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Introduction

Laboratory testing of materials used for highway construction and maintenance is an essential part of highway engineering. Many agencies determine the standards and specifications for these tests. This manual is based on B.S. and AASHTO standards. The manual is developed to meet the need for students and technicians in highway engineering. It presents the most commonly used test procedures for highway materials in a simplified way and considering time limitations and student's convenience. The manual includes testing procedures of soil, aggregates, asphalts and mix design procedures in five main parts. First part Subgrade Material test. Tests on aggregates are presented in the second part. Tests related to physical bituminous proprieties presented in third part. Marshall Asphalt mix design procedure covered in the fourth part. Fifth part covers Quality Control of Pavement. The test procedures were compiled in accordance with international and local standards and specifications. The tests are selected to provide knowledge of the basic properties and methods of testing. Guidance for analysis of the data and discussion of results is given at the end of each test.

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SECTION 1: Subgrade Material Tests

Introduction

- The subgrade is the material on which the road is constructed; highway subgrade (or basement soil) may be defined as the supporting structure on which the bound and unbound pavement courses rest.
- The tests employed on the subgrade vary according to whether the natural ground is the formation There are two important types of test which are designed the assess subgrade as bearing material and to generally control its quality. These are compaction tests and soil strength tests.
- The compaction test demonstrated in the laboratory is the standards and modified proctor procedures by which the maximum dry density and the optimum moisture content at which this is achieved are determined. The result of these determinations can be used as a guide to determine the effectiveness of on – site compaction of subgrade of those results are compared with the results of a field density determination by a technique known replacement method.
- The soil strength test, which is widely used for pavement thickness design is the California Baring Ratio Method or re-compacted material is being used as the formation material.

EXPERIMENT No.1: Standard Proctor Test

AASHO Designation T99

➢ Objective:-

To determine the relationship between water content and dry density of a soil sample compacted in a standard manner and to determine the optimum moisture content of the soil.

➢ Outline of Method:-

The soil is compacted in a specified manner over a range of moisture contents. The test is intended to give the optimum dry unit weight and the moisture content at which this occurs.

➢ Apparatus:-

1. A cylindrical metal mold; dimensions: Internal diameter 10.16cm and a volume of 946 cm^3. It has a detachable base plate and an extension of approximately 5cm height that is removable.
2. A metal rammer with a face of 5cm diameter, a weight of 2.5kg and a height of drop of 30cm.
3. A balance accurate to 1g.
4. A palette knife.
5. A straight edge.
6. A No.4 test sieve and receiver.
7. A large metal tray.
8. Apparatus to determine moisture content (tray, tins, etc...).
9. Apparatus to extrude samples from the mold.

