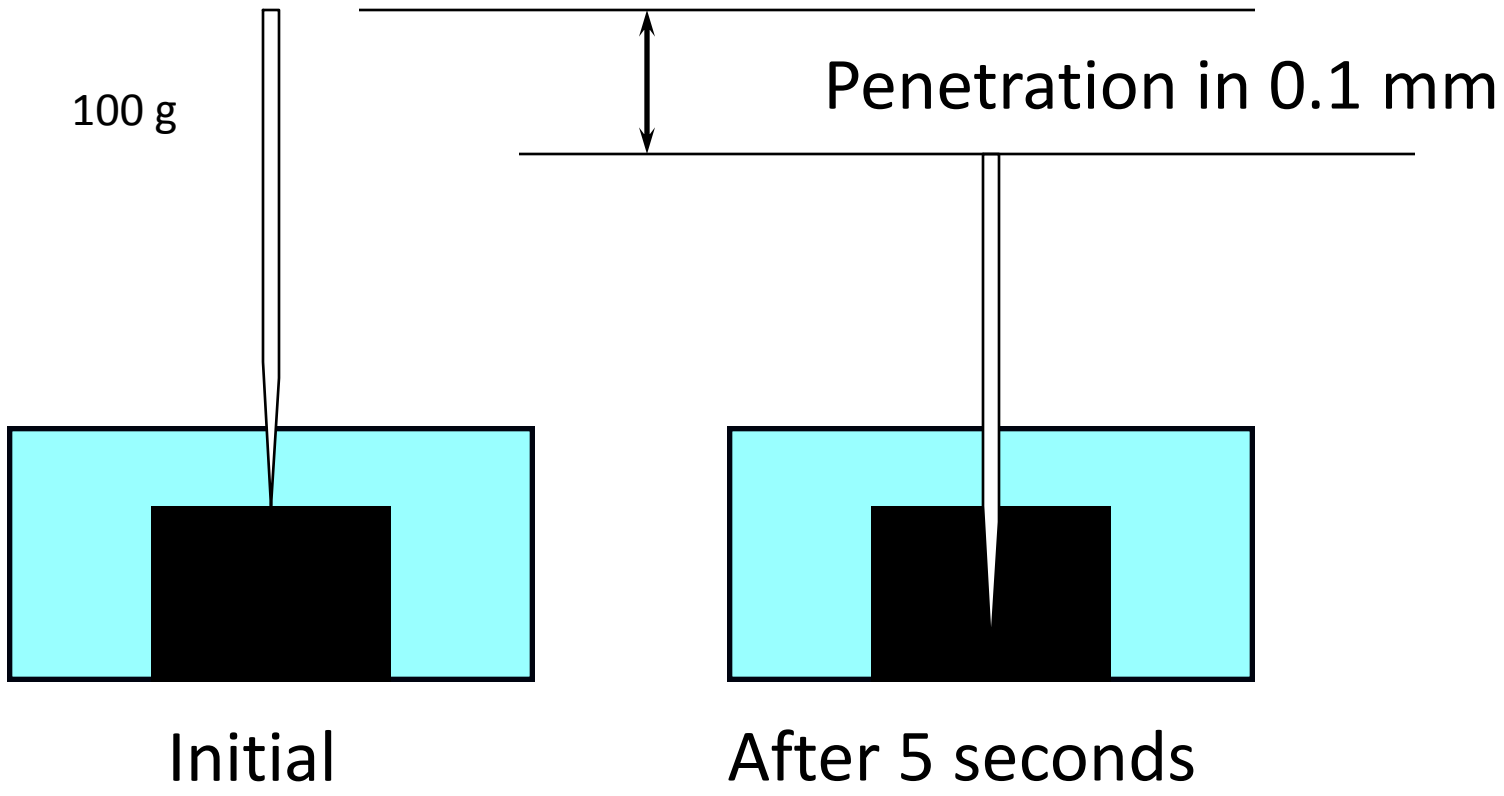
Asphalt Binder Specifications

Penetration Testing

- Sewing machine needle
- Specified load, time, temperature



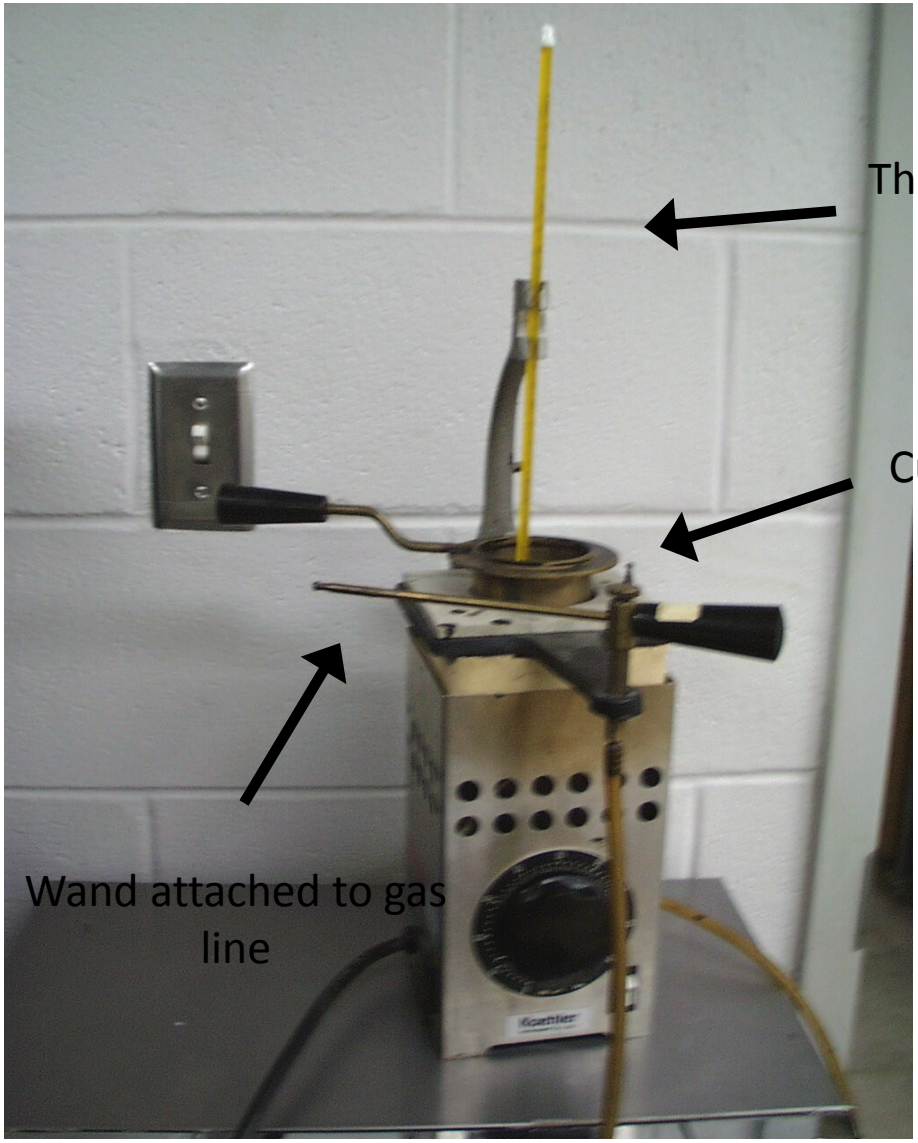
Penetration Specification

- Five Grades
  - 40 - 50
  - 60 - 70
  - 85 - 100
  - 120 - 150
  - 200 - 300

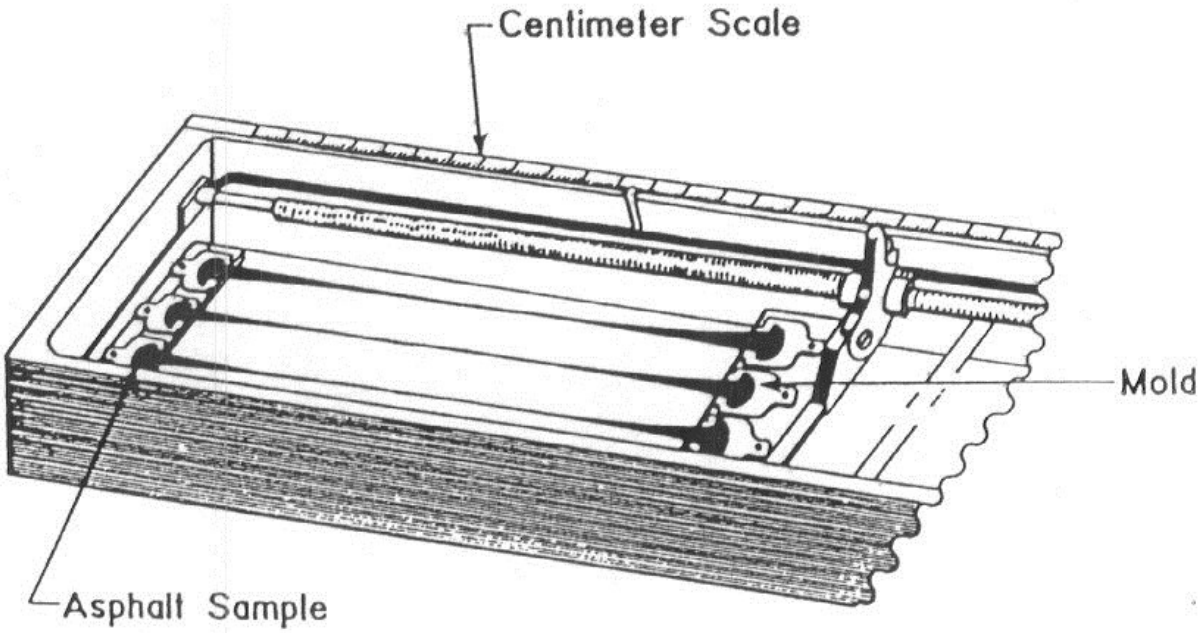
Penetration Gradation Specification

- Uses penetration results to specify
- Adds
  - Flash point test
  - Ductility
  - Solubility
  - Thin film oven aging
    - » Penetration
    - » Ductility

Flash Point (Safety)

