Pavement Materials

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Study of Pavement Materials

- Necessary to understand the behavior of the materials individually and in combination with other materials

- Characterization of materials – Purpose
  - To classify / Grade
  - To obtain necessary inputs for design of new pavement
  - To obtain inputs regarding the condition of materials in an existing pavement
  - To ensure proper quality during construction
Pavement Materials

- Soil
- Aggregates (Natural, Artificial)
- Bitumen, Tar, Emulsion, Cutbacks
- Modified Bituminous Binder (Polymer, Rubber)
- Bituminous Mixes
- Cement and Cement Concrete (Plain, RCC, PSC)
- Stabilised materials (Cement, Lime, others)
- Recycled Materials
- Geosynthetics
Pavement materials properties are evaluated by

- Conducting laboratory tests on representative samples
- Field Evaluation
- Estimation

The material properties to be considered should be relevant to the design approach adopted.

The properties should also reflect the performance of pavement structure.
Parameters

Parameters to be considered for Characterization of Pavement materials properties are

- **Loads**
  - Stationary/moving, heavy/light, application mode (normal & shear, Impact)

- **Climatic Conditions**
  - Temperature, rainfall, moisture

- **Weathering action**
  - Wetting/Drying, Chemical action, Freeze-Thaw
Material Behavior

Fundamental material behavior is characterized usually in terms of:

- Stress-Strain relationship
- Ability of material to recover after release of load
- Time dependency
- Temperature dependency
When we build

“Let us think that we build forever
Let it not be for the present delight
Nor for the present use alone
Let it be such work as our descendants will thank us for”

John Ruskin
Pavement Material – Soil

Soils are used in

- Subgrade
- Embankment
- Shoulders

Compacted soil and stabilized soil are often used in sub-base or base course
Significance of subgrade soil

- Primary function is to provide adequate support to the pavement
- Poor subgrade condition leads to:
  - Formation of waves
  - Corrugations
  - Rutting and Shoving
  - Pumping phenomena
  - Blowing – consequent cracking

- Black top pavements
- Cement concrete pavements
Pavement Material – Soil

Desirable Properties

- Stability
- Incompressibility
- Permanency of strength
- Minimum changes in volume
- Good drainage
- Ease of compaction
Pavement Material – Soil

Evaluation of Properties

❖ Index Properties
  ▪ Grain Size Analysis
  ▪ Consistency limits and Indices

❖ Strength
  ▪ Shear tests
  ▪ Bearing tests
  ▪ Penetration tests . . . .
Important Quality Control Tests on Soils

a) Liquid Limit and plastic Limit
   IS: 2720 –part 5 at 2 tests per 3000 cum
   Liquid limit < 70% and plasticity Index < 45%
   Liquid limit < 40% and plasticity Index < 20% for earthwork
   around structures (for a distance of 2 times the height of
   abutment)

b) Compaction Properties (IS: 2720- part 7&8, standard Procter’s for
   low traffic and modified Procter’s for high traffic at 2 tests per
   3000 cum for finding OMC and MDD

c) Field Moisture Content
   IS: 2720-part2 at 1 test per 250 cum of soil

d) Field Density by Sand Replacement or Core cutter
   Method at 1 test per 1000 square metres

e) Relative Compaction
   = Field Dry Density / Max Dry Density (lab)
   (95% for Embankment and 97% for sub Grade)

f) CBR test for materials to be incorporated in sub grade for every
   3000 cum
Pavement Material – Aggregates

• Major component – road construction

• Used in
  ▪ Granular bases and sub-bases
  ▪ Bituminous courses
  ▪ Cement concrete pavements
Types of Aggregates

- **Natural aggregates**
  - obtained from rock
- **Artificial aggregates**
  - Broken brick ballast
  - Slag
Natural Aggregates

- Igneous rocks
  - cooling of molten material

- Sedimentary rocks
  - deposition of granular material

- Metamorphic rocks
  - transformation due to heat & pressure
Igneous rocks

- **Granite**
  - Hard and durable
  - Resistant to abrasion
  - Low absorption of water
  - Fine grained to coarse grained texture