Figure 1.1.1: Manually operated compaction device

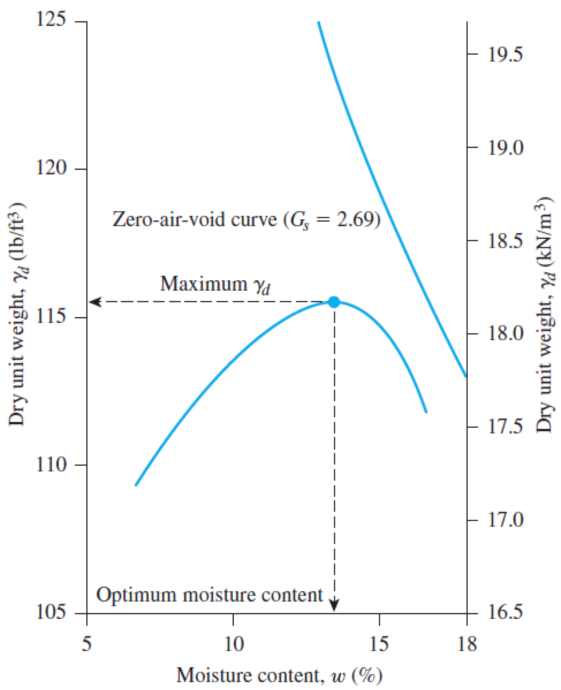
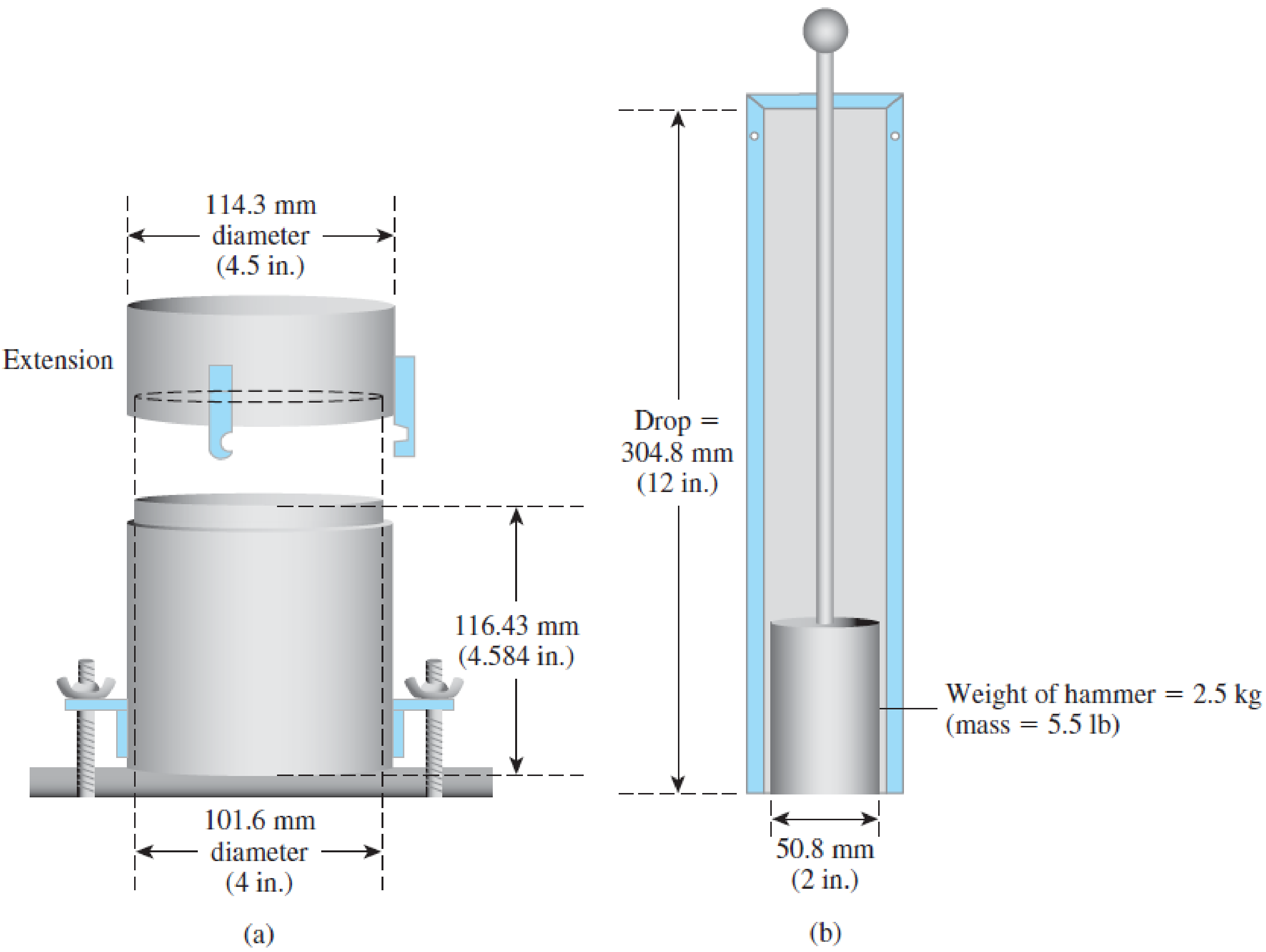


Figure 1.1.2: Moisture content with Dry unit weight



This design has been found satisfactory, but alternative designs may be employed if the essential requirements are fulfilled. (An asterisk indicates essential dimensions.)

Figure 1.1.3(a): Mold for compaction test.

The design has been found satisfactory, but alternative designs may be employed if the essential requirements are fulfilled. (An asterisk indicates essential dimensions).

Figure 1.1.3 (b): 2.5kg Rammer for the standard compaction test.

