Thi_ Qar University
College of Engineering/Civil Engineering Department

Highway Lectures

Fourth Class

Part #3: - Bitumen (Binder), (Asphalt Cement)

Lectures #7, #8 and #9

Bitumen Proprieties

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2019-2020

Objectives Learning Outcomes (OLC)

➢The main objectives of this chapter (Asphalt/Binder/Bitumen) are to make the student:-

i. Learnt about different types of binders used in pavement construction.
ii. Learn how paving grade of bitumens are produced.
iii. Bitumen sources.
iv. Iraqi standard and specifications of bitumen that required for pavement design and construction.
v. Asphalt tests that required and important in pavement design.
vi. Learn about the determination of important characteristics of bituminous binders that affect pavement performance

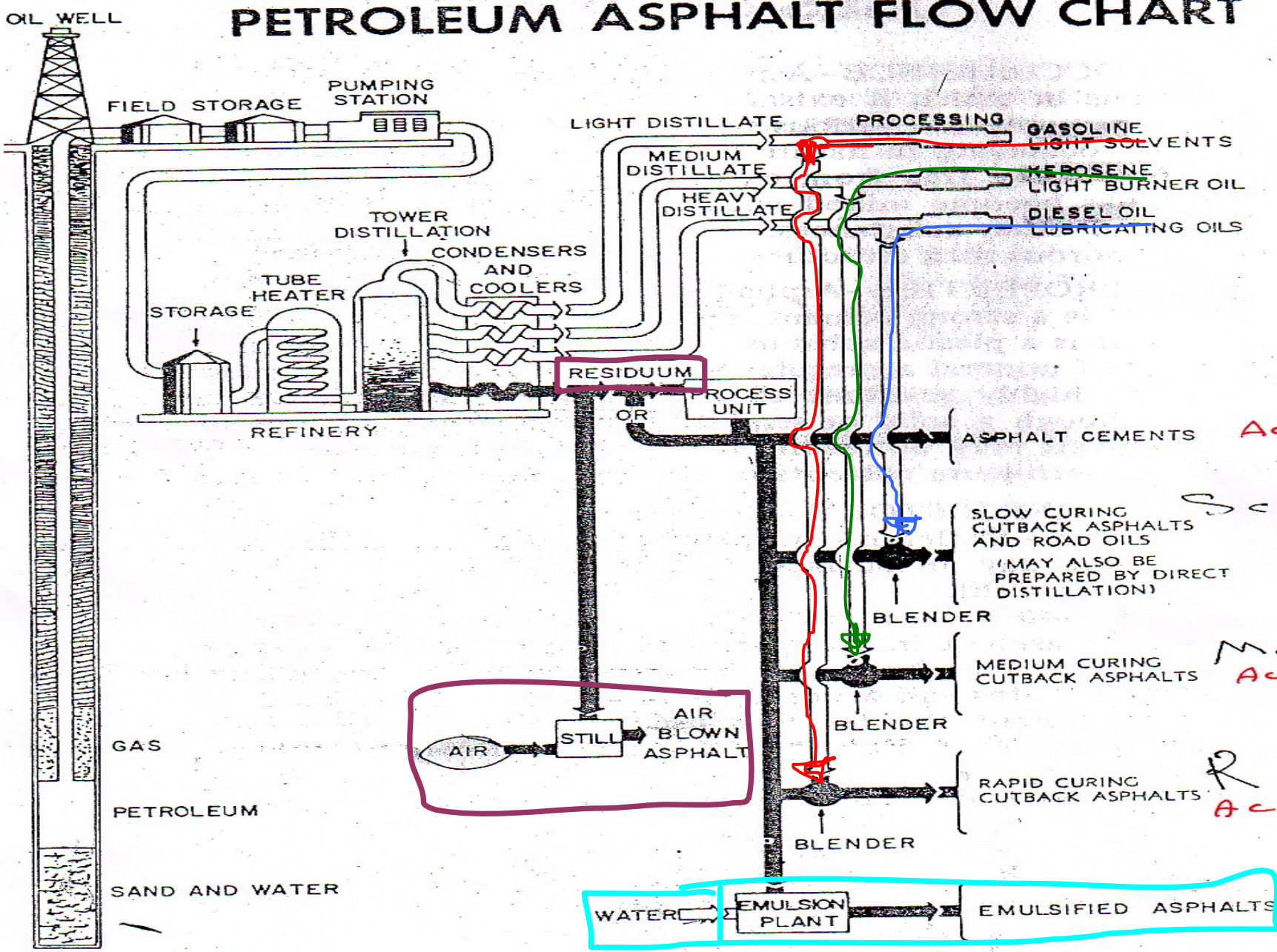


Figure I-1—Petroleum asphalt flow chart

Introduction

- Different types of paving Binders

i. Bitumen.

ii. Tar.

iii. Cutback.

iv. Emulsion.

v. Modified bitumen.

- American term is “Asphalt”

Introduction

Bitumen: is a viscous liquid or solid material. Black or dark brown color, having adhesion prosperities, consisting essentially of hydrocarbons components, non toxic. Soften when heated. Unaffected by most of acid, very complex material structure, Specific Gravity = 0.95 – 1.05.

Tar: manufactured from destructive distillation of bituminous coal. Is highly temperature susceptible compared to bitumen and its use is more health hazardous than bitumen.

Introduction

Behavior depends on (Visco-elastic):-

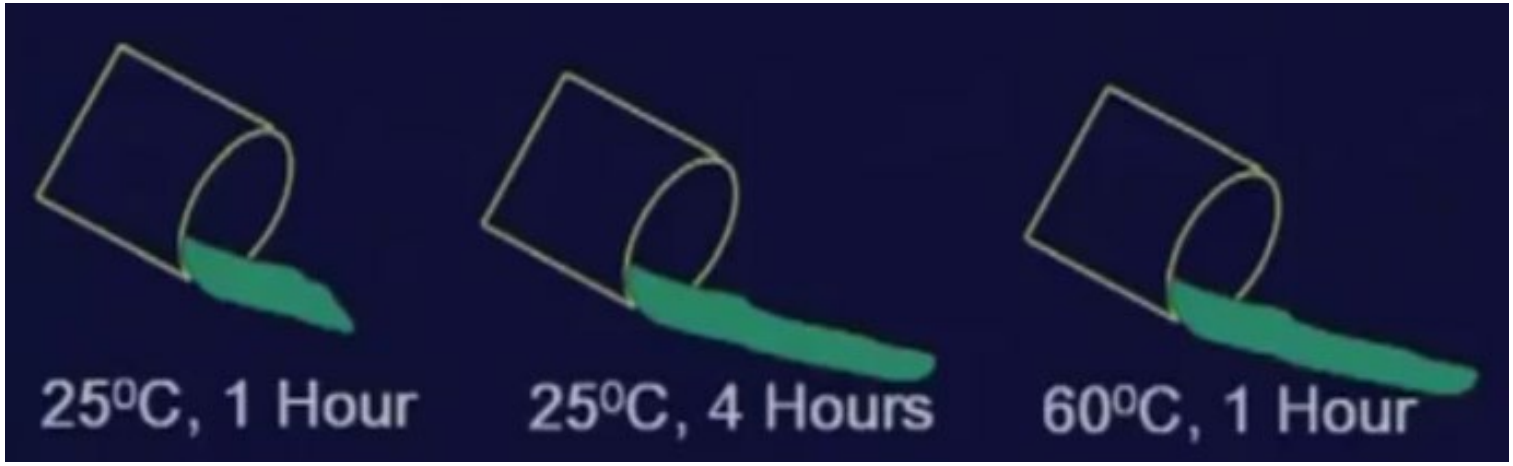
- Temperature.
- Time of loading (Traffic Speed).
- Aging (properties change with time).

Introduction

Bitumen Temperature

Typical temperatures considered :-

25 ^{0}C :- Average Temp. of pavement.
60 ^{0}C :- Maximum Temp. of pavement.
135 ^{0}C :- Mixing/Spraying Temp. of Mix.



Categories of Asphalt

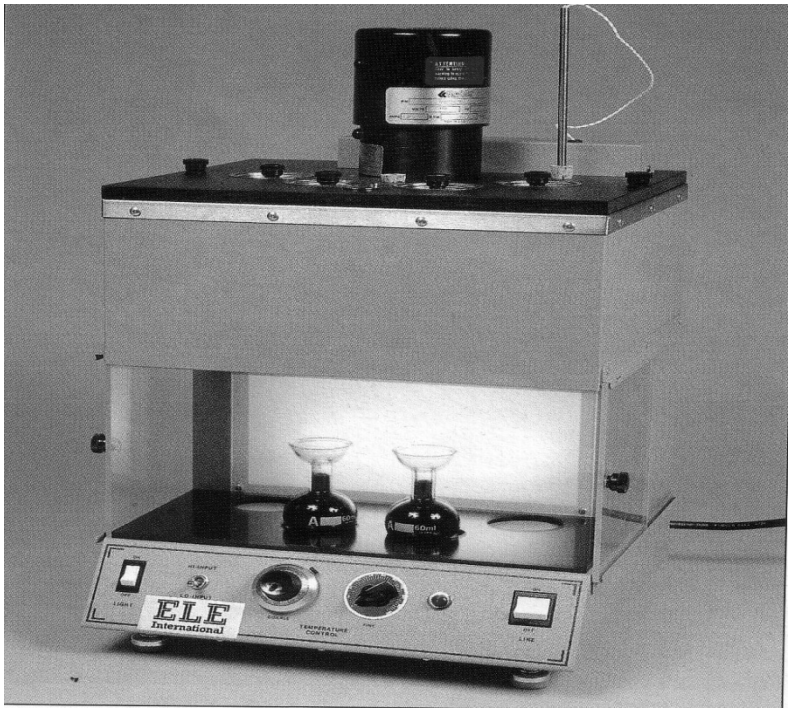
1) Natural Asphalt
   - ➢Lake Asphalt
   - ➢Rock Asphalt
   - ➢Gilsonite
2) Petroleum Asphalt
   - ➢From residuum of petroleum refinery

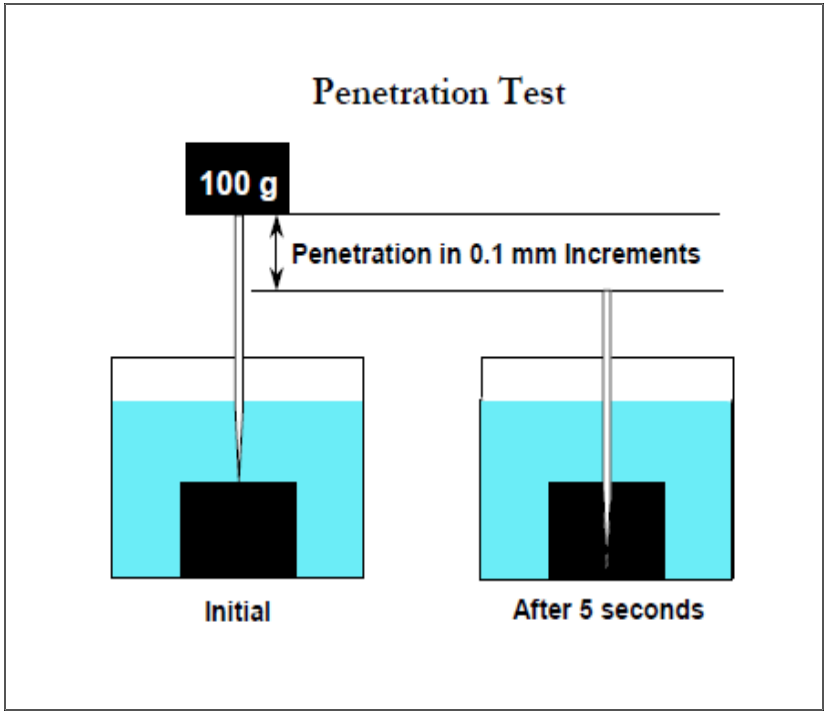
Chemical Properties

1. No standard chemical test is acceptable.
2. No relationship between the chemical components and the behavior of asphalt.
3. Chemical tests needs sophisticated and complex equipment and technicians.

