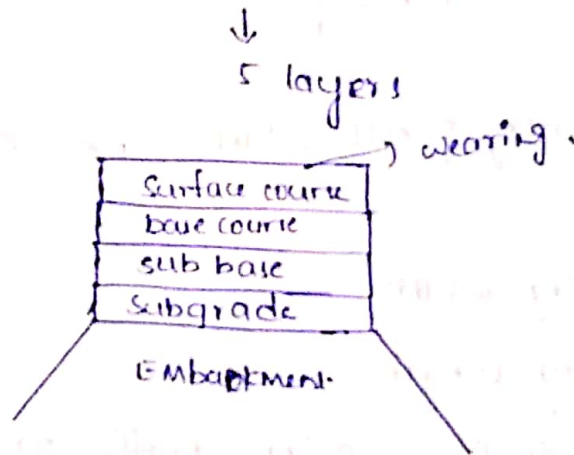


UNIT - IV

Highway Materials

→ Road construction
When flexible pavements



Components of the highway:

- Embankment
- Subgrade
- pavement layers of flexible on rigid
 - ↓
 - flexible {
 - Subbase
 - Base course
 - Surface course (Wearing course)
 - rigid {
 - Basecourse
 - Surface course (cc slab)

Materials used in the highway construction (pavement)!

Soil, stone aggregates, Bituminous materials, portland cement & cement concrete.

Soil: (Subgrade).

- It is the one of the component in the pavement structure.
- It provides the structural support to the pavement from the waste (or) beneath.
- for the design of pavements to know the type of the soil and its properties.
- The soil should be stable under the loading conditions and climate conditions.
- If the failure occurs in the pavement (cracking, rutting, deformations, corrugations) is due to the poor conditions of the Subgrade soil.

Properties of the subgrade soil:

1. Stability
2. Incompressibility
3. Strength
4. Good drainage conditions
5. Compaction.

Classification of soil:

- (a) Based on grain size.
- (b) Based on soil aggregates.

(a) Based on grain size:

(i) Gravel ($> 2 \text{ mm}$)

(ii) Sand ($2 - 0.06 \text{ mm}$)

* coarse ($2 - 0.6 \text{ mm}$)

* medium ($0.6 - 0.2 \text{ mm}$)

* fine ($0.2 - 0.06 \text{ mm}$)

(iii) Silt ($0.06 - 0.002 \text{ mm}$)

* coarse ($0.06 - 0.02 \text{ mm}$)

* medium ($0.02 - 0.006 \text{ mm}$)

* fine ($0.006 - 0.002 \text{ mm}$)

(iv) clay ($< 0.0002 \text{ mm}$)

* coarse ($0.002 - 0.0006 \text{ mm}$)

* medium ($0.0006 - 0.0002 \text{ mm}$)

* fine ($< 0.0002 \text{ mm}$)

Bureau

* The bureau of Indian standards adopt
MIT system as a Indian standard classification
of the soil based on the grain size

(b) Based on soil aggregates:

* It is the mixture of more than one
component (gravel, sand, silt, clay)

* The soil aggregates are different in
the structure and strength also location to
location

* The soil is classified based on their region conditions.

Group Index : (G.I)

To classify the fine grained soils in one group, an Indexing system is introduced. HRB classification and the index is called as group index.

[HRB - Highway research board]

HRB classification :

1. Granular soil
2. fine grained soil

1. Granular soil :

The portion of the material passing through 0.074 mm sieve is less than 35%.

2. fine grained soil :

The portion of the material passing through 0.074 mm sieve is greater than 35%.

$$G.I = 0.2a + 0.05ac + 0.01db$$

where
a → portion of the material passing 0.074 mm sieve greater than 35% and not exceeding 75%.

b → portion of the material passing through 0.075 mm sieve greater than 15% and not exceeding 35%.

c → The value of liquid limit is excess of 40% and less than 60%.

d → The value of plasticity index exceeding 10 and less than 30.

→ The value of group index is lies b/w 0-20.