- **Basalt (Trap)**

Very good for bituminous courses and cement concrete pavements
Metamorphic rock

- Quartzite
  - Reasonably hard and durable
  - Resistant to abrasion
  - Low absorption of water
  - Fine grained to medium grained texture

Good for base courses, bituminous courses and cement concrete pavements
Sedimentary rocks

- **Limestone**
  - Reasonably hard and durable
  - Liable to a smooth polish
  - Fine grained
  - High absorption of water

- **Sandstone**
  - Reasonably hard and durable
  - Liable to a smooth polish
  - Fine grained
  - High absorption of water

- **Kankar**
  - Soft to medium hard

**Good for sub-base and base courses**
Desirable Properties

- Strength
- Hardness
- Toughness
- Durability
- Shape
- Adhesion with bitumen
Desirable Properties....

• **Strength**
  - Bear the traffic load without getting crushed
  - Top layer – in direct contact with traffic – Strongest

Crushing strength test
Desirable Properties....

- **Hardness**
- Continuous wear and tear under the wheels of vehicles - **abrasion**
- Rubbed with each other due to application of traffic load - **attrition**

Hardness test – Los angeles abrasion test
Deval abrasion test
Polished stone test
Desirable Properties....

• **Toughness**
  - Ability to sustain impact loading

Impact test
Desirable Properties....

- Durability
  - Gradual deterioration due to continuous exposure to environment

Soundness test
Desirable Properties....

• **Shape**
  - Angular or rounded

Shape tests – flakiness index, elongation index, angularity number
Desirable Properties....

- **Adhesion with bitumen**
  - Thin film formed over the aggregates holds the whole mass together
  - Electrostatic attraction towards bitumen and water
  - More affinity towards water results in stripping off of bitumen

Stripping test
## Code of Practice

<table>
<thead>
<tr>
<th>Property</th>
<th>Code</th>
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<tbody>
<tr>
<td>Particle size distribution</td>
<td>IS 2386 – part – 1</td>
</tr>
<tr>
<td>Plasticity Index</td>
<td>IS 2720 – part – 5</td>
</tr>
<tr>
<td>Water absorption &amp; Bulk SG</td>
<td>IS 2386 – part – 3</td>
</tr>
<tr>
<td>Flakiness and Elongation</td>
<td>IS 2386 – part – 1</td>
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<tr>
<td>Mechanical Properties</td>
<td>IS 2386 – part – 4</td>
</tr>
<tr>
<td>Impact, abrasion, crushing</td>
<td>IS 2386 – part – 4</td>
</tr>
<tr>
<td>Soundness</td>
<td>IS 2386 – part – 5</td>
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<tr>
<td>Presence of deleterious materials</td>
<td>IS 2386 – part – 2</td>
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<tr>
<td></td>
<td>IS 2720 – part – 37</td>
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<tr>
<td>Bitumen coating &amp; stripping</td>
<td>IS 6241</td>
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<tr>
<td>Water sensitivity test</td>
<td>AASHTO T 283</td>
</tr>
</tbody>
</table>
ACV - Process
AIV
Soundness (AASHTO T 104)
Soundness

Before

After
Flakiness & Elongation
Flakiness & Elongation Apparatus
Coarse Aggregate Specific Gravity
Coarse Aggregate Specific Gravity
Coarse Aggregate Specific Gravity
PSV Sample Preparation
PSV Sample
PSV Polishing
PSV Skid Tester
Coating & Stripping
Splitter
Sieve Set
Sieve Analysis

[Graph showing sieve analysis with percent passing on the y-axis and sieve size on the x-axis.]
Types of Binders

1. Tar

2. Natural Asphalt / Rock Asphalt / Lake Asphalt

3. Bitumen
**Tar**

- **COKE OVEN TAR**
  - Produced at temperatures above 1200°C during manufacturing of coke.
  - High aromatic content.
  - Pitch content - 50 %.

