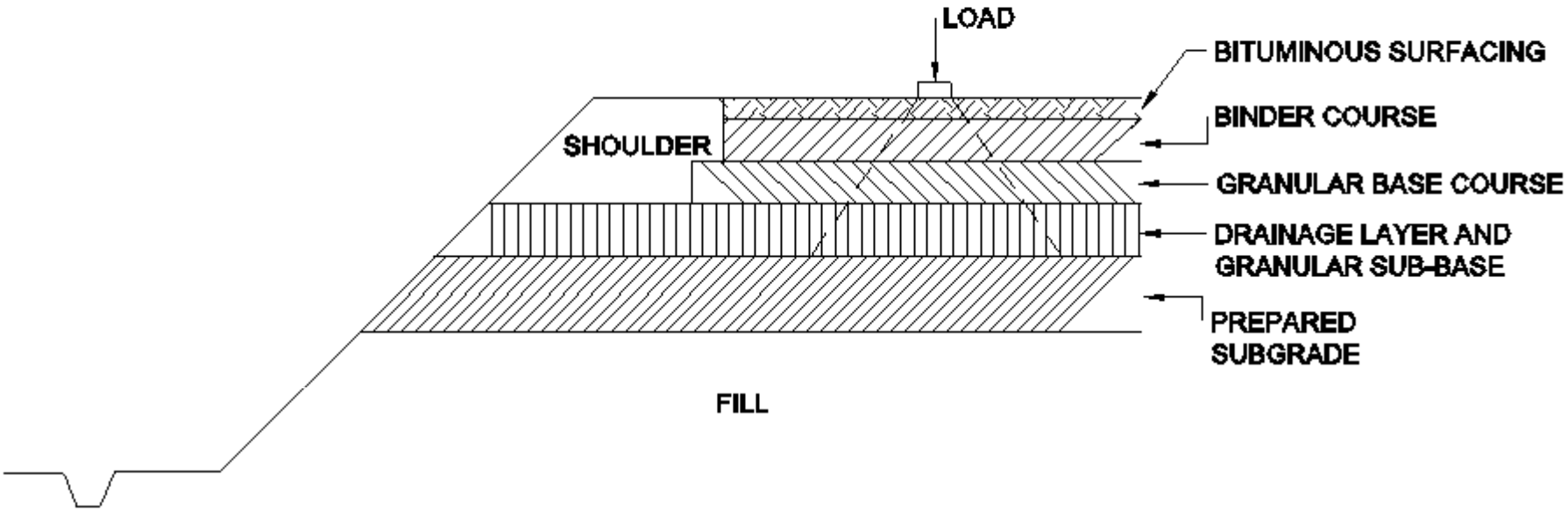


FIG. 2 TYPICAL CROSS SECTION OF FLEXIBLE PAVEMENT

Subgrade:

- Layer of Natural Soil Prepared to Receive Layers of Pavement Materials placed over
- The loads on Pavement are Received by Soil Subgrade for dispersion to the Earth mass

SubBase & Base:

- To improve the load supporting capacity by Distributing the load - Flexible pavement
- Prevent mud pumping, continuous support for slab & to protect subgrade

Wearing Course/ Surface Course

- To give Smooth riding surface
- To resist wear and tear due to traffic
- To resist Water infiltration

Flexible Pavements / Bituminous Pavements

1. Fill/ Subgrade - Soil Layers
2. Granular Layers -GSB, WBM, WMM, CRM
3. Bituminous Layers
3.1 Interface treatments
3.2 Thin Surface Layers
3.3 Thick Surface layers
4. Bituminous Binder Courses & Surface Coures
5. Functional & Structural Layers

Bituminous Layers _ Thick Layers

- Grouted / Penetration type
  - Built Up Spray Grout
  - Penentration Macadam
- Bituminous Precoated Layers
  - Bituminous Macadam
  - Dense Bituminous Macadam
  - Bituminous Concrete