→ If the G.I value is less the strength of the subgrade is good and vice versa.

Subgrade soil strength:

The following of the factors should be considered

Soil type

Structure of the soil

Moisture content.

density

type & Mode of stress application.

Evaluation of soil subgrade strength:

1. Bearing test

2. Shear test

3. Penetration test

→ Direct shear

→ Tri axial compression

→ unconfined compression

→ CBR (California bearing test)

→ cone penetrometer

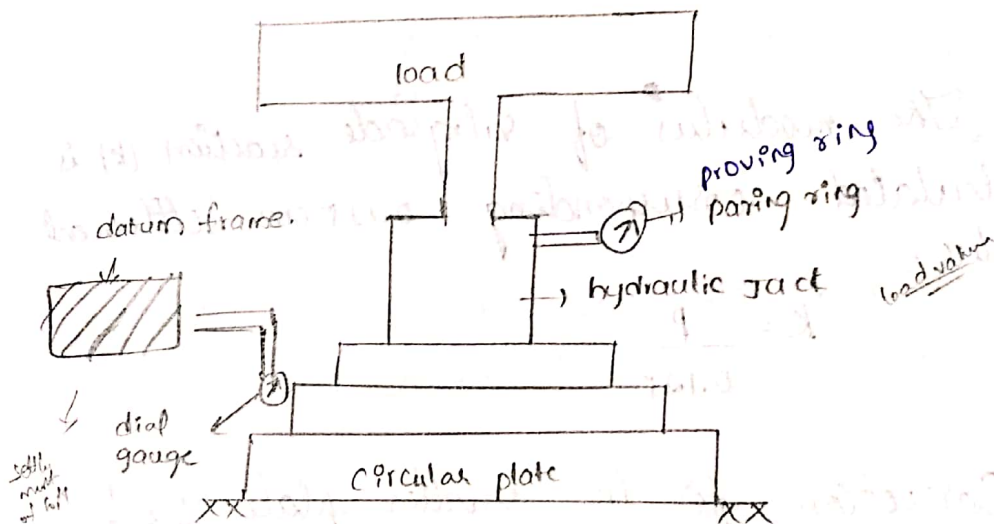
Plate load test!

It is used for the finding the strength of the subgrade soil and modulus reaction of the soil.

Modulus of subgrade reaction or modulus reaction is denoted by 'k'

$$k = \frac{P}{\Delta} \text{ kg/cm}^2 \text{ (cm)}^3$$

This test consists of a series of plates 75 cm, 60 cm, 40 cm, 30 cm are used.



A loading frame consists of a hydraulic jack with proving ring arrangement to measure the load values.

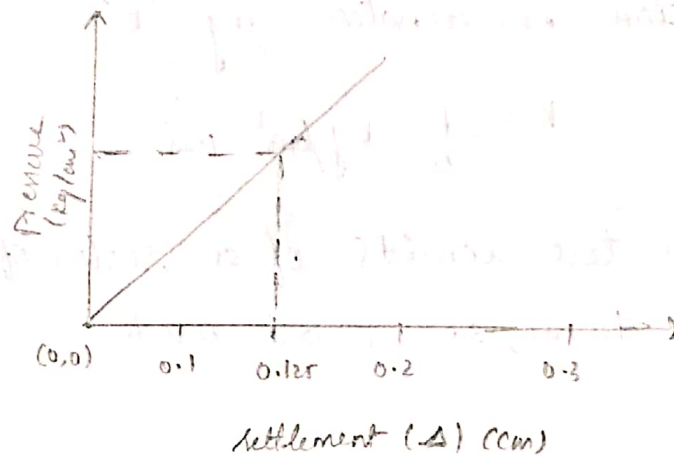
A datum frame is arranged with dial gauge to measure the settlement of the soil.

A seating load is applied with a pressure of 0.07 kg/cm^2

To set the dial gauge reading are to be zero.

An incremented load is applied to get a settlement value 0.125 cm.

The graph is plotted between the settlement values and the applied pressure value.