Figure 1.1.3

➢ **Theory:-**

- Compaction may be defined as the densification of soils by the application of mechanical energy. It may also involve a modification of the water content as well as the gradation of the soil. Cohesion less soil are compacted by some means of confining the soil coupled with vibrant energy. Fine-grained cohesive soils may be compacted in the laboratory by falling weights and hammers by special "kneading" compactors. In the field, the compaction equipment's include hand –operated tampers, sheep foot rollers, rubber-tired rollers, and other equipment's.
- The objective of compaction is the improvement of the engineering properties of the soil mass. There are several advantages which occur through compaction:
  1. Reduction in shrinkage.
  2. Reduction in settlements due to reduced void ratio.
  3. Increase in soil strength.
- While constructing dams for the Los Angeles Water District during the late 1920's R.P. Proctor developed a control specification for the compaction of cohesive soils. For this reason, the standard laboratory compaction test is commonly called the PROCTOR TEST.
- Proctor defined the four variables of soil compaction as:
  1. Dry Unit Weight.
  2. Water Content.
  3. Compaction Energy.
  4. Soil type (gradation, presence of silt, clay, etc.…).
- In the laboratory, the compaction effort or energy may be obtained by impact, kneading, or static means. During impact compaction, a hammer is allowed to drop several times on a soil sample confined in a mold. There are two types of compaction tests, the first is known as the standard proctor while the second is the modified AASHO test. The modified AASHO test uses a hammer weighing 4.5kg and is let fall 457mm on the soil sample, and the sample is compacted in 5lifts, getting 25 blows in each lift. The standard proctor hammer weighs 2.5kg and is let fall 308mm giving the soil sample 25 blows in three lifts.

➢ Procedure:-

The standard method prescribed in AASHO Designation T-99 lives four alternate procedures as follows:

- Method A: A 107mm mold; Soil material passing a 4.75mm sieve.
- Method B: A 152mm mold; Soil material passing a 4.75mm sieve.
- Method C: A 107mm mold; Soil material passing a 19.0mm sieve.
- Method D: A 152mm mold; Soil material passing a 19.0mm sieve.

If the method to be used is not specified, then the test is performed according to method (A).

Procedure (A):-

1. Mix a 5kg sample of air-dried soil passing the No.4 test sieve with a suitable amount of water.
2. Determine the mass of the mold complete with base plate to the nearest 1kg (M_1) and compact the soil into the mold with the extension attached in three layers of approximately equal mass. Each layer given 25 blows of the 2.5kg rammer falling through 300mm.
3. Fill the mold with sufficient: Lent soil to leave a depth' of approximately 6mm to be struck off when the extension is removed. Remove the extension from the top of the mold and strike off the excess soil using the straight edge. The surface of the compacted soil should be level with the ring of the mold. Determine the mass of the mold and contents to the nearest 1g (M_2).
4. Remove the compacted soil specimen from the mold by means of the extruder. Place the extruded soil on a large metal tray and take a representative sample to determine the moisture content. The amount of soil used for the moisture content should be of the order of 200g and the test should be carried out in the normal manner.
5. Mix the remainder of the soil sample passing the No.4 sieve with suitable increments of water and repeat the above procedure for each water content. The range of water contents should be such that it covers the optimum moisture content at which maximum dry density occurs. At least five separate determinations of density and corresponding moisture content should be carried out.

Procedure (Modified Compaction Test.):-

AASHO Designation T180

Follow the same steps in the standard (Proctor) test using the modified, test hammer (4.5kg, L=457mm drop) compacting the soil sample in five layers giving each layer 25 strokes. Then proceed as in the standard Proctor test.

➢ Calculations:-

- The bulk density, ρ in g/cm^3 of each specimen can be calculated prom the following equation:

$$\rho = \frac{M_2 - M_1}{946}$$

Where:

M_2: Mass of mold, base and soil (g).
M_1: Mass of mold and base (g).

- The dry density is calculated as follows:

$$\rho_d = \frac{100\rho_{bulk}}{100 + \omega}$$

Where:

ω: The moisture content.

- The results should be tabulated in the appropriate form. Plot the dry densities obtained in the series of tests against the corresponding moisture contents. Draw a smooth curve through the resulting points and note the position of the maximum on this curve. Plot the zero, 5% and 10% air void line from the SG of the soil.
- The air void line may be calculated from the equation:

$$\rho_d = \rho_w * \frac{1 - \frac{V_a}{100}}{\frac{1}{G_s} + \frac{\omega}{100}}$$

Where:

ρ_d: Dry density of the soil (g/cm^3).
ρ_w: Density of water (g/cm^3).
V_a: Volume of air voids in the soil, expressed as a percentage of the total volume of the soil.
G_s: Specific gravity of the soil particles.

- The zero air voids line (or saturation line) shows the dry density / moisture content relationship of soil containing no air voids. It is obtained by putting V_a=0 in the previous equation.