Grading System

- According to Penetration.
- According to Viscosity.
- Performance Grade (PG)





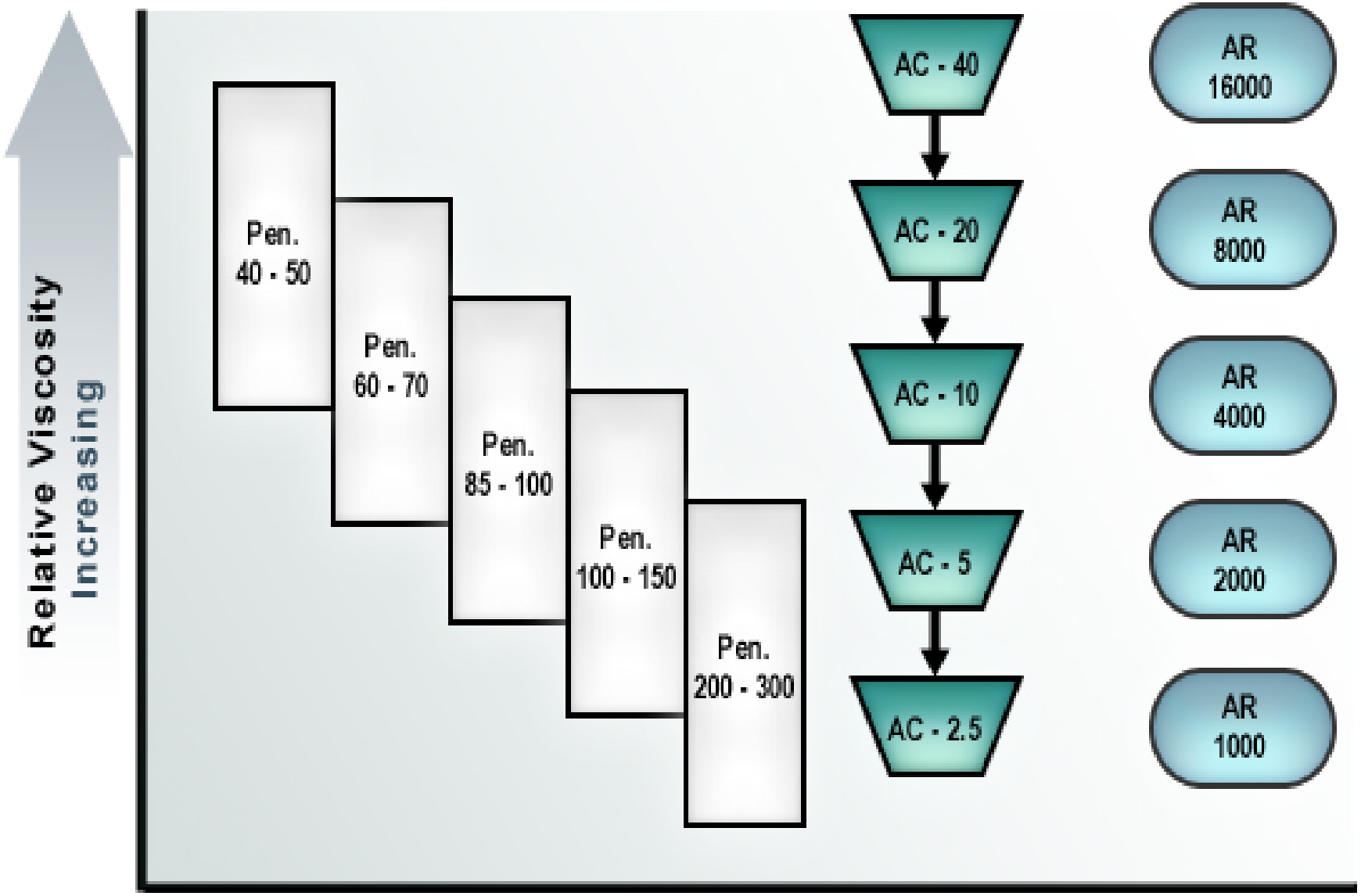
Grading System

1. According to penetration. at 25^0C penetration grade (40-50 & 60-70 & 85-100 &120-150 & 200-300).

2. According to Viscosity.

   - Absolute Viscosity at 60^0C by vacuum viscometer or canon vacuum viscometer. Unit is poise
   - Kinematic Viscosity at 135^0C by Arm viscometer or canon vacuum viscometer. Unit is centistokes

Absolute Viscosity (Poise)=Kinematic Vis. (stokes)*Sp. Gr.


Relative Viscosity
Increasing
Pen.
40 - 50
Pen.
60 - 70
Pen.
85 - 100
Pen.
100 - 150
Pen.
200 - 300
AC - 40
AC - 20
AC - 10
AC - 5
AC - 2.5
AR
16000
AR
8000
AR
4000
AR
2000
AR
1000

Relationship between Absolute and Kinematic viscosity

1 stock =100 centistokes

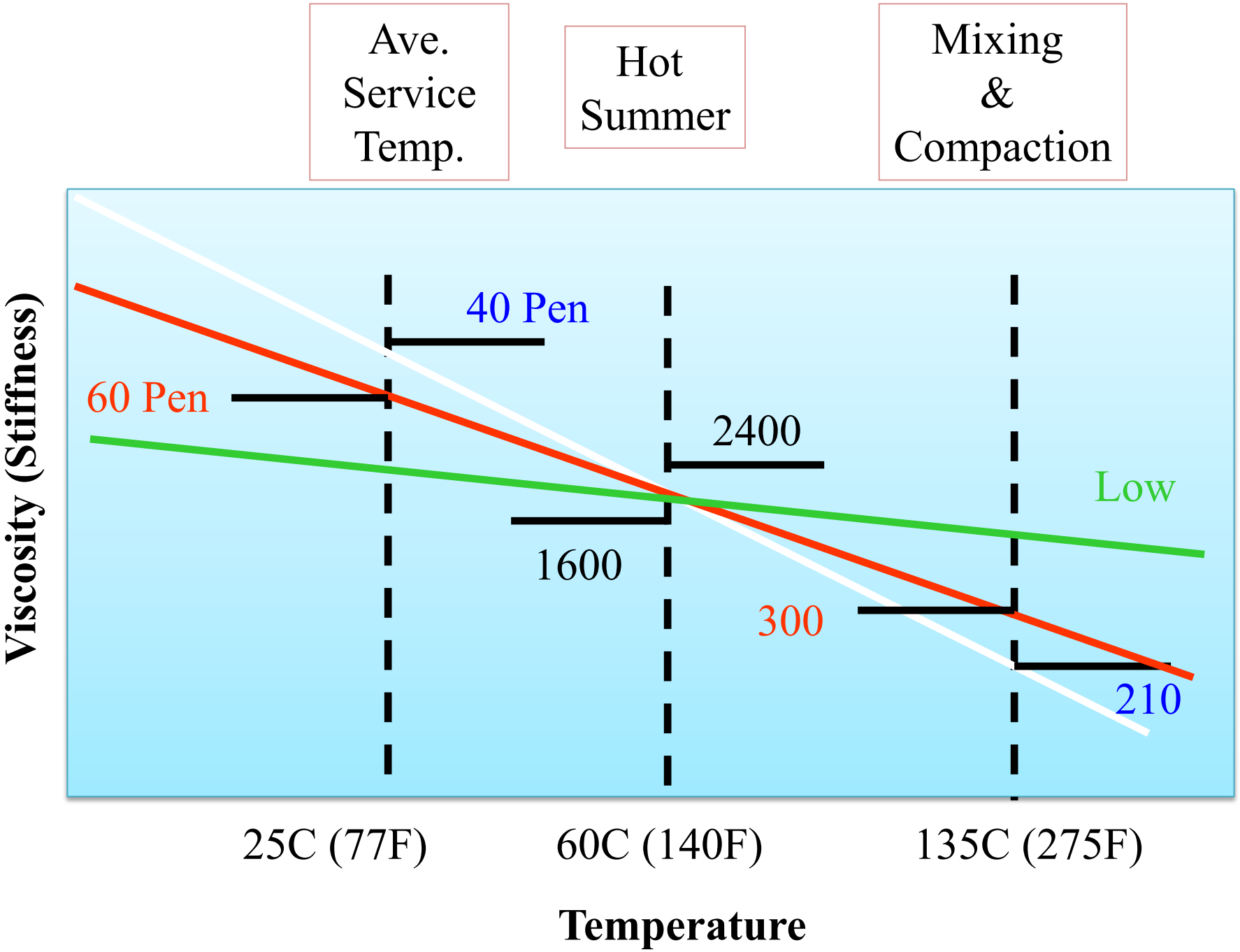
Absolute Viscosity= Kinematic viscosity× Sp.Gr.

For Ex. 800 centistokes, sp. Gr.1.03

Absolute Viscosity=800/100 × 1.03

=8.24 poise

- Poise = (Pa. S)*10
- Centi-poise = 100*Poise = Pa.S*1000


Ave. Service Temp.
Hot Summer
Mixing & Compaction
Viscosity (Stiffness)
40 Pen
60 Pen
2400
1600
Low
300
210
25C (77F)
60C (140F)
135C (275F)
Temperature

Penetration Grading

Advantage:-

1. Test time is short.
2. Equipment costs are low.
3. Testing at 25^0C provide a better correlation with low temp. properties than viscosity test.
4. Precision limits for the penetration test are well established.

Penetration Grading

Disadvantage:-

1. It is an empirical test and does not measure the consistency asphalt in fundamental units such as viscosity.
2. Shear rate is high during test.
3. Shear test is variable because it depends on the consistency of the asphalt cement
4. No viscosity is available to establish mixing and compaction temp.

Viscosity Grading

Advantage:-

1. Viscosity is a fundamental properly, rather than an empirical test.
2. It is suitable to a wide range of environments(25 to 60^0C).
3. It is near the maximum pavement surface (60^0C).
4. There is a residue overlap with other grading system.
5. Test standard are available with established limits

Viscosity Grading

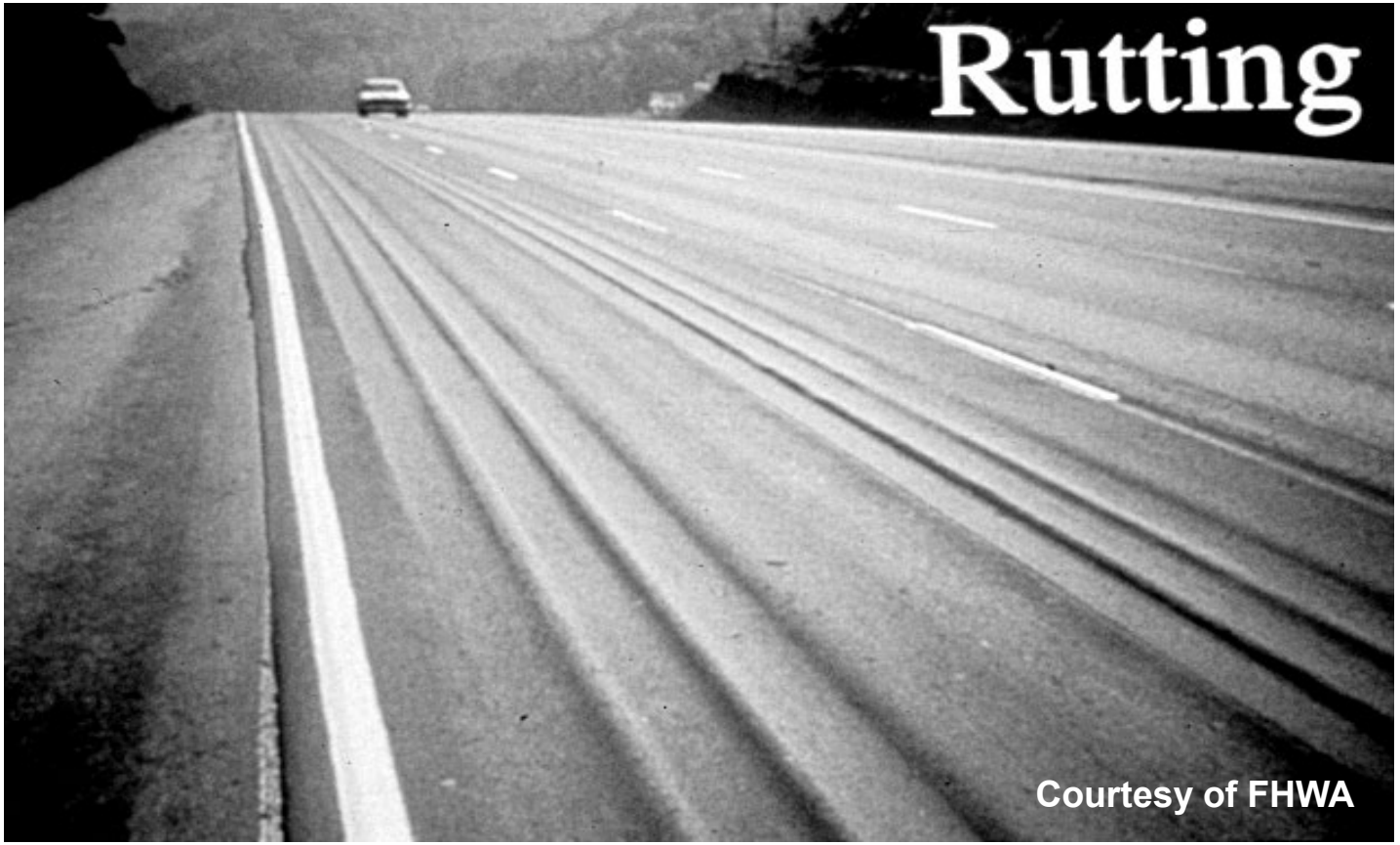
Disadvantage:-

1. Test time is longer.
2. The test system is more expansive than penetration test.
3. It is not adequate to safeguard against low temperature cracking.

