HIGHWAY ENGINEERING
SAB2832

HIGHWAY MATERIALS

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HIGHWAY MATERIALS

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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 18th century:

Robert Phillips – pioneer, suggest a layer of gravel resting on weel-drained base >> beaten by traffic into solid road surface

Tresaguet – cambered formation, differential settlement problem

John Metcalf – Blind Jack, built 290 km ++

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

John Macadam – true highway engineering specialist, surveyor, cambered formation, other layers even thickness, use angular aggregats, cheaper and easier

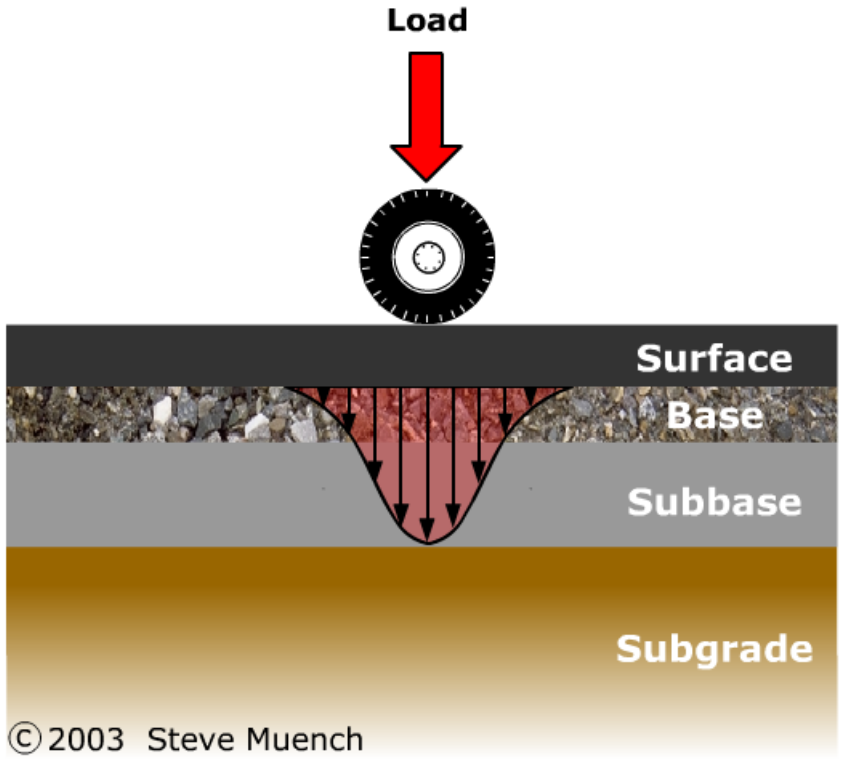
INTRODUCTION

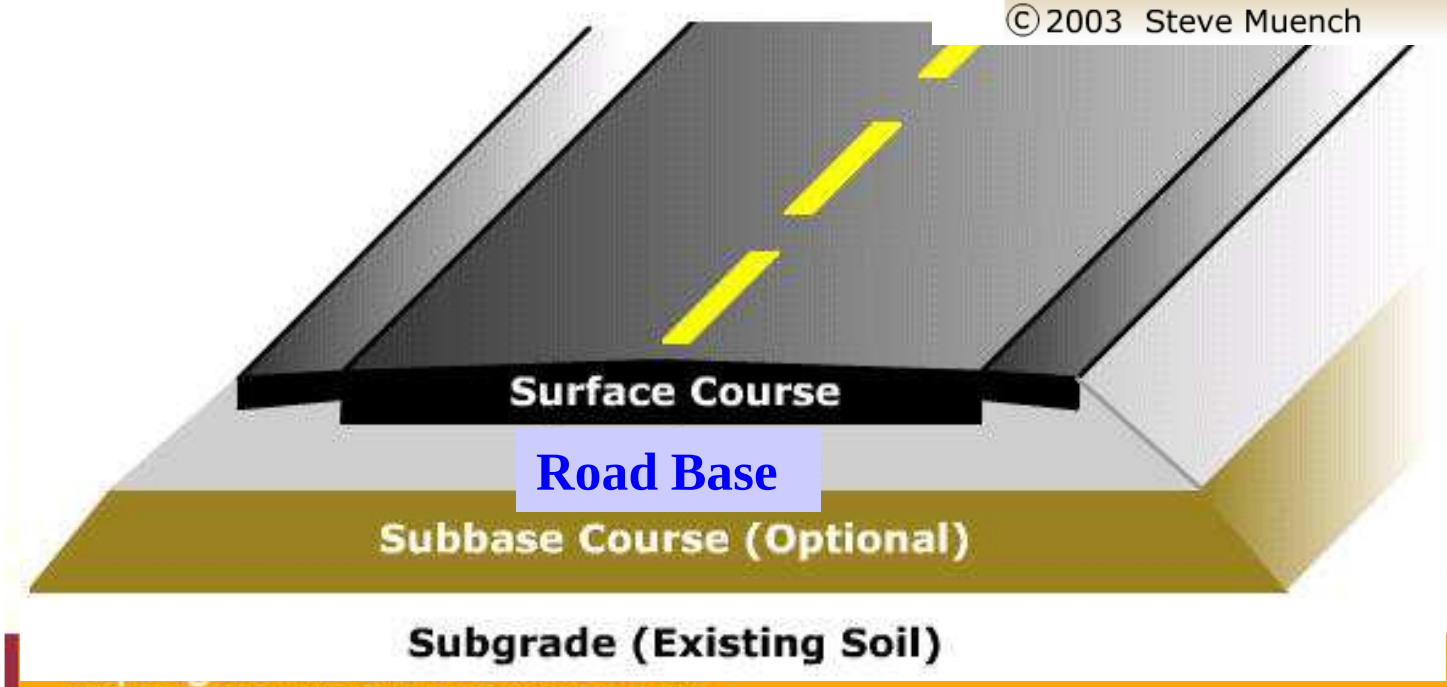
Types of road surface:

