THE UNIVERISTY OF ZAMBIA

School of Engineering

Department of Civil and Environmental Engineering

CEE 3111 - CIVIL ENGINEERING MATERIALS AND CONSTRUCTION PRACTICES

2023 ACADEMIC YEAR

SEMESTER 1

TOPIC 6

Bituminous Materials material Part 1

General Introduction

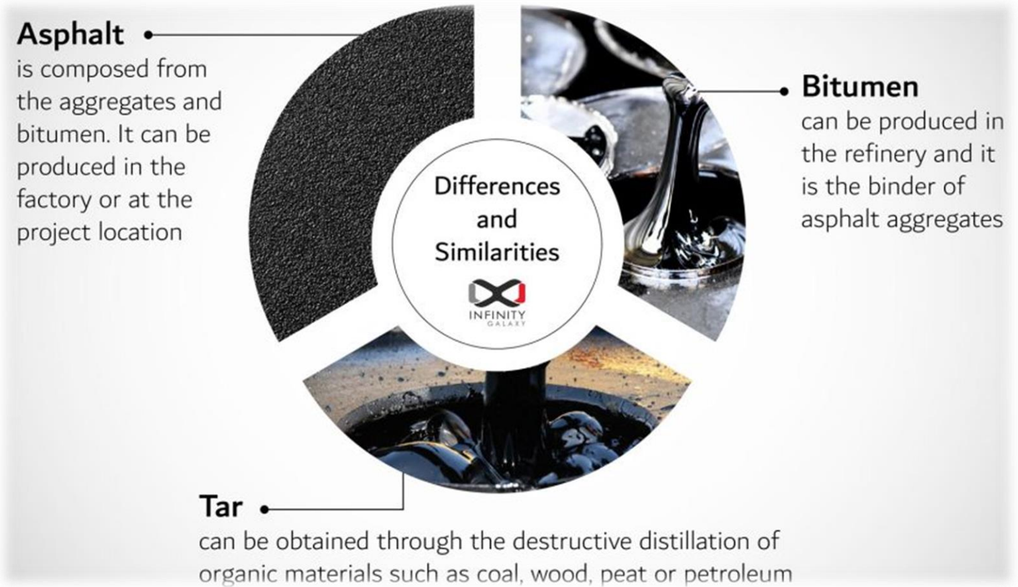
- Bituminous materials are classified as:
  - ✓ Asphalts and
  - ✓ Tars

- Asphalt cement came from natural deposits and refineries

- Presently, practically all asphalt cement is from refined petroleum

- Used mostly in pavement construction, but is also used as sealing and waterproofing agents

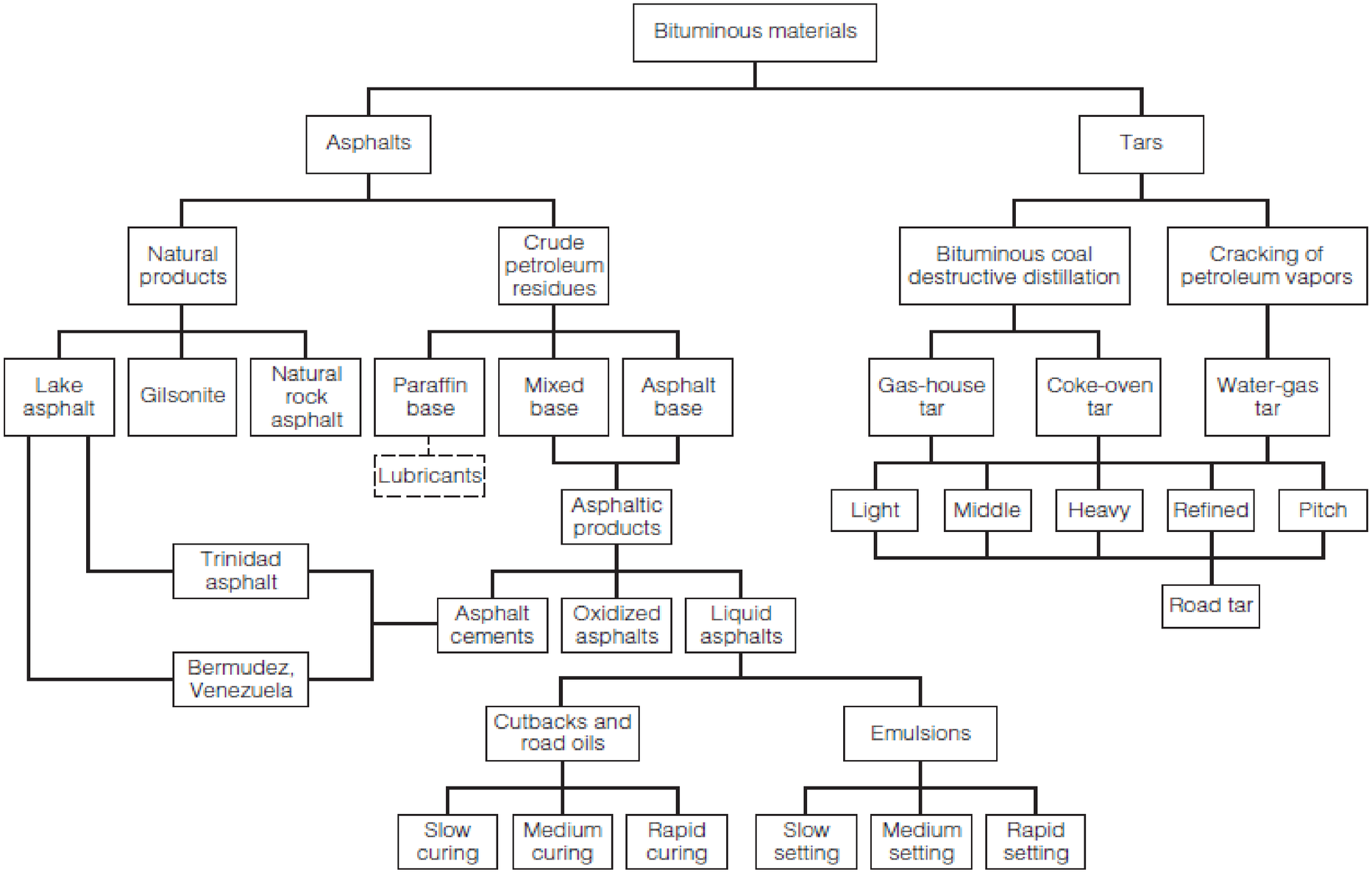
- Tars are generated by destructive distilling bituminous coal or breaking petroleum vapors.