PG Specifications

- Fundamental properties related to pavement performance
- High in-service temperature
  - ✓Desert climates
  - ✓Summer temperatures
  - ✓Permanent deformation (rutting)
  - ✓Depends on asphalt source, additives, and aggregate properties

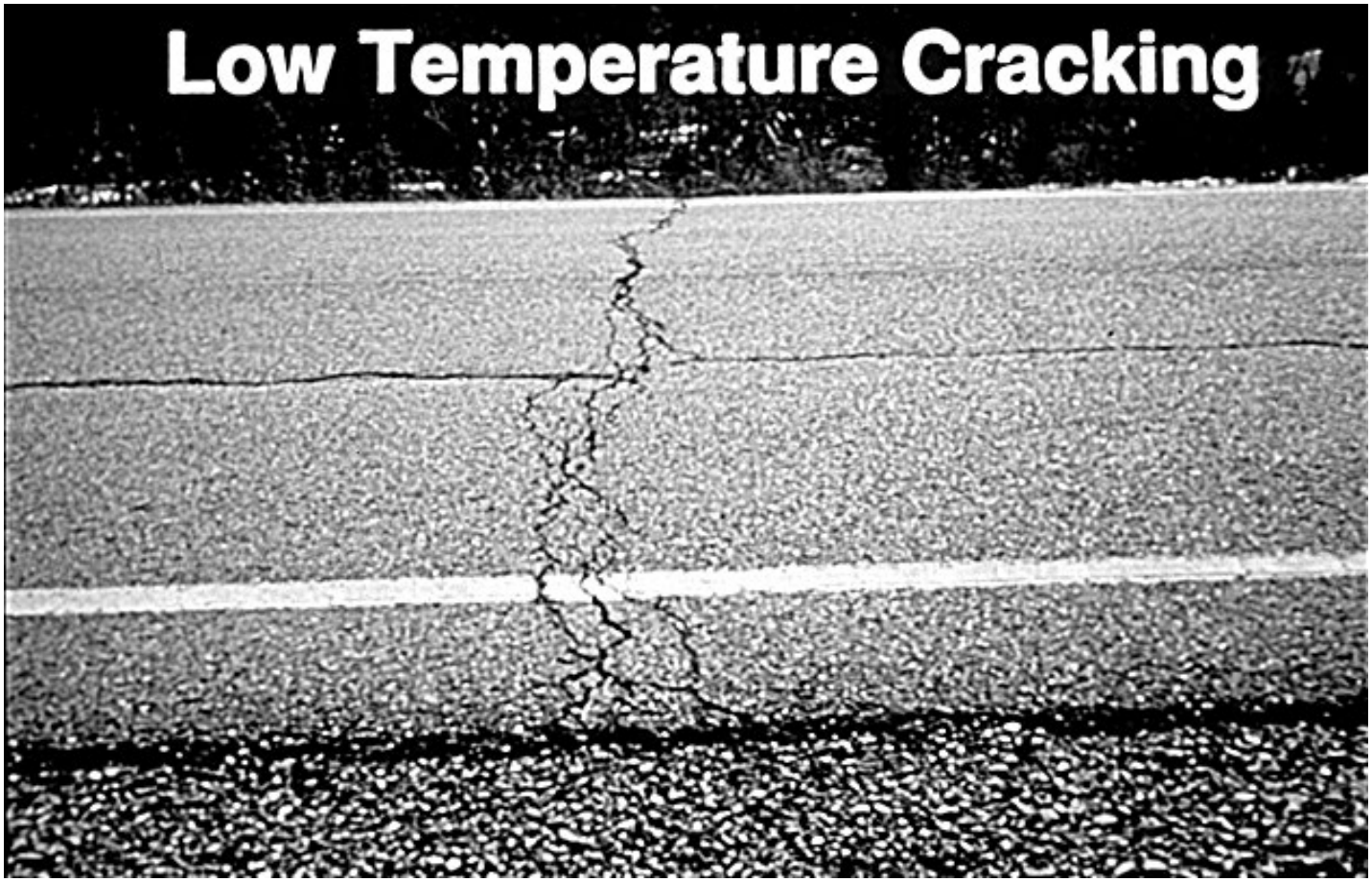
Permanent Deformation



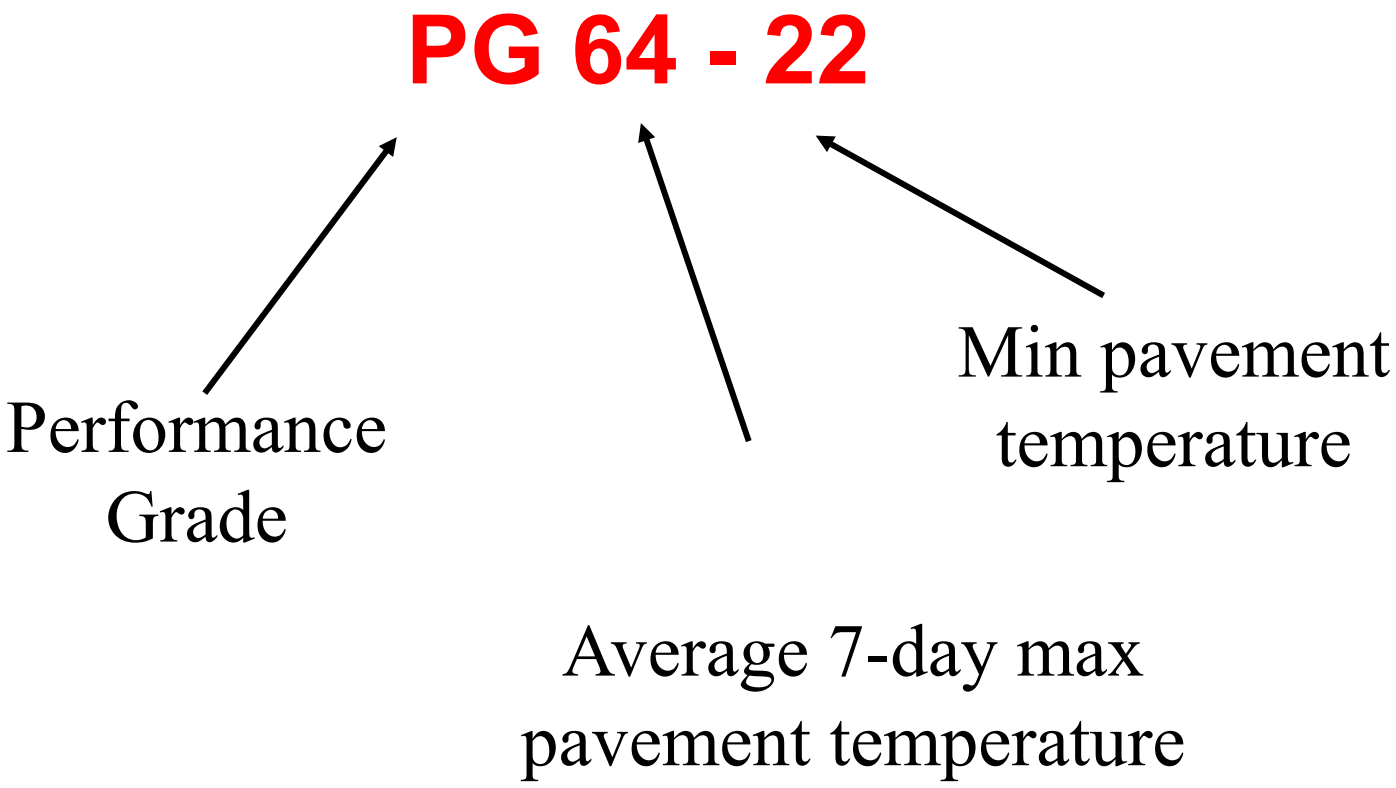
Low Temperature Behavior

- Low Temperature
  - ✓Cold climates
  - ✓Winter
- Thermal cracks
  - ✓Stress generated by contraction due to drop in temperature
  - ✓Crack forms when thermal stresses exceed ability of material to relieve stress through deformation

Thermal Cracking



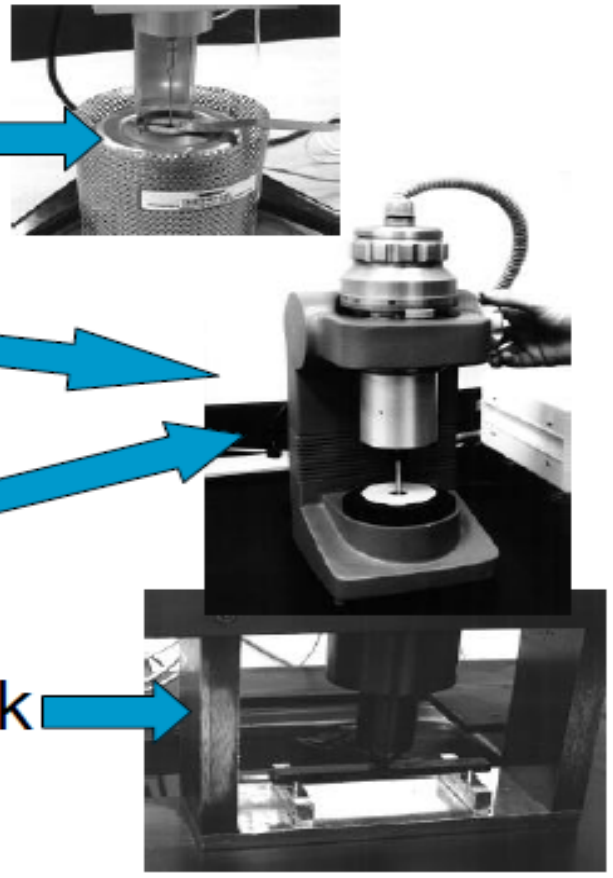
Superpave Asphalt Binder Specification



Superpave Asphalt Binder Specification

Performance Grade (PG) Binders AASHTO MP-1

- Construct-ability check
  - Pump-ability
- Rutting check
- Fatigue cracking check
- Low-temp cracking check

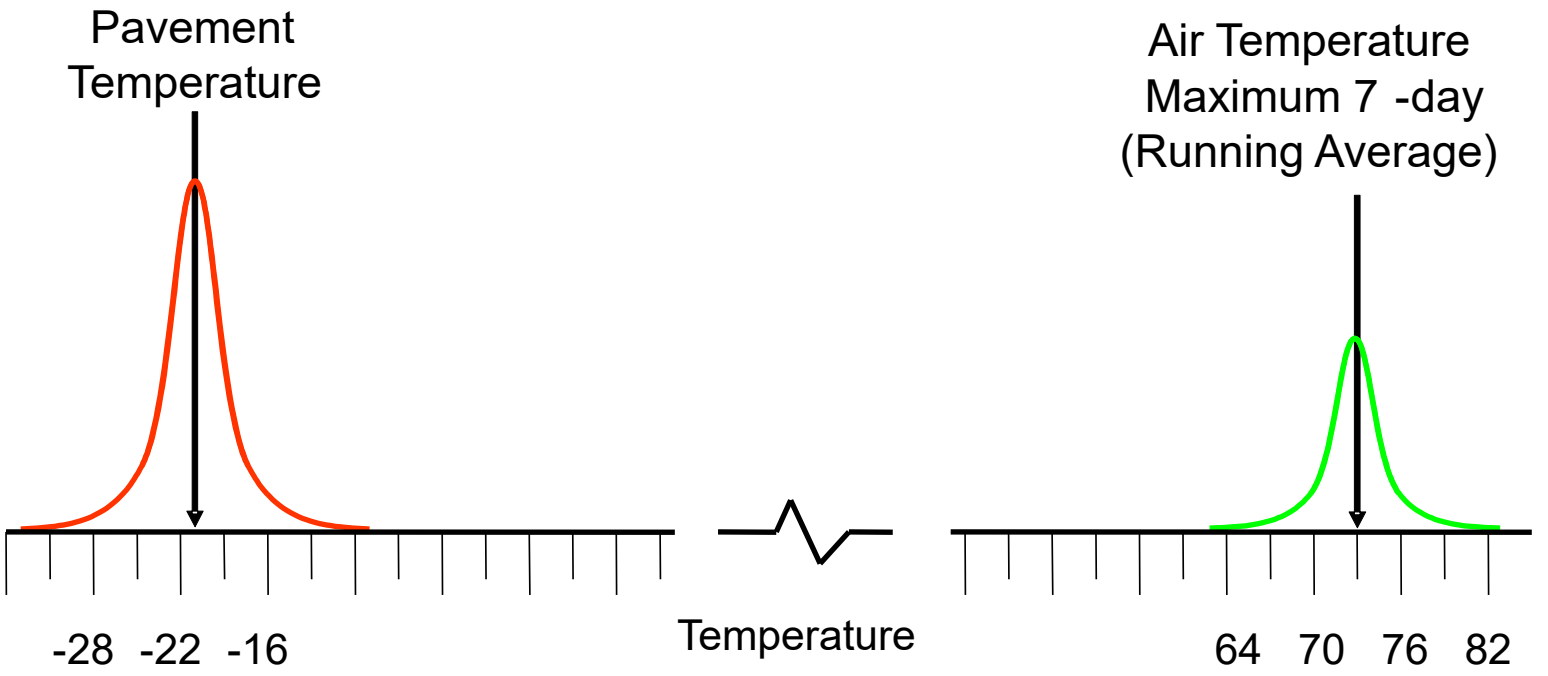


Performance-Graded Asphalt Binders

Maximum Temperature (ºC)	Minimum Temperature (ºC)						
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		

As an example, a PG 64-28 is acceptable for use in a climatic region where the maximum temperature is 64°C and the minimum temperature is -28°C.