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

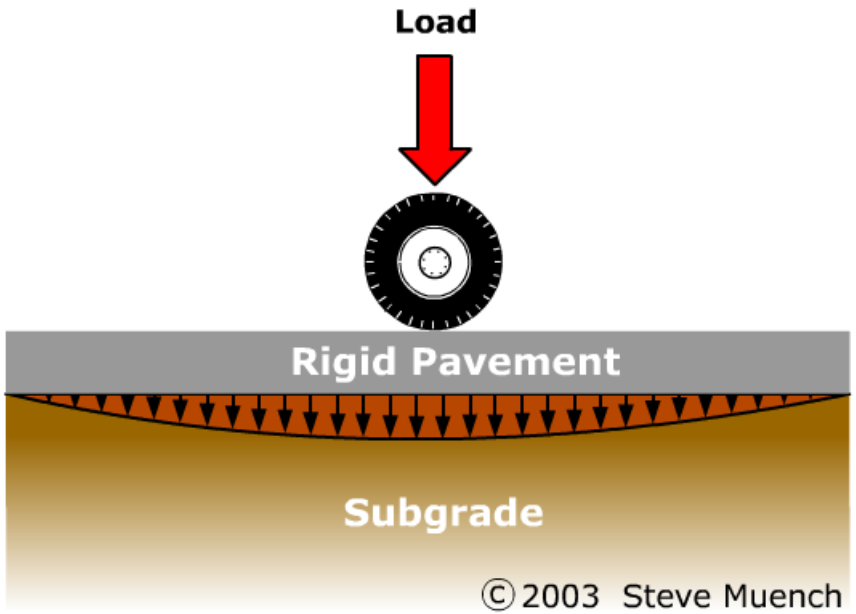
New technologies?? (material and gradation)

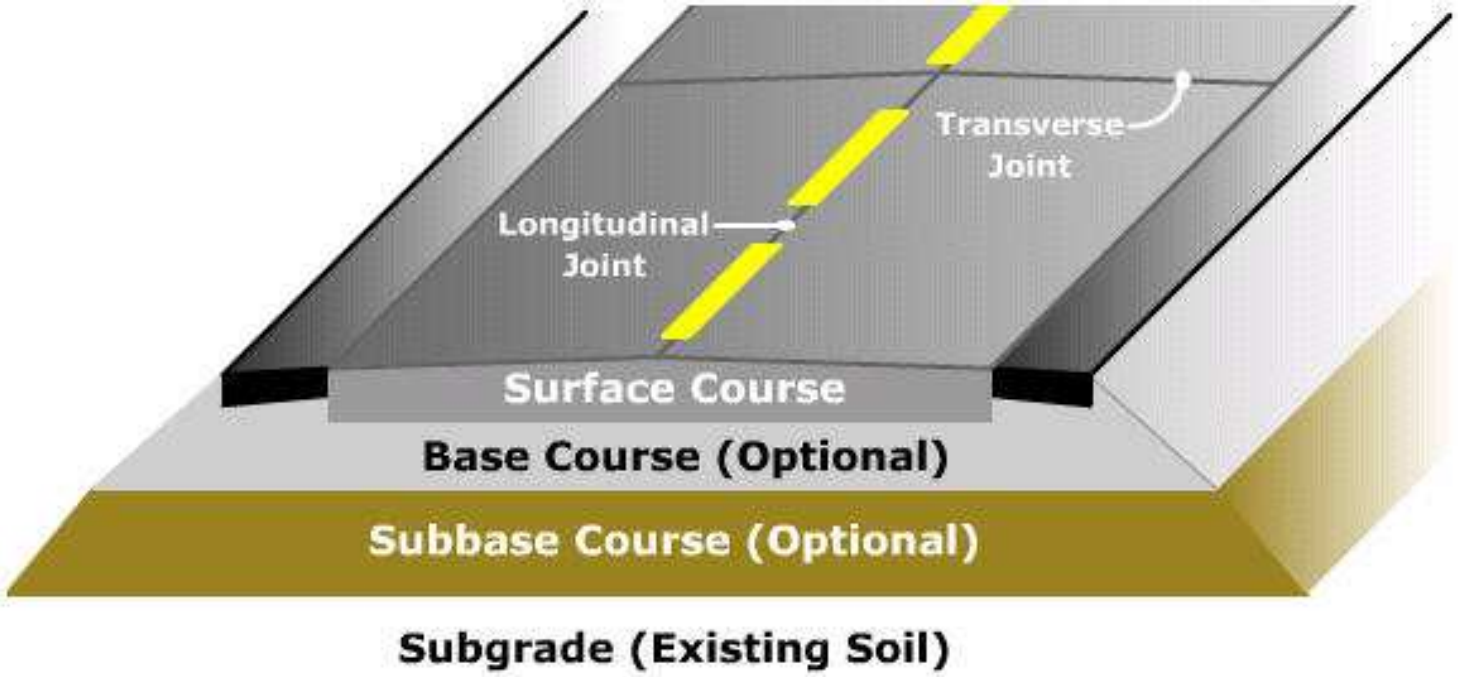
Flexible Pavement (dense, open, gap graded)



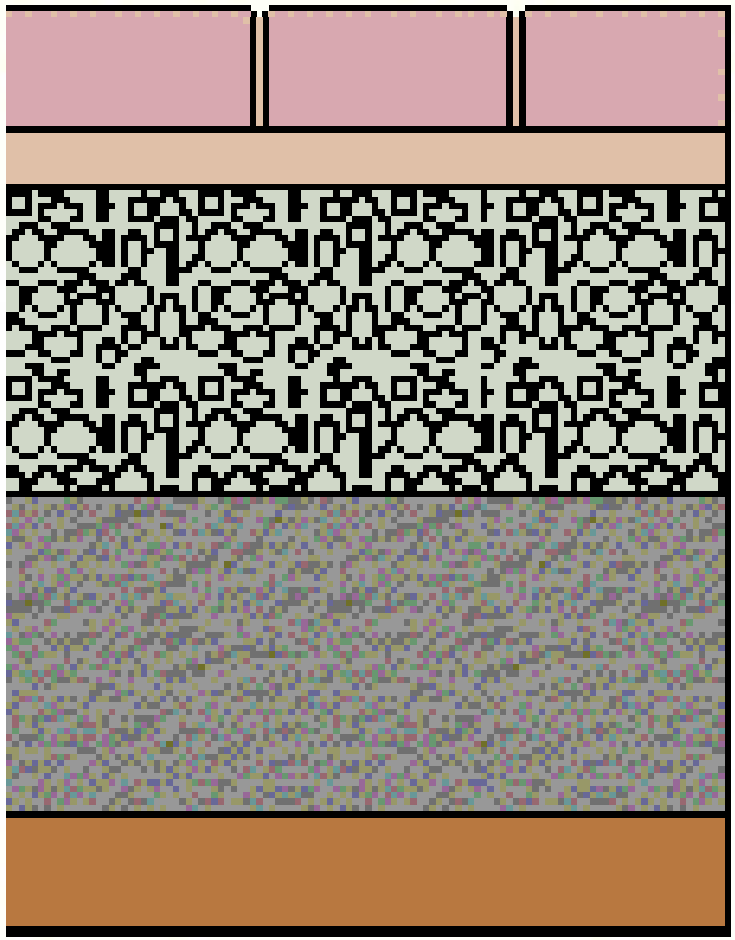


Concrete Pavement (Rigid)