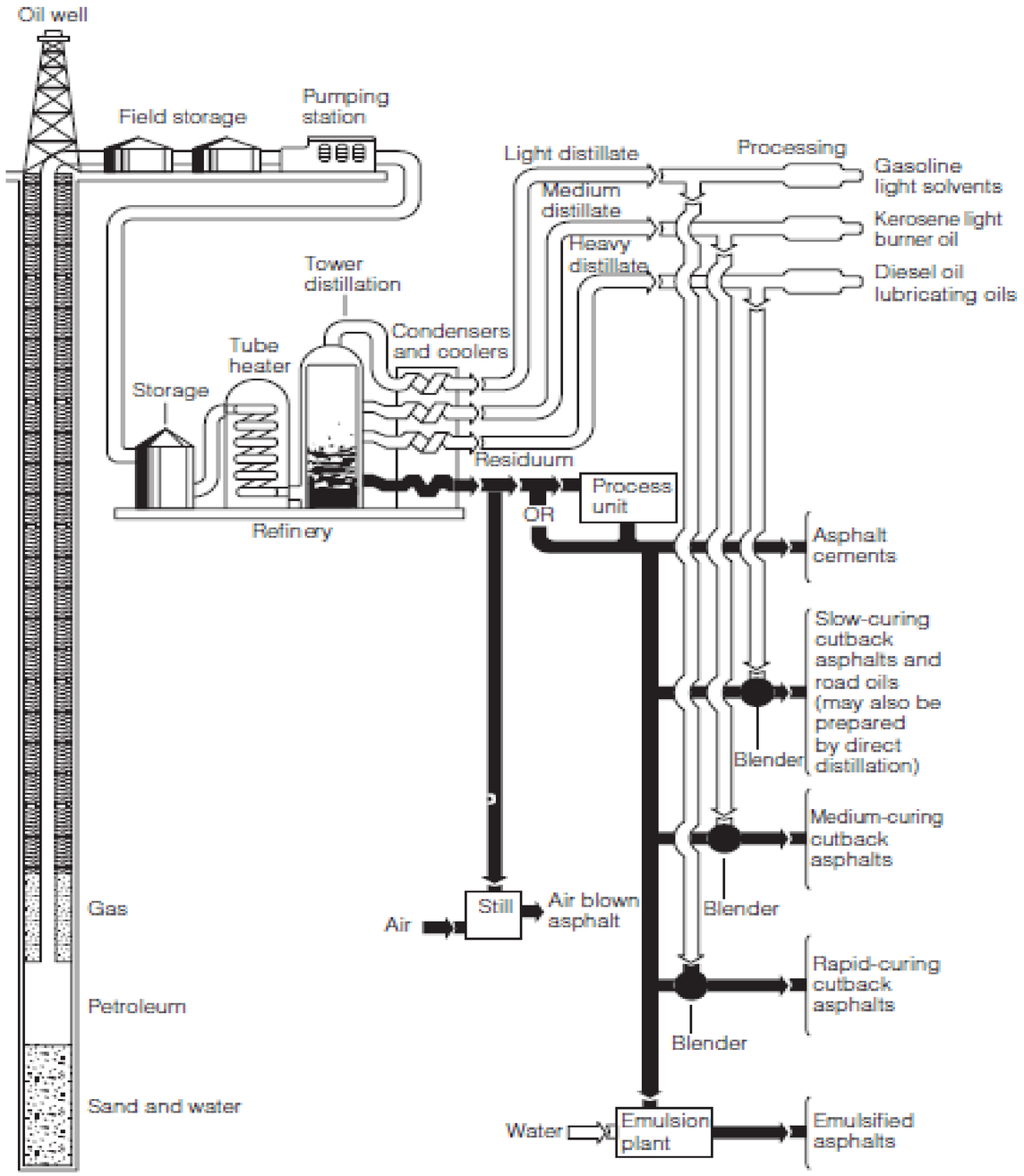
General Introduction

- Tar is mostly used for roof waterproofing.
- Can also be used to treat pavements, especially where fuel spills can degrade asphalt cement, like parking lots and airport aprons.
- Asphalt is less valuable than other crude oil products, thus refineries create more valuable fuels at the expense of asphalt.