The modulus of subgrade reaction (k) is calculated corresponding 0.125 cm settlement value.

$$k = \frac{P}{0.125}$$

Correction for the smaller plate size!

$$k = k_1 \frac{a_1}{a}$$

Where

k = Modulus of subgrade reaction of the standard plate.

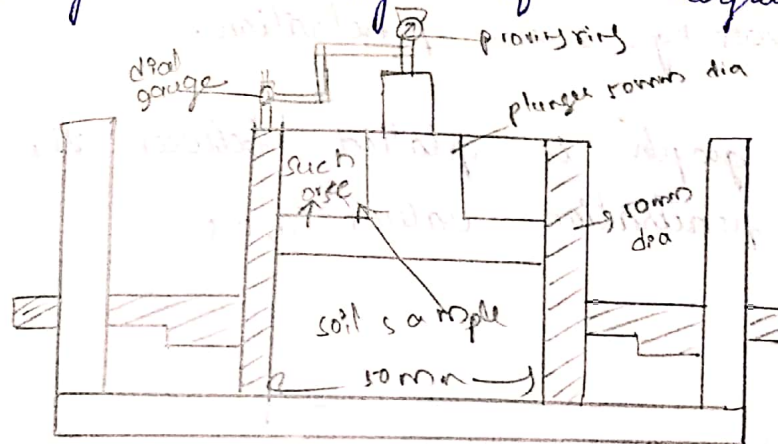
k_1 = Modulus of subgrade reaction of 30 cm plate

a_1 = radius of the 30 cm plate

a = radius of the standard plate (75 cm)

California Bearing ratio:

This test is developed by the California state highway department. It is used for the finding the strength of the subgrade soil.



A soil sample is collected and placed in the mould in the form of layers by using rammers.

The basic principle to calculate the CBR values. A cylindrical plunger 50 mm. dia is penetrated into the soil sample. The loads are noted @ 2.5 mm, 5 mm, penetration values are noted.

The CBR is defined as the ratio of

$$\text{CBR} = \frac{\text{load sustained by the soil sample @ } 2.5 \text{ mm, } 5 \text{ mm penetration}}{\text{load sustained by the standard aggregates @ } 2.5 \text{ mm, } 5 \text{ mm penetration}}$$

load sustained by the standard aggregates @ 2.5 mm, 5 mm penetration.

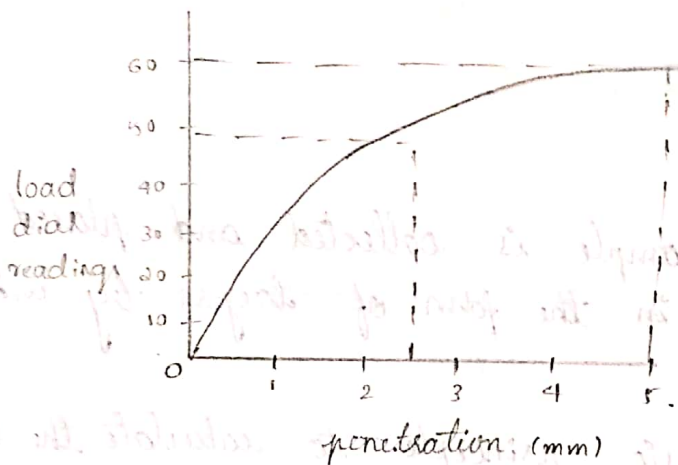
The standard values for the aggregates is

1370 kg, 2055 kg.

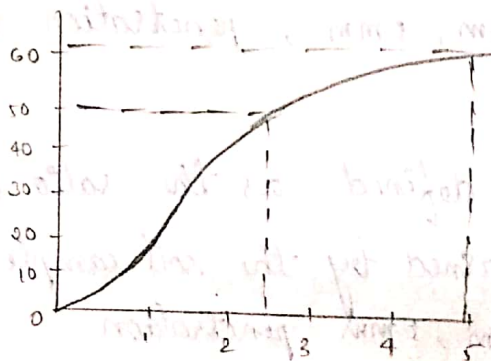
1370 kg = 0.5 mm penetration.