Interlocking Block



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 hierachy i.e. R1/U1 to R6/U6 according to traffic, speed/geometric design, and access control

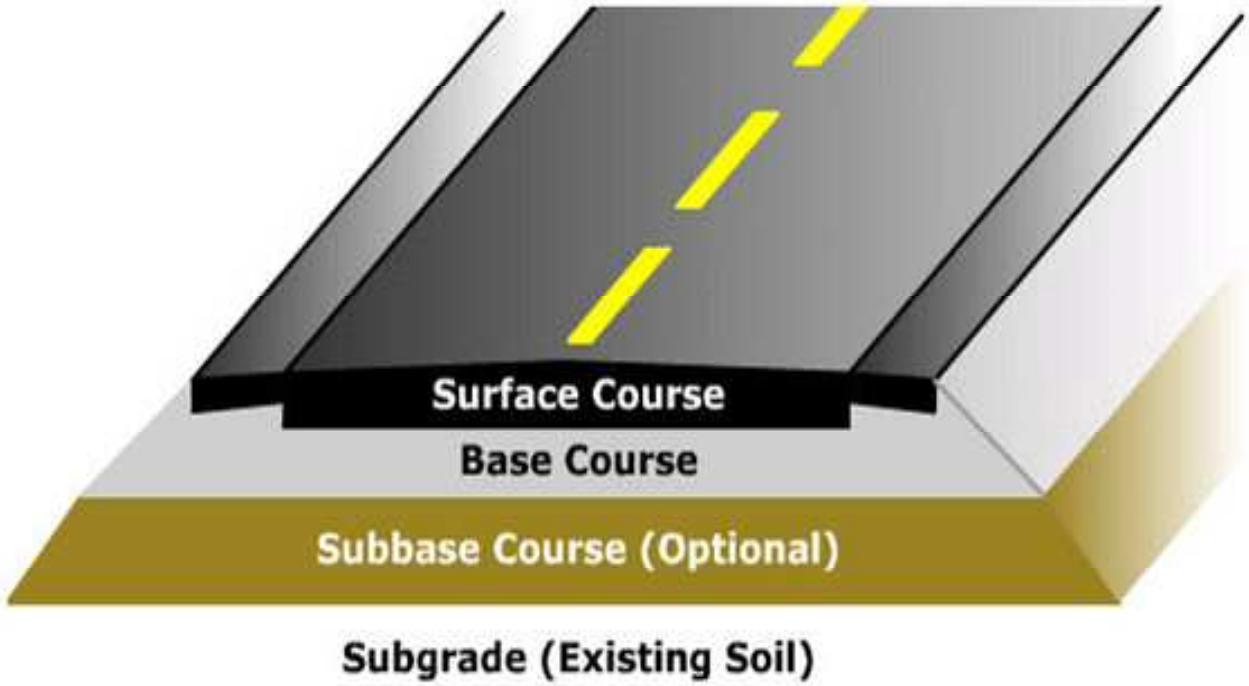
TABLE R/U

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 classfied as unsuitable

Sub-grade (cont…)

Properties of good sub-grade:

- Stable
- Consistent strength
- Able to drain away water

Factors affecting soil strength:

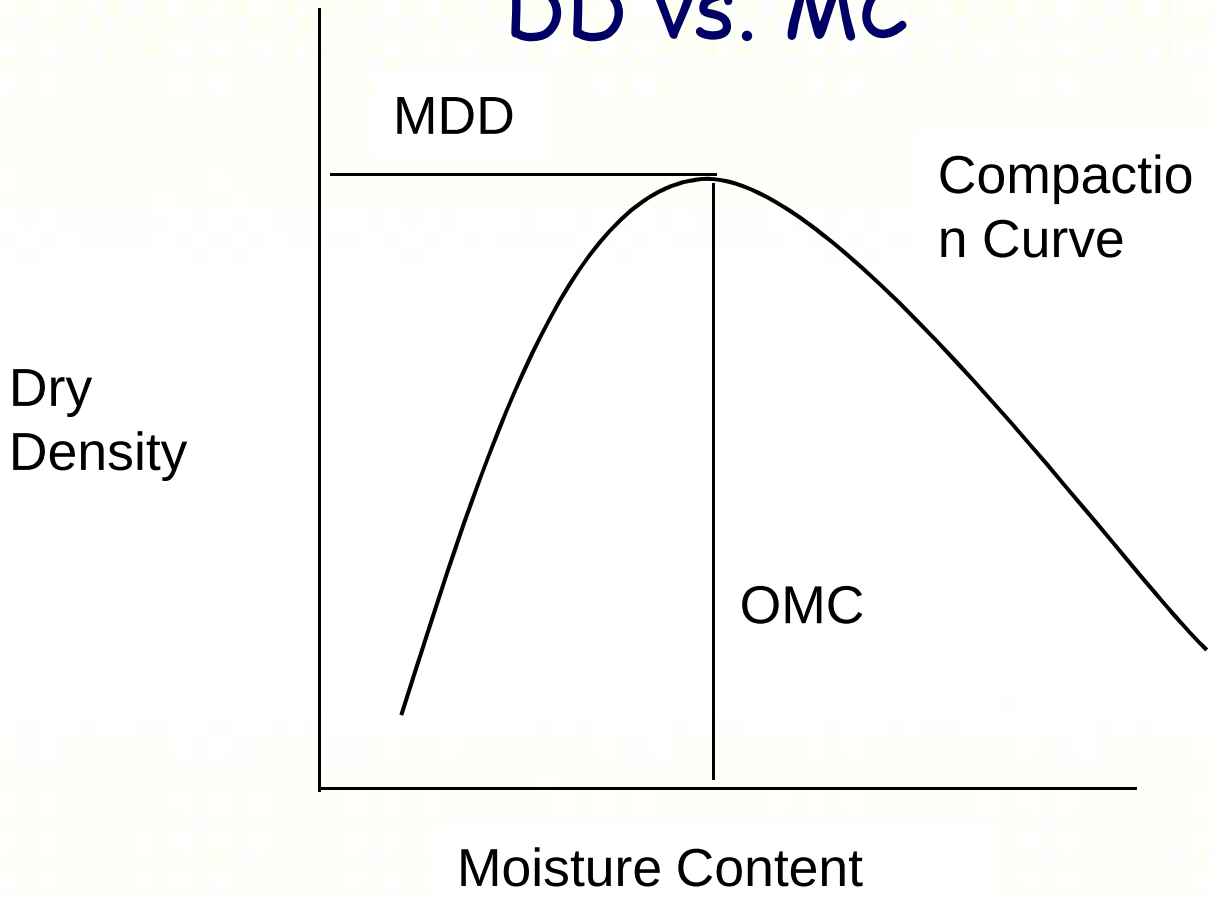
- Soil type
- Moisture content
- Method and compactive effort