Classification of Bituminous Materials



Distillation of Crude Petroleum

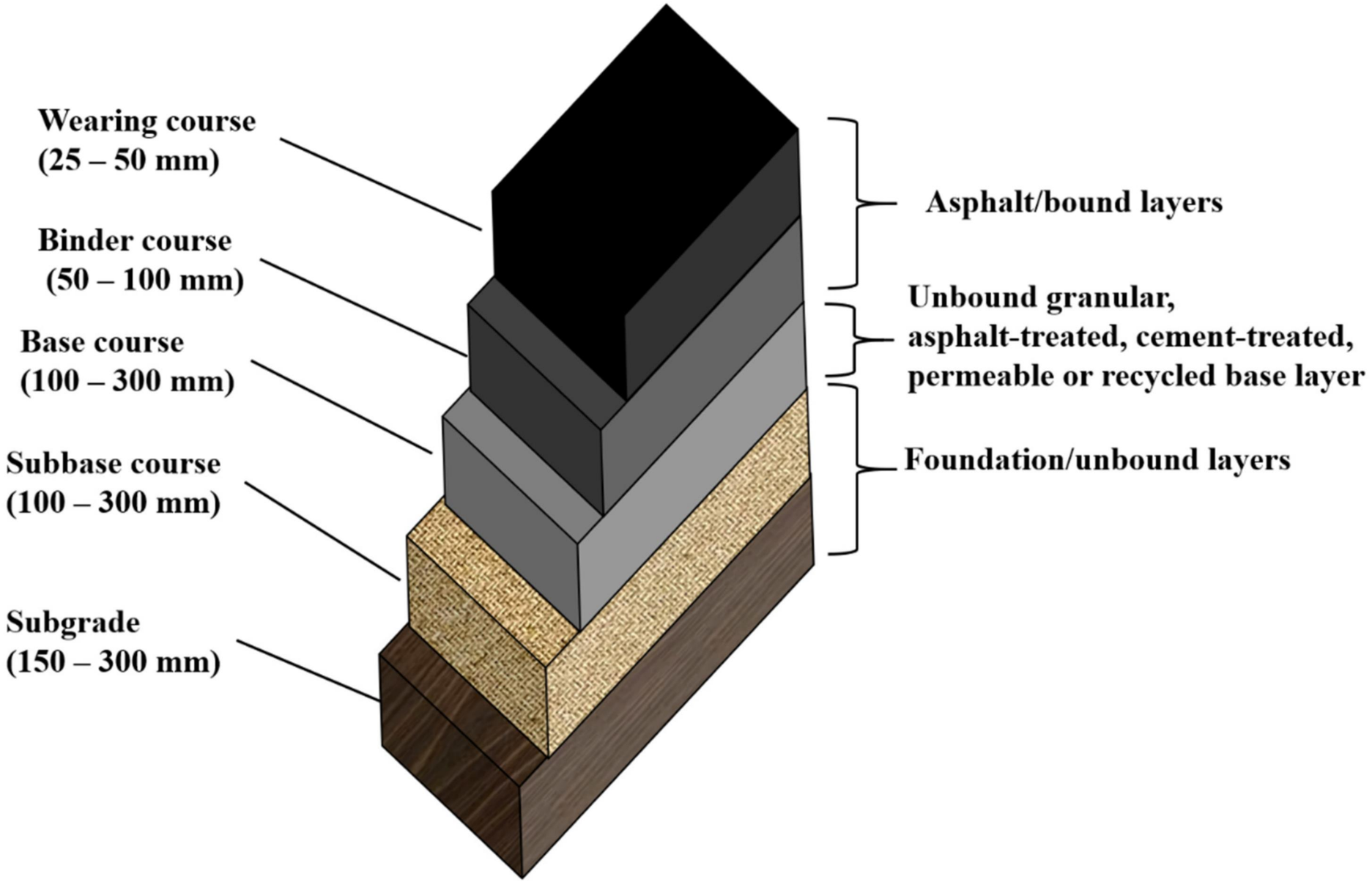


Types of Asphalt Products

- Pavement asphalt comes in three kinds.:
  - ✓ Asphalt cement,
  - ✓ Asphalt cutback, and
  - ✓ Asphalt emulsion

Asphalt cement

- Contains various hydrocarbon molecular weights.
- Semisolid at room temperature and cannot be used as a binder without heating.
- Softest asphalts used in road construction have penetration values of 200-300, while the toughest have penetration values of 60-70.
- Asphalt cement is a great binder for pavement, but it hardens and loses adhesion to aggregates when overheated or aged.


Wearing course
(25 – 50 mm)
Binder course
(50 – 100 mm)
Base course
(100 – 300 mm)
Subbase course
(100 – 300 mm)
Subgrade
(150 – 300 mm)
Asphalt/bound layers
Unbound granular,
asphalt-treated, cement-treated,
permeable or recycled base layer
Foundation/unbound layers

Types of Asphalt Products

Emulsified Asphalts

- Emulsified asphalts are liquid at room temperature.
- Designed for non-heating use.
- They are a suspension of tiny asphalt globules (60-70%) in water (30-40%) with a soap-like emulsifier (about 1%).
- Asphalt viscosity is reduced by emulsifiers, which are brown liquids.
- When water evaporates, asphalt cement sticks to aggregates.

Cutback Asphalts

- Similar to emulsified asphalts, cutbacks are liquid asphalt products at room temperature (mixed with diluent (thinning agent) that liquifies the asphalt.

Types of Asphalt Products

- Depending on the rate of curing, cutbacks can be classified as:
  - ✓ Slow-Curing (SC),
  - ✓ Medium-Curing (MC), or
  - ✓ Rapid-Curing (RC) Cutback Asphalts.