2055 kg = 5 mm penetration.

A graph is plotted between the load and the penetration values (0, 0.5



In this graph correction is not required.



If the CBR value at 0.5 mm penetration is greater than the 5 mm penetration.

If the CBR value at 5mm penetration is greater than the 2.5 mm penetration the test indicate the same values take the CBR value at 5mm penetration.

Aggregates.

Desirable properties of the aggregates.

- Resistance to impact
- Resistance to crushing
- Resistance to abrasion.
- Resistance to weathering.

Tests on the aggregates

- * Aggregate crushing value test
- * Aggregate impact value test
- * Aggregate abrasion test.
- * Aggregate specific gravity and water absorption test.
- * Aggregate shape test [elongation index, flakiness index, Angularity number].
- * Soundness test of the aggregate.
- * Stripping value of the aggregate.
- * Polished stone value.

1. crushing test :

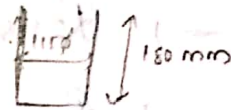
It is used for the finding the strength of the aggregate under the gradually applied test.

Apparatus :

1. Steel cylindrical mould 150 mm ϕ with a base plate.



2. cylindrical measure
115 ϕ - dia, 180 mm height



3. plunger 50 mm dia.

4. cylindrical testing machine, tamping rod.

5. I.S Sieves (2.5 mm, 10 mm, 2.36 mm.)

Procedure :

* Take required amount of aggregates and sieved by using 2.5 mm and 10 mm sieve.

* Take the aggregates passing from 2.5 mm sieve and retained on the 10 mm sieve.

* The aggregates filled in the cylindrical measures in 3 layers. Tamping each layer 25 times by tamping rod.

* Take the aggregate from the cylindrical measures and weights it (W_1).

* Again the aggregates filled in the cylinder in 3 layers, each layer tamping by 25 times.

- * Place the plunger on the top of the specimen.
- * The load is applied gradually 4 tonnes/minute.
- * Take the crushed aggregates from the steel cylinder and sieve on the 2.36 mm sieve
- * Take the weight of the passing aggregates on the 2.36 mm sieve (W_2)

formula:

$$\text{Aggregate crushing value} = \frac{W_2}{W_1} \times 100$$

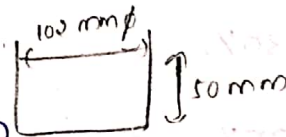
- * If the aggregate crushing value is less than 30% $\therefore$ it is used as a surface course.
- * If the aggregate crushing value is less than 45%, it is used as a base course.

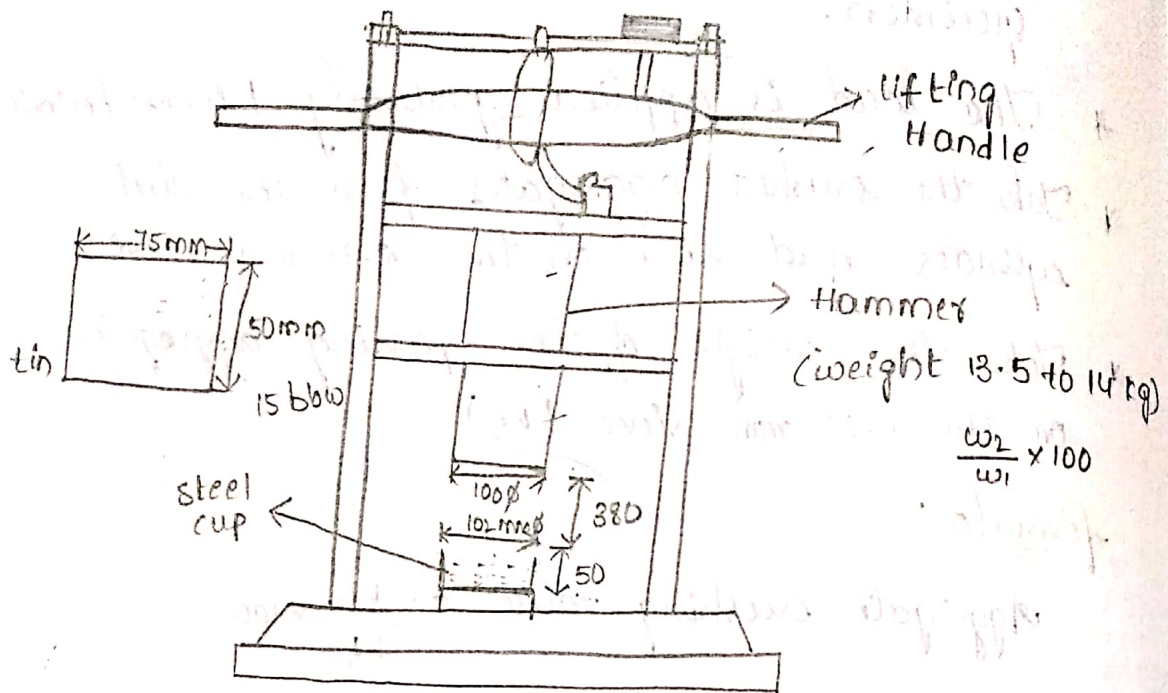
2. Impact test :