Selection of Grading Temperatures



Given that the minimum measured air temperature for a site is -21°C and the maximum 7-day average temperature is 73°C, which PG grade should be used for this site. Here, use PG 76 -22.

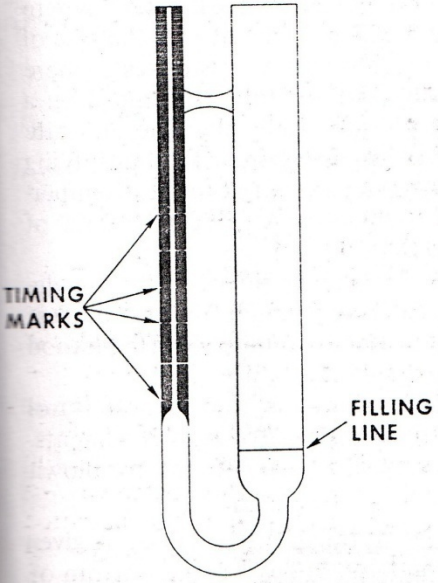


Figure III-1—The Asphalt Institute vacuum viscometer

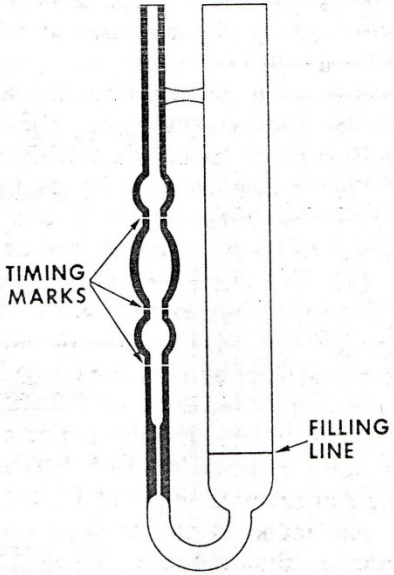


Figure III-2—Cannon-Manning vacuum viscometer

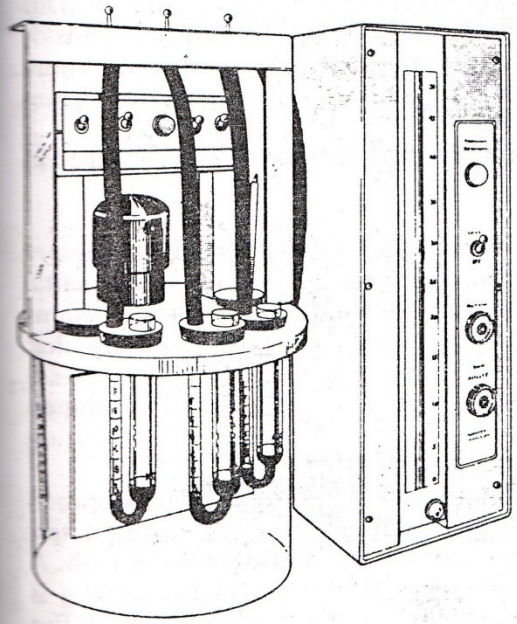


Figure III-3—Viscometer in bath

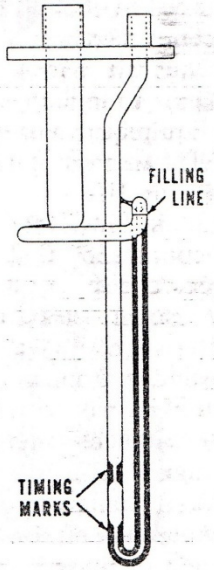


Figure III-4—Zeitfuchs cross-arm viscometer

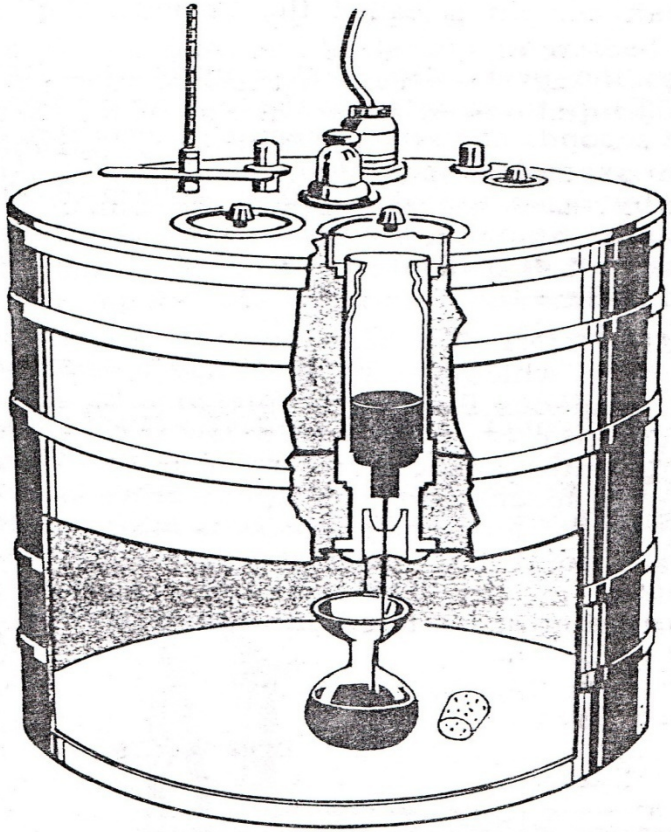


Figure III-5—Saybolt Furol viscosity test

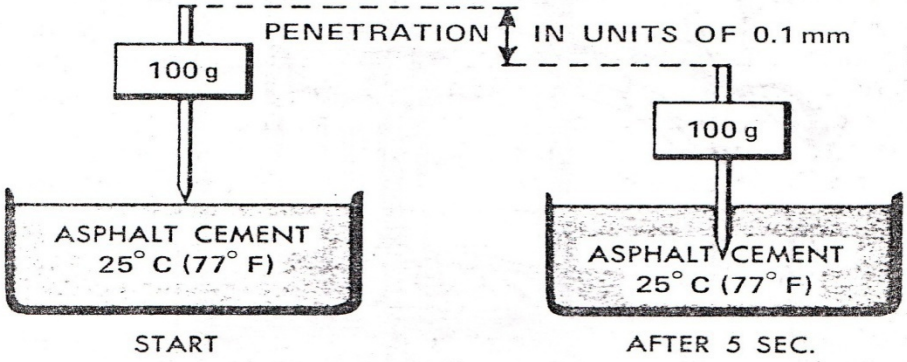


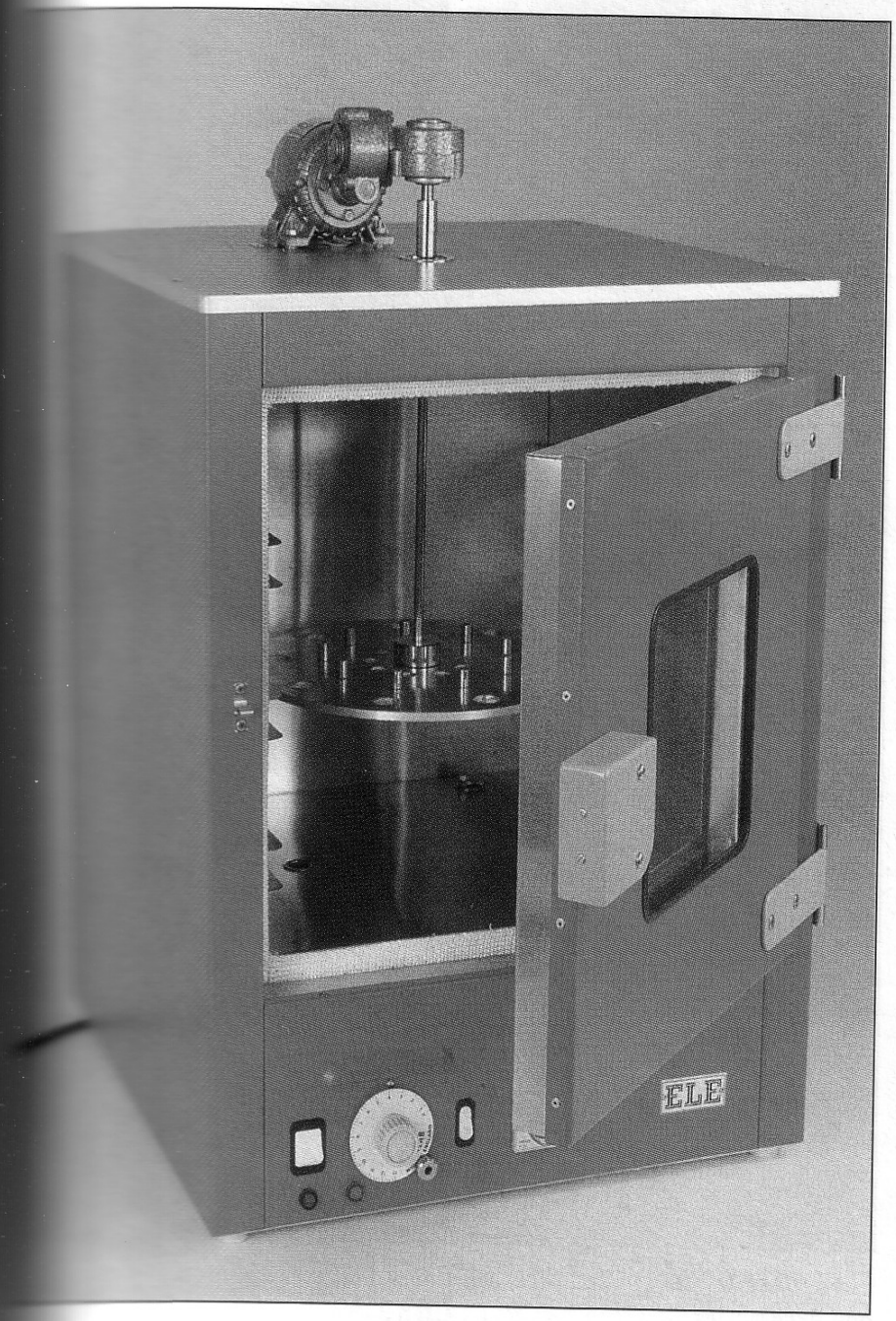
Figure III-6—Standard penetration test

Physical Properties

Durability: The ability of asphalt to retain its original characteristics when exposed to normal weathering and aging process. Tested by:-