- These cutbacks are usually designated as SC-70, MC-30, or RC-70 where the number relates to the approximate Kinematic viscosity in centistokes at 60°C

- The fluidity of MC cutbacks depends on the amount of solvent in the material

- MC cutback asphalts can be used in the construction of pavement bases, surfaces, and surface treatments

Types of Asphalt Products

- Liquid asphalts are convenient.
- In the past, cutbacks were widely used for highway construction. They were effective and could be applied easily in the field.
- However, they cannot produce a quality of asphalt concrete comparable to what can be produced by heating neat asphalt cement and mixing it with carefully selected aggregates.
- Although emulsions and cutbacks can be used for the same applications, the use of emulsions is increasing because they do not include hazardous and costly solvents.

Types of Asphalt Products

- The three main disadvantages of cutback asphalts include the following:

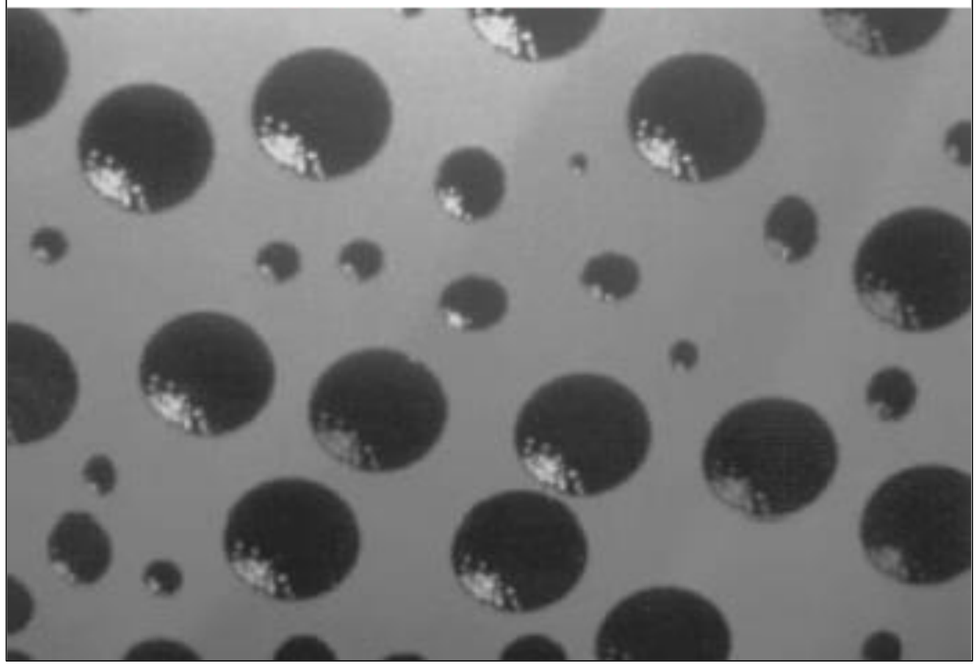
  i. Emulsified asphalts—dispensing asphalt in water—are a cheaper alternative to dissolving asphalt in expensive solvents due to rising petroleum prices.

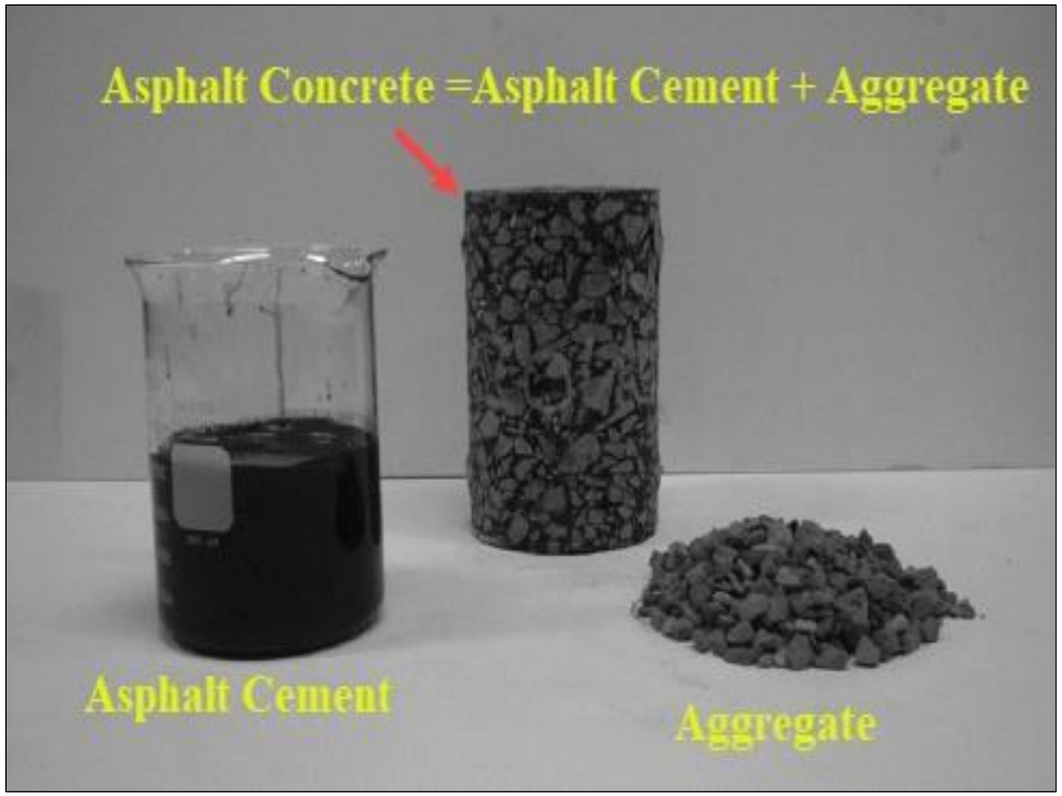
  ii. Second, solvent volatility makes cuts dangerous.

  iii. Cutbacks release harmful hydrocarbons into the atmosphere.