Tests on soil for sub-grade:

- LOI, LL and PL
- Compaction
- CBR

Compaction

DD vs. MC



CBR

Purpose – determine bearing capacity of material against standard crushed aggregate

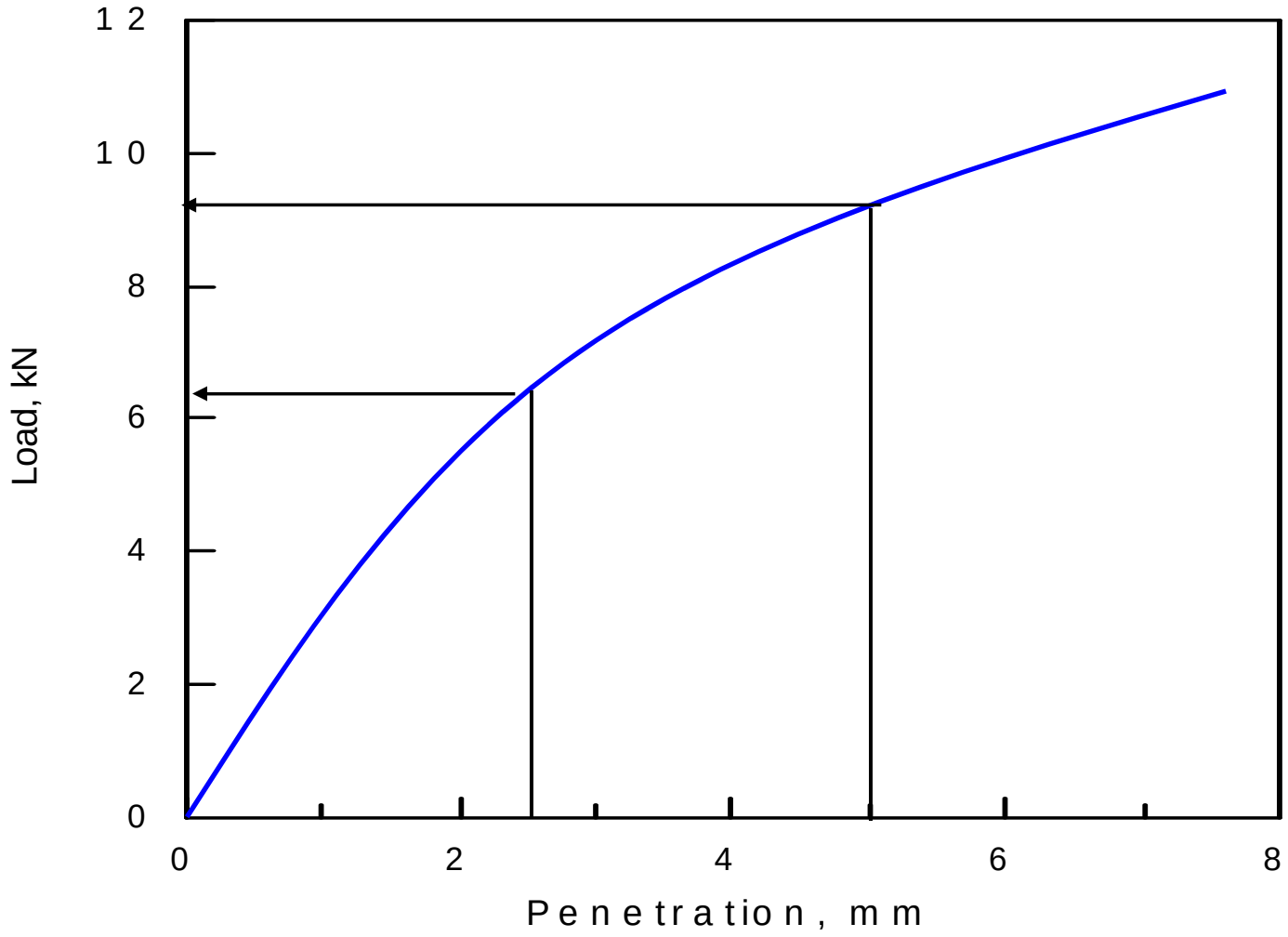
Two major processes – compaction test (determine MDD and OMC), and CBR test (determine CBR at 95% compaction)