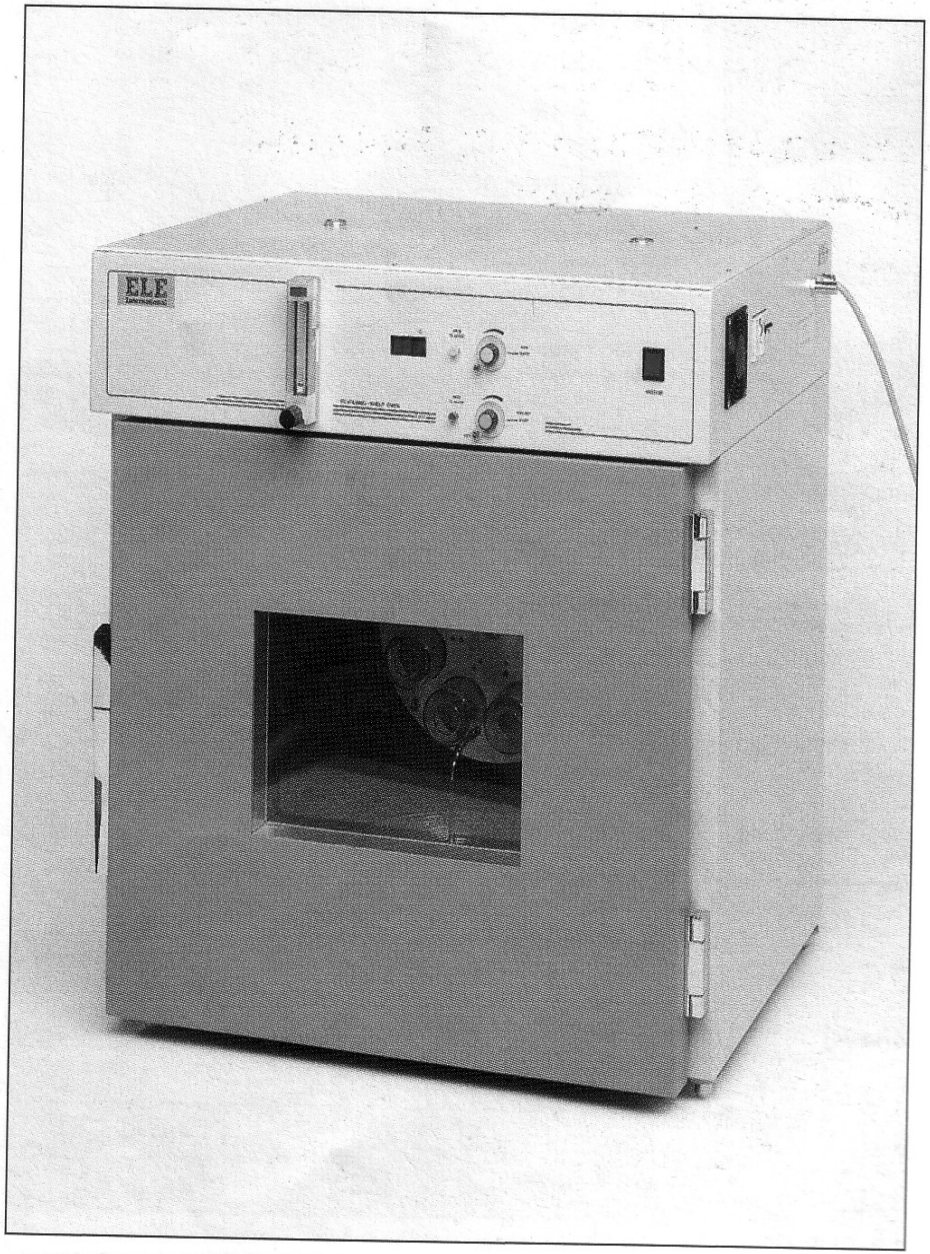
- ✓ Thin Film Oven Test (TFOT).
- ✓ Rolling Thin Film Oven Test (RTFOT) .

EL46-4100 series Loss on Heating/Thin Film Oven



Thermometer see EL82-5259

EL46-4150 series Rolling Thin Film Oven



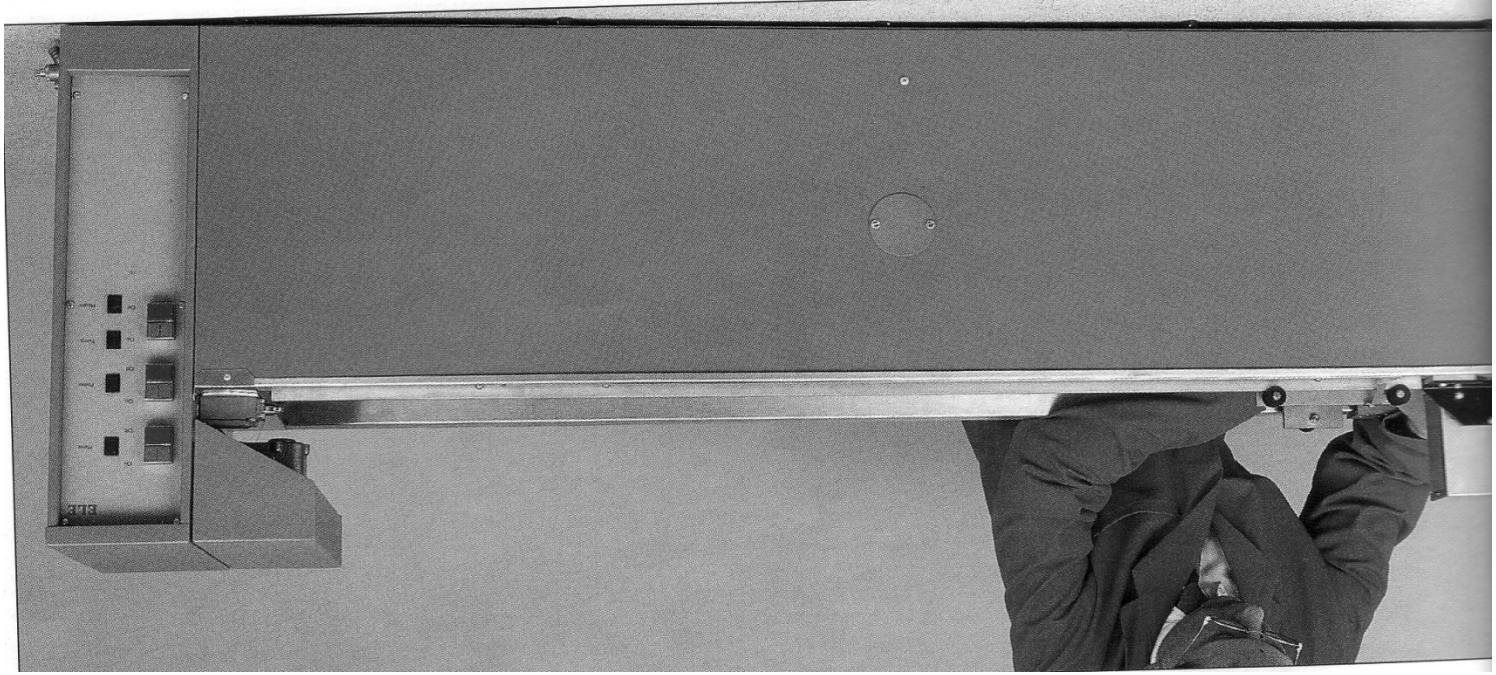
Physical Properties

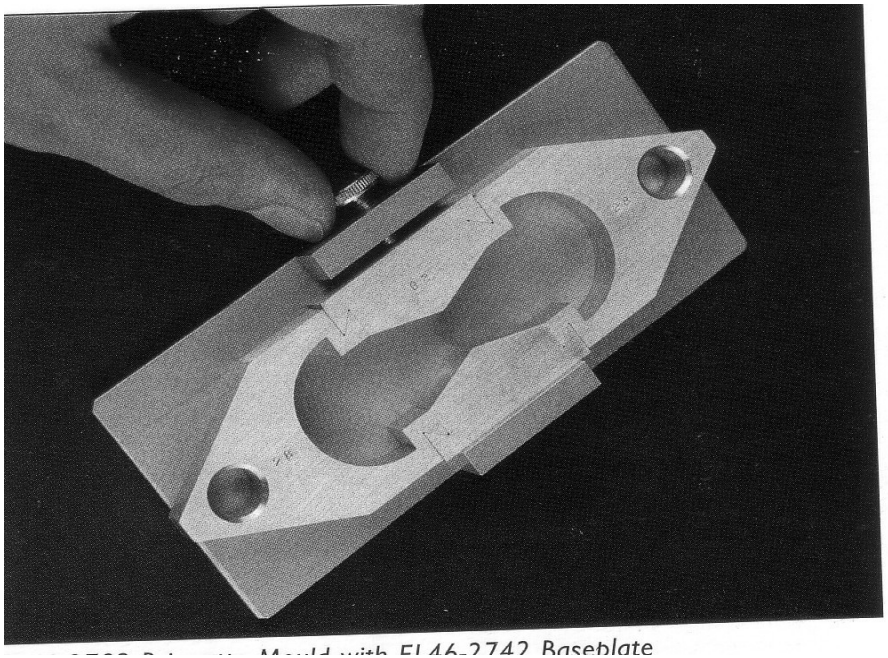
Adhesion: is the ability of asphalt to stick with aggregate. Tested by:-

- ✓ Stripping test.

Cohesion: is the ability of asphalt to hold the aggregate coated particles together in mix. Tested by:-

- ✓ Ductility test.





Mould with FL46-2742 Baseplate

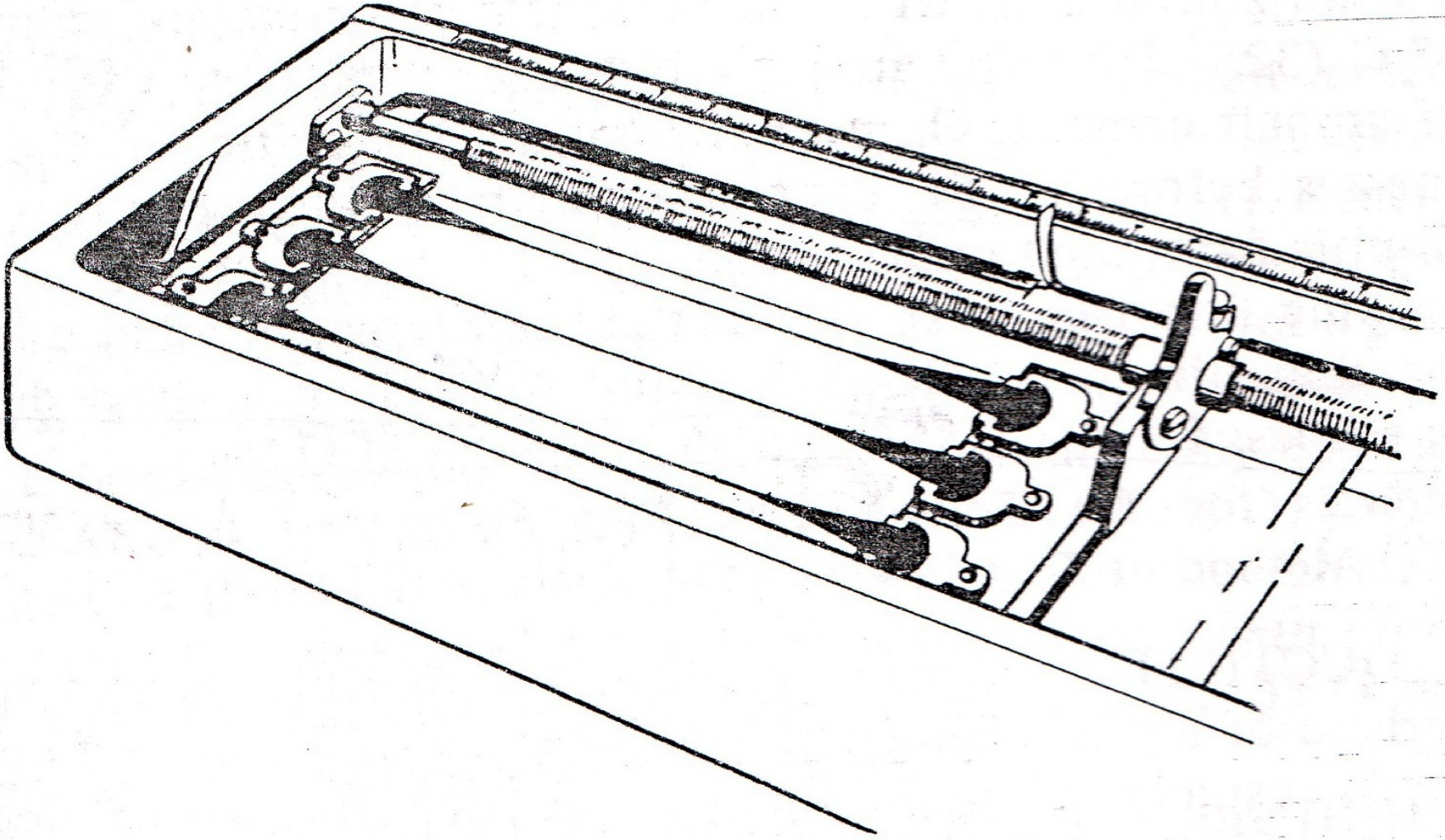


Figure III-11—Ductility test

Physical Properties

Temperature Susceptibility : Asphalt change in viscosity with temperature according to source. Parameter used to describe the temperature susceptibility of binders

Physical Properties

Temperature Susceptibility : Asphalt change in viscosity with temperature according to source.

$$PI = 20\frac{1-25*A}{1+50*A}$$

$$A = (\log(pen\ @\ T1) - \log(pen@T2))/(T1 - T2)$$

$$A = (\log(pen\ @\ 25) - \log(800)/(25 - T2)$$

$$PI = (1952 - 500 * \log(pen\ ) - 20 * \mathrm{SP})/(50 * \log\ (pen) - SP - 120)$$

- PI range from -3 (for high susceptibility bitumen) to +7 (for low susceptibility), highly blown bitumen.

Physical Properties

Harding &Aging: When asphalt material is attack by the oxygen in the air. This chemical reaction causes gradual Harding, Pavement harding loss of the plastic characteristics.

Short Term Aging:- During storage, Transportation, mixing temperature, Placing temperature (high temperature).

Long Term Aging:- During the service live of pavement due to oixidation.

Physical Properties

Short Term Aging measure by Thin Film Oven Test (TFOT) or Rolling Thin Film Oven Test (RTFOT), Bitumen is kept as film at 163 0C for 5 hrs, and then the properties of binder compared with un aged.