It is used for the finding the strength of the aggregate under sudden loads.

Apparatus:

1. Steel cup
dia 100 mm ϕ , height 50 mm
2. cylindrical measure
3. Tamping rod, Hammer (13-14 kg).





Formula:

Aggregate impact value = $\frac{\text{wt. of the aggregate passing on a 36 mm sieve (w)} \times 100}{\text{total wt. of aggregates}}$

Impact value

< 10%

10-20%

20-30%

> 35%

toughness

exceptionally strong.

very strong

Good for pavement surface

Weak for pavement surface.

3. Abrasion test

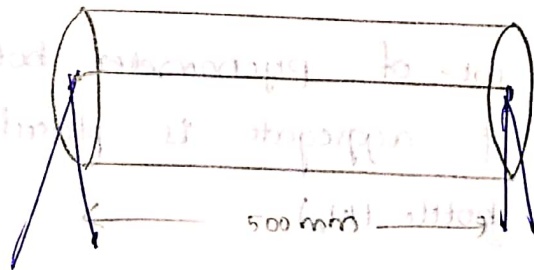
It is used to find out the resistance to wearing action.

There are 3 types of abrasion tests are available.

- (i) loss angels abrasion test
- (ii) Deval abrasion test
- (iii) Dorry abrasion test

(i) loss angels abrasion test:

Apparatus: loss angels testing machine of dia 700 mm and length 500 mm, steel balls of dia 48 mm dia, each ball weight 392-445 grams. is used as a abrasion charge, 1.7 mm ISO sieve



Formula:

$$\text{Aggregate abrasion value} = \frac{\text{wt. of aggregate passing } 1.7 \text{ mm sieve}}{\text{total wt. of aggregate}} \times 100$$

4 Soundness test:

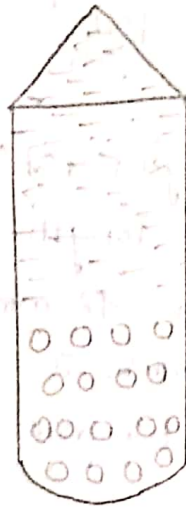
It is used to find out the strength of the aggregates during the weathering actions.

Apparatus:

Na_2SO_4 , Mg_2SO_4 Solutions.

Specific gravity & water absorption test:

→ coarse aggregate. Size is less than 6.3 mm



* Take the wt. of pycnometer bottle (W_1)

* 1000 grams of aggregate is placed in the pycnometer bottle (W_2)

* water is filled in the pycnometer bottle along with aggregate upto the top. (W_3)

* Take the wt. of pycnometer is filled with the water.

$$\text{Specific gravity} = \frac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)}$$

→ As per IRC → The specific gravity of aggregates lies b/w 2.6 - 2.9.

