HIGHWAY MATERIALS

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   Batch plant
INTRODUCTION

The needs for roads stems from the invention of wheels in Samaria -3000SM

Among early roads:
- Silk Route
- Persian Empire
- Britain/Europe - log-raft type
- India - bricks, piped surface drainage systems
- Mesopotamia & Egypt - paved in asphalt and bricks
- Roman roads - greatest road building era, 3 classes of road structures (levelled earth, gravelled surface, paved)
INTRODUCTION

Road designers in the 18\textsuperscript{th} century:
Robert Phillips – pioneer, suggest a layer of gravel resting on well-drained base >> beaten by traffic into solid road surface

\textbf{Tresaguet} – cambered formation, differential settlement problem

\textbf{John Metcalf} – Blind Jack, built 290 km ++

\textbf{Thomas Telford} – civil eng, built 1600 km ++, flat formation, other layers even thickness

\textbf{John Macadam} – true highway engineering specialist, surveyor, cambered formation, other layers even thickness, use angular aggregates, cheaper and easier
INTRODUCTION

Types of road surface:

- Earth road
- Gravelled surface
- Bituminous road - surface dressing (Flexible)
- asphalitic concrete
- porous pavement
- SMA
- Concrete road (rigid)
- Interlocking block pavement (semi?)

New technologies?? (material and gradation)
Flexible Pavement
(dense, open, gap graded)
Concrete Pavement (Rigid)
Interlocking Block

- Paving
- Bedding
- Base
- Sub-base* (optional)
- Sub-grade
MALAYSIAN ROAD SYSTEM

122,000 km (70% paved)

Five categories based on funds for construction and maintenance for administration purpose:

1. Federal Road - connects entry points and major cities
2. Toll Road - alternative, design, built & operates
3. State Road - providing intra-state travel
4. Municipal/City Council - including built by developer
5. Other Roads - jalan kampung by district office from state funds
MALAYSIAN ROAD SYSTEM

Two classification for geometric design purpose:
Urban - U
Rural - R

Subdivided into six hierarchy i.e. R1/U1 to R6/U6 according to traffic, speed/geometric design, and access control

TABLE R/U

Agencies in transportation system

ORGANISATION CHART
ROAD LAYERS

Usually consist of four layers of road construction materials, built up on formation (sub-grade)
Sub-grade

Part of the embankment or existing ground, top surface of sub-grade > formation level

Unsuitable materials (JKR/SPJ/1988):

1. Running silt, peat, logs, stumps, perishable or toxic material, slurry or mud, or

2. Any material
   - Consisting of highly organic clay and silt;
   - Having LL > 80% and/or PI > 55%;
   - Susceptible to spontaneous combustion;
   - Has LOI > 2.5%;
   - Containing large amounts of roots, grass and other vegetable matter.

Materials that are soft or unstable due to too wet or dry for effective compaction - not classified as unsuitable
Sub-grade (cont…)

Properties of good sub-grade:

- Stable
- Consistent strength
- Able to drain away water

Factors affecting soil strength:

- Soil type
- Moisture content
- Method and compactive effort

Tests on soil for sub-grade:

- LOI, LL and PL
- Compaction
- CBR
Compaction

DD vs. MC

Dry Density

Moisture Content

MDD

Compactation Curve

OMC
CBR

Purpose - determine bearing capacity of material against standard crushed aggregate

Two major processes - compaction test (determine MDD and OMC), and CBR test (determine CBR at 95% compaction)

Compaction: mold 2.3L, hammer 4.5 kg, 62 blows/layer, 5 layers, 5 different mc, obtain Bulk Density >>> Dry density >>> plot DD vs. MC

CBR: 3 mold at OMC, vary no. of blows to obtain 95% compaction, calculate DD, soak, drain, CBR test, plot Load vs. Penetration graph, calculate CBR at 2.5 and 5.0mm
CBR Testing
# CBR vs. DD Data

<table>
<thead>
<tr>
<th>Number of Blows</th>
<th>15</th>
<th>35</th>
<th>65</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry density, g/cu.m</td>
<td>Mg/cu.m</td>
<td>1.864</td>
<td>1.989</td>
</tr>
<tr>
<td>CBR Top</td>
<td>%</td>
<td>20.4</td>
<td>43.1</td>
</tr>
<tr>
<td>CBR Bottom</td>
<td>%</td>
<td>18.5</td>
<td>31.1</td>
</tr>
</tbody>
</table>
Sub-base