Long Term Aging measure by Pressure Aging Vessel (PAV), Bitumen is exposed to heat and pressure to simulate in-service aging over a 7 to 10 year period. The RTFO aged asphalt samples, places them in stainless steel pans and then ages them for 20 hours in a heated vessel pressurized to 305 psi (2.10 MPa). Samples are then stored for use in physical property tests.

Physical Properties

Purity: pure bitumen dissolve completely in carbon disulphide. % insoluble material indicates the purity of material. Bitumen should be free of water (causes foaming at high temperature). Water content test.

Physical Properties

Resistance to water action: If the bond between asphalt and aggregate is lost (when water is attack hot mix asphalt). The asphalt will strip from the aggregate (stripping distresses happened). Therefore antistripping agent (additives) are usually added to improve the asphalt ability to bond force. Such as (cement, lime, limestone dust, etc)


Without Asphalt
Control
3 % from weight of AC
5 % from weight of AC
7 % from weight of AC
10% from weight of AC
20 % from weight of AC
100 % from weight of AC

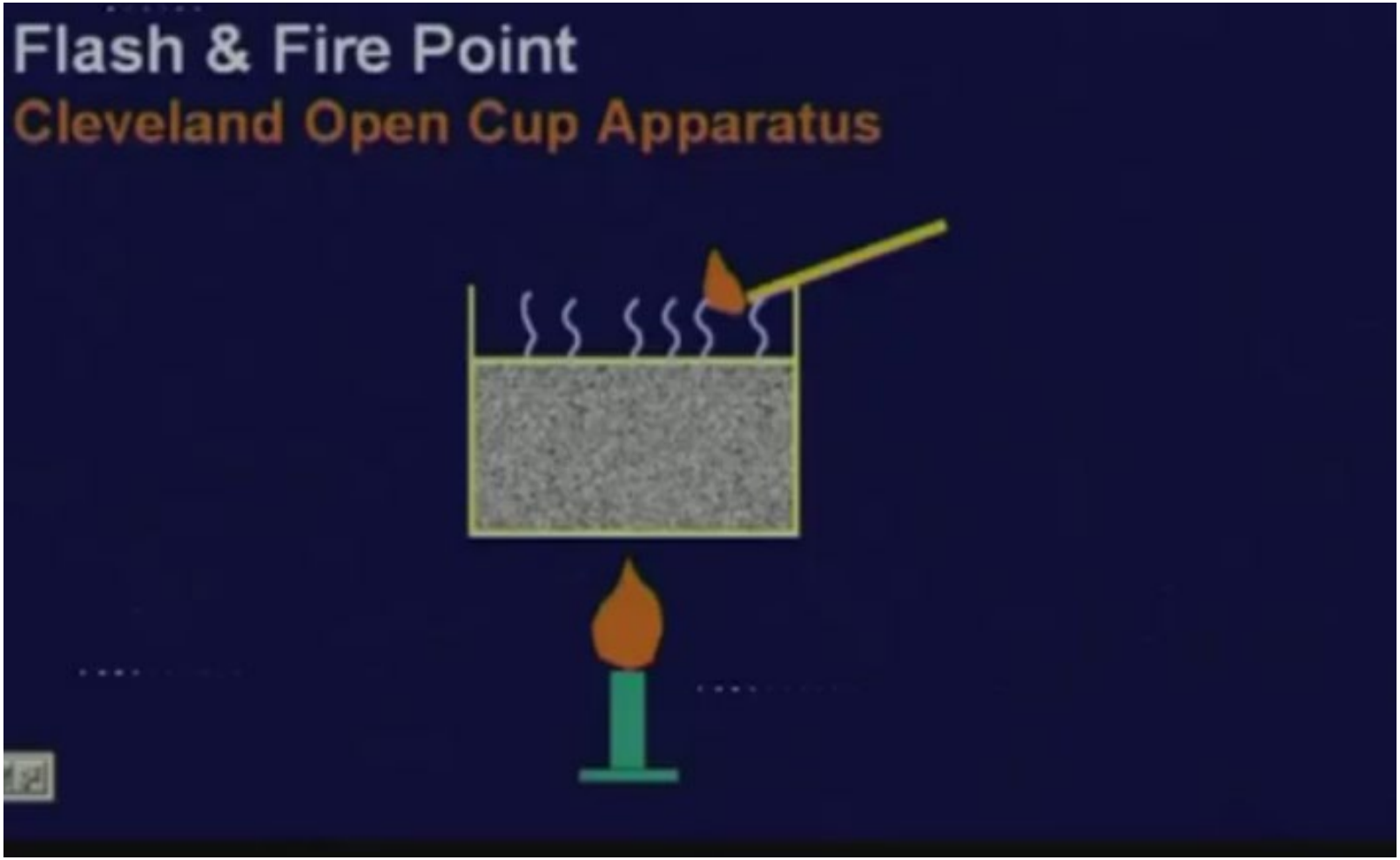

Control
0.05 Lem Ac (Hypo)

Physical Properties

Safety: Bitumen is heated to high temperature (more than 160 0C). It should be safe to handle bitumen at high temperature.

- Flash and fire points indicate fire hazard.
- Flash point:- Temperature at which bitumen gives off vapours, which ignite in presence of flame, but the vapoure don't burn.
- Fire point:- Temperature beyond flash point, the vapours ignite in presence of flame and continue burn.

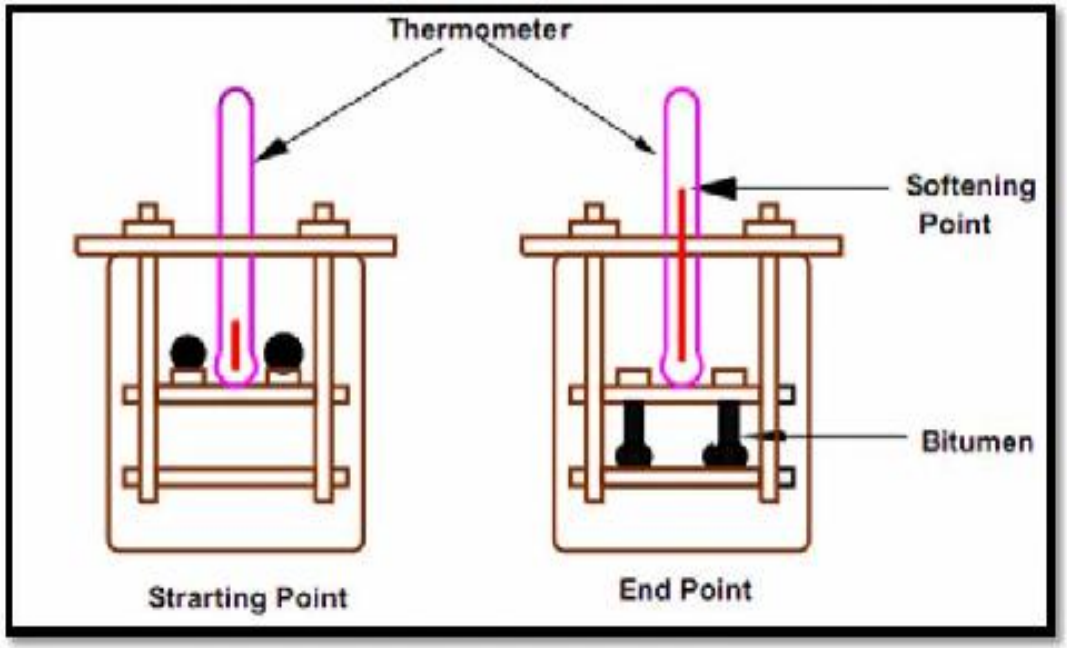
Physical Properties



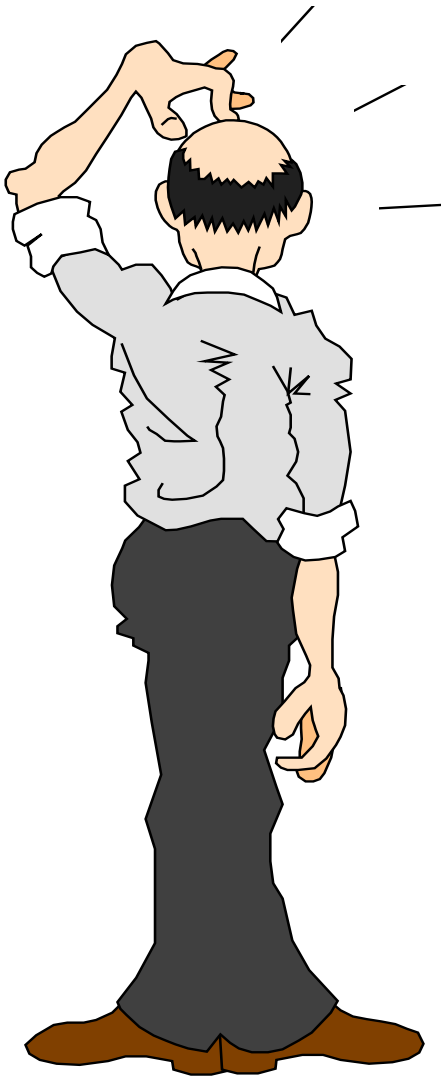
Ref. #1

Physical Properties

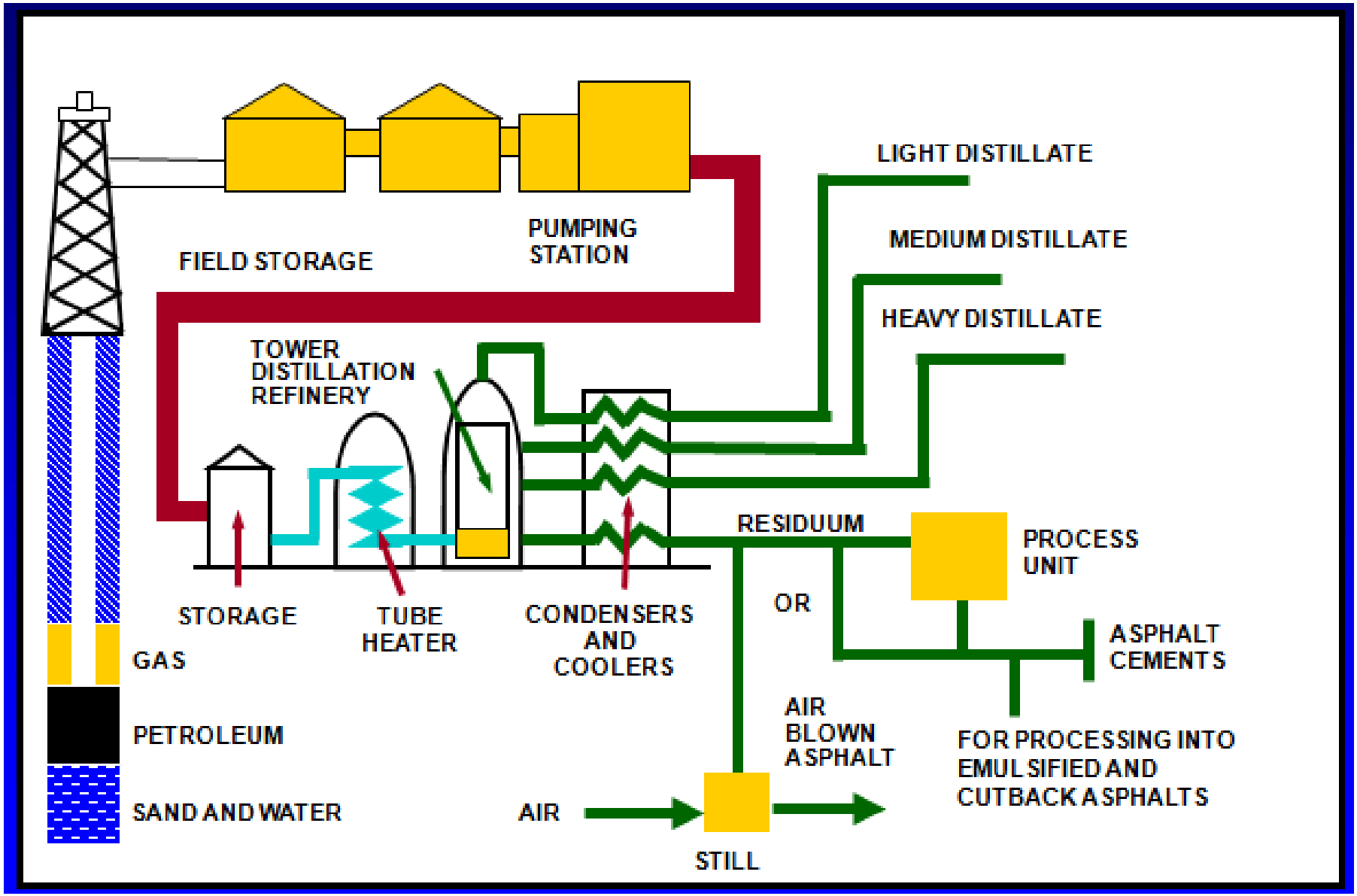
Softening point: If This test method covers the determination of the softening point of bitumen in the range from 30 to 157°C using the ring-and-ball apparatus immersed in distilled water (30 to 80°C) or USP glycerin (above 80 to 157°C).