Bituminous Thin Layers - Structural Layer

- Semi Dense Bituminous Concrete - 25 mm

Bituminous Thin Function Layers

- Pre Mix Carpet with Seal Coat
- Mix Seal Surfacing

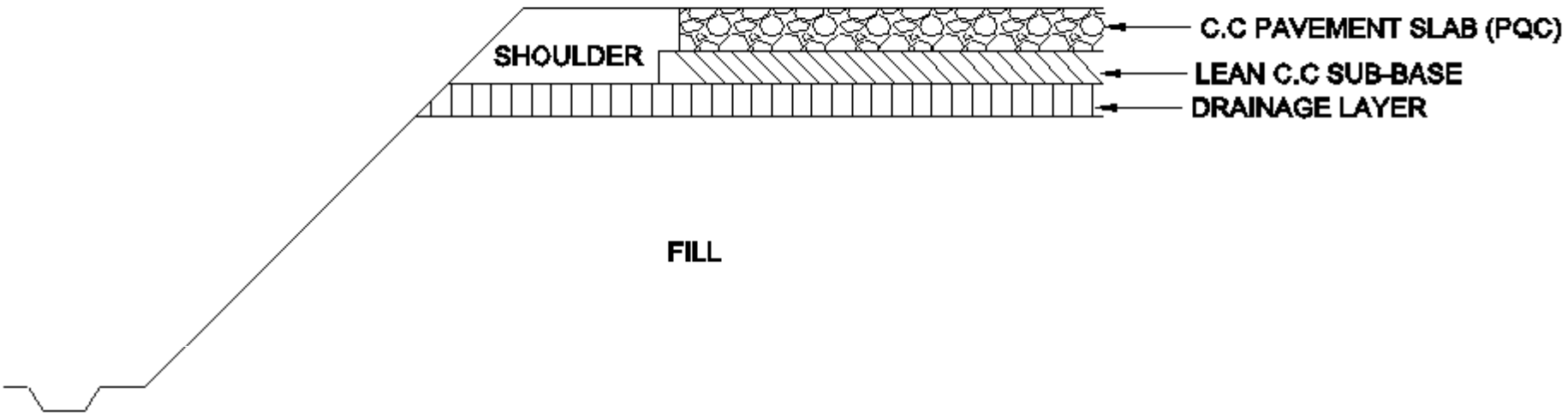


FIG. 3 TYPICAL CROSSSECTION OF CEMENT CONCRETE PAVEMENT

Rigid Pavements / Cement Concrete Pavements

Base layers:

- Granular layers - WBM etc
- DLC - Dry lean Concrete/ Roller compacted concrete

Surface Layers

- PQC
- Interlocking Concrete paving blocks

Cement Concrete Pavement

- Cement concrete pavement maintains a very high recognition among road engineers and road users

- Pleasing appearance

- Engineers have inherent confidence in CC material

- Life of CC road more

- Exhibits characteristics which can be predicted by elastic theory and designed on more rational basis

- CC pavements are constructed with/without sub base

- Requires high initial investment

- Not adopted for stage construction

- Joints are unavoidable in construction

- Minimum curing period is required before opened to traffic

Fill (Embankment) & Sub-grade

- Pavement failures due to settlement of embankment fill and sub-grade
- Soil - Most common fill material
- Need for suitable materials and proper quality control during execution
- Adoption of MoRTH or Rural Roads Manual specifications

Characteristics Of Soil

- **BIS Limits of particle size**
  - Gravel 80 to 4.75 mm
  - Sand
    - Coarse 4.75 to 2.00 mm
    - Medium 2.00 to 0.475 mm
    - Fine 0.475 to 0.075 mm
  - Silt 0.075 to 0.002 mm
  - Clay Less than 0.002 mm
- **Clay minerals (problematic soil)**
  - Electrochemically active
  - Crystal sheets in clay - Tetrahedral or silica and Octahedral or alumina

Desirable Properties Of Soil

- Stability
- Incompressibility
- Permanency of strength
- Minimum changes in volume & stability
- Good drainage
- Ease of compaction

Undesirable Types Of Soil

- Highly plastic soils
- Soils which favour capillary rise of water
- Frost susceptible soils
- Organic and sulphatic soils
- Permissible limits
  - Total sulphate - 0.5 per cent maximum
  - Organic matter - 1.0 per cent maximum

SOIL SURVEY

- The objective of soil survey is to determine the soil types occurring along alignment and to locate the sources of borrow soil for embankments
- Soil sampling at an interval of 200 m
- Soil samples to be evaluated for different geotechnical properties

Earthwork For Embankment/sub-grade (As Per Specifications)

- **Suitability of materials**
  - Free from peat, perishable and other organic material
  - Should not be spontaneously combustible
  - LL should be less than 70, PI should be less than 45
  - Soils having salts are not suitable
  - Free Swell Index more than 50 % should not be used
  - Total sulphate content more than 0.5 % must be avoided

Earthwork For Embankment/Sub-grade (Contd...)