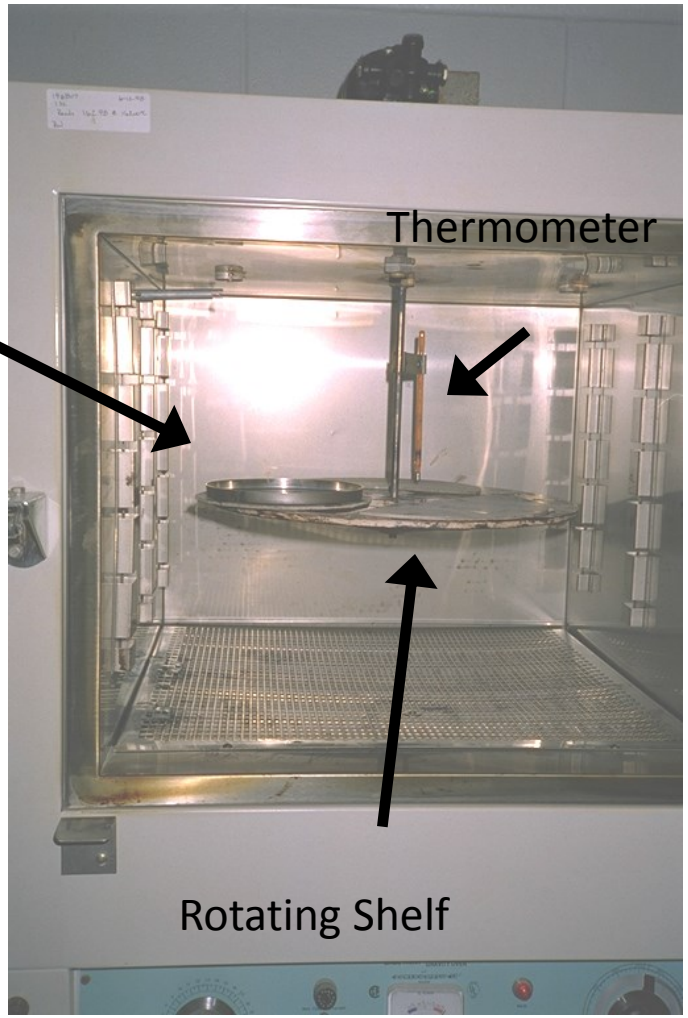


Ductility



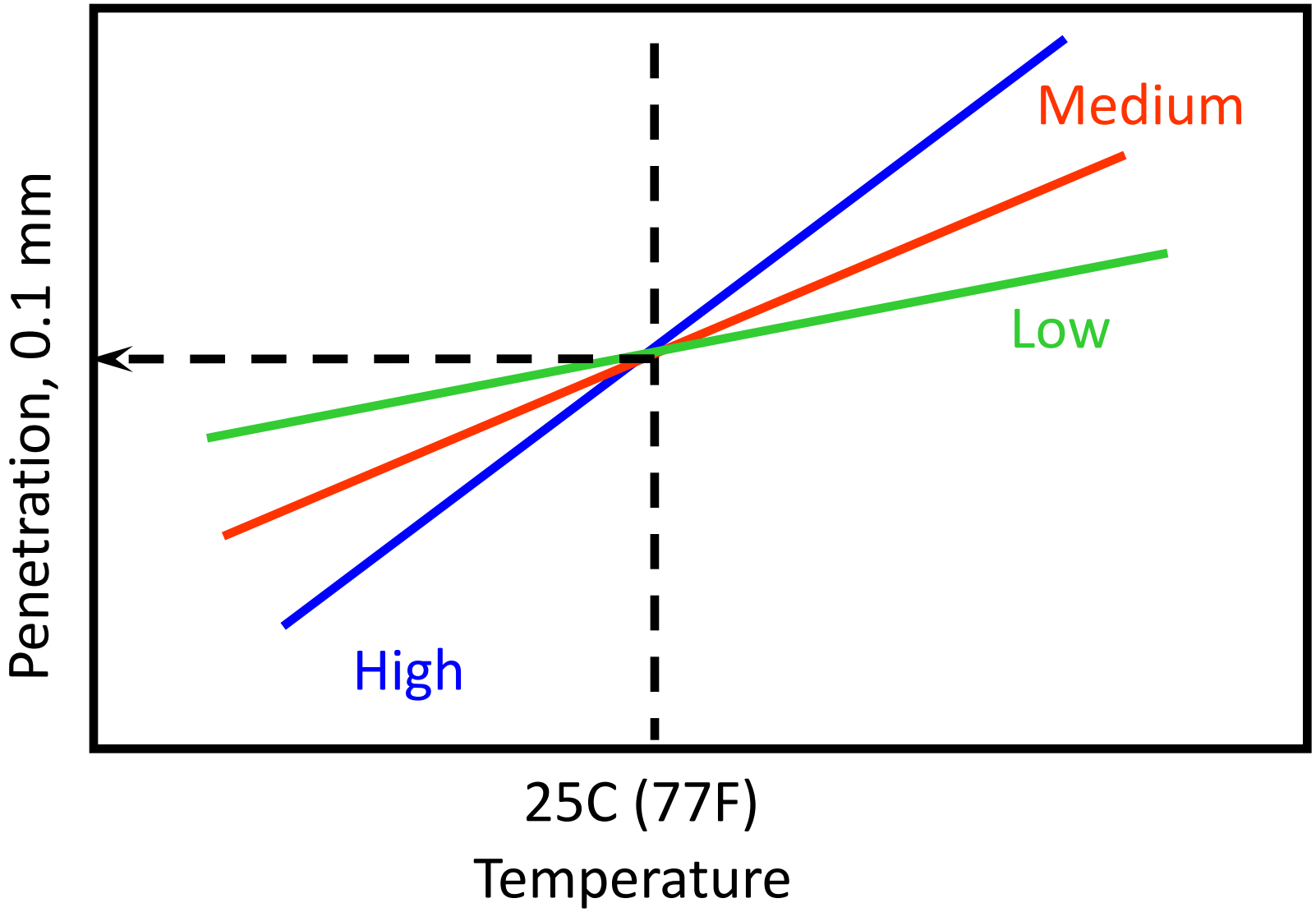
Solubility (Purity)

Thin Film Oven



Typical Penetration Specifications

Penetration	40 - 50	200 - 300
Flash Point, F	450+	350+
Ductility, cm	100+	100+
Solubility, %	99.0+	99.0+
Retained Pen., %	55+	37+
Ductility, cm	NA	100+


Medium
Low
High
Penetration, 0.1 mm
25C (77F)
Temperature

Advantages

- Grades asphalt binders near average in-service temp.
- Fast
- Can be used in field labs
- Low capital costs
- Precision well established
- Temp. susceptibility can be determined

Disadvantages

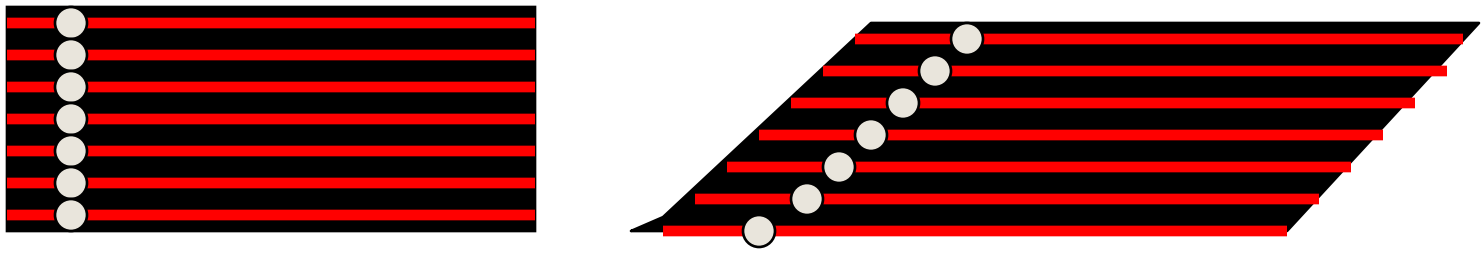
- Empirical test
- Shear rate
  - High
  - Variable
- Mixing and compaction temp. information not available
- Similar penetrations at 25C (77F) do not reflect wide differences in asphalts

Viscosity Graded Specifications

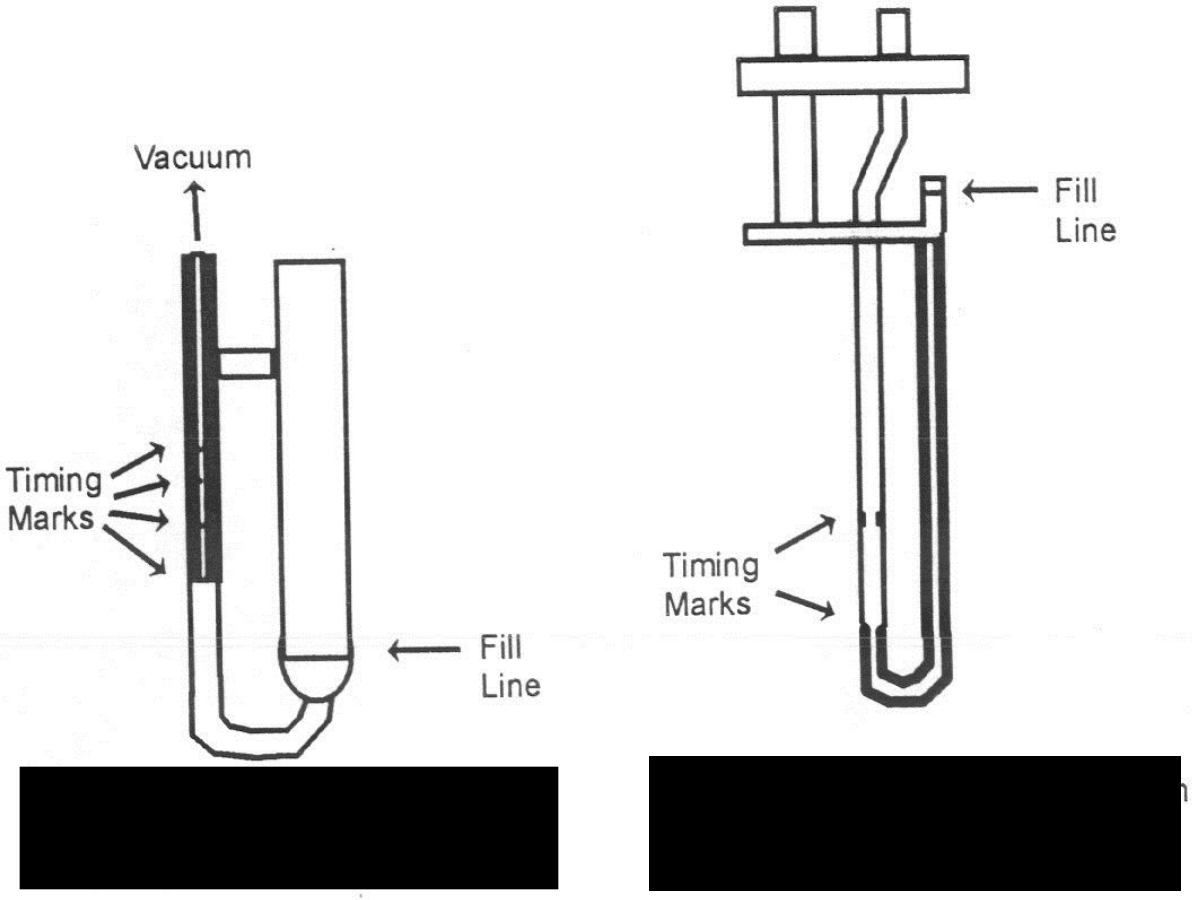
Definition

Viscosity: the ratio between the applied shear stress and the rate of shear.