Questions /Discussion



Refinery Operation



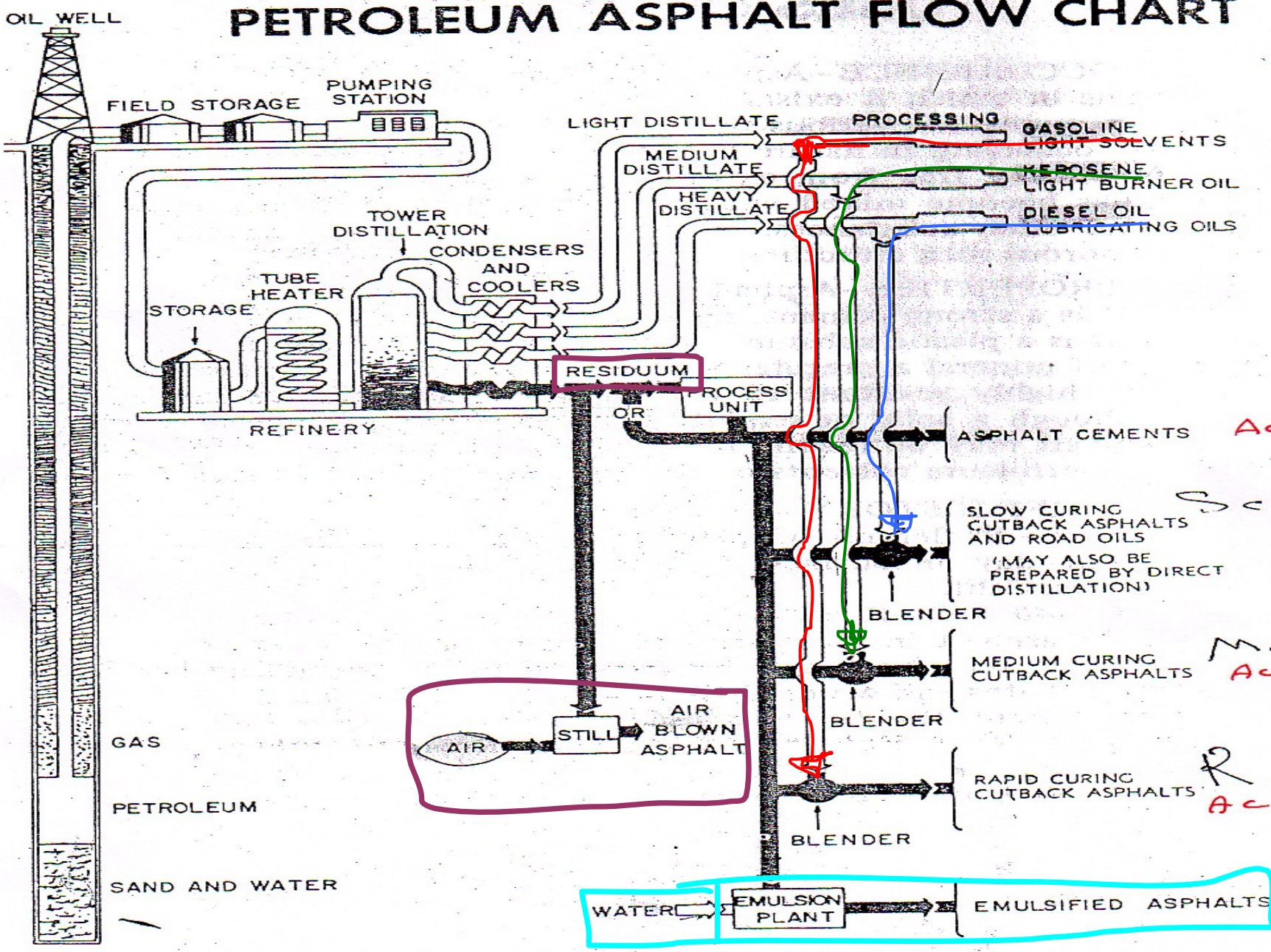
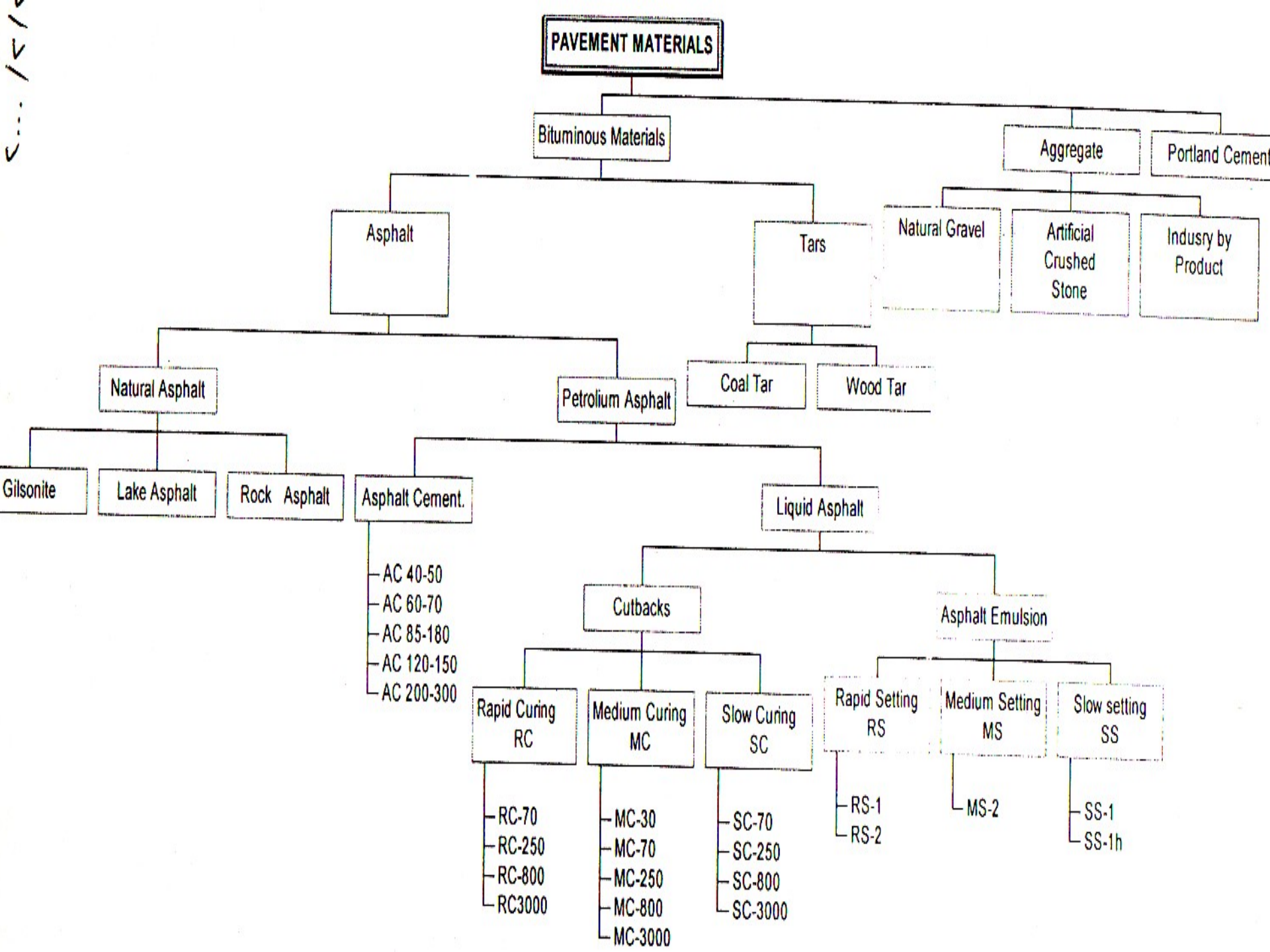


Figure I-1—Petroleum asphalt flow chart


PAVEMENT MATERIALS
Bituminous Materials
Aggregate
Portland Cement
Asphalt
Tars
Natural Gravel
Artificial Crushed Stone
Indusry by Product
Natural Asphalt
Petrolium Asphalt
Coal Tar
Wood Tar
Gilsonite
Lake Asphalt
Rock Asphalt
Asphalt Cement.
Liquid Asphalt
AC 40-50
AC 60-70
AC 85-180
AC 120-150
AC 200-300
Cutbacks
Asphalt Emulsion
Rapid Curing RC
Medium Curing MC
Slow Curing SC
Rapid Setting RS
Medium Setting MS
Slow setting SS
RC-70
RC-250
RC-800
RC3000
MC-30
MC-70
MC-250
MC-800
MC-3000
SC-70
SC-250
SC-800
SC-3000
RS-1
RS-2
MS-2
SS-1
SS-1h

Petroleum Asphalt Materials

1-Asphalt Cement: This asphalt produced by fractional distillation of crude oil petroleum. The residual material often separation of light oil is contain the asphalt which is refined into specific grade called penetration grade (40-50 & 60-70 & 85-100 &120-150 & 200-300).

Petroleum Asphalt Materials

2- Cut Back Asphalt: Asphalt cement which has been liquefied by blending with petroleum solvent called (diluents). It low viscosity, can be divided into three main types depending on solvent used:

- ✓ Slow curing cut back (Sc)
- ✓ Medium curing cut back (Mc)
- ✓ Rapid curing cut back (Rc)

Petroleum Asphalt Materials

2- Cut Back Asphalt:

- ✓ Slow curing cut back (Sc):-SC 70; SC 250; SC 800; SC 3000.
- ✓ Medium curing cut back (Mc):- MC 30; MC 70; MC 250; MC 800; MC 3000.
- ✓ Rapid curing cut back (Rc):- RC 70; RC 250; RC 800; RC 3000.
- ➢ Number indicate to kinematic viscosity (cst) at 60 0C

Petroleum Asphalt Materials

2-1 Slow curing (Sc): Composed of asphalt cement and slowly diluents (diesel oil). its used to :-

- In the surface of soil –aggregate roads in warm climate in order to Keep the dry soil particles from creating a dust under traffic.
- Maintenance (patching)
- Soil Stabilization.

Petroleum Asphalt Materials

2-2 Medium curing (Mc): Composed of asphalt cement and medium diluent (kerosene oil). its used to :-

- Pavement stabilization.
- Prime coat.
- Dust laying.
- Maintenance (patching)

Petroleum Asphalt Materials

2-3 Rapid curing (Rc): Composed of asphalt cement and high diluents (gasoline oil). its used to :-

- tack coat.

Petroleum Asphalt Materials

3- Emulsified (AE): This emulsion asphalt produced by asphalt cement into minute particles and dispersing then in water. This particles have two charge

- Anionic : positive charge.
- Cationic: Negative charge.

Petroleum Asphalt Materials

- Emulsion divided into
  - ✓ Rapped setting.
  - ✓ Medium setting .
  - ✓ Slow setting.
- Its used to
  - ✓ maintenance work (sand seal, fog seal, slurry seal)
  - ✓ Tack coat.
  - ✓ Prime coat.
  - ✓ Soil Stabilization.

Petroleum Asphalt Materials

4- Blown Asphalt:-Is obtained by blowing air through the asphalt cement. It is stiff when compared with other type. its not used in paving material , its useful as

- Roofing.
- Pipe coating.
- In joints.

Petroleum Asphalt Materials

5- Oiling :- Divided into

- Prime coat.
- Tack coat.
- Seal Coat :-divided into
  1- Sand Seal.
  2- Chip Seal.
  3- Double Seal.
  4- Triple Seal.
  5- Slurry Seal.
  6- Fog Seal.

Petroleum Asphalt Materials

- **Prime coat:-** it is used to prepare an untreated base for an surface , its help bind to the overlaying asphalt course.

*Uses:- MC-70 (1-1.25)Kg /m2

SS (1-2.5)Kg /m2

AE (1-2.5)Kg /m2

*No allow use RC

- If increase lead to Bleeding.
- If decrease lead to Shoving.*

Pushing, Shoving

Bleeding

Petroleum Asphalt Materials

- **Tack coat:-** it is used to ensure bond between the surface being pavement and the overlaying course.

*Uses:- RC (0.25-1)Kg /m2

AE (0.25-1)Kg /m2

AC (120-200) (0.25-1)Kg /m2

Petroleum Asphalt Materials

- **Seal coat:-**it is used waterproof and improve skid resistance in wearing surface when aggregate polished. Depending on purpose it may or may not be covered with aggregate. It is dived into main groups:-
  1- Sand Seal.
  2- Chip Seal.
  3- Double Seal.
  4- Triple Seal.
  5- Slurry Seal.
  6- Fog Seal.

Petroleum Asphalt Materials

- **Sand Seal:-**Spray asphalt then sand and use pneumatic roller.

