



# **Physical Properties of Materials- Bitumen and Aggregates**

# Specific gravity of bitumen

## Working Principle (ASTM D 70, 2021)

- Specific gravity is measured using a pycnometer.
- The specific gravity of bitumen is calculated from its mass and water displaced by the bitumen in the pycnometer.



**Pycnometers**

## Application

- Specific gravity is useful for converting volumes to units of mass, and for volume correction based on temperature.
- It is used to calculate the theoretical specific gravity of bituminous mixture.

# Rotational Viscometer

## Working Principle (ASTM D4402, 2015)

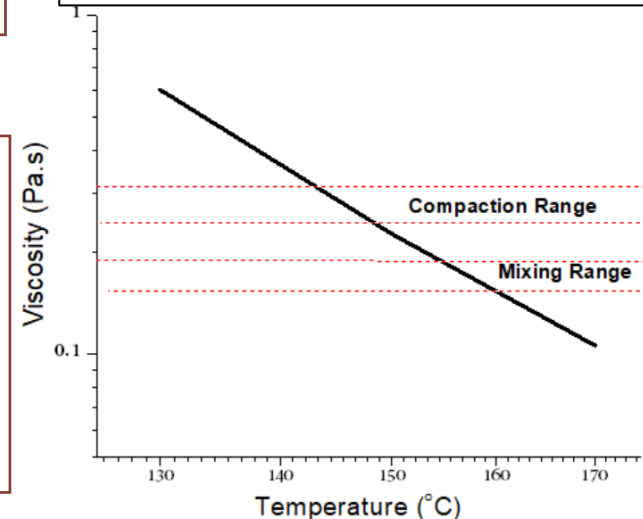
- The equipment has a Couette type arrangement with viscometer head, apparatus-measuring geometries (spindles), temperature controlled thermal chamber, temperature controller and sample chamber.
- The torque required to rotate the measuring geometry immersed in the sample at a selected speed of rotation is measured and used to compute the shear stress. The shear rate is calculated from speed of rotation of spindle (angular velocity) using the Margules equation.
- The viscosity of the material is computed as the ratio of shear stress and shear rate. All the measurements are recorded at fixed time intervals using a software interface.



**Brookfield, USA:  
Rotational Viscometer**

## Application

- Characterization of Newtonian and non – Newtonian (shear rate independent viscosity and stress overshoot) response of materials over a temperature range of 25 to 200°C
- Determination of mixing and compaction temperature of unmodified bitumen.



# Specific gravity of aggregates

## Working Principle

- Specific gravity is measure is the ratio mass of a given volume of aggregate to the weight of an equal volume of water.
- Coarse Aggregate specific gravity:
  - ASTM C 127, 2015
  - ASTM D 7370, 2014
- Fine Aggregate specific gravity:
  - ASTM C 128, 2015
  - ASTM D 7370, 2014



**Pycnometers**

## Application

- Specific gravity is used for the calculation of volume occupied by aggregates in various mixtures like bituminous mixture.
- It is used to calculate the theoretical specific gravity of bituminous mixture.



**InsroTek, USA:  
AggPlus**

# Aggregate shape test (IS 2386:Part-1, 1963)



## Significance

- The morphology of aggregates is a significant parameter which dictates the strength, interlocking, and durability.
- The presence of flaky and elongate aggregates will cause the strength reduction due to its breaking.



## Application

- Used as a quality indicator for the selection of aggregate in Pavement construction
- To obtain flakiness and elongation Index

# Aggregate angularity number (IS 2386:Part 1, 1963)



## Significance

- Angularity or absence of roundness of an aggregate is a property which affects the ease of handling the aggregate in bituminous mixture



## Application

- Angularity number of aggregates is used to determine the void content, packing density and workability of aggregate mixtures.

# Aggregate impact test (IS 2386:Part 4, 1963)



## Significance

- Aggregate Impact test gives a relative measure of resistance of the aggregate to sudden shock or impact, which in some aggregates differ from their resistance to slow compressive load

## Application

- Aggregate impact test is used as an indicator of relative quality of aggregates having similar mineral composition.



**AIMIL, India:  
Aggregate impact  
testing apparatus**



# Volumetric Measurements

# CoreLok

**Working Principle (ASTM D6752, 2018; ASTM D6857, 2018; ASTM D7063, 2018)**

- Samples are automatically vacuum sealed in a specially designed puncture resistant polymer bags
- The densities of sealed samples can be measured by water displacement method
- Samples of different shapes and material types (aggregate, loose and compacted bituminous mixture and reclaimed pavement bituminous mixture) can be vacuum sealed



**Instrotek, USA:  
Corelok.**

## Application

- To measure bulk specific gravity and maximum theoretical specific gravity of bituminous mixture samples.
- To measure apparent specific gravity, porosity of aggregate and bitumen content (%) in mixture.