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

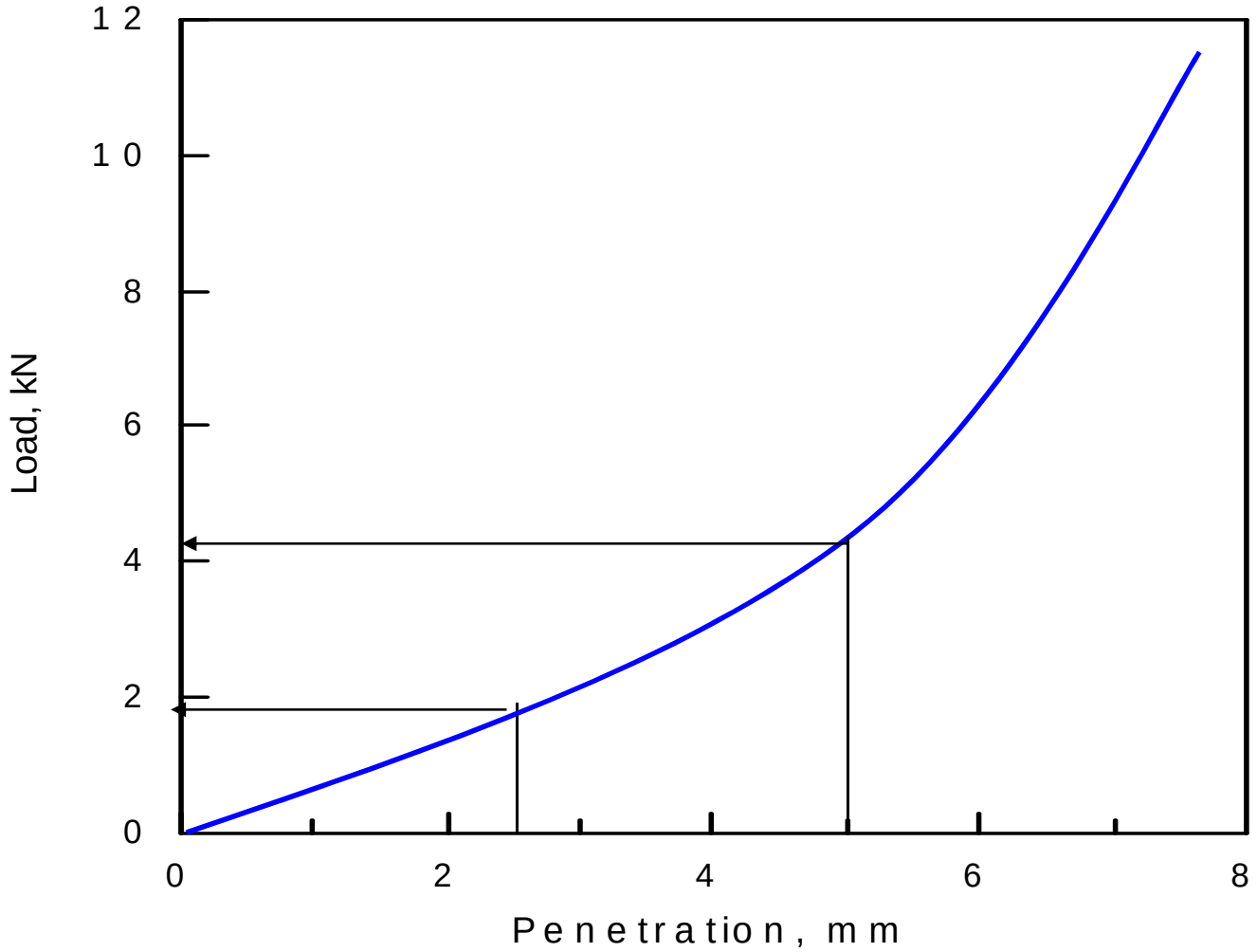
CBR: 3 mold at OMC, vary no. of blows to obtain 95% compaction, calculate DD, soak, drain, CBR test, plot Load vs. Penetration graph, calculate CBR at 2.5 and 5.0mm