Types of Asphalt Products

Emulsified Asphalt
=Asphalt cement dispersed in water medium





Properties of Asphalt Materials

Four asphalt properties are relevant to pavement construction:

- ✓ Consistency
- ✓ Aging and temperature sustainability
- ✓ Rate of curing
- ✓ Resistance to water action

Consistency

- Consistency properties refer to:
  - ✓ Variation of properties with temperature
  - ✓ Properties at a specified temperature

- Temperature inversely affects asphalt viscosity.

- Only asphalt with the right viscosity will work well with aggregates.

Properties of Asphalt Materials

- High viscosity makes the combination excessively brittle and prone to low-temperature breaking.

- The mixture will flow easily if the viscosity is low, rutting the wheel path permanently.

- Due to temperature susceptibility, asphalt cement grade should match the local climate.

- Optimal asphalt viscosity depends on the area's yearly temperature range, with soft-grade asphalts for cold regions and hard-grade asphalts for hot climates.

Aging and temperature sustainability

- Aging is when asphalt loses its plasticity and becomes brittle due to chemical and physical reactions that take place when the material is exposed to environmental elements

Properties of Asphalt Materials

Two common reactions are:

1. Air oxygen attacks asphalt material, oxidizing it.
2. Volatilization—loss of lighter hydrocarbons from asphalt

- These two reactions degrade asphalt's plasticity.

- Higher temperatures accelerate oxidation and volatilization.

- Asphalt becomes hard and brittle at low temperatures and soft at high temperatures.

Rate of Curing

- Curing is the process by which asphalt material increases its consistency as it loses solvent by evaporation. The smaller the quantity of solvent, the faster the curing rate

Properties of Asphalt Materials

Resistance to water action

- Pavement construction requires asphalt to stick to aggregates even when wet.
- If this bond between asphalt and aggregates is lost, asphalt will strip off aggregates, deteriorating pavement.
- Asphalt must stick to aggregates even when wet.

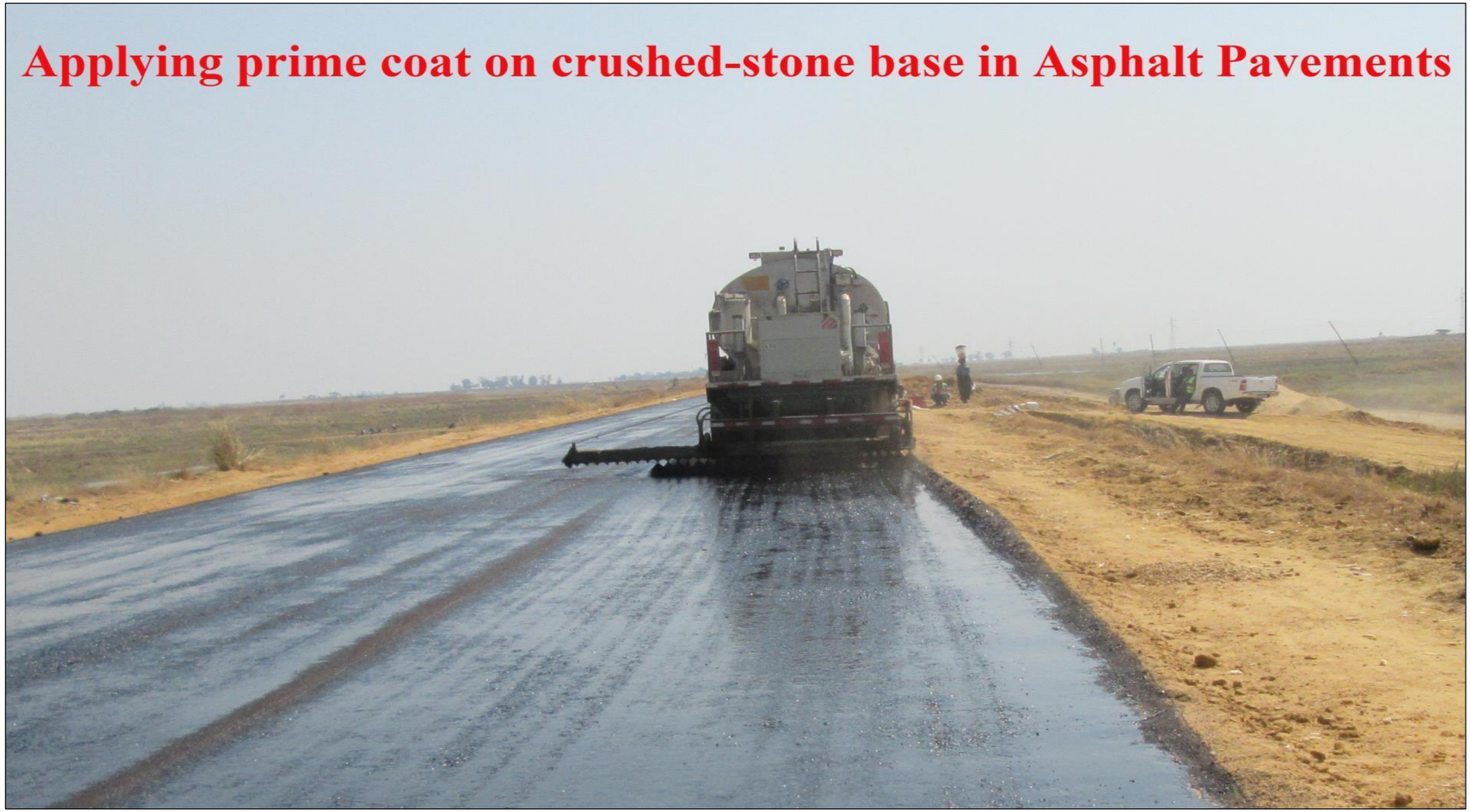
- Hot-mix, hot-laid asphalt concrete, where the aggregates are totally dried before combining, rarely strips, therefore no preventive intervention is needed.
- To improve asphalt adhesion to aggregates, commercial antistrip additives are added to hot-mix, cold-laid asphalt concrete when water is applied.