# Measurement of submerged weight



Working Principle (ASTM D6752-18, ASTM D6857-18 , ASTM D7063-18)

- Hanging wired basket with a weighing balance
- The weight of testing samples in air, and its weight when immersed in water can be taken



**InstroTek, USA.  
Water tank with hanging  
basket and weighing  
balance**

## Application

- To determine specific gravity of aggregates, bulk specific gravity and theoretical specific gravity of bituminous mixture samples.



# Production of Bituminous Mixtures

# Automated mixing machine

## Working Principle

- The equipment has a temperature controlled mixing drum, a rotating paddle to ensure uniform mixing.



## Application

- Used for preparation of bituminous mixtures with precise temperature control at laboratory scale.
- Mixing machine with batch capacity of 20 kg



# Automated mixing machine

## Working Principle

- The equipment has a temperature controlled mixing drum with two rotating paddles having planetary motion to ensure uniform mixing.
- The paddle arrangement is adjustable to suit mixing bituminous mixtures having different Nominal Maximum Aggregate Size

## Application

- Used for preparation of bituminous mixtures with precise temperature control at laboratory scale.
- Mixing machine with batch capacity of 35 kg



**Automatic Mixture Machine: Designed and Fabricated in IIT Madras**



# Compaction of Bituminous Mixtures

# Marshall compactor

## Working Principle (ASTM D6926, 2020)

- Marshall Compactor provides a rigid mechanism for the preparation of samples for Marshall
- Compaction blows can be preset to meet the compaction criteria.

## Application

- Preparation of Marshall test samples



**Automated Marshall  
Compactor,  
Humboldt, USA.**

# SHRP gyratory compactor



## Working Principle (ASTM D6925, 2015; ASTM D7229, 2013)

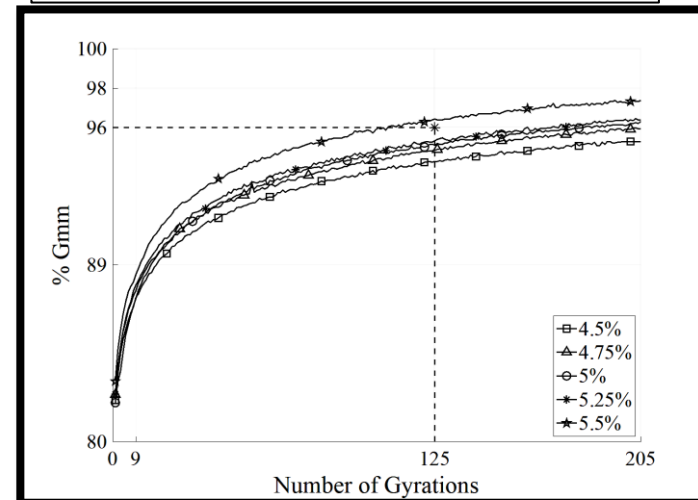
- Adopts gyratory technique for the compaction of bituminous mixtures
- Aids in the preparation and compaction of cylindrical specimens of dense graded hot mix asphalt samples
- The run time compaction data is measured and recorded using computer controlled software interface.



**Gyratory Compactor,  
Rainhart, USA**

## Application

- To determine the optimum binder content of bituminous mix design as per Superpave specifications
- Cylindrical samples can be prepared at varied levels of compaction
- Compactibility indices can be analysed.



# Gyratory compactor

## Working Principle

- The mechanical parts are situated in the overhead chamber of the compaction hood, enables the compactor to for the application of compaction samples with extra water content.
- Aids in the preparation and compaction of cylindrical specimens for cold mix bituminous samples.

## Application

- To determine the optimum binder content of bituminous mix .
- Cylindrical samples can be prepared at varied levels of compaction.
- Compatibility indices can be analyzed.