*Uses:- RC & RS & AC (120-150)

*Used in city street.

- **Chip Seal:-**Spray asphalt then aggregate and use pneumatic roller.

*Uses:- RC & RS (1-1.5)Kg/m2

*Aggregate ½-1/4 (in)

Petroleum Asphalt Materials

- **Slurry Seal:-** Crushed aggregate than mixed with asphalt.

*Uses:- RC

*Used in mainly in airport.

- **Fog Seal:-** Light application of AE with water.

*Uses:- (1:1&1:1.5)

*Used to renew old pavement to seal small crack

* Rate 0.5-0.9 Kg/m2

Modified Bitumen

- Limitations of Oil Refining Practice
  - ✓Asphalt is only one of many products
  - ✓Little incentive to improve quality

- Physical Nature of Asphalt
  - ✓Very sensitive to temperature
  - ✓Soft at high temperature /Brittle at low temperatures

- Increased heavy traffic (trucks) volumes

- Different modifiers are used to improve the performance of bitumen. Such as:-
  - ✓Sulphur
  - ✓Rubber
  - ✓Polymer (SBS, EVA,…)

Modified Bitumen

The main reasons to modify asphalts with polymers could be summarized as follows [4]

- ✓To obtain softer blends at low temperatures and reduce cracking.
- ✓To reach stiffer blends at high temperatures and reduce rutting
- ✓To reduce viscosity at layout temperatures.
- ✓To increase the stability and the strength of mixtures.
- ✓To improve fatigue resistance of blends.
- ✓To improve oxidation and aging resistance.
- ✓To reduce structural thickness of pavements.
- ✓To reduce life costs of pavements.

Modified Bitumen

Polymer	Advantages	Disadvantages	Uses
Ethylene-vinyl-acetate (EVA) Ethylene-methacrylate (EMA)	Outstanding compatibility in some cases. Minimal viscosity changes compared to competitive products. Thermally stable at normal mixing and handling temperatures. Low cost, as compared to block copolymers Increased tack.	No improvement in elastic recovery	Paving and roofing
PVC	Lower cracking PVC disposal	Acts mostly as filler	Not commercially applied.
Styrene-butadiene block copolymer (SBS) Styrene-isoprene block copolymer (SIS)	Higher flexibility at low temperatures (*) Better flow and deformation resistance at high temperatures Strength and very good elasticity Increase in rutting resistance	High cost Reduced penetration resistance Higher viscosity at layout temperatures Resistance to heat and to oxidation is lower than that of polyolefins (due to the presence of double bonds in the main chain)	Paving and roofing

Modified Bitumen

Notes:-

1) No excessive heating of modified binder as it will result in.
   - ✓Degradation and rapid oxidation of binder.
   - ✓Modified binder losing its important properties.
   - ✓Stiff mix causing difficulty in rolling.

2) Multiple heating should be avoided
3) Excess quantity modifier may cause difficulty in mixing.

Modified Bitumen

Separation Test

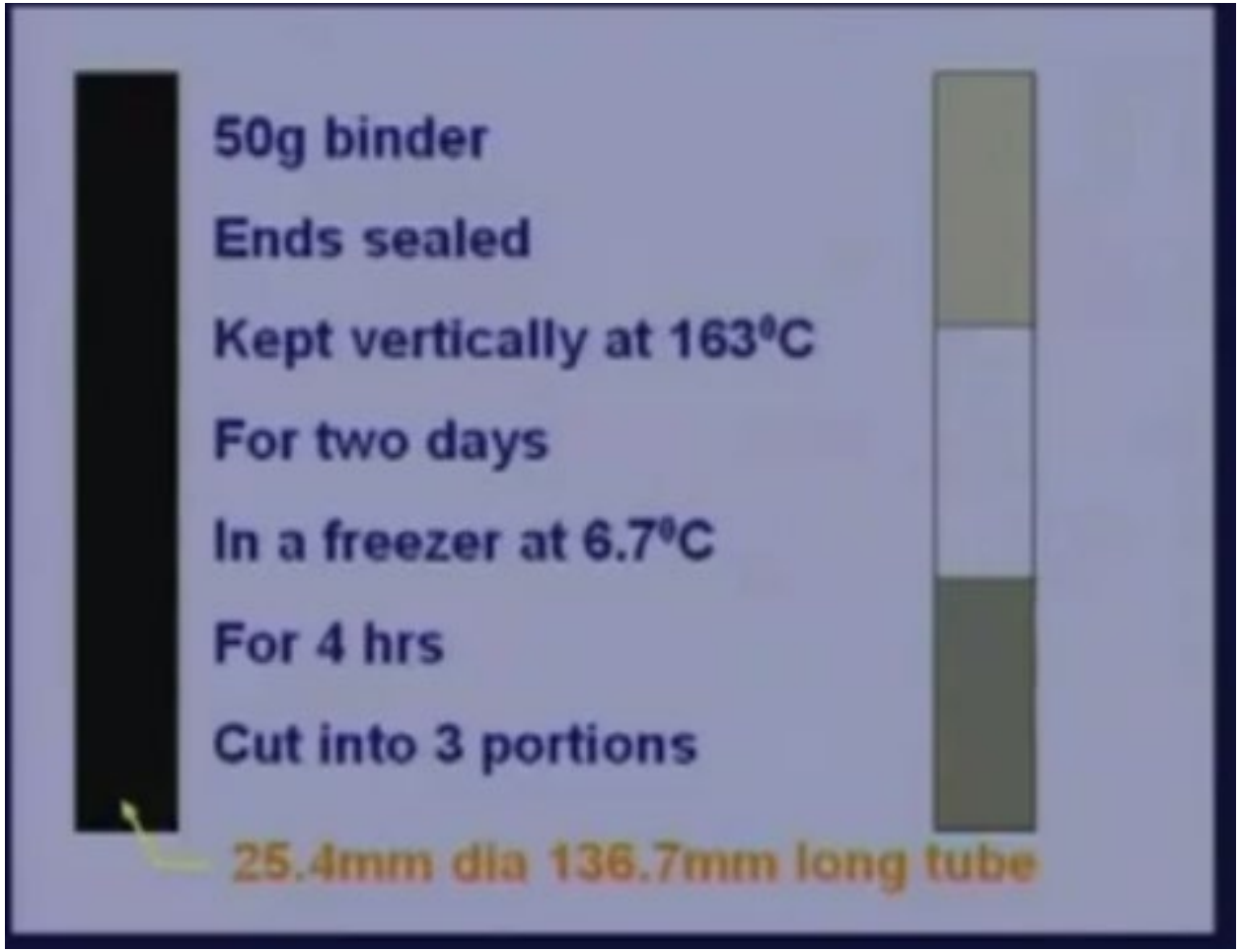
Storing the modified binders at elevated temperatures can cause the constituents of the binders to separate resulting in variation of properties from the top to the bottom of the storage tank.

Storage stability test is meant for evaluating the susceptibility of binder to separate

Binder is filled in a tube and stored for a period of time in an oven. The tube is frozen and cut into three pieces. Properties of the binder collected from the top and bottom portions are compared.

Reference #2

Modified Bitumen

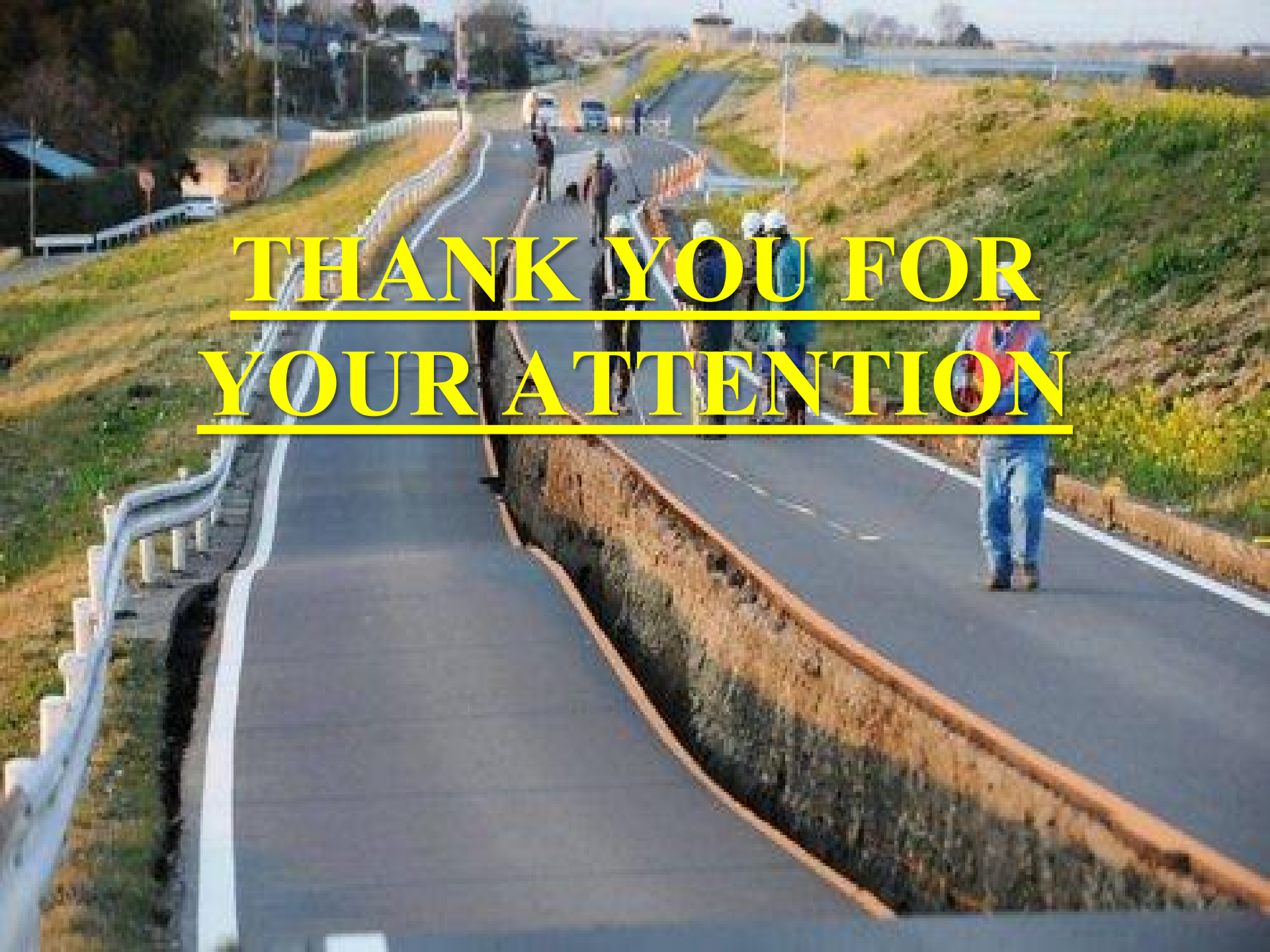


Reference #2

Petroleum Asphalt Materials

See Notes

See Tables (Asphalt Uses & tests)


THANK YOU FOR
YOUR ATTENTION

Mix (HMA) Requirements

- Stability.
- Flexibility.
- Workability.
- Durability
- Safety (Skid Resistance).

Mix (HMA) Requirements

1-Stability:-To resist permanent deformation. Good stability is achieved by:-

- Aggregate with high crushing strength.
- Aggregate with angular in shape.
- Aggregate with rough surface.
- High asphalt content, but with limit.
- Sand &filler percent.
- Degree of compaction.

Mix (HMA) Requirements

2-Flexibility:-Ability of (HMA) to bent without creaking (to resist creaking). Good Flexibility is achieved by:-

- Type of Aggregate graded. (Open graded with high asphalt content).
- High asphalt content, but with limit.

Mix (HMA) Requirements

3-Workability:-To be able to spread easily and compacted to maximum density. Good workability is achieved by:-

1. High temperature of mixing.
2. Coarse Aggregate percent.(Difficult spread)*
3. Filler Aggregate percent.(Difficult spread)
4. High asphalt content, but with limit.
5. Low viscosity of asphalt.

Mix (HMA) Requirements

4-Durability:-To resist weather change & rapid aging. Good durability is achieved by:-

- Type of Aggregate graded. (Dense graded)
- Aggregate Type (strong, hard, clean, dry aggregate resistant to polishing, crushing, freeze-thaw effects; not water sensitive
- High asphalt content, but with limit.
- Degree of compaction.

Mix (HMA) Requirements

5- Skid Resistance:-(wearing Course)

- Mix should provide surface with good skid resistance property. It is achieved by (Using coarse Aggregate which has a high resistance to Polishing).
- Asphalt content:-(Bleeding)

References

1) Asphalt Institute book
2) K. Sudhaker Reddy, “Highway Materials Lecture” IIT Kharagpur, India.
3) Lewandowski, L.H. Polymer Modification of Paving Asphalt Binders. Rubber Chemistry and Technology, 67(3): 447, July-August, 1994.
4) Internet websites.

THANK YOU FOR LISTENING