CBR Testing

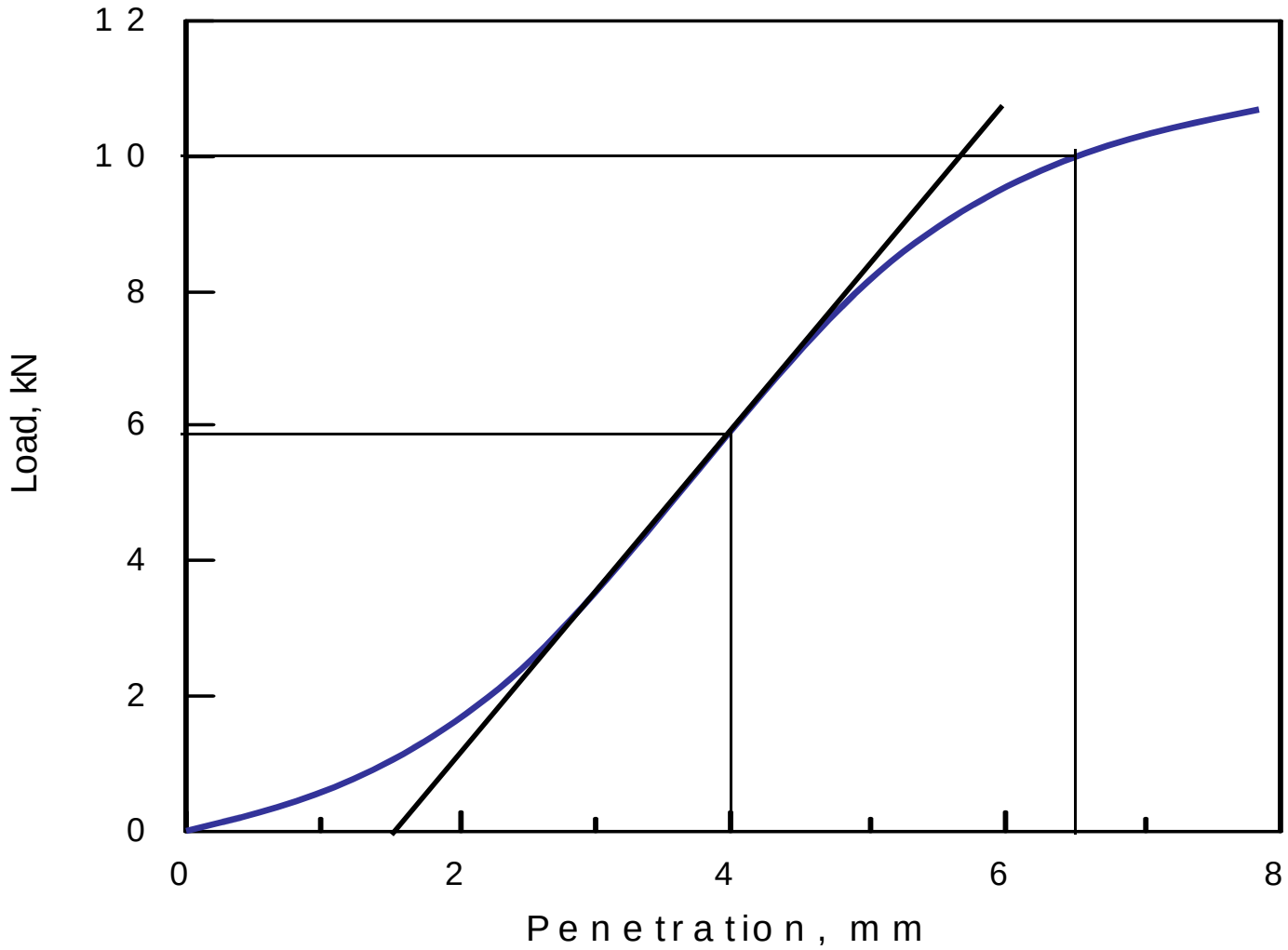
CBR 1



CBR 2



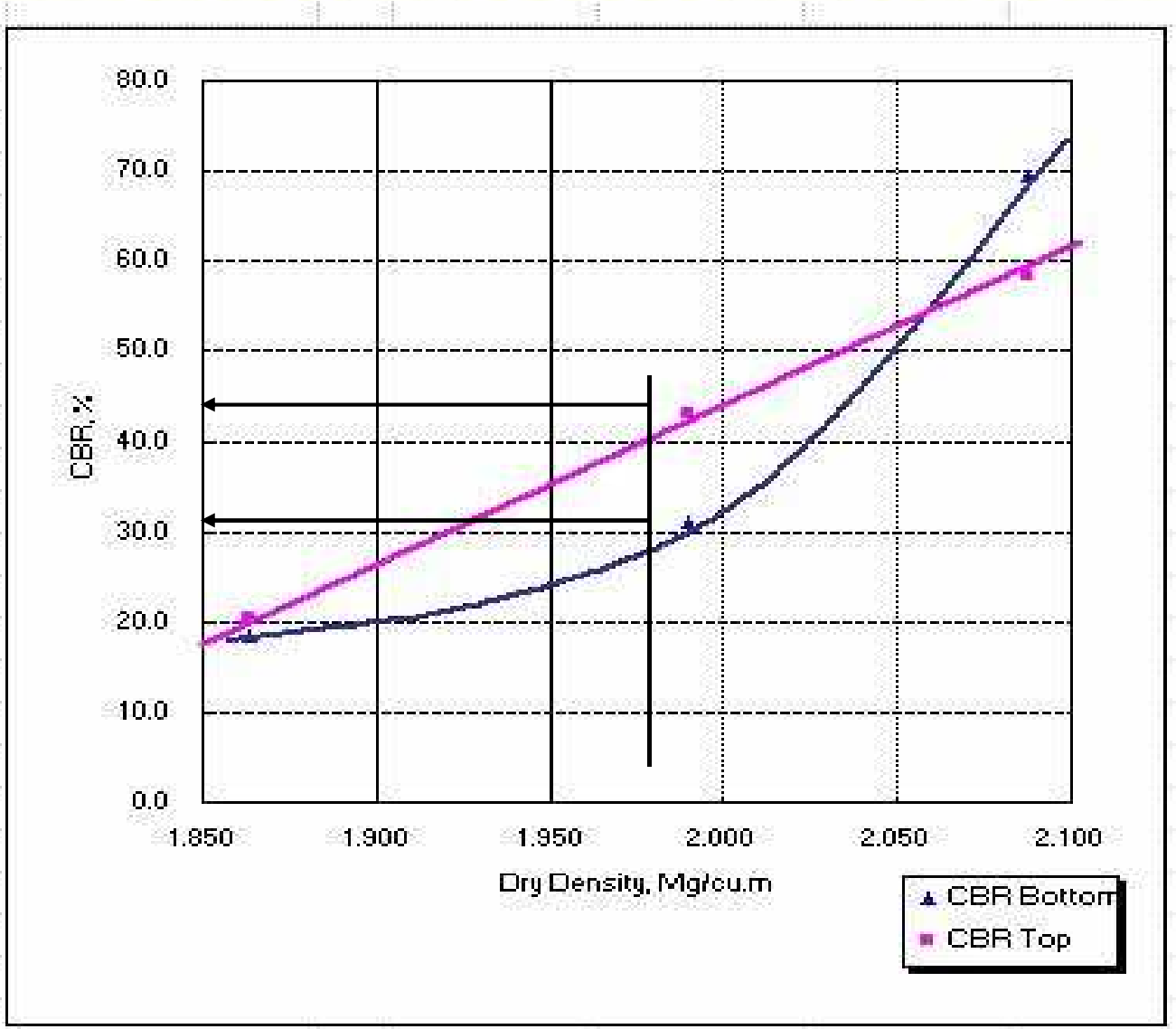
CBR 3



CBR vs. DD Data

Number of Blows		15	35	65
Dry density, g/cu.m	Mg/cu.m	1.864	1.989	2.088
CBR Top	%	20.4	43.1	58.2
CBR Bottom	%	18.5	31.1	69.5

CBR vs. DD


80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
CBR, %
1.850
1.900
1.950
2.000
2.050
2.100
Dry Density, Mg/cu.m
CBR Bottom
CBR Top

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.

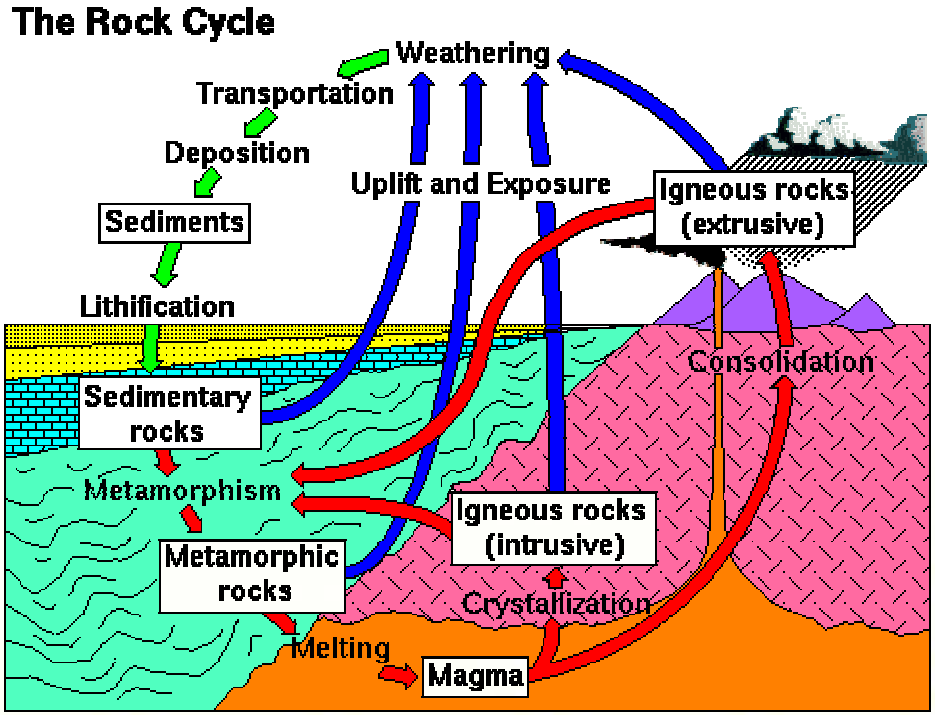
1. Aggregate – carry traffic load, main interlocking structure
2. Binder – bind aggregates producing strong, durable & stable mixture
3. Filler – fill small voids, durable mixture, increase viscosity of binder, reduces binder run-off

Aggregate

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 essestially of hydrocarbons, derived from petroleum or occuring 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 (cont…)

Bitumen used in paving include:

- Natural/rock – in geological strata, (lake - soft, rock pores - hard)
- Petrolium – 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.