Uses of Asphalt

- The main use of asphalt is in pavement construction and maintenance.
- Used in sealing and waterproofing various structural components, such as roofs and underground foundations
- The selection of the type and grade of asphalt depends on the type of construction and the climate of the area.
- Asphalt cements, also called asphalt binders, are used typically to make hot-mix asphalt concrete for the surface layer of asphalt pavements
- Asphalt concrete is also used in patching and repairing both asphalt and portland cement concrete pavements.
- Liquid asphalts (emulsions and cutbacks) are used for pavement maintenance applications, such a fog seals, chip seals, slurry seals, and micro surfacing. Also to seal cracks in pavements
- Liquid asphalts are mixed with aggregates to produce cold mixes, as well.
- Cold mixtures are normally used for patching (when hot-mix asphalt concrete is not available), base and subbase stabilization, and surfacing of low-volume roads

Uses of Asphalt

Uses of Asphalt



Uses of Asphalt

Common Paving Applications for Asphalts

Term	Description	Application
Hot mix asphalt	Carefully designed mixture of asphalt cement and aggregates	Pavement surface, patching
Cold mix	Mixture of aggregates and liquid asphalt	Patching, low volume road surface, asphalt stabilized base
Fog seal	Spray of diluted asphalt emulsion on existing pavement surface	Seal existing pavement surface
Prime coat	Spray coat asphalt emulsion to bond aggregate base and asphalt concrete surface	Construction of flexible pavement
Tack coat	Spray coat asphalt emulsion between lifts of asphalt concrete	Construction of new pavements or between an existing pavement and an overlay
Chip seal	Spray coat of asphalt emulsion (or asphalt cement or cutback) followed with aggregate layer	Maintenance of existing pavement or low volume road surfaces
Slurry seal	Mixture of emulsion, well-graded fine aggregate and water	Resurface low volume roads
Microsurfacing	Mixture of polymer modified emulsion, well-graded crushed fine aggregate, mineral filler, water, and additives	Texturing, sealing, crack filling, rut filling, and minor leveling

Tests of Asphalt

- Asphalt materials are tested for uniformity and quality to ensure highway construction materials satisfy specifications.
- The common tests for asphalt;

I. Viscosity

This is a property used to describe asphalt materials in liquid state. Viscosity can be determined by the following methods

1. Saybolt Furol Viscosity Test
2. Kinematic Viscosity Test or
3. Ring and Ball Softening Point (Not used often in highway specification)

II. Penetration Test

- The test gives an empirical measurement of the consistency of a material in terms of the distance a standard needle sinks into that material under a prescribed loading and time.

Tests of Asphalt

III. Ring-and-Ball Softening

- Used to measure the susceptibility of blown asphalt to temperature changes by determining the temperature at which the material will be adequately softened to allow a standard ball to sink through it

IV. Ductility Test

- This test measures the property of asphalt binders to elongate under traffic load without getting cracked in road construction works. Ductility test on bitumen measures the distance in centimeters to which it elongates before breaking

V. Thin-Film Oven Test (TFO)

- One test used to evaluate the susceptibility characteristics of asphalt materials to changes in temperature and other atmospheric factors

VI. Flash-Point Test

- This is the temperature at which the asphalt material vapors will ignite instantaneously in the presence of an open flame

Classification of Asphalts

- Common methods of classifying asphalt binders (asphalt cements), asphalt cutbacks, and asphalt emulsions include;
  - ✓ Performance Grading method developed by Strategic Highway Research Program (SHRP)
  - ✓ The traditional viscosity, penetration, ductility, and softening point temperature approach
- The four methods typically used for classifying asphalt binders include:
  1. Performance grading
  2. Penetration grading
  3. Viscosity grading
  4. Viscosity of aged residue grading

Performance Grade Specifications and Selection

- Different binder grades are based on field performance. Grade names begin with PG (Performance Graded) and two Celsius values denoting the maximum and minimum pavement design temperatures.

Classification of Asphalt

Performance Grade Specifications and Selection

- An asphalt binder PG 52–28 meets the design high and low pavement temperatures of 52°C and -28°C, respectively.
- High temperature is calculated 20 mm (0.75 in.) below pavement surface, whereas low temperature is estimated at pavement surface.
- The way Performance Grade specifications function differs from standard specifications.
- The physical qualities (criteria) are consistent for all classes, but the temperatures at which they must be accomplished vary based on the binder's intended use climate.
- The binder meets maximum and lowest pavement temperature design standards.

