Concepts and Terminologies

Mass

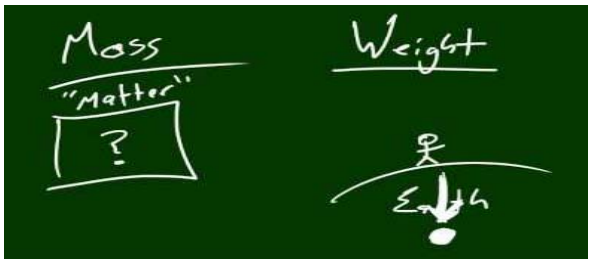
- Quantity of matter contained in a body is called its mass
- Every object has a mass
- Mass has no particular direction
- Generally measured in pounds (lbs), kilograms (kgs) and tons (T)
- 1000 kg = 1 T
- 1kg = 2.204 lbs

Weight

- It is a force
- Downward effect of mass due to the gravity of earth
- In other words it is a force with which earths attracts a body/object towards its centre
- Weight of an object is proportional to its mass

Weight

- W = mg
  - M = Mass
  - g = acceleration due to gravity = 9.81 m/s^2
- Measured in Newton (N)
- 1kg mass has a weight of 9.81N



Density

- Density is mass per unit volume of a material
- D = m/V
- Measured in kg/m³, lb/ft³, g/cc
- Rock 2500-3000kg/m³
- Soil 1500-2000kg/m³
- Unbound material 2200kg/m³
- Asphalt 2400kg/m³

Surface area, density and volume

- Sum of the area of all the surfaces/faces of a material
- For the same volume, a single unit of a material will have a higher density in comparison to if it is crushed into pieces
- In other words a crushed material will occupy more volume because of increase in surface area

Unit Weight

- For convenience, often densities are replaced by unit weights
- It is defined as weight per unit volume of a material
- Expressed as kN/m^3 or N/m^3
- Pavement layers unit weights lie in the range
  - 18-24 kN/m^3

Specific Gravity

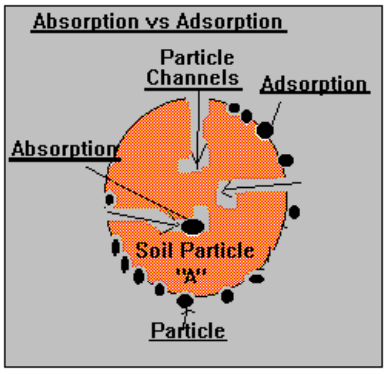
- How much a substance is heavier or lighter than water
- A material may have a higher or lower specific gravity depending upon the ratio of their densities to that of water
- Water has a specific gravity of 1
- If a material is denser than water, it will have a specific gravity greater than 1

Specific Gravity

- Bitumen has a specific gravity of 1.02 to 1.03
- Density of a material can be determined by multiplying its specific gravity with density of water
- Water
  - 1000 kg/m³, 62.4 lb/ft³, 1 g/cc

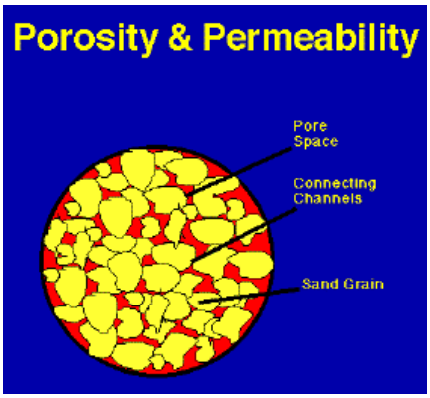
Absorption and Adsorption

- The increase in mass of a material due to the water entering into the pores of the material is referred to as absorption
- Adsorption is defined as the water molecules/vapours adhering to the surface of the material