- **LOW AROMATIC TAR**
  - Produced at temperatures 600°C to 700°C.
  - Less viscous.
  - Paraffinic in nature.
  - Pitch content - 35 %.
Natural / Rock / Lake Asphalt

- Naturally occurring Bituminous binder.
- Biggest deposits in Trinidad
  - 100 Acres,
  - 90 meter deep
  - 10 to 15 Million MT
  - Pen - 5 max
- Asphalt found in France, Italy & Switzerland - Rock Asphalt.
Bitumen

- Conventional Bitumen
  - Paving Grade Bitumen
  - Industrial Grade Bitumen
- Cutback
- Bitumen Emulsions
- Modified Bitumen
- Modified Bitumen Emulsions
What is Bitumen?
What is Bitumen?

- Last residue obtained from fractional distillation of Crude Oil
- Is black or dark brown in colour
- Is a visco-elastic material
  - Does not have a distinct melting point
  - Gradually softens when heated
  - More solid at low temperatures and more liquid at high temperatures
- Has adhesive properties
- Has water proofing properties
- Forms good bond with a variety of aggregates
What are Performance Parameters?

- Mix and form a good bond with aggregate (at high temperature)
- Not melt on the road at highest atmospheric temperature
- Not crack at extreme low atmospheric temperature
- Be able to withstand repeated cycles of loading and unloading
- Be able to withstand repeated cycles of temperature change
- Not be inflammable
- Be free from impurities
What type of tests do we develop?

- Tests should be simple
- Tests should replicate the actual field conditions as accurately as possible
- Rate of change of properties with time, temperature and load should be measurable or predictable
Modes of Failure
Rutting/ Permanent Deformation
Fatigue Cracking
Methods of Classification

- Penetration
- Viscosity
- Viscosity of TFOT
- Performance
Penetration Based System

- More than 100 years old
- Has stood the test of time
- Based on Penetration at 25 °C
- Penetration 30 to 100 are suitable for road construction
- Harder grades suitable for heavier traffic loads
- Softer grades suitable for light traffic loads
Viscosity Based System

- Viscosity is considered to be the primary property
- Most tests overlap with that of Penetration based classification
- Classified as VG 10, 20, 30 and 40 based on viscosity at 60°C
Viscosity of TFOT Residue Based System

- Simulates aging of Bitumen
- Viscosity ranging from 40 to 700 pascal seconds at 60°C are suitable for road construction
- Most tests overlap with that of Penetration based classification
- Higher viscosity for higher traffic and low viscosity for lower traffic
Performance Based System

• Radically different from Penetration & Viscosity based system
• New set of tests developed for better simulation of field conditions
• Long term & short term aging taken into consideration
• Classification is based on the maximum and minimum pavement temperature that the Bitumen can withstand (PG 58 -22)
Test methods
Penetration Test

- Arbitrary Empirical Number
- Depth of penetration of a standard size needle under standard test conditions
- Very easy to perform at field level
- Helps in classification and traceability
Testing Binders

- Softening point test
Softening Point Test

- Arbitrary test to indicate the temperature at which bitumen is more of a liquid and less of a solid
- Higher softening points indicate higher resistance to melting on road
- Higher resistance to melting indicates higher rutting resistance
Ductility Test

- Arbitrary empirical test to measure the cohesive strength
- Cohesive strength is loosely related to the fatigue strength
- Testing temperatures may vary from country to country and from grade to grade also
Fraass Breaking Point

- Tests low temperature properties
- This mode of failure likely to take place only when temperatures are less than 0°C
• Viscosity at 135°C is a fair indicator of the coating ability of Bitumen
• Viscosity at 65°C is a replacement for Softening Point test and is an indicator of the ability of Bitumen to resist rutting.
• This test simulates the process of aging of Bitumen during mixing and laying
• Sample is kept in an oven at 163°C for 5 hours
• TFOT aged bitumen can be tested for Penetration, Softening Point, Ductility, Viscosity, etc.
Other Tests