Classification of Asphalt

Performance Grade Specifications and Selection

- The average seven-day maximum pavement temperature determines the design maximum, while the lowest is the design minimum.
- Since the maximum and minimum pavement temperatures vary from one year to another, a reliability level is considered

Binder Grade Specifications

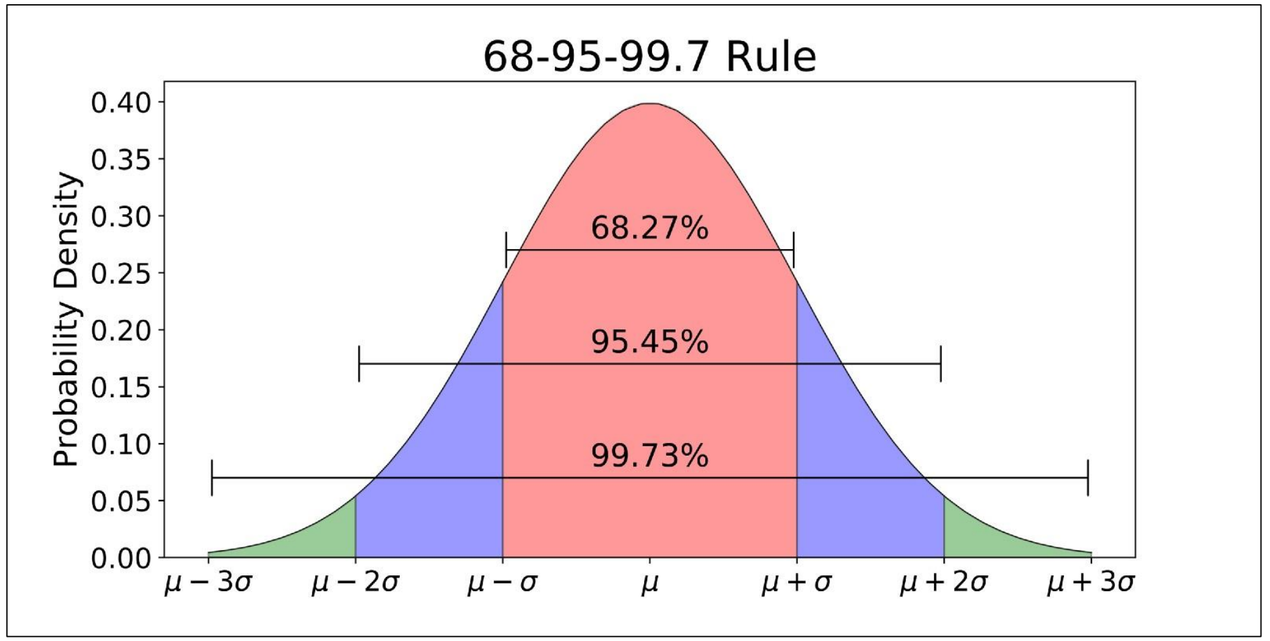
High Temperature Grades (°C)	Low Temperature Grades (°C)
PG 46	−34, −40, −46
PG 52	−10, −16, −22, −28, −34, −40, −46
PG 58	−16, −22, −28, −34, −40
PG 64	−10, −16, −22, −28, −34, −40
PG 70	−10, −16, −22, −28, −34, −40
PG 76	−10, −16, −22, −28, −34
PG 82	−10, −16, −22, −28, −34

Classification of Asphalt

Performance Grade Specifications and Selection – Example

- What standard PG asphalt binder grade should be selected under the following conditions: The seven-day maximum pavement temperature has a mean of 57°C and a standard deviation of 2°C. The minimum pavement temperature has a mean -6°C of and a standard deviation of 3°C. Reliability is 98%.

Solution



At 98 % reliability: Min Temp/Max Temp = Mean$\mp 2 * \boldsymbol{Standard\ Deviation}$

Wood cutting techniques

Performance Grade Specifications and Selection – Example

$$\Pr(\mu - 1\sigma \leq X \leq \mu + 1\sigma) \approx 0.6827$$
$$\Pr(\mu - 2\sigma \leq X \leq \mu + 2\sigma) \approx 0.9545$$
$$\Pr(\mu - 3\sigma \leq X \leq \mu + 3\sigma) \approx 0.9973$$

For an approximately normal data set;

i. The values within one standard deviation of the mean account for about 68% of the set;
ii. The values within two standard deviations account for about 95%; and
iii. The values within three standard deviations account for about 99.7%

At 98 % reliability: Min Temp/Max Temp = Mean$\mp 2 * \boldsymbol{Standard\ Deviation}$

$$T_{min/max} = T_{min/max} \mp 2\sigma$$

Classification of Asphalt

Performance Grade Specifications and Selection – Example

Solution

At 98 % reliability: Min Temp/Max Temp = Mean$\mp 2 * \boldsymbol{Standard\ Deviation}$

- High-temperature grade ≥ 57+ (2*2) ≥ 61°C
- Low-temperature grade ≤ -6- (2*3) ≤ -12°C

Summary

- Using table in previous slide, the closest standard PG asphalt binder grade that satisfies the two temperature grades is PG 64–16.