W_1 → wt. of empty pycnometer

W_2 → wt of aggregate + pycnometer

W_3 → wt of pycnometer + aggregate + water

W_4 → wt. of water + pycnometer

Water absorption test!

procedure:

formula:

$$\text{The water absorption} = \frac{W_1 - W_2}{W_2} \times 100$$

(when aggregate size below 10mm)

* The size of the coarse aggregate is greater than 10mm

Apparatus:

wire basket, container, tray, distilled

water.

procedure:

formula:

$$\text{Specific gravity} = \frac{W_4}{[W_4 - (W_2 - W_1)]}$$

* The size of the coarse aggregate is less than 10mm

$$\text{Water absorption} = \frac{W_3 - W_4}{W_4} \times 100$$

Shape test:

Flakiness index

Elongation index

Angularity (number)

(i) Flakiness index! (Thickness gauge)

It is used to find out the flakiness index of the aggregates.

-Apparatus:

63 mm sieve, 40 mm sieve, 50 mm sieve

Sieve numbers:

63 - 50, 50 - 40, 40 - 35, 35.5 - 25, 25 - 20,

20 - 16, 16 - 12.5, 12.5 - 10, 10 - 6.3.

procedure:

-Formula:

$$\text{The flakiness index} = \frac{\text{wt. of aggregate passing through the thickness gauge (W}_1\text{)}}{\text{Total wt. of the aggregates (W)}} \times 100$$

-As per IRC F_i value is less than 25%.

It is used as a bituminous & concrete pavements

If the F_i value is less than 15%. It is used as a water bound macadam.

(ii) Elongation index! (Length gauge)

It is used to find out the elongation index of the aggregates.

-Apparatus:

63 mm, 40 mm, 50 mm sieve

Sieve numbers:

63-50, 50-40, 40-31.5, 31.5-25, 25-20, 20-16,
16-12.5, 12.5-10, 10-6.3

procedure:

formula:

$$\text{Elongation index} = \frac{\text{wt. of the aggregates retaining on the length gauge (W}_1\text{)}}{\text{Total wt. of the aggregates (W)}} \times 100$$

* The gauge length = $\left(\frac{63+50}{2}\right) 1.8$

G.L = (Avg size of sieves) $\times$ K.F
- as per spec

* As per spec the elongation index not less than 15%, then it is used as a pavement material

(iii) Angularity number:

- Apparatus: metal cylinder, tamping rod

- Note down the wt. of the specified size of the aggregates after tamping -
- water is filled in the cylinder & note down the wt. of water

$$\text{Angularity number} = GA - \frac{100W}{G_a}$$

W → wt. of the aggregate, G_a → wt. of water filled in cylinder

G_a → Specific gravity of the aggregates

The angularity number is lies the 0 to 11.

If the value is more, it indicates more angular.

Stripping value test!

It is used to find out the stripping value (uncovered area) of the aggregates and the binder.

Apparatus:

Thermostatically bath, oven to heat the aggregates, beaker having the capacity of 500 ml, 15 sieves 20 mm, 12.5 mm

Procedure:

- * Take the sample of aggregates which is passing 20mm sieve and retaining on 12.5 mm sieve (200 gms)
- * Place the 200 gms of aggregates in the oven upto 150° .
- * Take the binder 5% of the aggregate sample (10 gms)
- * And the binder is heated upto 160° .
- * The heated aggregates & the binder is placed in the mixture and properly mixing.
- * The material is heated aggregate + binder is transferred into beaker having 500 ml capacity.

and placed in the room temperature for 2 hours.

* The beaker is removed from the room temperature and covered placed in a thermostat-cally water bath. for 24 hours.

* The temp of the water in the bath 40°

* The stripping value is determined, the uncovered area of the aggregates to the total aggregates expressed as a percentage.

As per IRC recommendation the stripping value of aggregate is less than 15%.

✓ Bitumen :

Bitumen is obtained from the fractional distillation of the crude oil the last stage waste product is called Bitumen.

It is a hydrocarbon material and black in colour. It is soluble in carbon disulphide and carbon tetrachloride.