**Gyratory Compactor.  
Pine, USA**

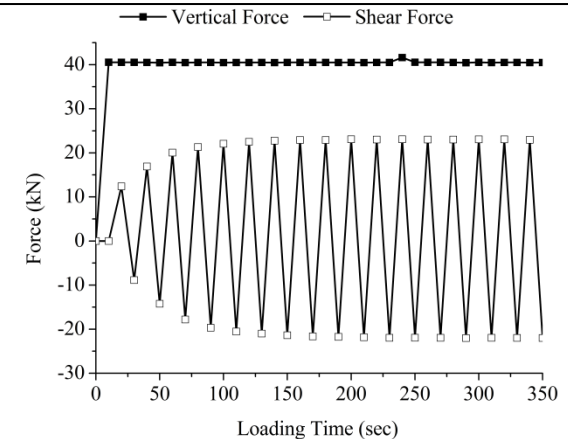
# Shear box Compactor

## Working Principle (ASTM D 7981, 2020)

- Fully automatic apparatus for compaction of loose bituminous mixtures
- Applies a combination of a static vertical force (600 kPa) and a horizontal cyclic shear force to twin vertical parallel platens upto a fixed maximum shear angle (4 degree)
- Computer controlled input to specify level of compaction and it records the applied compaction forces and sample height during compaction



## Shear box compactor: IPC global, Australia.



## Application

- Serves as a large sample compactor for the fabrication of prismatic bituminous mixture samples of size 450 mm long, 150 mm wide and height varying from 145 to 185 mm.
- Compacted asphalt prisms can be used to obtain specimens of further testing (dynamic modulus, fatigue, flow number, flow time etc.)
- Fabrication of glass fibre grid inlaid samples

## Compaction curve for VG30 BC bituminous mixture

# Gyratory compactor for concrete



## Working Principle

This machine uses the vertical actuator for accurate load measurement and feedback control

It also consists of inbuilt sensor to measure compaction energy, direct shear and torque resistance

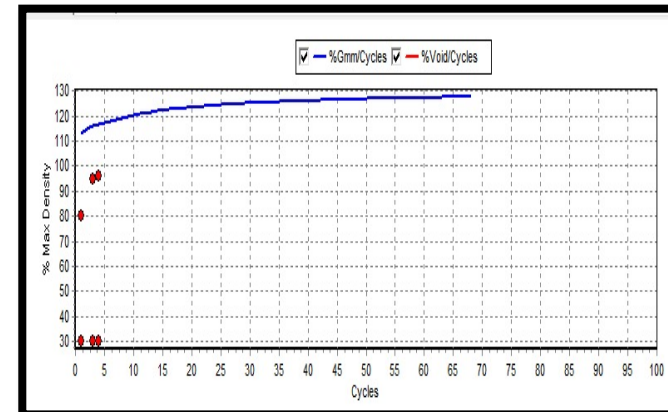
It simulates the field compaction in the laboratory by imparting the kneading action



**Gyratory compactor:  
Controls, USA.**

## Application

This machine can be used for mix design of various zero slump concrete mixtures such as roller compacted concrete pavements and paving blocks



**Maximum density vs no of gyration**



# Preparation of Test Samples

# Slicing machine

## Working Principle

- Test samples can be sliced with utmost dimension precision to meet global testing standards



## Application

- For preparation of beams for fatigue test, rut wheel samples and for slicing the ends of cylindrical samples



# Coring machine



## Working Principle

- Test samples can be cored at various diameters with dimension precision to meet global testing standards, using core bits of various diameters 100 mm, 150 mm, and 13mm



**Coring Machine:  
Hilti, India.**

## Application

- For preparation of cylindrical samples



**Cored Samples**



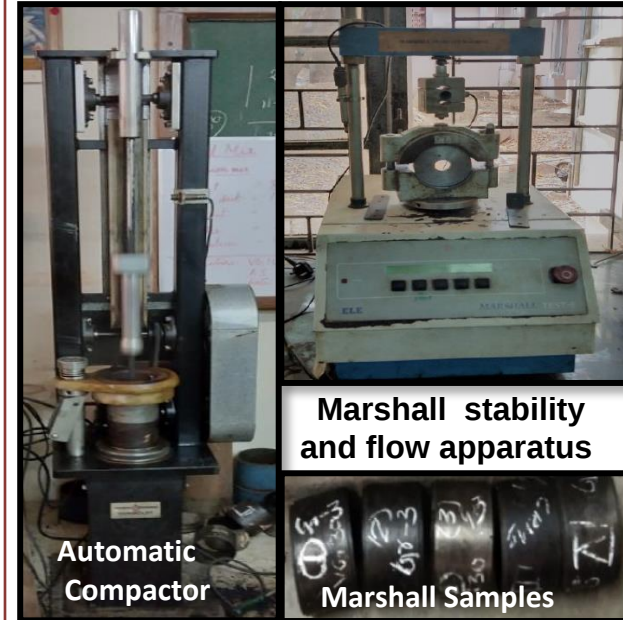
# Mix Design

# Marshall method- Marshall apparatus



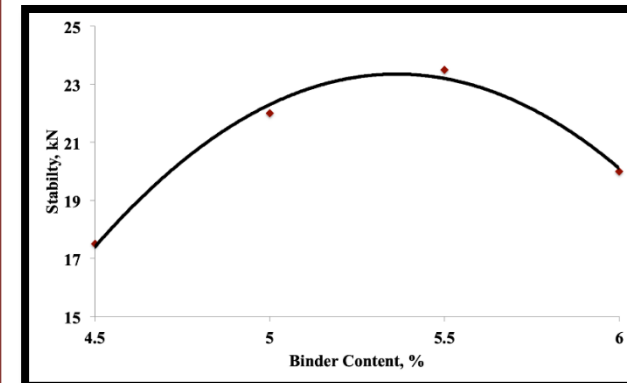
## Working Principle (ASTM D6927, 2015)