2.5 kg*/4.5kg* (Rammer method)							
Operator:	Job:	Site:					
Date:		Borehole No:					
Description of soil:		Sample No:					
Single / separate * samples		Depth of sample:					
Amount retained on 20 mm BS test sieve:	g						
Total mass of sample:	g						
Test number							
Mass of mold + base + compacted specimen (m_2)	g						
Mass of mold + base (m_1)	g						
Mass of compacted specimen ($m_2 - m_1$)	g						
Bulk density $\rho = \frac{M_2 - M_1}{946}$	Mg/m^3						
Moisture content container No.							
Moisture content (w)	%						
Dry density $\rho_d = \frac{100\rho_{bulk}}{100+\omega}$	Mg/m^3						

EXPERIMENT No.2: Field Density Test

AASHO Designation T91 – 61

➢ Objective:-

To determine the dry density of natural or compacted soils in the site using the Sand-Cone Method.

➢ Theory:-

- Continuous testing of the moisture content and the density of the compacted fill is essential to ensure that the finished product meets the requirement.
- The Sand-Cone method is often used for gravelly soils. A hole 10–15cm in diameter and 15cm deep is done, and the soil since it is weighed and tested for moisture.
- The volume of the hole is measured by filling it with loose, dry sand that falls from a fixed height through a cone shaped stand. The volume of the hole can thus be calculated and therefore the soil bulk density and dry density can be determined. The standard sand used should pass sieve No.30 and he retained on sieve No.50.

➢ Apparatus:-

1. A pouring cylinder of specified dimensions.
2. Tools for excavating a hole in the soil (e.g. a bent spoor dibber, a small scoop and a scraper tool).
3. A cylindrical metal container to calibrate the apparatus, (e.g. a proctor or GBR mold).
4. A balance readable and accurate to 1g.
5. A glass plate.
6. A container for the excavated material.
7. Apparatus for moisture content determination.
8. A metal tray 300mm square and 40mm deep with a 100mm diameter hole in the center.

Figure 1.2.1: Density Plate

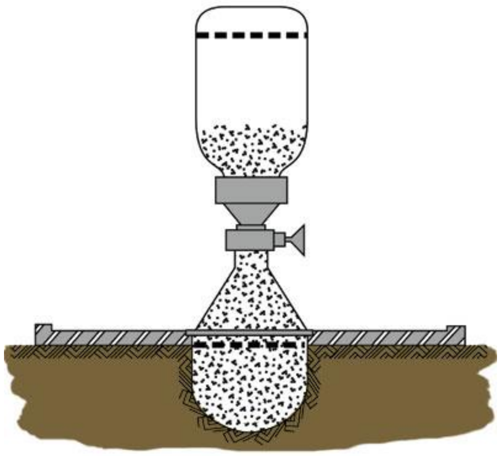


Figure 1.2.2: Sand-Cone

➢ Calibration of Apparatus:-

A. Determine the Mass of Sand in Cone:-

1. Fill the pouring cylinder BD that the level of sand is within approximately 15mm of the top. Determine the initial total weight of sand (M_1) and maintain this weight throughout the tests.
2. Allow a Volume of sand equivalent to that of the calibrating container to run out.
3. Close the shutter of the pouring cylinder and place it on a glass plate.
4. Open the shutter and allow the sand to run out until it ceases moving· Then clone the shutter and remove the cylinder carefully. Do not disturb or tap the cylinder during the operation.
5. Collect and weigh the sand that has filled the cone to the nearest 1g.
6. Repeat the procedure at least three times and find the mass of sand in the cone (M_2).

B. Determine the Bulk Density of Sand:-

1. Determine the internal volume of the calibrating container by finding the mass of water required to fill it.
2. Place the pouring cylinder filled with the constant mass of sand (M_1) concentrically on top of the calibrating container.
3. Open the shutter and allow the sand to run out. The pouring cylinder should never be disturbed during the operation.
4. Close the shutter when the sand ceases to flow and then weigh the cylinder and contents to the nearest 1g.
5. Repeat this procedure at least three times and determine the mean mass of sand in the calibrating container (M_3).