- **Size of material**
  - Maximum size of clod should be less than 75 mm in embankment fill
  - Maximum size of clod should be less than 50 mm in sub-grade
  - Maximum particle size should be less than two third of compacted layer thickness

Earthwork For Embankment/Sub-grade (Contd....)

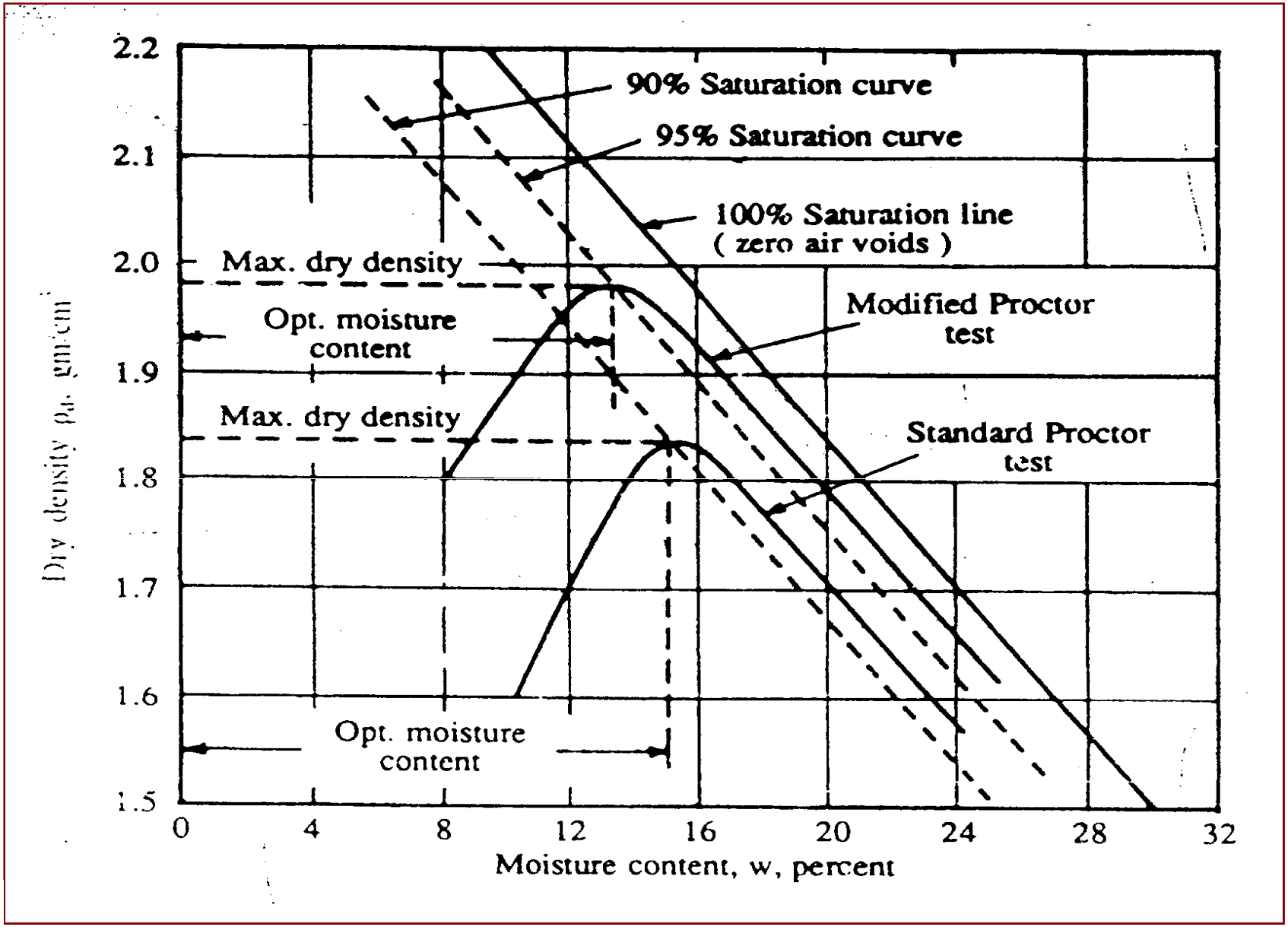
- Spreading of material in layers and bringing to appropriate moisture content.
  - Maximum compacted layer thickness should not exceed 200 mm
  - Moisture content between OMC - 2 % to OMC + 1%
  - Expansive soils to be compacted at OMC or on wet side of optimum