- The Marshall testing machine is a compression testing device conforming to ASTM D6927-15
- Automatic Marshall Compactor provides a rigid mechanism for Marshall sample
- Marshall stability testing head is equipped with a calibrated proving ring for determining the applied testing load and Marshall flow meter aids to determine the deformation at the maximum load in the test



## Application

- To determine the resistance to plastic flow of bituminous mixtures
- To determine the optimum binder content in bituminous mix design (MS 2-2014, IRC 111-2009)



# Superpave Mix Design



## Selection of Binders

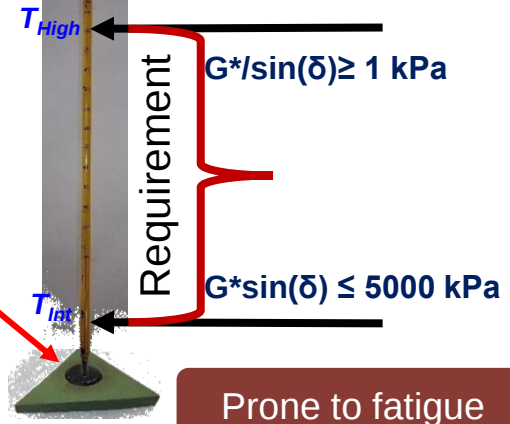
### Performance Grading

Air and  
pavement  
temperature

Traffic loading



Prone to rutting



## Selection of Aggregate

### Aggregate Properties

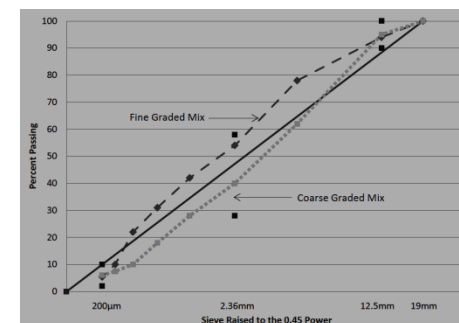
#### CONSENSUS PROPERTIES

- coarse aggregate angularity (CAA)
- fine aggregate angularity (FAA)
- flat and elongated particles
- clay content

#### SOURCE PROPERTIES

- toughness
- soundness
- deleterious materials

### Aggregate Gradation



# Binder content estimation in bituminous mixture- Centrifuge Extractor (ASTM D2172, 2017)



## Working Principle

- Reagent and bitumen available in the bituminous mixture form a solution (i.e. bituminous mixture + solvent) and this solution can be separated by centrifugal rotation.

## Application

- For quantitative determination of asphalt binder content in asphalt mixtures and pavement samples.
- For evaluation of mixture composition by determining remaining aggregates gradation and density.
- Extract obtained can be used for binder recovery and characterization.



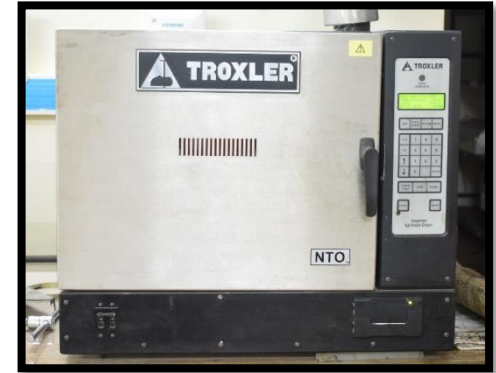
**Centrifuge extractor:  
ASI, India.**

# Binder content estimation in bituminous mixture- Ignition Oven (EN-12697-39,2013)



## Ignition Oven - Working Principle

- The asphalt burns and leaves aggregate alone. The loss in mass resulting from the burn is the bitumen content in the asphalt mixture.



**Ignition oven:  
Troxler, USA.**

## Application

- For quantitative determination of asphalt binder content in asphalt mixtures and pavement samples
- Used for process control or checks on the compliance of mixtures
- For evaluation of mixture composition by determining remaining aggregates gradation and density