Tar :

It is obtained from the destructive distillation of the coal and wood.

It is also in black colour. The free carbon content is more in the tar compare to bitumen.

The bituminous is available in different grades.

paving grade bitumen

Industrial grade bitumen

1. Paving grade bitumen:

If the bitumen is used in the construction of the roads is called as paving grade bitumen.

2. Industrial grade bitumen:

If the bitumen is used as a waterproof and the industrial floors is called as I.G.B.

* The paving grade bitumen is used for the construction of the roads, first heat the bitumen at the temp. of $130-140^{\circ}$ then only it is used.

3. cut back bitumen:

It is prepared while by diluting the paving grade bitumen with the volatile solvent (oil, kerosene).

4. Bitumen emulsion:

For obtaining the fluid consistency of the bitumen we use the emulsifying agents.

Properties of bitumen:

1. Binding property.
2. It act as a waterproof course
3. easy of mixing
4. forms the thinfilms around the aggregate
5. Adhesion property.

6. Interlocking property.

Test on the bitumen!

1. Penetration test
2. Viscosity test
3. Ductility test
4. Flash & fire point
5. Softening point
6. Loss on heating test
7. Solubility test
8. Specific gravity test
9. Spot test
10. Water absorption test.

* ASTM → American Society for testing of the materials

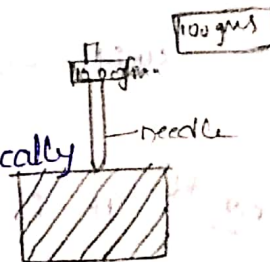
* BIS → Bureau of Indian Standard test

1. Penetration test!

Aim: It is used to find out the bitumen grades classification.

Apparatus:

Container, needle, thermostatically water bath, penetrometer, stopwatch.

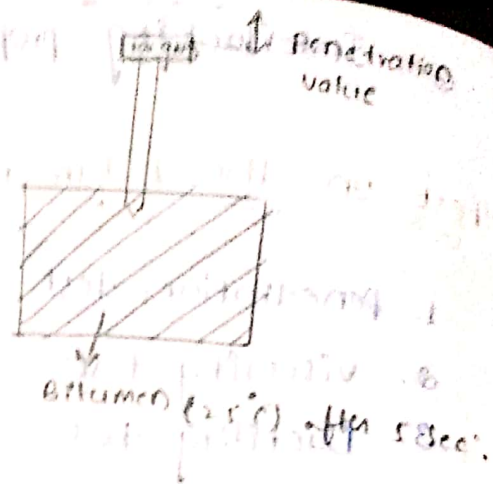
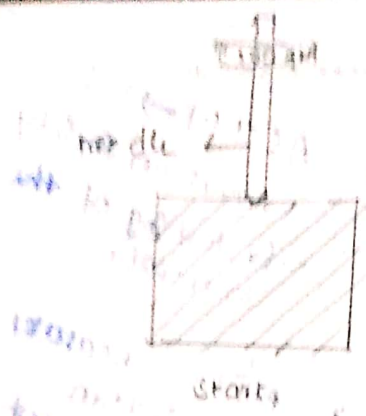


Principle:

By measuring the depth of the penetration of the needle under specified conditions.

(load = 100 gms, time = 5 sec, temp = 25°)

[Penetration → measuring the depth]



Procedure:

(1 dial = 0.1 mm)

2 Viscosity test:

~~mass~~ It is the resistance to flow.
v.d. viscosity is defined as the ratio of shear stress to rate of shear.
 - formula:

$$\tau = \mu \frac{du}{dy}$$

$$\mu = \frac{\tau}{(du/dy)}$$

units $\rightarrow$ poise, $\frac{N \cdot sec}{m^2}$

K.V. d.f. It is defined as the ratio of viscosity to the density of the liquid.