Objectives Of Soil Compaction

- Increase in strength
- Reduction in compressibility
- Reduction in tendency for subsequent changes in moisture content
- Reduction in erodability
- Reduction in frost susceptibility

Factors Influencing Compaction

- Type of soil
- Moisture content
  - Dry of optimum
  - Optimum
  - Wet side of optimum
- Compactive effort
  - Energy applied per unit weight of soil
- Weight of rammer, height of fall, number of blows
- Weight of roller, number of passes



Moisture-density relationship

Compaction Requirements For Embankment And Sub-grade (MORTH Specifications)

S.No.	Type of work/material	Relative compaction as percentage of maximum laboratory dry density as per IS: 2720 (Part 8)
1.	Sub-grade and earthen shoulders	Not less than 97 %
2.	Embankment	Not less than 95 %
3.	Expansive clays (a) Sub-grade and 500 mm portion just below the sub-grade (b) Remaining portion of embankment	Use not allowed Not less than 90 %

Compaction Requirements For Embankment And Sub-grade (For Rural Roads)

S.No.	Type of work/material	Relative compaction as percentage of max. laboratory dry density
1.	GSB and stabilised sub-base	Not less than 98 % as per IS: 2720 (Part 8)
2.	Embankment	Not less than 97 % as per IS: 2720 (Part 7)
3.	Sub-grade (Natural soil or stabilised soil, 30 cm in two layers) and earthen shoulder	Not less than 100 % as per IS: 2720 (Part 7)

Density Requirements For Embankment And Sub-grade (MORTH Specifications)

Sl.No	Type of work	Maximum laboratory dry unit weight when tested as per IS: 2720 (Part 8)
1	Embankments up to 3 metres height, not subjected to extensive flooding	Not less than 15.2 kN/cu.m
2	Embankments exceeding 3 metres height or embankments of any height subject to long periods of inundation	Not less than 16.0 kN/cu.m
3	Sub-grade and earthen shoulders/ verges	Not less than 17.5 kN/cu.m

Density Requirements For Embankment And Sub-grade (For Rural Roads)

S.No	Type of work	Maximum laboratory dry unit weight when tested as per IS: 2720 (Part 7)
1	Embankments up to 3 metres height, not subjected to extensive flooding	Not less than 14.4 kN/cu.m
2	Embankments exceeding 3 metres height or embankments of any height subject to long periods of inundation	Not less than 15.2 kN/cu.m
3	Sub-grade and earthen shoulders	Not less than 16.5 kN/cu.m

Comparison Of Compaction Tests

Standard Proctor Test	Modified Proctor Test
Soil passing 20 mm / 37.5 mm IS sieve	Soil passing 20 mm / 37.5 mm IS sieve
Soil compacted in 3 layers, 25 blows / 55 blows	Soil compacted in 5 layers, 25 blows / 55 blows
Soil compaction by 2.6 kg hammer, 31 cm is height of fall	Soil compaction by 4.89 kg hammer, 45 cm is height of fall
Adopted for rural roads specifications	Adopted for MORTH specifications
Used for Internal roads in urban areas and village roads	Used for NH, SH, MDR and arterial roads in urban area

Machinery for earthwork - Dozers

JCB (Backhoe cum Loader)

Motor grader

Tractor as grader

Tractor as plough

Vibratory roller

Tandem vibratory roller

Static roller

Small vibratory roller

Plate compactor

Compacted sub-grade

Field Control Of Compaction

- **Measurement of dry density**
  - **Core cutter method (IS: 2720 (Part 29) - 1975)**
  - **Sand replacement method (IS: 2720 (Part 28) - 1974)**
  - **Nuclear density & moisture gauge (ASTM D- 2922)**

Field Control Of Compaction (Contd..)