$$\eta = \tau / \dot{\gamma}$$



Types of Viscosity Tubes



Testing

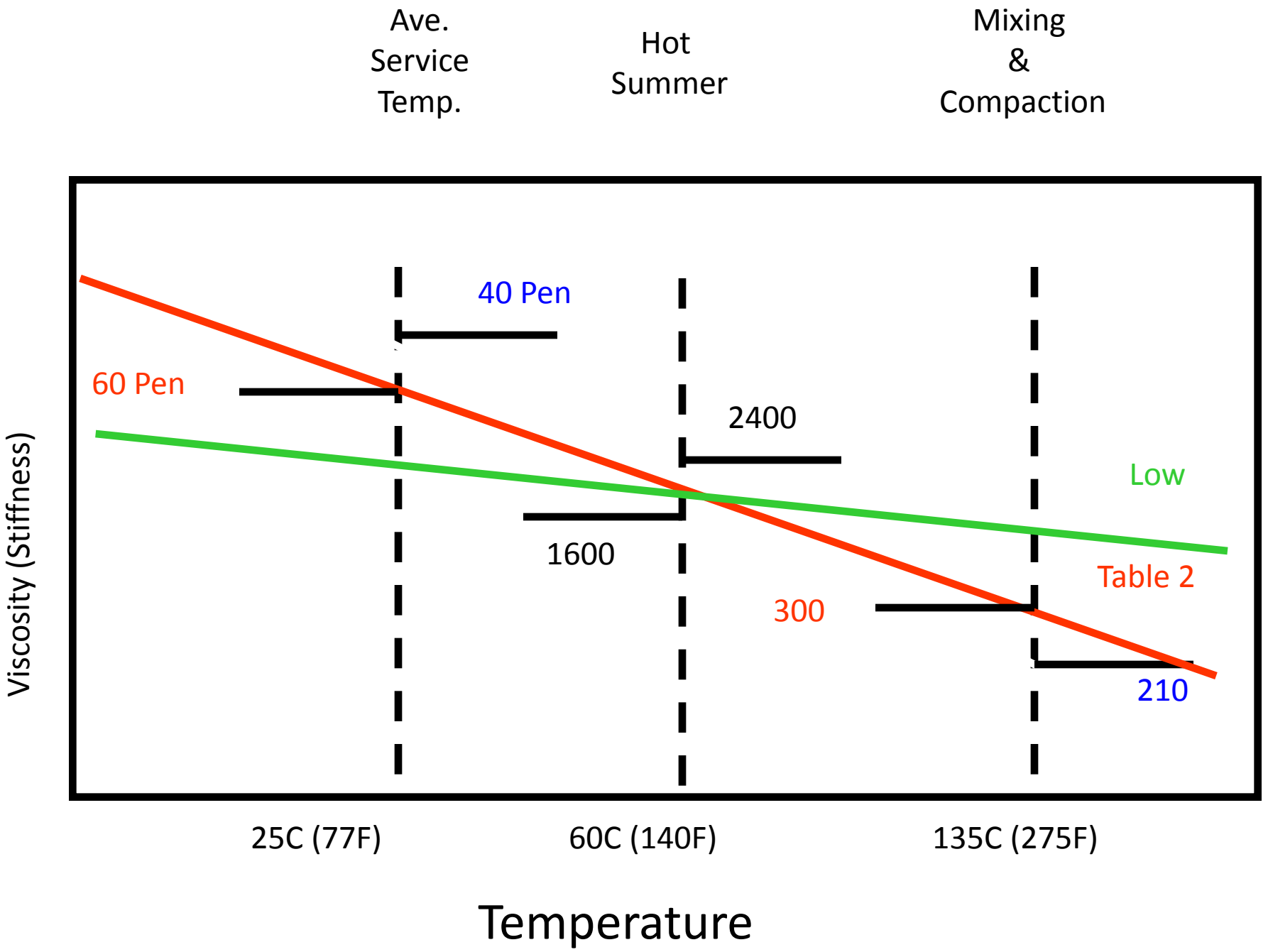
- Absolute viscosity
  - U-shaped tube with timing marks & filled with asphalt binder
  - Placed in 60C bath
  - Vacuum used to pull asphalt through tube
  - Time to pass marks
  - Visc. in Pa s (Poise)

Testing

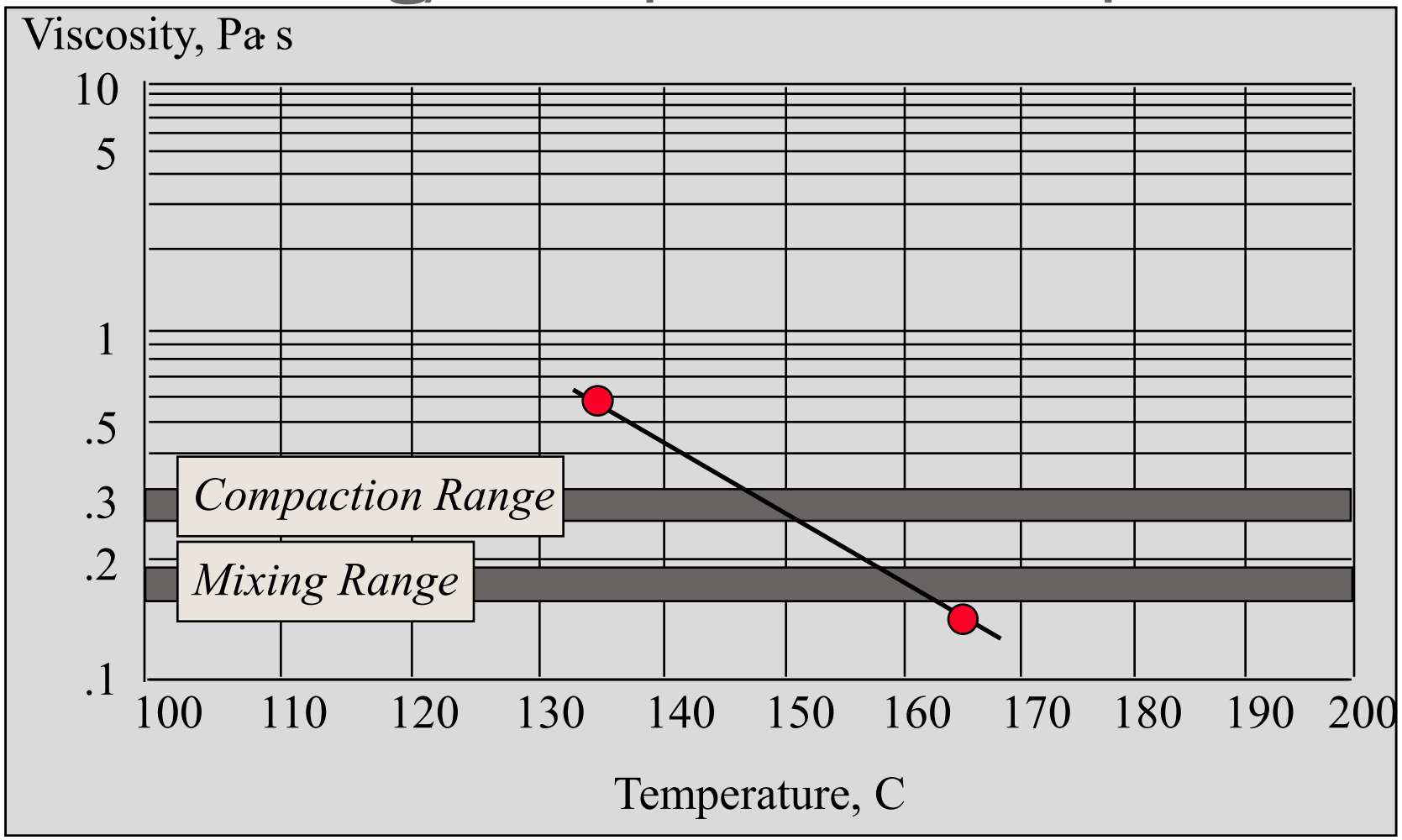
- Kinematic viscosity
  - Cross arm tube with timing marks & filled with asphalt
  - Placed in 135C bath
  - Once started gravity moves asphalt through tube
  - Time to pass marks
  - Visc. in mm^2 / s (centistoke)

Example

	AC 2.5	AC 40
Visc, 60C	250 ± 50	4,000 ± 800
Visc, 135C	80+	300+
Penetration	200+	20+
Visc, 60C	<1,250	<20,000
Ductility	100+	10+


Ave.
Service
Temp.
Hot
Summer
Mixing
&
Compaction
40 Pen
60 Pen
2400
1600
Low
Table 2
300
210
Viscosity (Stiffness)
25C (77F)
60C (140F)
135C (275F)
Temperature

Mixing/Compaction Temps



Advantages
(Original AC Visc. Grade)

- Fundamental property
- Wide range of temperatures
- Based on max. pavement surface temp.
- Wide range of instruments
- Test method precision established
- Temperature susceptibility is controlled
- Limits aging
- Information on mixing & compaction temps.