Classification of Asphalt

- **Other (Traditional) methods of classifying asphalts**

Viscosity Grading System of Asphalt Cement

Grade	Absolute Viscosity (poises)
AC-2.5	250 ± 50
AC-5	500 ± 100
AC-10	1000 ± 200
AC-20	2000 ± 400
AC-30	3000 ± 600
AC-40	4000 ± 800

Penetration Grading System of Asphalt Cement

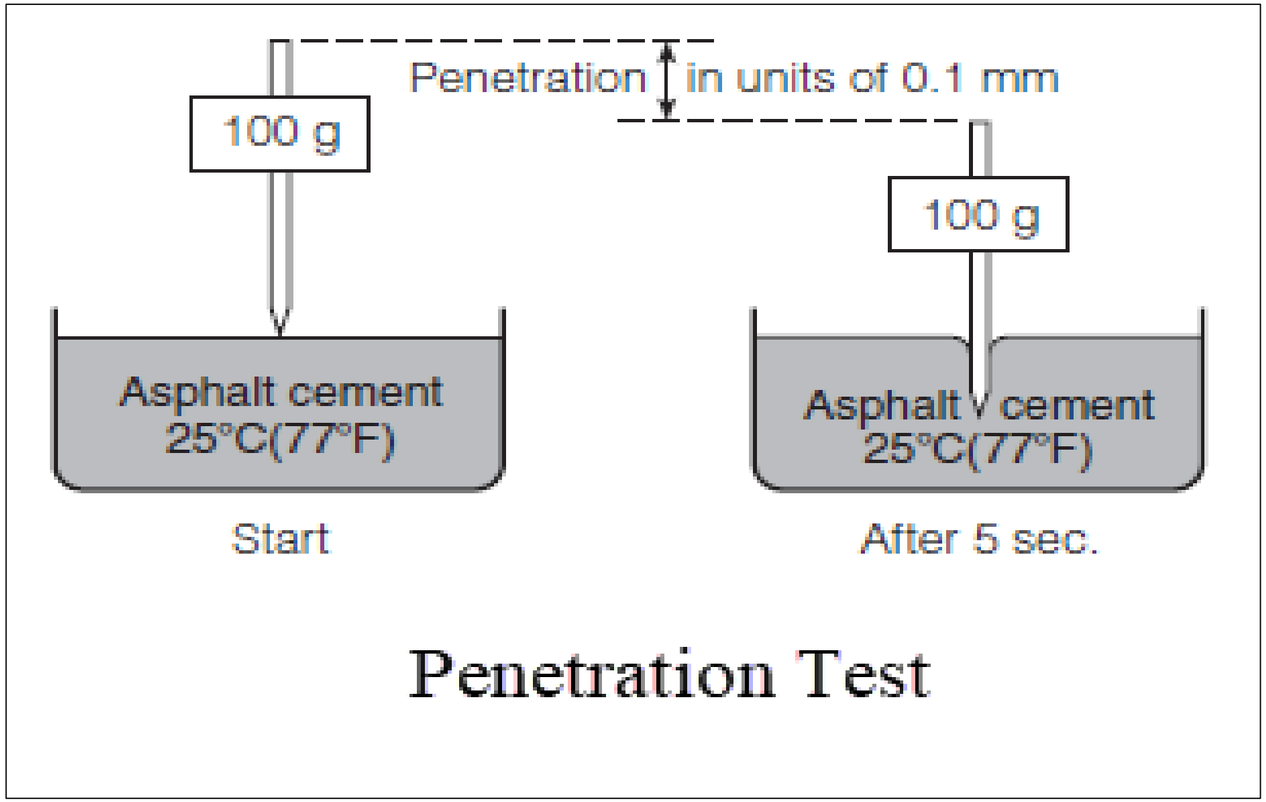
	Penetration	
Grade	min.	max.
40–50	40	50
60–70	60	70
85–100	85	100
120–150	120	150
200–300	200	300

Aged-Residue Grading System of Asphalt Cement

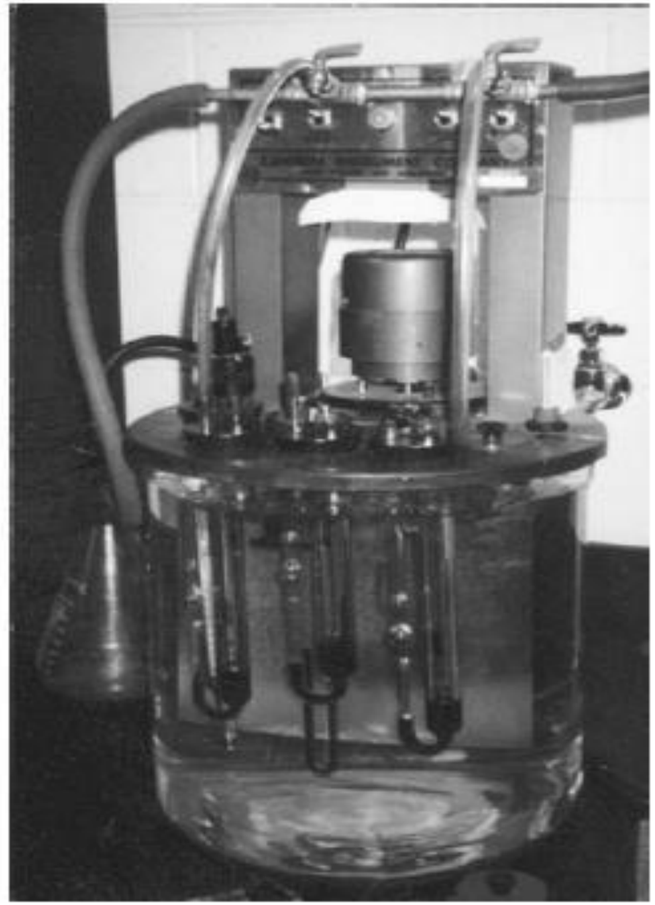
Grades	Absolute Viscosity (poises)
AR-1000	1000 ± 250
AR-2000	2000 ± 500
AR-4000	4000 ± 1000
AR-8000	8000 ± 2000
AR-16000	16000 ± 4000

Classification of Asphalt

- **Other (Traditional) methods of classifying asphalts**



Penetration Test



Absolute Viscosity Aparatus

Thank You!!!