- **Measurement of moisture content**
  - **Pan drying method**
  - **Speedy moisture meter (IS 2720 (Part 2 - 1973)**
  - **Microwave oven method (ASTM D: 4643-1989)**

Quality Control

- **Tolerances in surface levels in sub-grade**

  + 20 mm to -25 mm

- **Acceptance criteria**

Mean density should not be less than specified density +

$$[1.65 - \frac{1.65}{(N)^{0.5}}] \text{ times the standard deviation}$$

Quality Control Tests (MORTH)

Sl.No	Test	Relevant code	Frequency of test
1.	Deleterious content	IS:2720 : Part - 27	As & when required by engineer
2.	**Moisture content**	**IS:2720 : Part - 2**	**1 test / 250 m^3**
3.	**Sand content**	**IS:2720 : Part - 4**	**2 tests / 3000 m^3**
4	**Plasticity Index**	**IS:2720 : Part - 5**	**2 tests / 3000 m^3**
5.	**Compaction tests**	**IS:2720 : Part - 8**	**2 tests / 3000 m^3**
6.	**C.B.R**	**IS:2720 : Part - 16**	**1 test / 3000 m^3**
7.	**Field density** **(a) Embankment** **(b) Sub-grade/shoulders**	**IS:2720 : Part – 28**	**1 test / 1000 m^2** **1 test / 500 m^2**

Quality Control Tests (Rural Roads Manual)

Sl.No	Test	Relevant code	Frequency of test
1.	Deleterious content	IS:2720 : Part - 27	To be decided by engineer
2.	Moisture content	IS:2720 : Part - 2	1 test / 250 m^3
3.	Sand content	IS:2720 : Part - 4	1 test / 4000 m^3
4	Plasticity Index	IS:2720 : Part - 5	1 test / 4000 m^3
5.	Compaction tests	IS:2720 : Part - 8	1 test / 4000 m^3
6.	C.B.R	IS:2720 : Part - 16	1 test / 5000 m^3
7.	Field density (a) Embankment (b) Sub-grade/shoulders	IS:2720 : Part – 28	1 set of test / 2000 m^2 area comprising of 5 to 6 measurements

High Embankment

- **Failures within the body of embankment**
  - Incorrect design practices
  - Poor quality fill materials
  - Improper construction methods
  - Lack of quality control
- **Failures involving foundation**
  - Inadequate subsoil investigation
- **Design of high embankment**
  - Using MoRTH or any other suitable software
  - Target FS = 1.25 for economical design

Earthwork Under Special Conditions

- Earthwork over existing road surface
- Embankment construction in waterlogged areas
- Construction of embankment over soft soils
- Inadequate compaction of backfill material in trenches dug for services in urban areas

Compaction Of Ground With Underlying Cables, Water Pipelines, Sewer Lines, Etc.

Settlement of pavement due to improper compaction of backfill material in the trenches

Effect Of Earthquake On Embankment

Shallow cracks in road pavement

Deep and wide cracks in embankment

- Depth of crack upto 1m
- width of crack 10 cm- 80 cm

Major slides/ subsidence

Erosion Control Of Slopes

- **Common methods**
  - Simple vegetative turfing
  - Transplantation of ready made turf of grass
  - Straw with cowdung or wood shavings or sawdust as mulch
- **Special techniques**
  - Asphalt mulch technique
  - Use of jute/ coir netting
- **Slopes in cohesionless sands and black cotton soils**