Disadvantages
(Original AC Visc. Grade)

- More expensive
- Longer testing time
- More technician skill needed
- Not applicable for Non-Newtonian materials
- Wide range of properties for same grade

AR Grades

- AR Grades
  - AR 1000, AR 2000, AR 4000, AR 8000, AR 16000
- Tests on RTFO aged residue
  - Viscosities at 60 and 135^{o}C
  - Penetrations at 25^{o}C
  - % of Original Penetration
  - Ductility
  - Properties of unaged asphalt binders
    - » Flash point and solubility

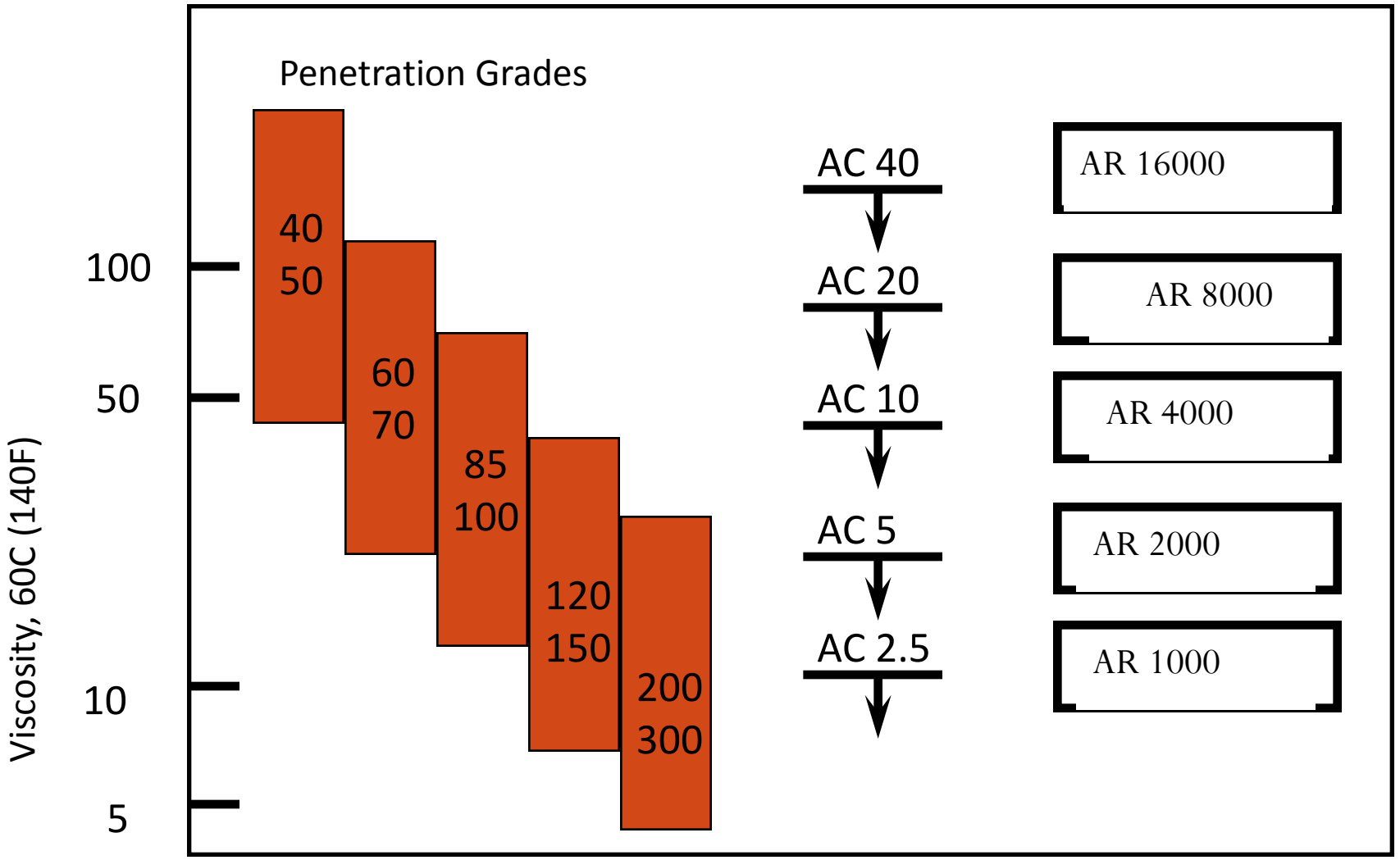
Rolling Thin Film Oven

Advantages (AR Visc. Grade)

- Represents asphalt binder properties after mixing
- Fundamental properties
- Covers wide range of temperatures
- Limits aging

Disadvantages (AR Visc. Grade)

- Highly regional
- Requires different testing equipment
- Longer testing time
- No consistency test on original Asphalt Binder
- Not applicable for Non-Newtonian materials
- Wide range of properties for same grade

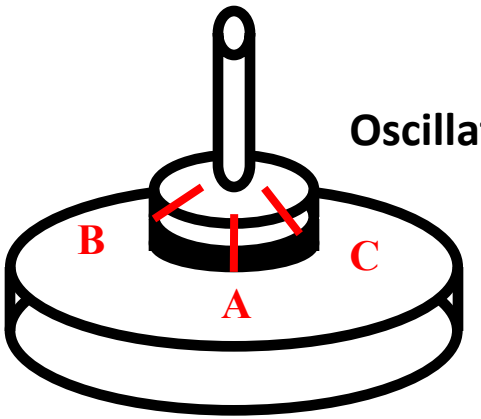

Penetration Grades
Viscosity, 60C (140F)
100
50
10
5
40
50
60
70
85
100
120
150
200
300
AC 40
AC 20
AC 10
AC 5
AC 2.5
AR 16000
AR 8000
AR 4000
AR 2000
AR 1000

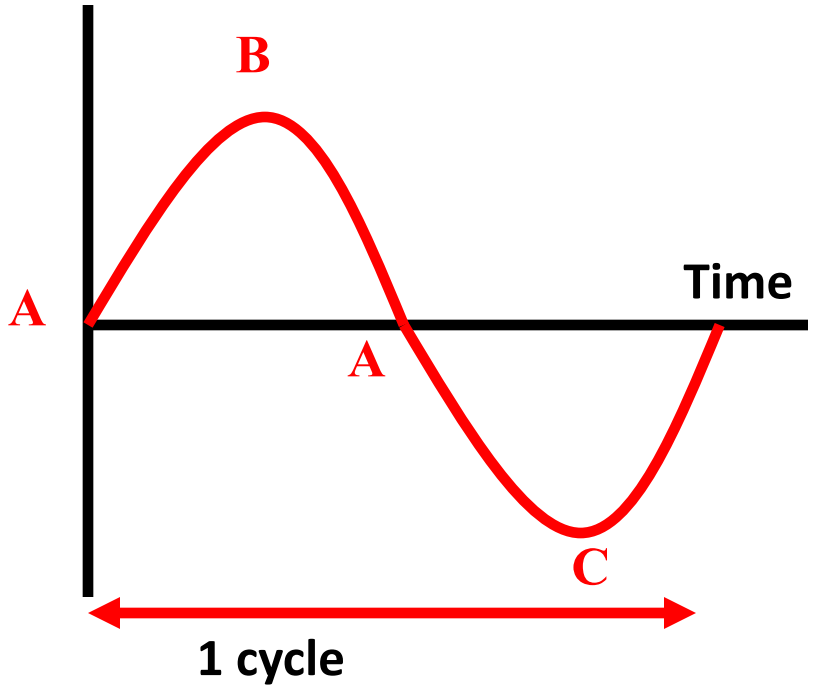
Rheology

- Rheology:
  - the study of flow and deformation
- Constitutive relations
  - fundamental relationships between force and deformation

Rheometers

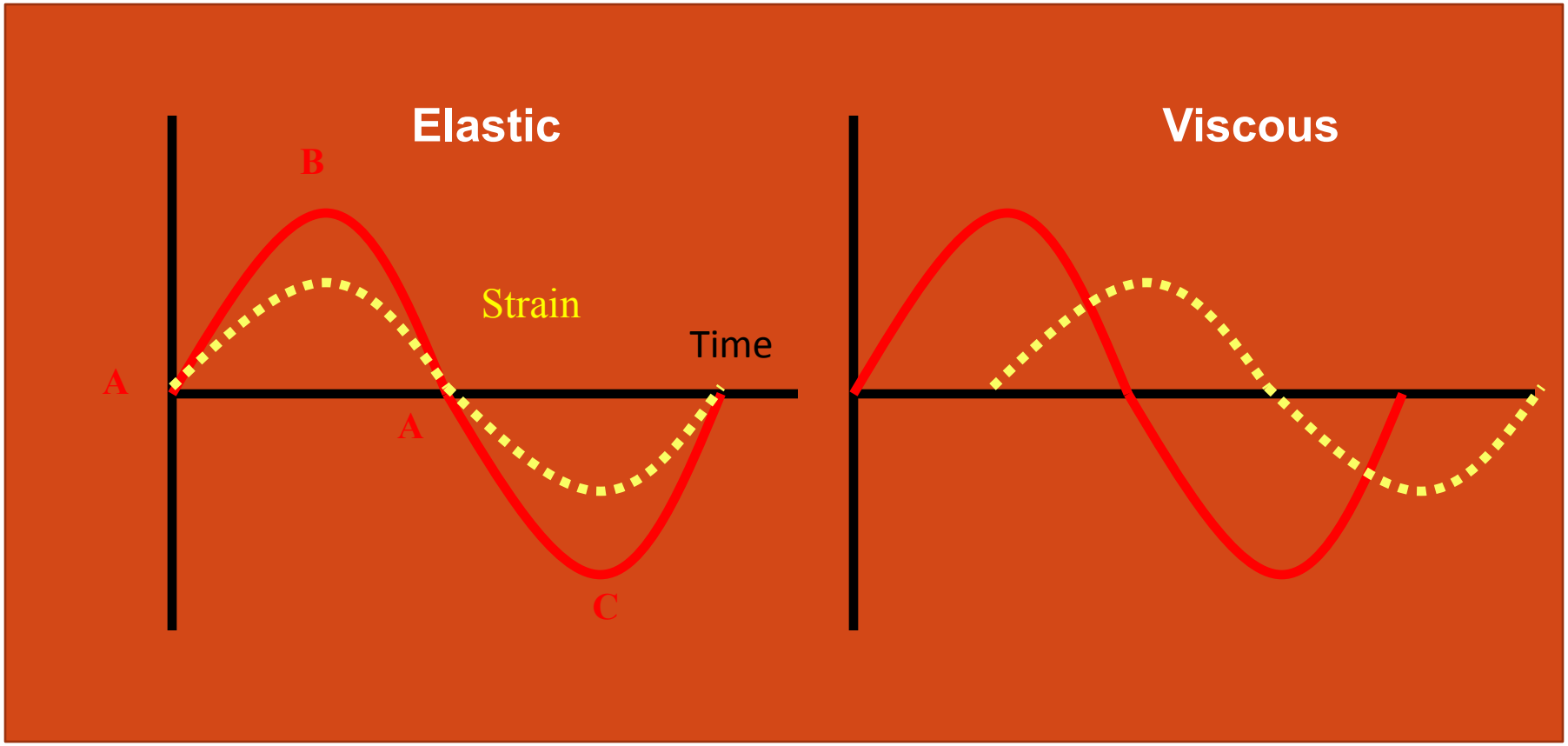
- Equipment used to measure rheology
- Shear rheometers
  - Drag flow
  - Pressure driven flows
- Rheometers for measuring stiffness and strength
  - Bending beam
  - Direct tension