Permeability and Porosity

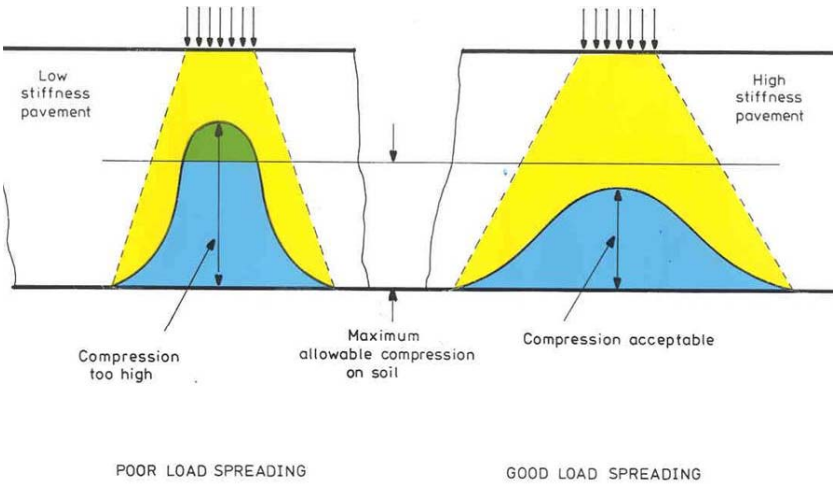
- Ability of a material to allow water to pass through it is called its permeability
- Porosity is the property of a material to retain water because of presence of pores
- A material may be highly porous but if the pore spaces are not connected it will not allow any flow of liquid through it



Force and Load

- Force
  - Weight is a form of a force
  - Measured in N and kN
  - Examples of force on a pavement structure are the forces generated by e.g. acceleration, braking, impact etc.
- Load
  - It is also a form of a force
  - In pavement engineering it is considered as the weight coming from the tyres of a vehicle

Load on a Pavement



Energy

- Capacity of doing work
- Measured in (force x distance) units
- It has the units of work and is expressed as; N.m or joules (in heat units)
- Strain Energy
  - It is the potential energy stored in a deformed body

Strength

- It is the capacity to resist a demand (e.g. load, stress)
- After that capacity or limit the material will fail
- May be expressed as a limiting stress or a failure load etc.
- The term is used both for humans and other materials

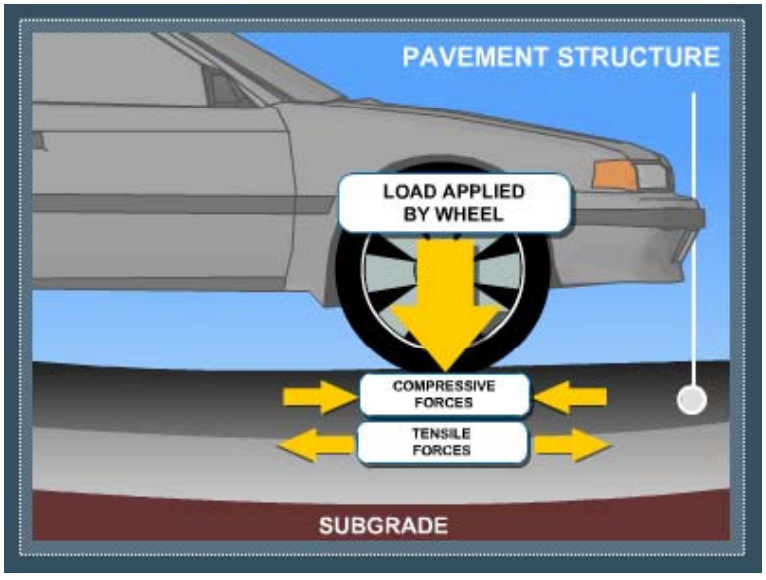
Stress and Pressure

- Both are defined as force per unit area
- Units of N/m^2 or Pascal
- The term stress is generally used for solids while pressure is used for liquids and gases
- In pavement engineering it is important to not only know the load on a pavement structure but also the intensity of that load (contact stress)

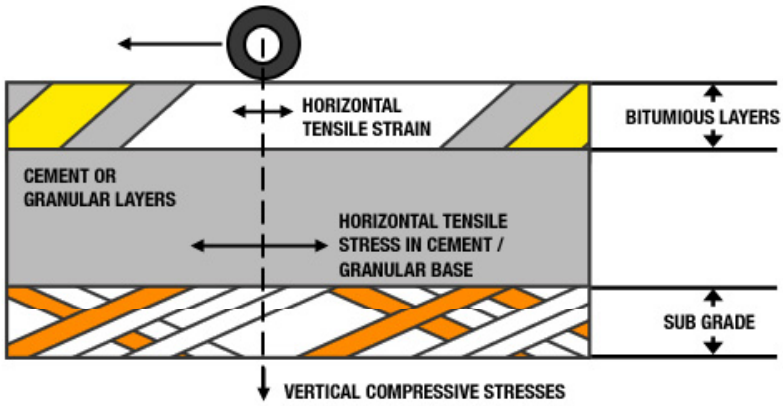
Strain

- Strain is often the consequence of stress
- It is expressed as the change in dimension divided by the original dimension i.e. the degree to which a material deforms
- It may be expressed as percentage (%) but generally as small strains are generated within a pavements, the term micro-strain is used to describe strain in a pavement structure