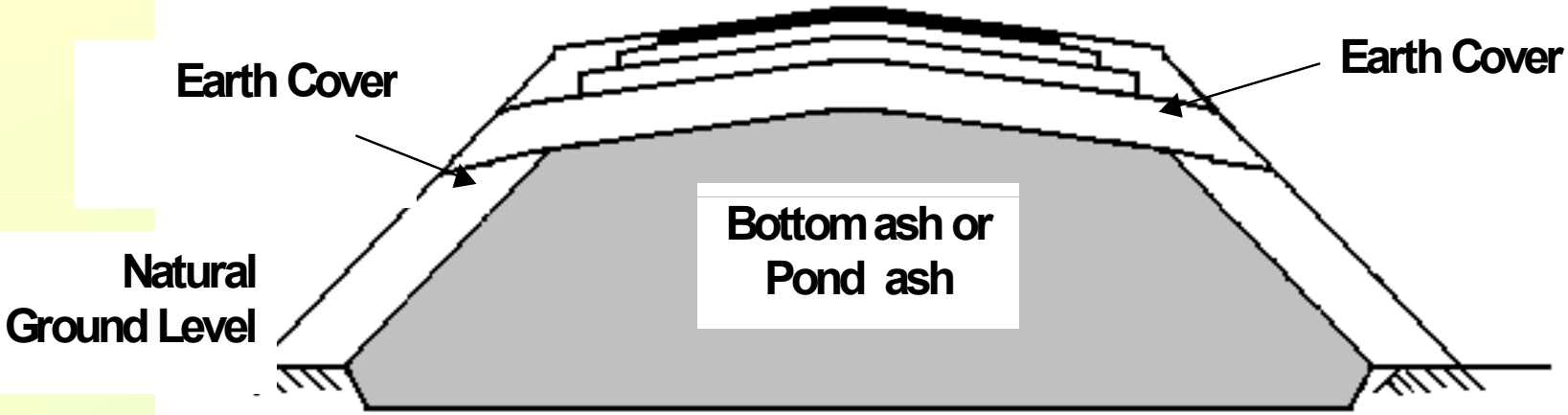
Erosion Control of Slopes

Use of jute geotextile for erosion control

Fly Ash For Road Embankment

- Ideally suited as back fill material for urban/ industrial areas and areas with weak sub soils
- Higher shear strength leads to greater stability
- Design is similar to earth embankments
- Intermediate soil layers for ease of construction and to provide confinement
- Side slope erosion needs to be controlled by providing soil cover
- Can be compacted under inclement weather conditions
- Use of vibratory rollers is preferred