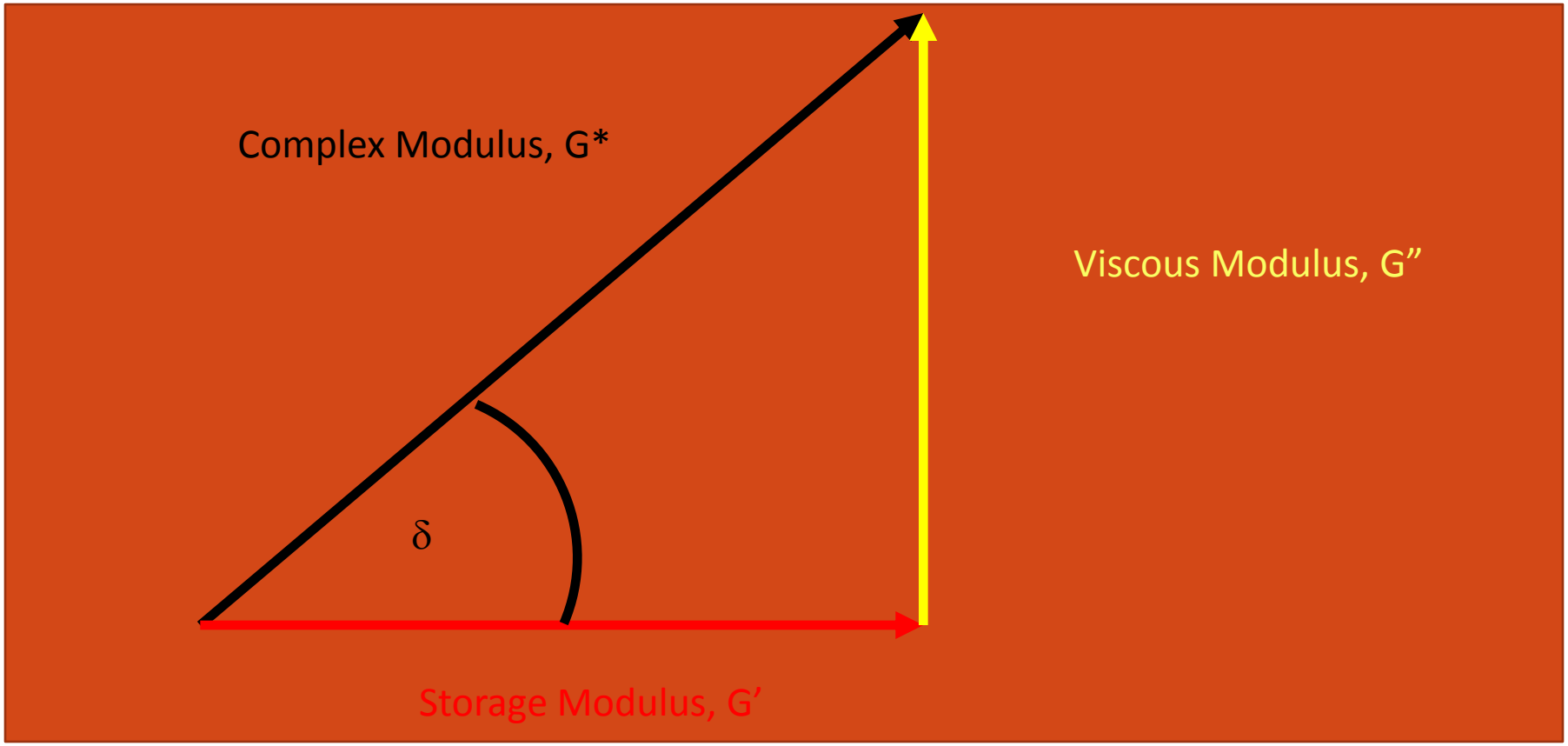
Test operates at 10 rad/sec
or 1.59 Hz

360^{o} = 2 p radians per circle
1 rad = 57.3^{o}



Strain in-phase
$\delta = 0^o$

Strain out-of-phase
$\delta = 90^o$



Complex Modulus is the vector sum of the storage and viscous modulus

Fine Aggregates

Shape, Angularity, and Surface Texture

Cleanliness

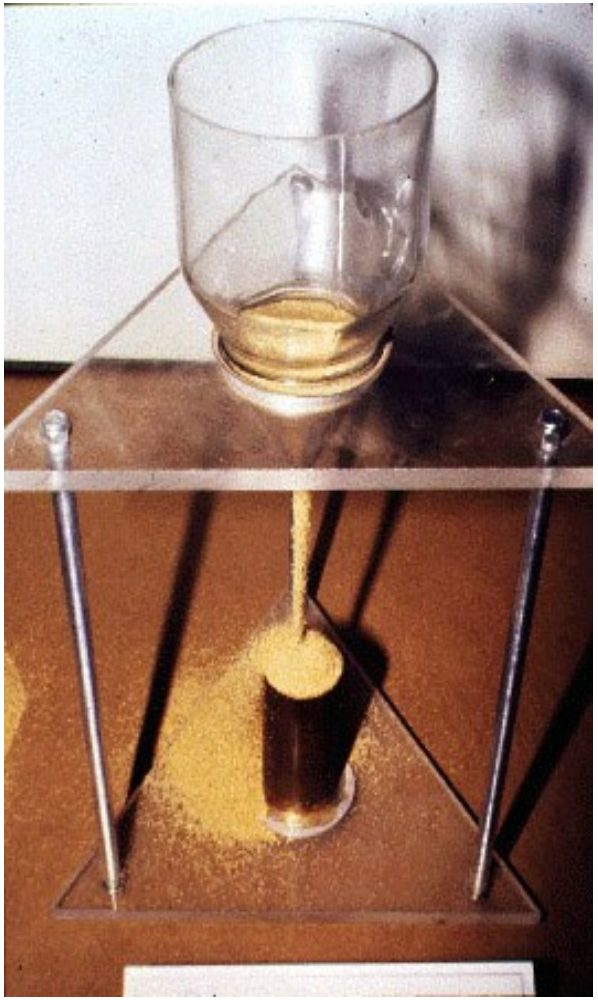
Properties of Minus 0.075 mm

Particle Index
ASTM D3398

- Vol. of voids between packed, uniform-size aggregate particles indicate combined effect of shape, angularity and surface texture
  - 76, 51, and 38 mm diameter molds
  - each of three layers tamped 50 mm above surface
    - 10 blows/layer
    - 50 blows/layer
  - $I_a = 1.25\,V_{10} - 0.25\,V_{50} - 32.0$
  - Particle index increases with angularity

Fine Aggregate Angularity (ASTM C1252)

- Void volume indicator of shape, surface texture
- Uncompacted voids in fine aggregate



Fine Aggregate Angularity (ASTM C1252)

Examples of Test Results

Method	Type Agg.	95% Confidence Limits
A	Natural	39.5 - 45.5
	Manufact.	42.8 - 53.4
B	Natural	43.0 - 49.2
	Manufact.	46.8 - 57.0

Plastic Fines in Fine Aggregate

- Mineral Finer than 0.075 mm in Mineral Aggregate by Washing
- Sand Equivalent
- Plasticity Index

Minus 0.075mm by Washing (ASTM C117)

- Only measures quantity not quality of minus 0.075 mm (P200).