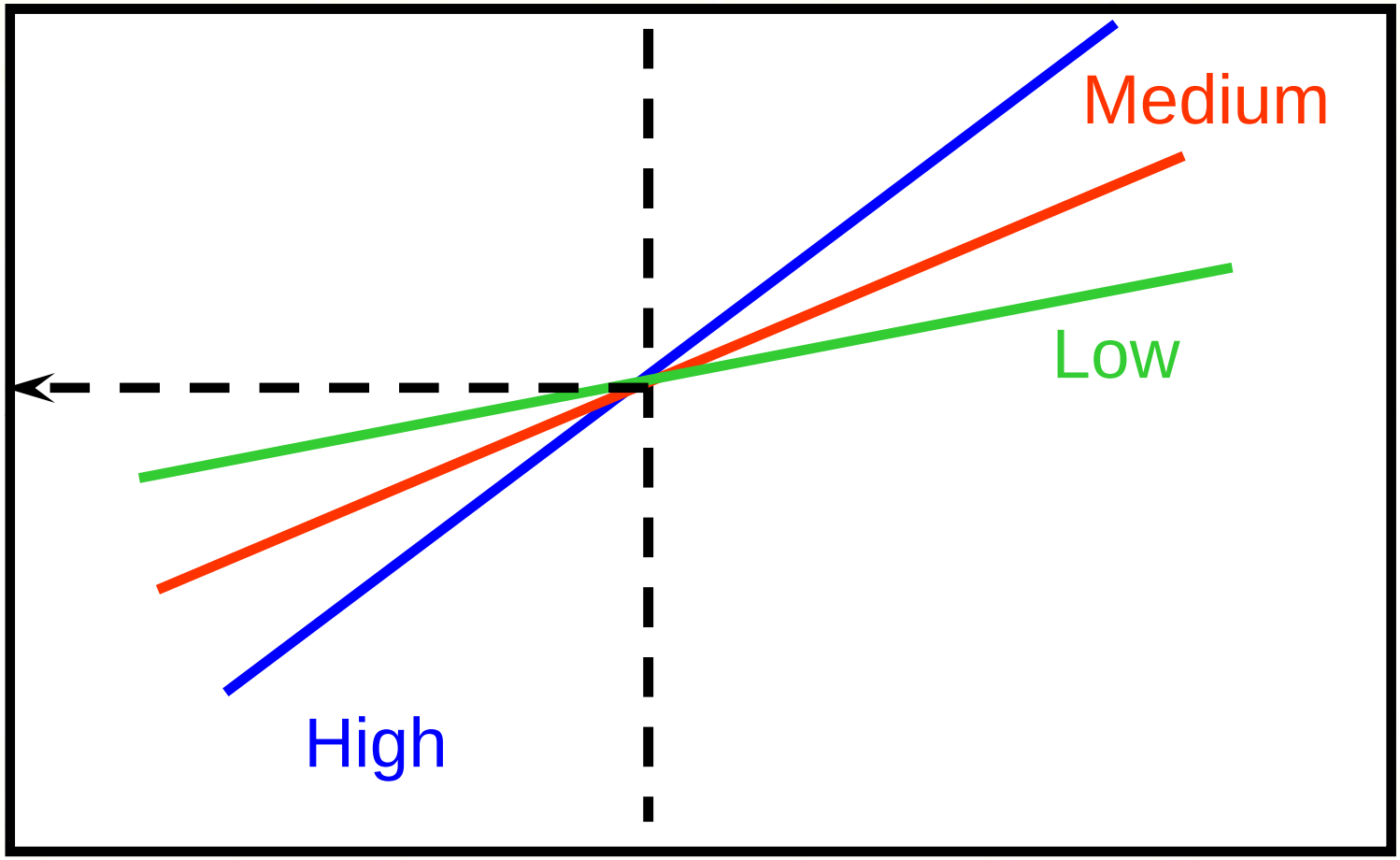
     Tests involved: penetration, softening point, flash point, ductility, solubility, TFOT (penetration & ductility)
  2. *Viscosity Graded* – based on viscosities of original and aged AC.

     Tests involved: viscosities, penetration, flash point, solubility, TFOT (viscosity, ductility)
  3. *Performance Graded* – Binder specification based on extreme hot and cold pavement temperature.