Stresses and Strains in a pavement



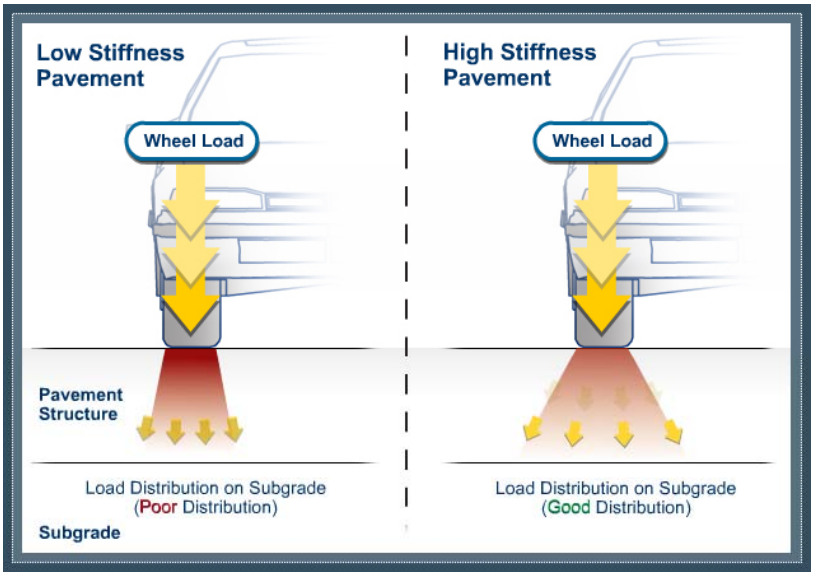
Stresses and Strains in a pavement



Stiffness (Rigidity)

- Resistance of a material to deformation/deflection or stress
- Relationship between load and deformation (ratio of a wheel load to pavement deformation)
- It does not have one specific definition and use
- Examples;
  - Bending stiffness, shear stiffness etc.

Pavement Stiffness



Elasticity and Resilience

- Elasticity
  - Property of a material to come back to its original position after deformation when a load is removed
- Resilience
  - It is the capacity of a material to absorb energy elastically (without undergoing a permanent distortion)

Plasticity, ductility and toughness

- Plasticity
  - Ability of a material to undergo some degree of permanent deformation without failure
- Ductility
  - This property enables a material to draw out into a thin wire on application of load
- Toughness
  - Ability of a material to withstand both plastic and elastic deformations

Fatigue Strength and Creep

- Fatigue Strength
  - The fatigue strength of a material is the maximum stress at which failure may occur after a certain number of cyclic load applications (repeated alternating stresses over an extended period of time)
- Creep
  - Deformation under sustained load. The slow and continuous elongation of a material with time at constant stress and high temperature below elastic limit is called creep

Modulus and Elastic Modulus

- Modulus
  - It is the ratio of applied stress to induced strain (stress/strain)
- Modulus of Elasticity
  - Ratio of applied stress to induced strain assuming that the behavior of the concerned material is linear (stress directly proportional to strain)
  - Concrete behaves linearly under normal working conditions
  - Un-bound material is non-linear
  - Asphalt stiffness varies w.r.t temperature and loading rate and therefore cannot have one elastic modulus

Stiffness and Resilient Modulus

- Stiffness Modulus
  - This term is generally used for asphalt as it has a viscous (temperature-dependent) component to its behavior
- Resilient Modulus
  - The term is used for soils and other unbound materials because of their non-linear behavior