Clay Content

- Sand equivalent
- Plasticity index
- Methylene blue

Plasticity Index

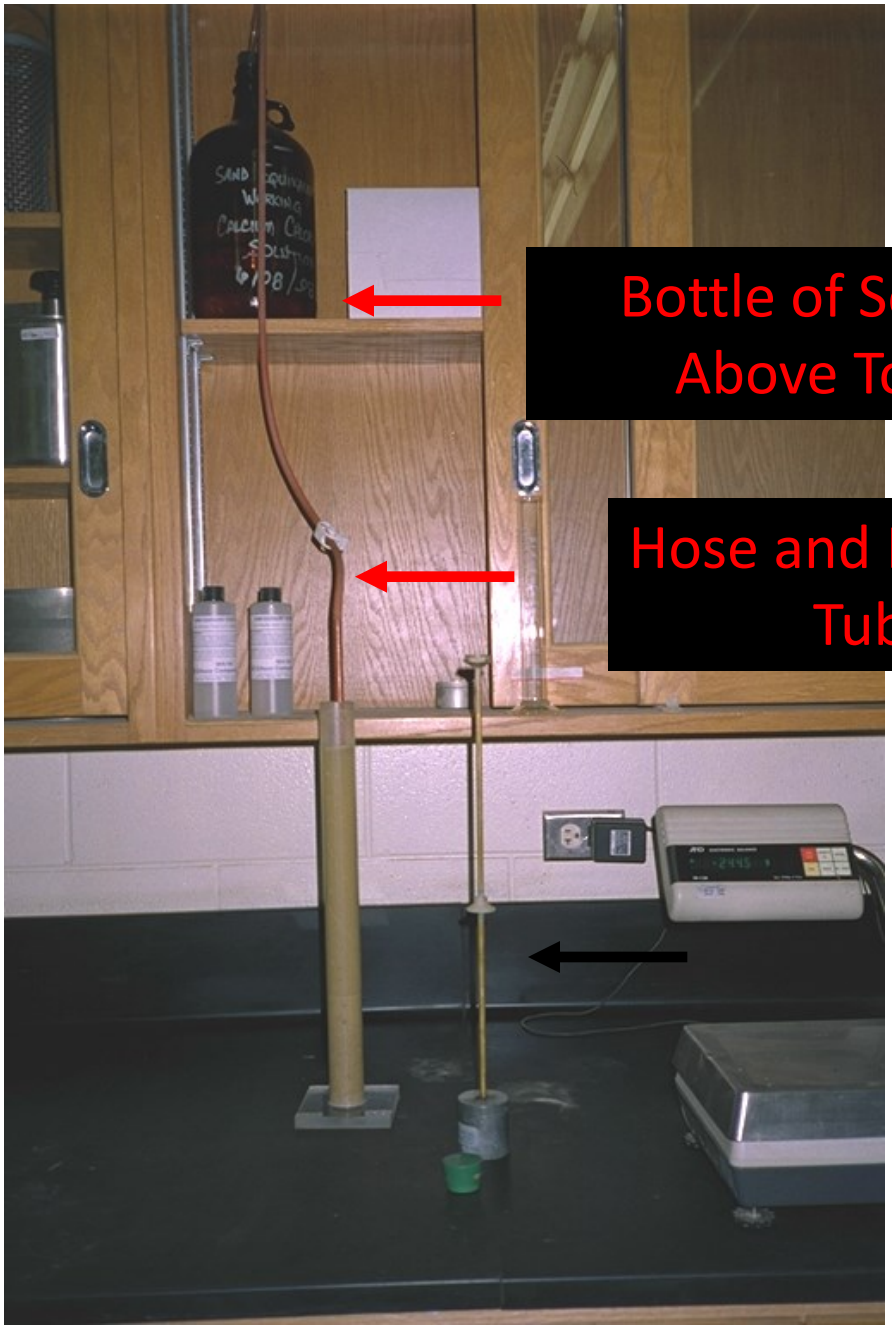
- Atterberg limits
  - Used to determine
    - Liquid limit
    - Plastic limit
    - Plasticity index
      - LL - PL

Plasticity Index

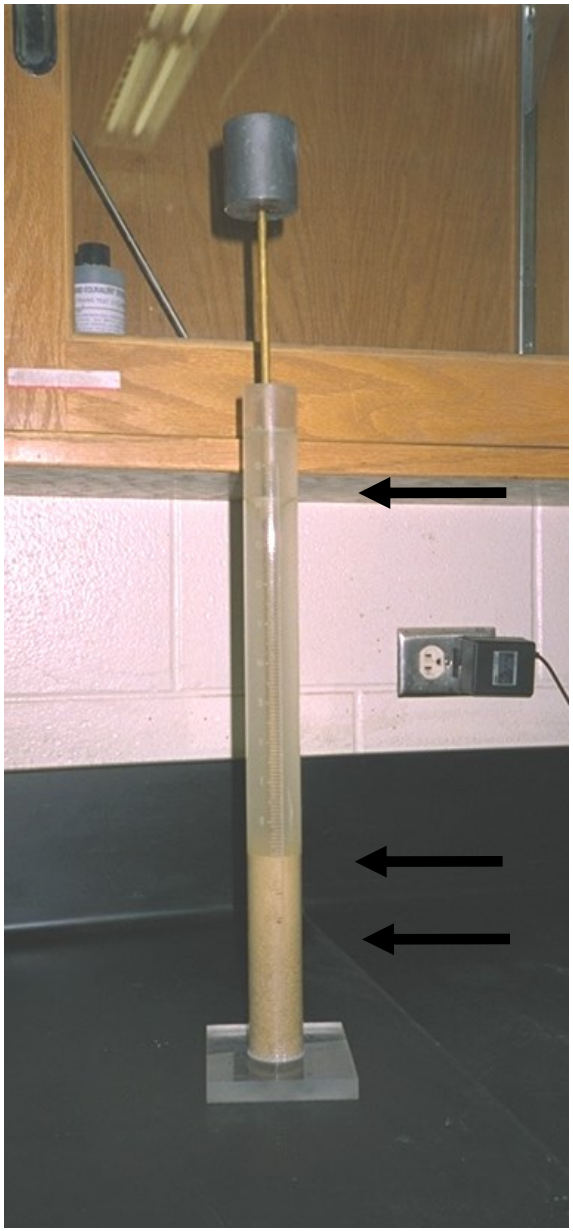
- Non-plastic for highway construction
  - PI < 4 to 6

Clay Content (ASTM D2419)

- Percentage of clay in material finer than 4.75 mm sieve ASTM D2419 or AASHTO T 176
  - Sand equivalent test method


Bottle of Solution on Shelf Above Top of Cylinder
Hose and Irrigation Tube
Measurement Rod

$$SE = \frac{\text{Sand Reading}}{\text{Clay Reading}} * 100$$



Flocculating Solution

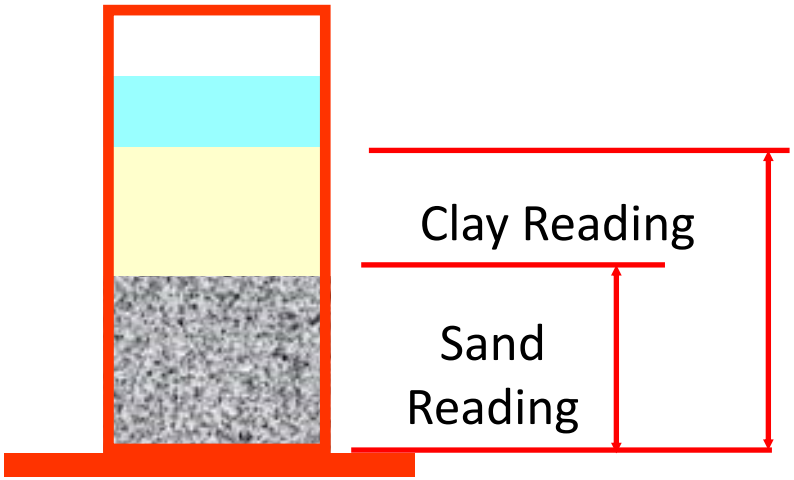
Suspended Clay

Sedimented Agg.