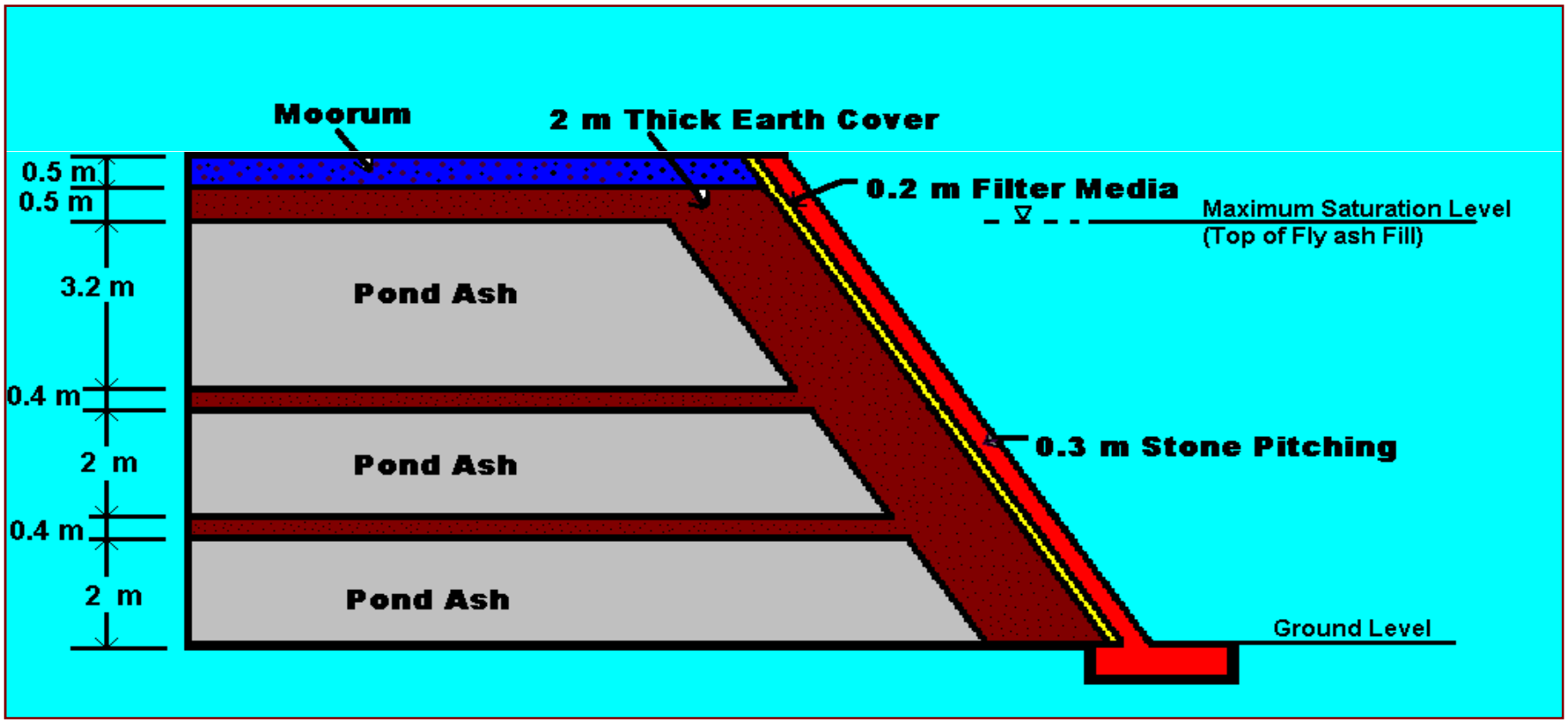
Fly Ash For Road Embankment



Typical cross section of fly ash embankment

Approach Embankment For Second Nizamuddin Bridge At Delhi

Length = 1.8 Km, Height = 6 to 9 m,
Ash utilised = 1.5 lakh cu.m,
Savings = Rs.1 crore



Granular Sub-base

Materials

- Shall be natural sand, moorum, gravel, crushed stone or combination thereof.
- Crushed slag, crushed concrete, brick metal and kankar may **also be used.**
- Shall be free from organic or other deletrious constituents and conform to one of the three gradings given as follows:

TABLE 400-1. GRADING FOR CLOSE-GRADED GRANULAR SUB-BASE MATERIALS

IS Sieve Designation	Per cent by weight passing the IS sieve		
	Grading I	Grading II	Grading III
75.0 mm	100	—	—
53.0 mm	80-100	100	—
26.5 mm	55-90	70-100	100
9.50 mm	35-65	50-80	65-95
4.75 mm	25-55	40-65	50-80
2.36 mm	20-40	30-50	40-65
0.425 mm	10-25	15-25	20-35
0.075 mm	3-10	3-10	3-10
CBR Value (Minimum)	30	25	20

TABLE 400-2. GRADING FOR COARSE GRADED GRANULAR SUB-BASE MATERIALS

IS Sieve Designation	Per cent by weight passing the IS Sieve		
	Grading I	Grading II	Grading III
75.0 mm	100	—	—
53.0 mm		100	
26.5 mm	55-75	50-80	100
9.50 mm			
4.75 mm	10-30	15-35	25-45
2.36 mm			
0.425 mm			
0.075 mm	<10	<10	<10
CBR Value (Minimum)	30	25	20

Note : The material passing 425 micron (0.425 mm) sieve for all the three gradings when tested according to IS : 2720 (Part 5) shall have liquid limit and plasticity index not more than 25 and 6 per cent respectively.

Physical Requirements

- Material shall have 10% fines value of 50 kN or more under soaked conditions
- Water absorption value – coarse aggregate should be less than 2%
- If the water absorption value is less than 2%, then soundness test should be conducted. CBR value should be determined at the density and m/c
- The index properties of water in which passing 425 micron (0.425 mm) sieve

Construction Operation

- Preparation of Sub-grade
- Spreading
- Compaction and Rolling

Water Bound Macadam Sub-base /Base

- It consist of clean, crushed aggregates mechanically interlocked by rolling and bonding together with screening, binding material where necessary and water, laid on a properly prepared sub-grade/ sub-base/ base on existing pavement.

MATERIALS

- **Crushed aggregate**

Test	Test Method	Require ments
Los Angeles Abrasion value or	IS: 2386 (Part-4)	40 % Max.
Aggregate Impact value	IS:2386 (Part-4) or IS5640	30 % Max.
Combined Flakiness and Elongation Indices	IS:2386 (Part-1)	30% Max.

Construction Operation

- Preparation of base
- Inverted choke
- Spreading coarse aggregate
- Rolling
- Application of Screening
- Sprinkling of water and grouting
- Application of Binding Material
- Setting and Drying

Contd.…

- Crushed Slag
- Physical Requirements
- Chemical stability - to comply with required of appendix of B.S. – 1047

Sulphur - Maximum 2%

Water absorption - Maximum 10%

TABLE 400-7. GRADING REQUIREMENTS OF COARSE AGGREGATES

Grading No.	Size Range	IS Sieve Designation	Per cent by weight passing
1.	90 mm to 45 mm	125 mm	100
		90 mm	90-100
		63 mm	25-60
		45 mm	0-15
		22.4 mm	0-5
2.	63 mm to 45 mm	90 mm	100
		63 mm	90-100
		53 mm	25-75
		45 mm	0-15
		22.4 mm	0-5
3.	53 mm to 22.4 mm	63 mm	100
		53 mm	95-100
		45 mm	65-90
		22.4 mm	0-10
		11.2 mm	0-5

Note : The compacted thickness for a layer with Grading 1 shall be 100 mm while for layer with other Gradings i.e. 2 & 3, it shall be 75 mm.