Function:

1. Assist in load spreading
2. Drainage layer
3. Provide platform for construction
4. Protection to the exposed sub-grade
5. Separator

Should be laid across to side drain - drainage & edge support

Materials:

1. Sandy laterite - CBR > 20
2. Crushed aggregate - CBR > 30
3. Cement stabilised - CBR > 60

Quality tests - CBR, LL, PI, ACV, LAAV, Grading
Road Base

Main load spreading layer
Material - crushed aggregate 50mm to dust
Five types of road base:
1. Dry Bound Macadam (natural interlock)
2. Wet Mix Macadam (water bound)
3. Bituminous bound road base
4. Cement Stabilised (cement bound)
5. Composite
Quality tests - CBR, LL, PI, ACV, FI, Soundness, Grading
Surfacing

Two layers - binder/base and wearing course

Cambered for drainage

Material - crushed aggregate + binder + filler

1. Binder Course:
   Distribute load over road base, provide good shape and regular surface to lay WC
   Example: ACB28, BMB20

2. Wearing Course:
   Provide durable skid-resistance surface, protect pavement, withstand abrasion and traffic stresses, provide good and safe running surface, drainage
   Example: ACW20, BMW14

Quality tests - aggregate, binder, and premix
ROAD PAVING MATERIALS

Consist mainly of aggregate, small amount of binder and filler.

1. Aggregate - carry traffic load, main interlocking structure
2. Binder - bind aggregates producing strong, durable & stable mixture
3. Filler - fill small voids, durable mixture, increase viscosity of binder, reduces binder run-off
Aggregate:
Natural/artificial
3 major classes of rock - **igneous** (alkali/acid), **sedimentary**, **metamorphic** (heat & pressure)
**Types of Aggregate**

Artificial aggregate – *slag* waste from ore to produce iron, steel, nickel, etc.

For road construction, aggregate classified according to size:

1. **Coarse** – (> 2.36mm) crushed aggregate
2. **Fine** – (2.36 – 75 micron) fine crushed aggregate, sand (river, mining)
3. **Filler** – (< 75 micron) fine materials such as cement, lime, crushed aggregate dust

**Mix Gradation** – maximum size, nominal maximum size

Important mix props influenced by gradation

Typical gradations – Dense/well, gap, open, uniform
Aggregate Properties

Important properties of aggregates are:

1. **Strength** - crushing, impact, during construction & traffic load
2. **Durability** - resistance to disintegration under weathering
3. **Shape & surface texture** - interlocking, resistance to sliding, affect strength
4. **Deleterious substance** - affect bond, break up during mixing
5. **Affinity** - properly coated by binder
6. **Relative density & absorption** - stripping, drying time, mix design
7. **Resistance to wear (hardness)** - rounded under traffic, skid resistance
8. **Gradation** - quality & pavement strength
Aggregate Tests

Tests to evaluate aggregates properties:

- **ACV/TFV** - resistance to crushing under gradually applied compressive load
- **AIV** - resistance to sudden shock or impact
- **LAAV** - degradation under combination of abrasion or attrition, impact, and grinding
- **Soundness** - resistance to disintegration due to cycle of wetting and drying, heating and cooling (weathering)
- **Flakiness/Elongation Index** - shape tests
- **SG & WA** - relative density, pores, and absorption
- **Coating & Stripping** - stripping susceptibility
- **PSV** - WC, resistance to polishing of a pneumatic tyre
- **Sieve** - particle size distribution
Bitumen

Two types of binder - (interchangeably due to misconception, diff. origin, chem. composition, physical characteristics.)

Bitumen - viscous liquid/solid, black or brown in color, having adhesive qualities, consisting essentially of hydrocarbons, derived from petroleum or occurring naturally and soluble in carbon disulphate (80-85% C, 10% H)

Tar - black-brown, adhesive quality, a product of coal (insoluble in petroleum, high temperature susceptibility, heavier, health hazards, distinct odor)
Bitumen used in paving include:

**Natural/rock** - in geological strata, (lake - soft, rock pores - hard)

**Petroleum** - products of distillation of crude oil (most commonly used bituminous paving materials today)

Oldest engineering material - shipbuilding, mortar for building and bricks, waterproofing, mumification

Earliest pavement in US - Pennsylvania Ave 1876, Trinidad lake asphalt
Types of Bitumen

In Malaysia use bitumen/asphalt from crude oil distillation.