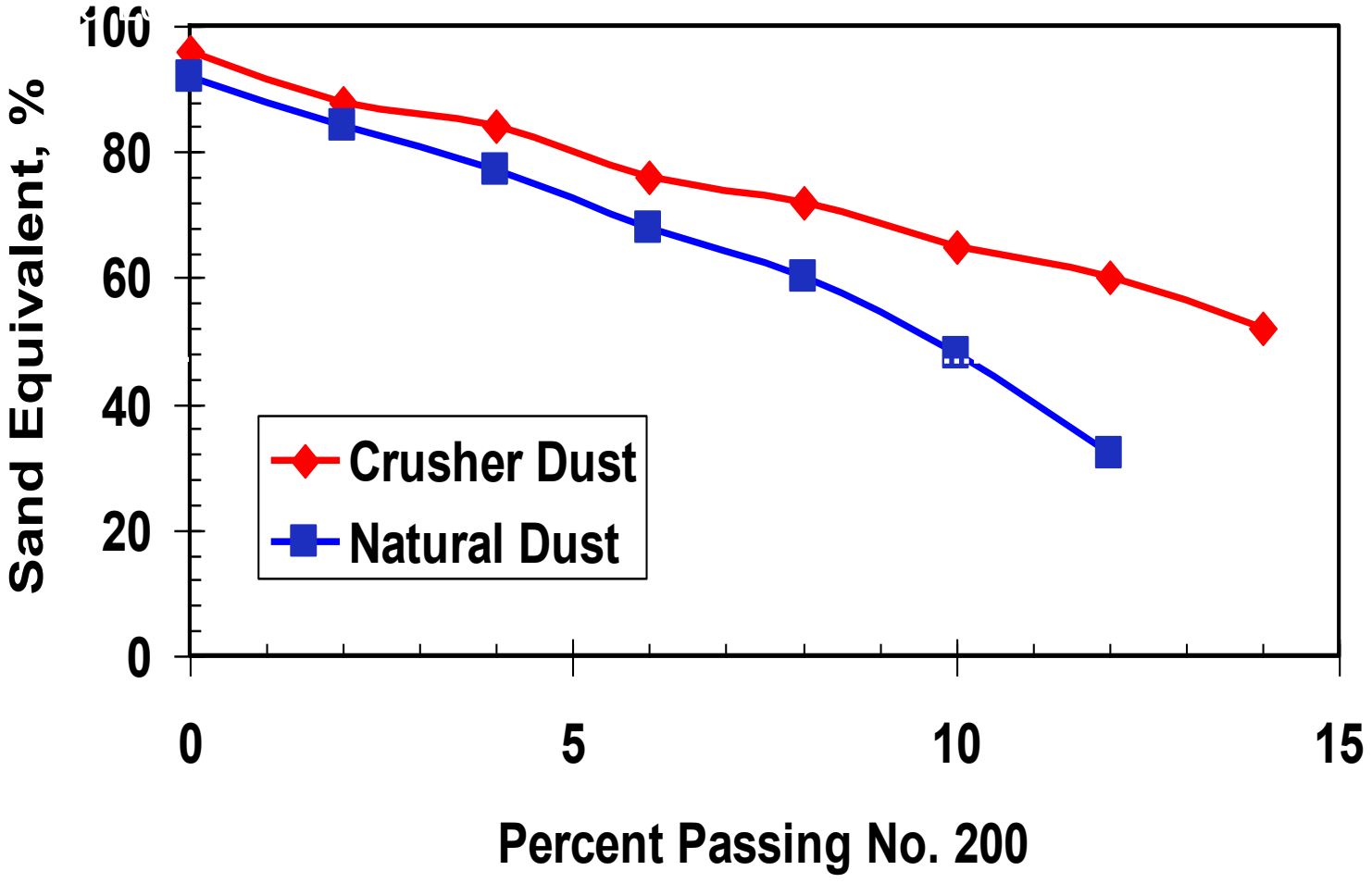
Marker on Measurement Rod

Top of Suspended Material

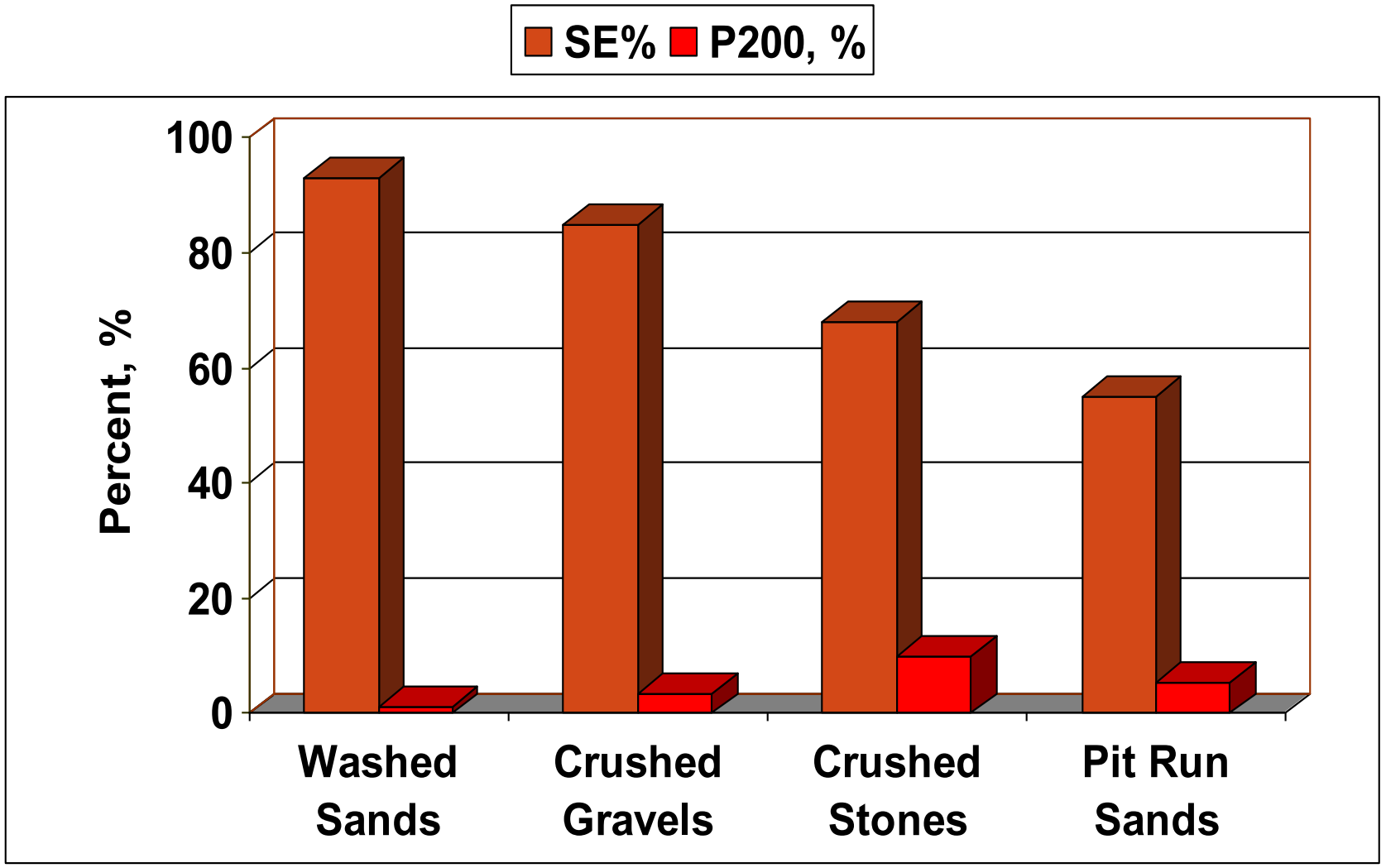
Top of Sand Layer



Effect of Percent Passing 0.075 mm Sieve

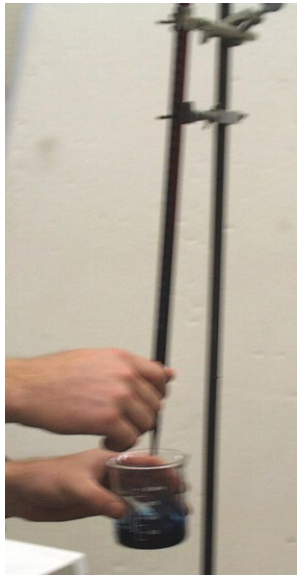


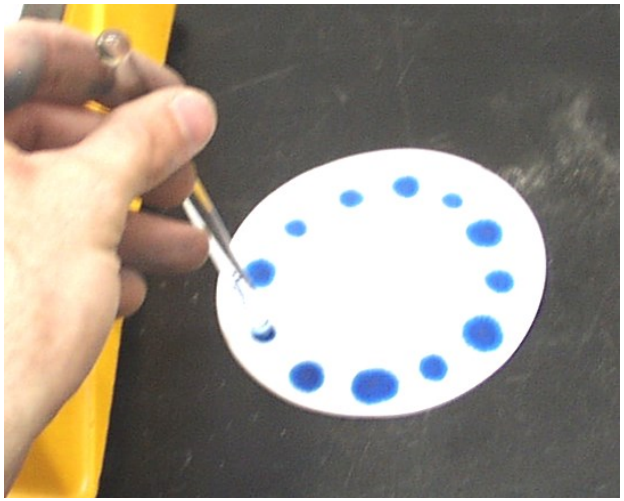
P200 and Sand Equivalent



Methylene Blue

- ISSA recommended method
  - Quantifies amount
    - Harmful clays (smectite)
    - Organic matter
    - Iron hydroxides





Methylene Blue

- General guidelines for methylene blue values

Methylene Blue mg/g	Expected HMA Performance
5 - 6	Excellent
10 – 12	Marginally Acceptable
16 – 18	Problems or possible failure
20+	Failure

Properties of Minus 0.075 mm

- Traditional
  - Size distribution by hydrometer
- New
  - Laser evaluation

Coarse Aggregates

Deleterious Materials
ASTM C142

- Mass percentage of contaminants such as clay lumps, shale, wood, mica, and coal
- Test
  - Wet sieving agg. size fraction over specified sieves
  - Mass lost = % contaminants
- Range from 0.2% to 10%, depending upon contaminant

Coarse Agg. Angularity

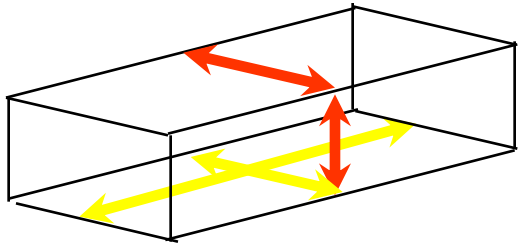
- Traditional and Newly Recommended
  - Particle Index
  - Flat and elongated
  - Percent crushed faces
  - Uncompacted voids

Particle Index
ASTM D3398

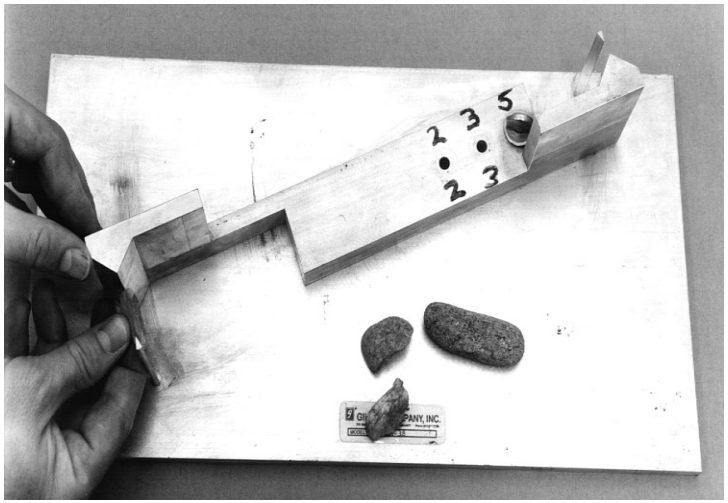
- Vol. of voids between packed, uniform-size aggregate particles indicate combined effect of shape, angularity and surface texture
  - 203 mm (8 in), 152 mm (6 in), 102 mm (4 in), 76 mm (3 in), and 51 mm (2 in) diameter mold
  - Blows on each of three layers 50 mm above surface
- $I_a = 1.25\,V_{10} - 0.25\,V_{50} - 32.0$
- Particle index increases with angularity
- I_a weighted on basis of % of each fraction

Flat and Elongated Particles

- ASTM D4791
  - Flat
  - Elongated
  - Total flat and elongated
- Superpave
  - Flat or Elongated
  - Maximum to minimum dimension
    - 1:5
    - 1:3
    - 1:2