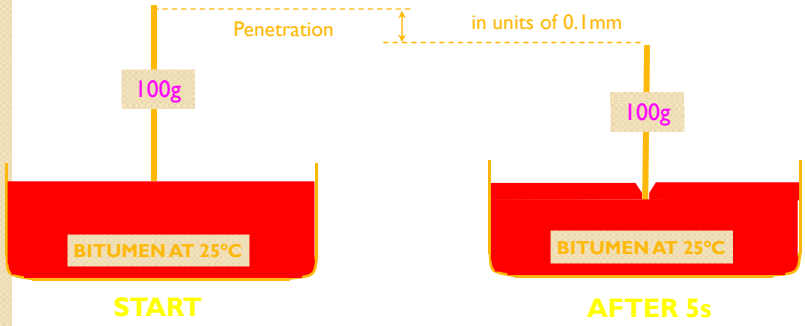
BASIC BITUMEN TESTS

- Needle Penetration Test
- Ring & Ball Softening Point Test
- Ductility Test

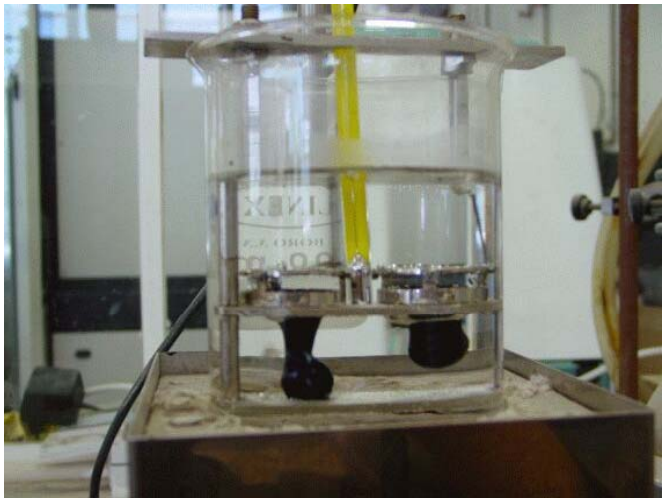
Penetration Test

Penetration Test

- Temperature - 25°C
- Load - 100g
- Loading Time - 5 seconds

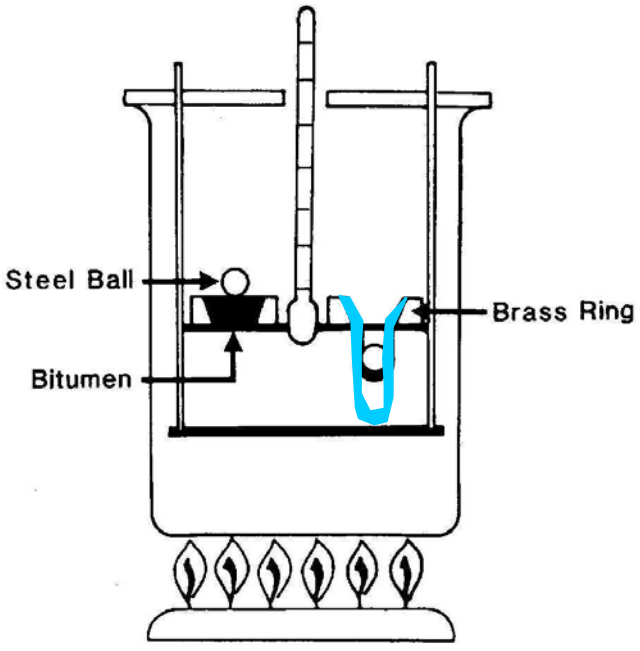


Softening Point Test



Softening Point Test

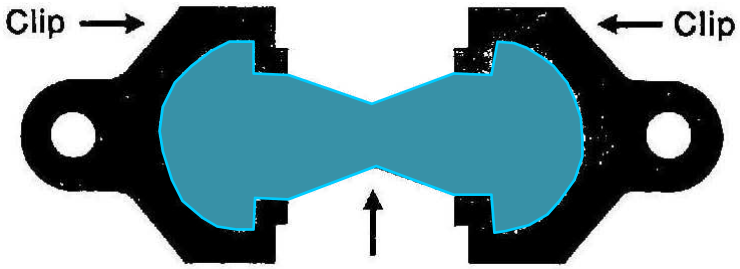
- Temperature increase rate - 5°C/min
- Fall Distance - 25mm