Four types of asphalt, only three used in paving works:

1. Asphalt Cement – residual or straight-run
2. Cutback Asphalt – blended with solvent
3. Asphalt Emulsion – mixed with water and emulsifying agent
4. Blown Asphalt (oxidized) – hot air
5. Foamed??
Bitumen Grading System

• Three grading systems:
  1. *Penetration Graded* – uses the penetration of the original AC.
     Tests involved: penetration, softening point, flash point, ductility, solubility, TFOT (penetration & ductility)
  2. *Viscosity Graded* – based on viscosities of original and aged AC.
     Tests involved: viscosities, penetration, flash point, solubility, TFOT (viscosity, ductility)
     Tests involved: RV, DSR, BBR, DTT, RTFO, PAV
Problem with PEN system??

Temperature susceptibility

Temperature

25°C (77°F)

Temperature

High

Medium

Low
Mixing/Compaction Temps

- **Viscosity, Pa s**
  - 10
  - 5
  - 1
  - 0.5
  - 0.3
  - 0.2
  - 0.1

- **Temperature, C**
  - 100
  - 110
  - 120
  - 130
  - 140
  - 150
  - 160
  - 170
  - 180
  - 190
  - 200

- **Compaction Range 2.8 ± 0.3**
- **Mixing Range 1.7 ± 0.2**
Bitumen Tests

Tests to determine bitumen quality:

- **Penetration** - consistency test, hardness
- **Softening Point** - consistency, temp at which phase change occurs
- **Ductility** - elongation before breaking
- **Flash Point** - safety, max safe operating temp
- **Viscosity** - consistency test, resistance to flow
- **Loss on heating-volatility**
- **TFOT** - short term aging
- **Solubility** - purity (trichloroethylene)
PG Specifications

- Fundamental properties related to pavement performance
- Environmental factors
- In-service & construction temperatures
- Short and long term aging
PG Specifications

• Based on rheological testing
  – Rheology: study of flow and deformation
• Asphalt cement is a viscoelastic material
• Behavior depends on:
  – Temperature
  – Time of loading
  – Aging (properties change with time)
Superpave Asphalt Binder Specification

The grading system is based on Climate

PG 64 - 22

Performance Grade

Min pavement temperature

Average 7-day max pavement temperature

Note: example Malaysian specification use PG 76
Petroleum Distillation

- Gasoline
- Kerosene
- Lt. Gas Oil
- Diesel
- Motor Oils
- Asphalt

FIGURE 15-8 Simplified flow chart of recovery and refining of petroleum asphalts. (Courtesy The Asphalt Institute)
Asphalt Cements

- At ambient temp., black, sticky, semisolid and highly viscous
- Strong and durable cement with excellent adhesive and waterproofing characteristics
- Highly resistant to action of most acids, alkalis and salts
- Largest use – production of Hot Mix Asphalt
- Can readily be liquefied by applying heat for mixing with aggregate to produce HMA, after cooling will become very strong paving material and able to sustain heavy traffic loads
- Classified true penetration or viscosity test, Superpave PG?
- Grade according to Penetration 40 to 300, Viscosity 5 to 40.
Cutback Asphalts

Liquid asphalt manufactured by adding (cutting back) petroleum solvent to asphalt cement (50-80%) This will reduce the viscosity for lower application temperatures.

Application to aggregate or pavement causes solvent to evaporate, leaving residue on the surface.

Divided into three types according to rate of curing:

- RC – gasoline
- MC - kerosene
- SC - diesel
Emulsified Asphalt (Emulsion)

Mixture of bitumen (55 - 65%), water and emulsifying agent passed under pressure through a colloid mill

Emulsions are made to reduce the viscosity for lower application temperatures

Two most commonly used emulsions:

i. Anionic – electro negatively charges asphalt droplets. Compatible with positive charge aggregate such as limestone.

ii. Cationic – electro positively charges asphalt droplets. Compatible with negative charge aggregates (most siliceous aggregates) such as sandstone, quartz, gravel
Emulsion

When mixed or sprayed, it sets or breaks because asphalt droplets react with the surface of aggregate and squeezing out the water between them.

Evaporation of water – primary mechanism for anionic breakup

Electrochemical process - primary mechanism for cationic

Further graded according to setting rate – RS, MS, SS

Setting rate is controlled by the type and amount of the emulsifying agent.

Emulsion are increasingly being used in lieu of cutback due to:

1. Environmental regulations
2. Waste of high energy products
3. Safety
4. Lower application temperature
REFERENCES

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