$$\nu = \frac{\mu}{\rho} \quad (\text{kinematic viscosity})$$

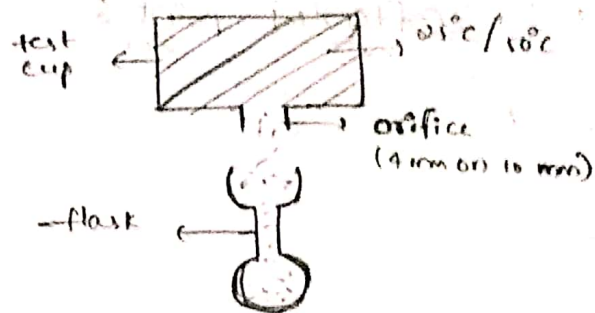
units $\rightarrow$ Stokes, m^2/sec

Aim:

It is used to find out the viscosity of the bituminous binders.

Apparatus!

Orifice viscometer



Procedure!

1. Take the Sample bituminous Sample (50 ml) filled in the test cup.
2. At a temperature of 25°/50° : Sample is filled in the test cup.
3. Orifice is arranged at bottom of the test cup.
4. The size of the orifice 4mm (or) 10 mm.
5. The flask is arranged at the bottom of the orifice
6. The time taken for the bituminous Sample filled in the flask from the test cup through the orifice is taken as viscosity.

Specific gravity:

$$S.G = \frac{w_2 - w_1}{(w_2 - w_1) - (w_3 - w_4)}$$

w_1 = empty wt. of pycnometer

w_2 = empty wt. of pycnometer + bitumen

w_3 = empty wt. of pycnometer + bitumen + water

w_4 = empty wt. of pycnometer + water.

← Loss on heating test:

It is used for the finding the volatile matter of the bitumen.

Procedure:

Wt $\begin{matrix} W_1 \\ 163^\circ\text{C} \rightarrow \text{oven} \end{matrix}$

W_2

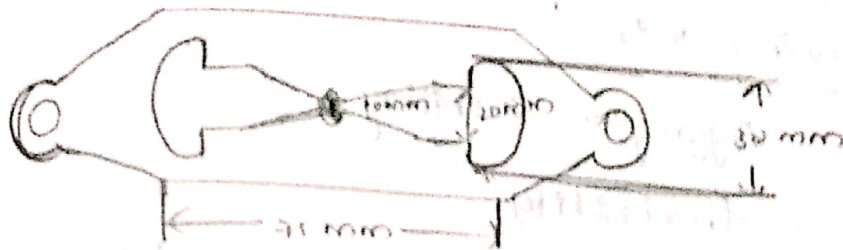
$$\frac{W_1 - W_2}{W_1} \times 100$$

Ductility test:

It is used for the testing on the bitumen ability to stretch.

Apparatus:

1. Briquette mould
2. Metal plate
3. Thermostatically water bath.
4. ductility machines.



Spot test:

It is used for the checking the bitumen is or not heated.

Apparatus:

Naptha, bitumen

Water content test:

It is used for the finding the water content in the given sample.

Apparatus:

Bitumen

petroleum distillate.

As per the IRC recommendation the water content does not exceed 0.2% by the weight of the sample.

Bituminous paving mixes:

The components of bituminous paving mix.

- coarse aggregate
- fine aggregate
- filler (material passing through the 0.075 mm sieve)

Requirements & the properties of the bituminous paving mix:

- Aggregate stability
- flexibility
- resist the permanent deformations
- durable
- resist the low temp cracking.
- workability
- skid resistance.

Steps for design of bituminous paving mixes

- * Selection of aggregates
- * Selection of aggregate grading.
- * Determination of specific gravity -
Specific gravity of the component
- * Proportioning of the aggregate
- * Preparation of the test specimen
- * Determination of specific gravity of the compacted specimen.
- * Determination of the density and void analysis.

Hardness
toughness
strength
soundness

2. Two types of grading

1. dense graded (less voids & impermeable)
2. open graded (voids content more & permeable)

4. → fine aggregate & coarse aggregate
→ filler
→ Bitumine binder

} By using trial & error method.

* 1000 gms of aggregate heated & binder heated
Both are mixed in mould.

placed at stability testing machine.

Marshall method of mix design!