Screening Material

TABLE 400-8. GRADING FOR SCREENINGS

Grading Classification	Size of Screenings	IS Sieve Designation	Per cent by weight passing the IS Sieve
A	13.2 mm	13.2 mm	100
		11.2 mm	95-100
		5.6 mm	15-35
		180 micron	0-10
B	11.2 mm	11.2 mm	100
		5.6 mm	90-100
		180 micron	15-35

Presence of excessive soil binder/moorum on WBM base course

Wrong practices in WBM construction - spreading of excessive quantity of soil / moorum over single course of aggregates and also inadequate rolling / compaction

Binding Material

Wet Mix Macadam Sub-base/ Base

Consists of:

- Laying and compacting clean, crushed aggregates and granular material, premixed with water to a dense mass on a prepared sub-grade/ sub-base/ base.
- Laid in one or more layers as necessary to line grades and cross section
- Thickness of single compacted WMM layer shall not be less than 75 mm

Advantages of Using WMM

- Homogeneous mix as it is controlled mechanically

- Laying by Pavers , Graders hence better surface finish

- Quicker

- Mix can be mixed at suitable locations - where water is available

- Because of premixing with water seggregation reduces

- Can achieve higher unit weight hence higher strength

- Less compactive effort to achieve max density

  uniform coating of moisture film around

  aggregates

- More output in construction

- Controlled gradation / crushed

Limitations

- After construction of top layer immediate sealing with bituminous surface

- Lateral confinement

- Normally mechanically crushed aggregates tends to be rounded than manually crushed aggregates

Grading Requirements

the grading given in Table 400-11.

TABLE 400-11. GRADING REQUIREMENTS OF AGGREGATES FOR MACADAM

IS Sieve Designation	Per cent by weight passing
53.00 mm	100
45.00 mm	95-100
26.50 mm	—
22.40 mm	60-80
11.20 mm	40-60
4.75 mm	25-40
2.36 mm	15-30
600.00 micron	8-22
75.00 micron	0-8

Construction

- Provision of lateral confinement of aggregates
- Preparation of mix
- Spreading of mix
- Compaction of mix

Crusher Run Macadam Base

selected, it shall not be changed

TABLE 400.12. AGGREGATE GRADING REQUIREMENTS

Sieve size		Per cent passing by weight	
		53 mm max. size	37.5 mm max. size
63	mm	100	100
45	mm	87-100	90-100
22.4	mm	50-85	35-55
5.6	mm	25-45	10-30
710	micron	10-25	2-9
90	micron	2-9	

TABLE 400-13. PHYSICAL REQUIREMENTS OF COARSE AGGREGATES FOR CRUSHER-RUN MACADAM BASE

	Test	Test Method	Requirements
1.	*Los Angeles Abrasion value	IS : 2386 (Part-4)	40 maximum
	or		
	*Aggregate Impact value	IS : 2386 (Part-4) or IS : 5640	30 maximum
2.	Combined Flakiness and Elongation Indices (Total)	IS : 2386 (Part-1)	30 maximum***
3.	**Water absorption	IS : 2386 (Part-3)	2 per cent Maximum
4.	Liquid Limit of material passing 425 micron	IS : 2720 (Part-5)	Not more than 25
5.	Plasticity Index of material passing 425 micron	IS : 2720 (Part-5)	Not more than 6

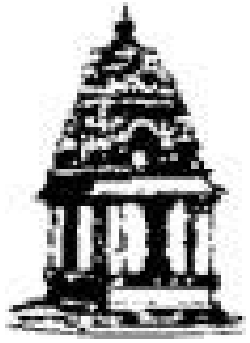
* Aggregate may satisfy requirements of either of the two tests.

** If the water absorption is more than 2 per cent, soundness test shall be carried out as per IS:2386 (Part-5).

*** To determine this combined proportion, the flaky stone from a representative sample should first be separated out. Flakiness index is weight of flaky stone metal divided by weight of stone sample. Only the elongated particles be separated out from the remaining (non-flaky) stone metal. Elongation index is weight of elongated particles divided by total non-flaky particles. The value of flakiness index and elongation index so found are added up.

Construction Operation

- Preparation of Sub-grade
- Spreading, watering
- Compaction



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