- Penetration ratio or penetration index
- Wax content
- Specific gravity
- Water content
- Matter soluble in organic solvents
- Flash Point
Performance Grade Tests
• Tested in rotational viscometer
• Max. viscosity of 3 Pa-s at 135°C
Aging of Bitumen

- During Construction
- Early in Pavement’s life
  - Post construction up to two years
- Late in pavement’s life
  - Seven plus years of life

Rolling thin film oven test (RTFOT)
RTFOT + Pressure Ageing Vessel (PAV)
Rutting

- Due to melting of bitumen on the road
- Always occurs at max. pavement temp.
- Test to be conducted at max. pavement temp.
- Tested in Dynamic Shear Rheometer
- Complex Shear Modulus $G^*/\sin\delta$ min. 1 kPa, @ 10 rad/s for unaged bitumen
- $G^*/\sin\delta$ min. 2.2 kPa, @ 10 rad/s for RTFOT aged bitumen
Fatigue

- Due to repeated loading, unloading cycles
- Always occurs near the average pavement temp.
- Test to be conducted at average + 4°C pavement temp.
- Tested in Dynamic Shear Rheometer
- Fatigue Strength $G*\sin\delta$ max. 5000 kPa, @ 10 rad/s for RTFOT + PAV aged bitumen
Low Temp. Cracking

- Due to loss of elasticity at very low temp.
- Always occurs at lowest pavement temp.
- Testing done at min. temp. + 10°C
- Bending Beam Rheometer
- Creep Stiffness of max. 300,000 kPa, Rate of Change of Creep with load (m-value) min. 0.30
- Direct Tension Test - For Modified Bitumens
- Failure strain min. 1%
Performance Vs Tests

- **Mixing and Laying**
  - Viscosity at 135°C

- **Rutting**
  - Softening Point
  - Viscosity
  - Penetration
  - Complex Shear Modulus

- **Fatigue Cracking**
  - Ductility
  - Creep Stiffness
  - Fatigue Strength
  - Softening Point, Viscosity & Penetration after Aging

- **Low Temperature Cracking**
  - Fraass Breaking Point
  - Rate of change of Creep
  - Failure Strain
Selection of Grade
Choice of Grade

Choice of Bitumen is based on

- Climatic Conditions - Maximum & Minimum temperature & rainfall.
- Intensity of Traffic - Number of vehicles per day, Traffic speed & axle load of vehicles.
Applications of 30/40 Grade

- Suited for areas where diff. between min. & max. temp. < 25°C.
- Suited for traffic intensity > 1500 cvpd
- Used in metropolitan areas.
- Used in airport runways.
Applications of 60/70 Grade

- More viscous grade.
- Higher softening point.
- Suited for traffic intensity > 1500 cvpd.
  - Can withstand heavier axle loads.
  - Better suited for highways, expressways & urban roads.
- Suited for areas where difference between min. & max. temp. is > 25°C.
- Reduced stripping in presence of water.
Applications of 80/100 Grade

- Less viscous grade.
- Used in all climatic conditions.
- Suited for traffic load < 1500 cvpd.
- Better suited for high altitude/snow bound regions irrespective of traffic intensity.
<table>
<thead>
<tr>
<th>Grade</th>
<th>Bitumen</th>
<th>Agg.</th>
<th>Mix</th>
<th>Rolling</th>
<th>Laying</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>150 - 165</td>
<td>150 - 170</td>
<td>165 Max</td>
<td>90 Min</td>
<td>125 Min</td>
</tr>
<tr>
<td>90</td>
<td>140 - 160</td>
<td>140 - 165</td>
<td>155 Max</td>
<td>80 Min</td>
<td>115 Min</td>
</tr>
</tbody>
</table>
Advantages

- Smooth
- Safe
- Economical
- Speed
- Quiet
- Environment friendly
- Versatile
- State of-the-art
- Stage Construction
- Resistant to de-icing material
- Serviceability
Thank you