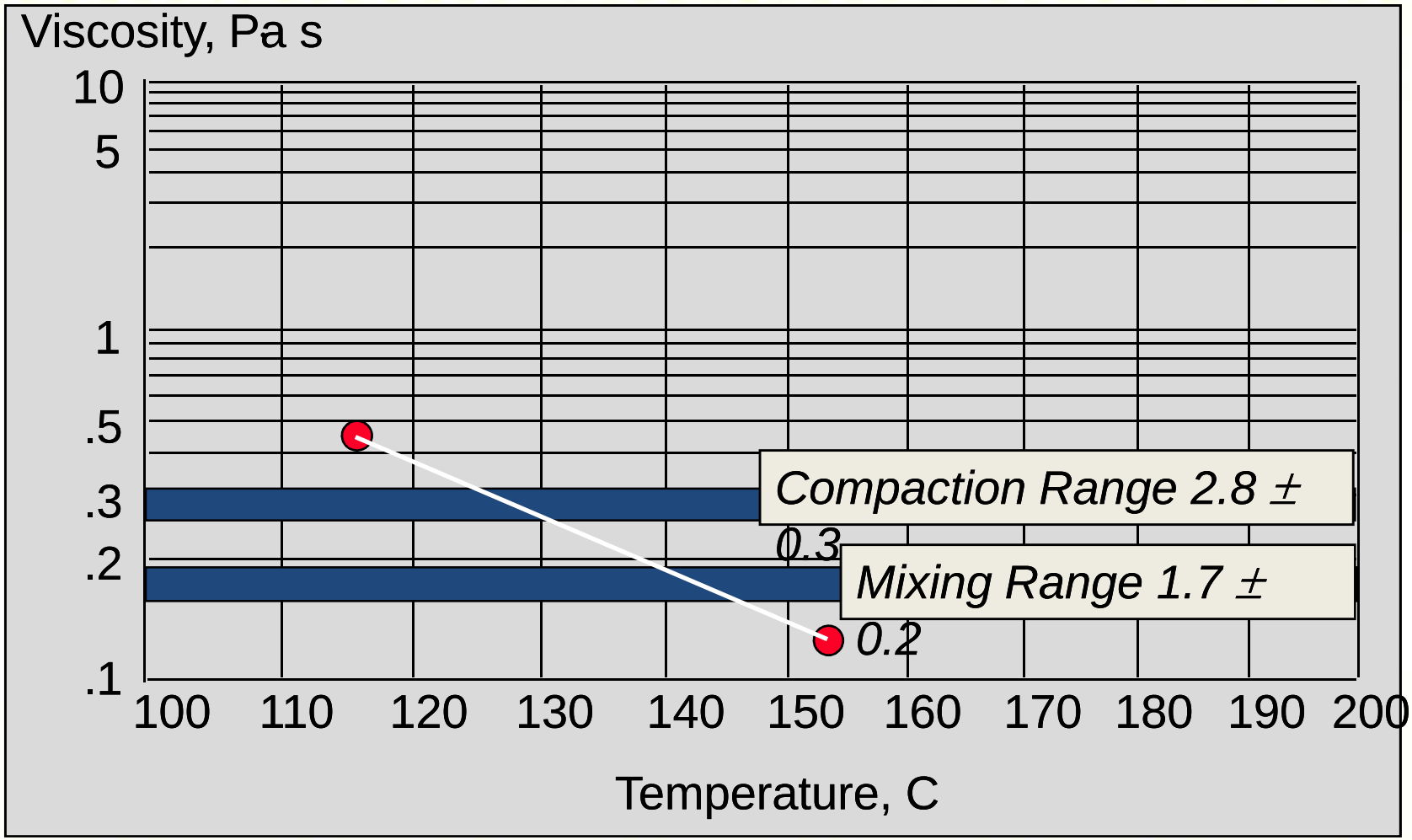
     Tests involved: RV, DSR, BBR, DTT, RTFO, PAV

Problem with PEN system??

Temperature susceptibility



Mixing/Compaction Temps



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

Average 7-day max pavement temperature

Min pavement temperature

Note: example Malaysian specification use PG 76

Petroleum Distillation

Gasoline
Kerosene

Lt. Gas Oil
Diesel
Motor Oils

Asphalt

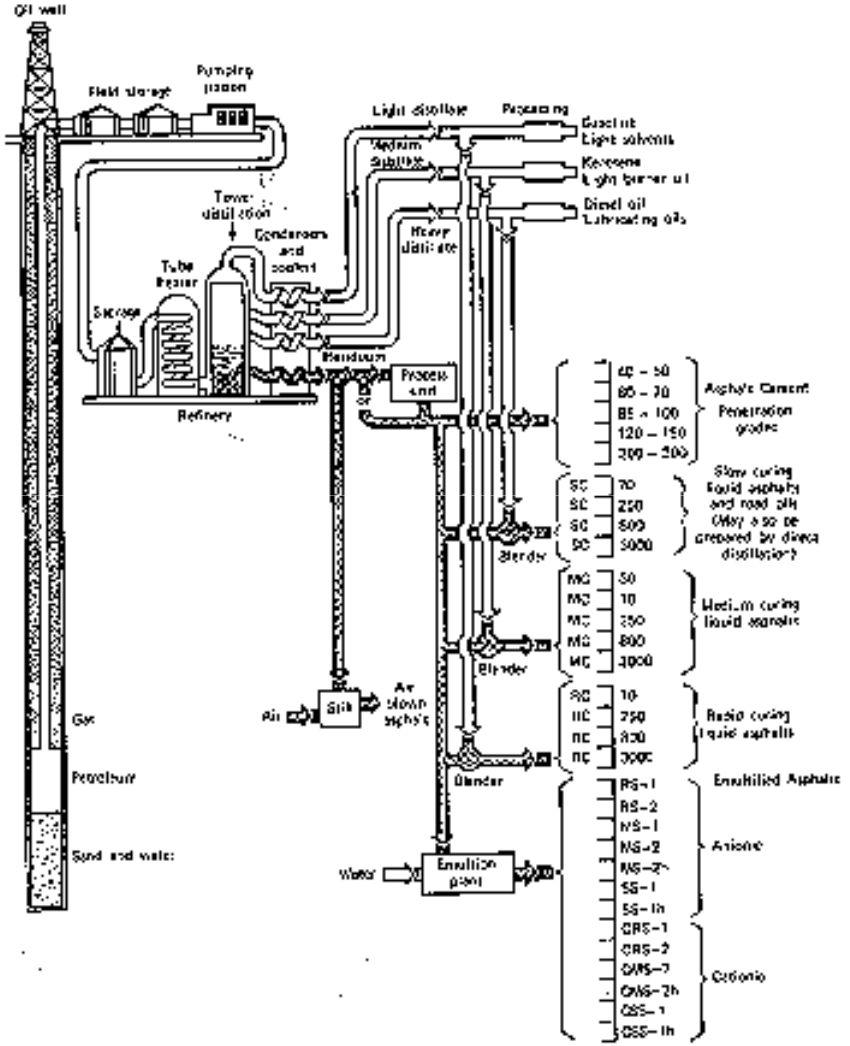


FIGURE 15-8 Simplified flow chart of recovery and refining of petroleum asphalts. (Courtesy The Asphalt Institute.)

Asphalt Cements

- At ambient temp., black, sticky, semisolid and highly viscous
- Strong and durable cement with excellent adhesive and waterproofing characterisrics
- Highly resistant to action of most acids, alkalies 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 becomes very strong paving material and able to sustain heavy traffic loads
- Classified tru 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 tru 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 reacts 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

1. Roadwork Theory and Practice, Wignall. 1991
2. HMA Materials, Mixture Design and Construction, Roberts et. al., 1991.
3. MS, BS, ASTM, AASHTO
4. Highway Engineering, Wright, 1996
5. Traffic and Highway Engineering, Garber & Hoel, 1988.
6. Pengenalan Pembinaan Jalan Raya Berbitumen, Rehan, 1991
7. Washington Asphalt web page