Ductility Test

Ductility Test

Ductility Test Specimen



Briquette: minimum cross-sectional area 100mm^2

Binder Specifications

Property	Grade of bitumen									
	15 pen	25 pen	35 pen	HD40	50 pen	70 pen	100 pen	200 pen	300 pen	450 pen
Penetration @ 25 °C	15±5	25±5	35±7	40±10	50±10	70±10	100±20	200±30	300±45	450±65
Softening point, °C	63-76	57-69	52-64	58-68	47-58	44-54	41-51	33-42	30-39	25-34
Loss on heating for 5h @ 163°C										
(a) loss in mass, %	0.1	0.2	0.2	0.2	0.2	0.2	0.5	0.5	1.0	1.0
(b) drop in penetration, %	20	20	20	20	20	20	20	20	25	25
Solubility in trichloroethylene, %	99.5	99.5	99.5	99.5	99.5	99.5	99.5	99.5	99.5	99.5

Property	15 pen
Penetration @ 25 °C	15±5
Softening point, °C	63-76
Loss on heating for 5h @ 163°C	
(a) loss in mass, %	0.1
(b) drop in penetration, %	20
Solubility in trichloroethylene, %	99.5

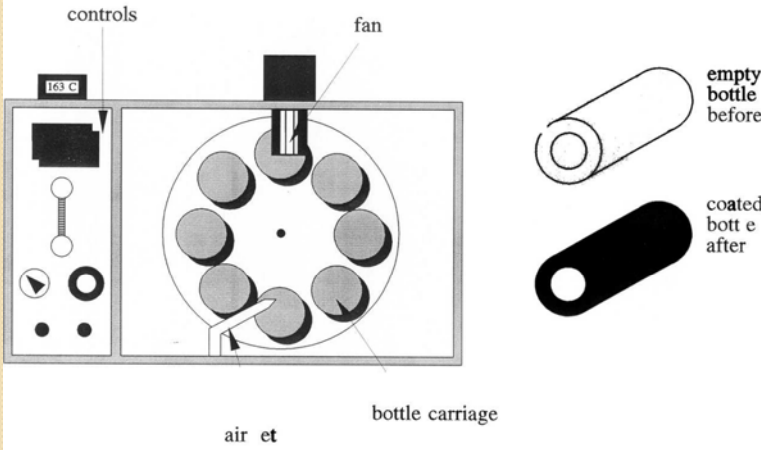
Bitumen Ageing

- Short-term laboratory ageing (simulating hours of actual field ageing)
- Long-term laboratory ageing (simulating years of actual field ageing)

Rolling Thin Film Oven Test (RTFOT) Ageing

- Simulation of short term ageing
- Ageing occurring during the batching process (mixing of aggregate and bitumen at high temperatures)
- 35 g of bitumen
- Temperature - 163°C
- Air flow rate - 4000 ml/min
- Time - 75 minutes

RTFOT

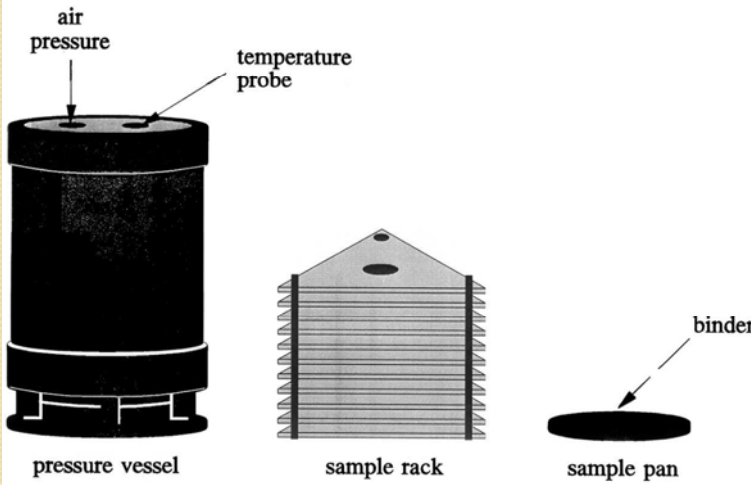

controls
fan
163 C
empty
bottle
before
coated
bott e
after
bottle carriage
air et

RTFOT

Pressure Ageing Vessel (PAV) Ageing

- Simulation of long term ageing
- Residue from RTFOT ageing
- 50 g of bitumen
- Temperature - 90°C, 100°C or 110°C
- Air pressure - 2.1 MPa
- Time - 20 hours

PAV



Pressure Aging Vessel and Components