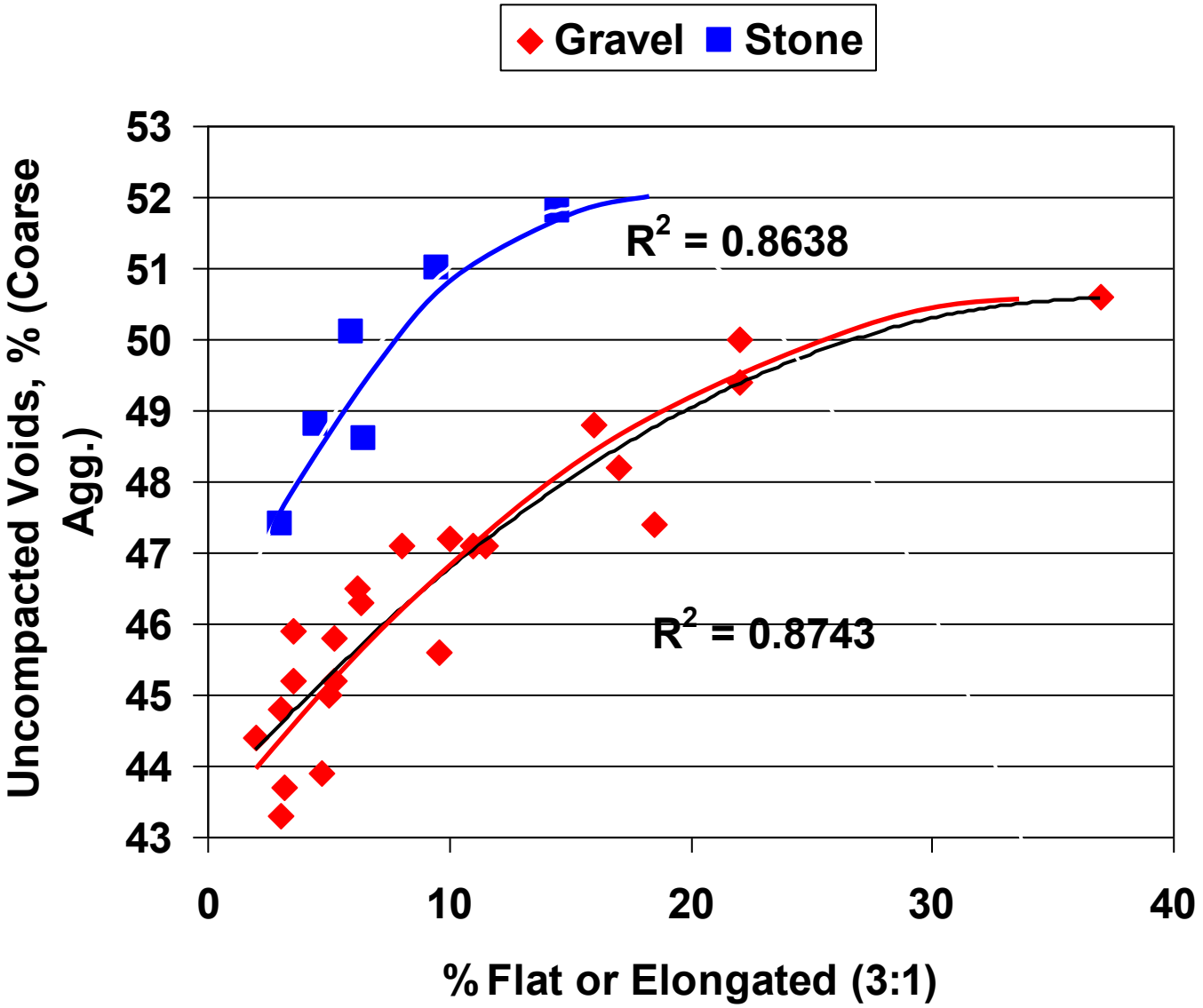
Max : min



Percent Fractured Faces ASTM D5821

- Retained on 4.75 mm
- Fractured = min 25% of area
- Clean, well-defined edges
- Can specify
  - 1 or more fractured faces
  - 2 or more fractured faces

Uncompacted Voids
AASHTO TP 56


Gravel
Stone
53
52
51
50
49
48
47
46
45
44
43
Uncompacted Voids, % (Coarse Agg.)
R^2 = 0.8638
R^2 = 0.8743
0
10
20
30
40
% Flat or Elongated (3:1)

Toughness

Degradation due to handling, construction, and in-service

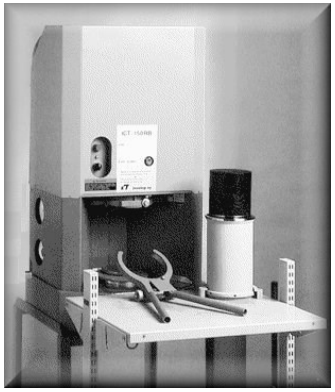
- Traditional or newly recommended
  - Los Angeles Abrasion
  - Micro-Deval
- Advanced topics
  - Aggregate Impact Value
  - Aggregate Crushing Value
  - Gyratory Compactor

LA Abrasion

Micro Deval Abrasion Test

Gyratory Compactor

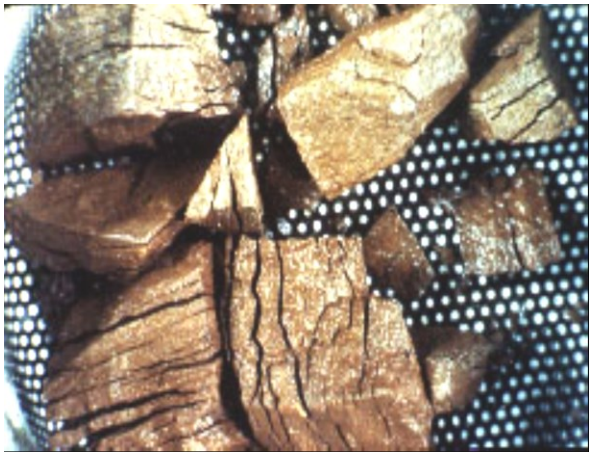
- 0.6 MPa (87 psi), 1.25° angle, 30 rpm/min
  - Can be use with just coarse, fine, or blend
    - Gradation before and after specified numbers of gyrations
    - Differences can be analyzed for given particle sizes
      - Research indicates changes in % passing 4.75 mm (No. 4) good indicator





Soundness

- Evaluates coarse aggregate resistance to weathering (freeze/thaw)
- Most common methods
  - Sodium or magnesium sulfate
    - AASHTO T104

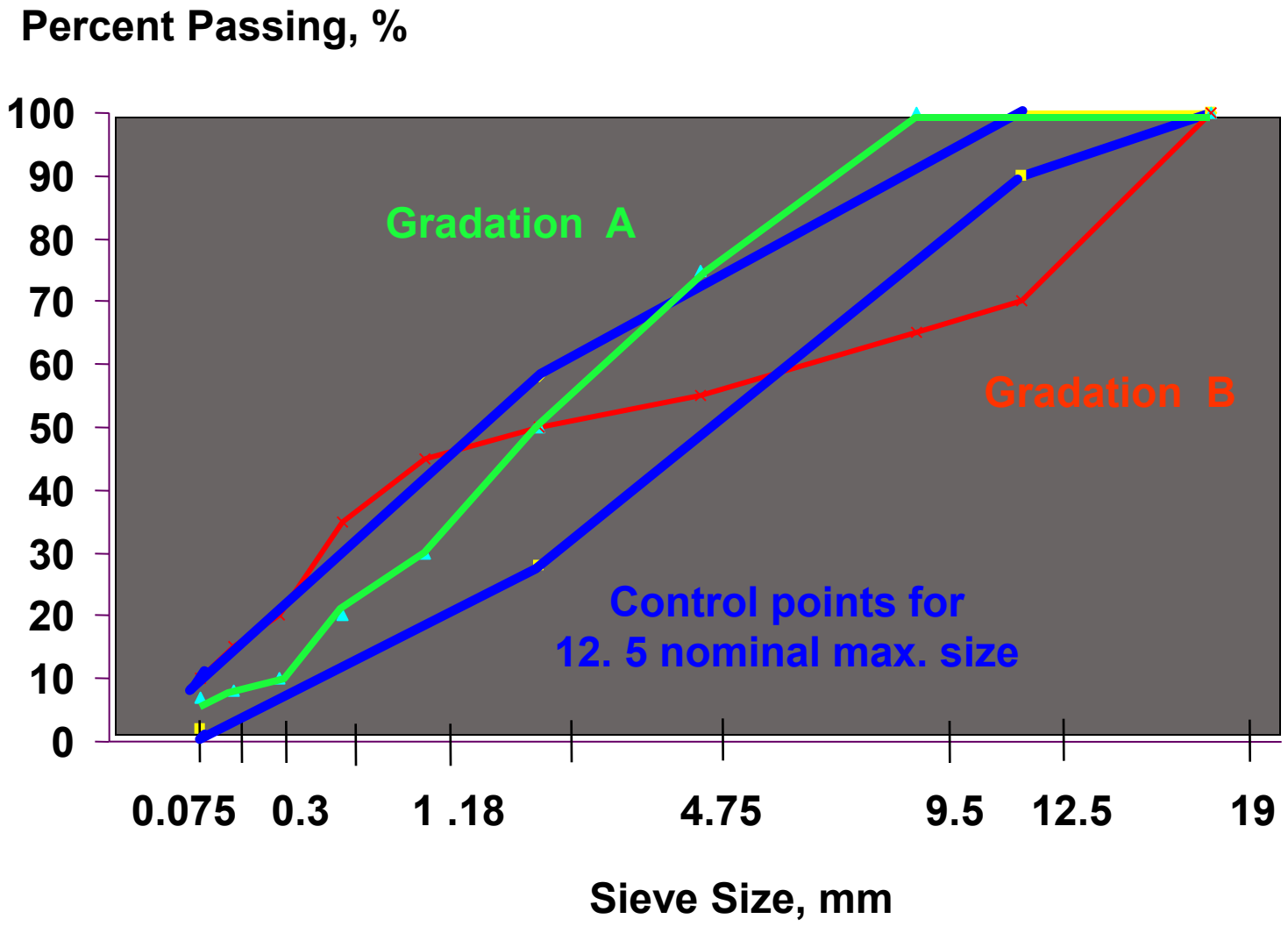


Aggregate Durability Index
ASTM D3744

- Resistance to producing clay-like fines when aggregates are subjected to mechanical agitation in the presence of water
- Especially suitable for basalt type aggregates containing interstitial montmorillonite

Blending of Aggregates

- Reasons for Blending
  - Obtain desirable gradation
  - Single natural or quarried material not enough
  - Economical to combine natural and process materials


Percent Passing, %
100
90
80
70
60
50
40
30
20
10
0
Gradation A
Gradation B
Control points for
12. 5 nominal max. size
0.075
0.3
1 .18
4.75
9.5
12.5
19
Sieve Size, mm

Blending of Aggregates

- $P = Aa + Bb + Cc + \ldots$
  - Where:
    - P = % of material passing a given sieve for the blended aggregates A, B, C, …
    - A, B, C, … = % material passing a given sieve for each aggregate A, B, C, …..
    - a, b, c, …. = Proportions (decimal fractions) of aggregates A, B, C, … to be used in Blend

Combined Specific Gravities

$$G = \frac{1}{\frac{P_1}{100\ G_1} + \frac{P_2}{100\ G_2} + \ldots\ldots \frac{P_n}{100\ G_n}}$$

HMA Volumetric Properties

- Bulk specific gravity (BSG) of compacted HMA
- Maximum specific gravity
- Air voids
- Effective specific gravity of aggregate
- Voids in mineral aggregate, VMA
- Voids filled with asphalt, VFA

Volumetric Relationships