➢ Procedure:-

1. A flat area about 450mm square of the area to be tested is exposed and made level with the scraper tool.
2. Place the metal tray on the prepared surface and excavate a hole approximate 100mm in diameter and 150mm deep using the hole in the tray as a pattern.
3. Remove all the material from the hole carefully and avoid distorting the immediate surround to the hole. Weigh the excavated material to the nearest 1g. (M_w).
4. Take a representative sample of tile-excavated soil and determine its moisture content.
5. Remove the tray with the hole pattern and place the pouring cylinder filled with constant mass of sand concentrically over the hole.
6. Open the shutter and allow the sand to flow into the hole, when it has ceased flowing close the shutter and then weight the cylinder to the nearest 1g. (M_4).

➢ Calculations:-

- The mass of sand required to fill the calibration container (M_a) is calculated as follows:

$$M_a = M_1 - M_3 - M_2$$

Where:

M_1: Mass of the cylinder and sand before pouring (g).
M_2: Mean mass of sand in cone (g).
M_3: Mean mass of cylinder and sand after pouring into calibration container (g).

- The bulk density of the sand ρ_s in g/cm^3 is obtained from this equation:

$$\rho_s = \frac{M_a}{V}$$

Where:

V = Volume of the calibrating container in cm^3.

- The mass of sand required to fill the excavated hole M_b is obtained by this equation:

$$M_b = M_1 - M_4 - M_2$$

Where:

M_1 = Mass of cylinder and sand before pouring (g).
M_2 = Mean mass of sand in cone (g).
M_4 = Mass of cylinder and sand after pouring into hole (g).

- The bulk density of the soil is calculated from this equation:

$$\rho = \frac{M_w}{M_b} * \rho_s$$

Where:

M_w: Mass of soil excavated (g).
M_b: Mass of sand required to fill the hole (g).
ρ_s: Bulk density of sand (g/cm^3).

- The dry density ρ_d in g/cm^3 is calculated as follows:

$$\rho_d = \frac{100\rho_{bulk}}{100 + \omega}$$

Where:

ω: The moisture content.

Sand replacement method						
Small pouring cylinder, Large pouring cylinder, Hand scoop method						
Operator: Date:	Job:	Site:				
Description of soil:						
Depth of hole excavated:						
Calibration Mean mass of sand in cone (of pouring cylinder) (m_2) g						
Volume of calibrating container (V) cm^3						
Mass of sand (+ cylinder) before pouring (m_1) g						
Mean mass of sand (+ cylinder) after pouring (m_3) g						
Mass of sand to fill calibrating container $M_a = M_1 - M_3 - M_2$ g						
Bulk density of sand $\rho_s = \frac{M_a}{V}$ Mg/m^3						
Sample No.						
Mass of wet soil from hole (m_w)						
Mass of sand (+ cylinder) before pouring (m_1)	g					
Mass of sand (+ cylinder) after pouring (m_4)	g					
Mass of sand in hole ($m_b = m_1 - m_4 - m_2$)	g					
Ratio $\frac{M_w}{M_b}$						
Bulk density $\rho = \frac{M_w}{M_b} * \rho_s$	Mg/m^3					
Moisture content container NO.						
Moisture content (w)	%					
Dry density $\rho_d = \frac{100\rho_{bulk}}{100+\omega}$	Mg/m^3					

EXPERIMENT No.3: California Bearing Ratio Test

AASHO T193

➢ Objective:-

To determine the California bearing ratio (C.B.R) of a soil sample containing a small amount of material retained on the 3/4 inch sieve.

➢ Theory:-

- CBR: California bearing ratio is a ratio between the load carried by soil or base course sample at a certain penetration under known conditions to a standard load for crushed stone aggregate at the same penetration.
- The California Bearing Ratio is the most widely used method of designing asphalt pavement structures. The California division of Highways around 1930’s (USA) developed this method. The C.B.R. is considered a comparative measure of the shearing resistance of a soil. It is used with empirical curves to design asphalt pavement structures. The test consists of measuring the load required to specimen at a specified rate.
- Usually depths of 2.5mm (0.1-in) & 5mm (0.2-in) are used, but depths of up to 12.5mm can be used if desired.

➢ Apparatus:-

- Accessories:-
  1. Compaction Hammer.
  2. C.B.R. mold.
  3. Extension collar.
  4. Solid has for mold.
  5. Tool for base plate.
  6. Surcharge weight (2.27 kg)
  7. Spanner (to mount and dismount collar from mold).
  8. Perforated plate with adjustable stem.
  9. Split surcharge weight (2.25 kg).
  10. Compaction plug with handle.
  11. Swell dial gauge.
  12. Soaking tank.

Figure 1.3.1: Accessories

- Machine:-

1. Cylindrical mold.
2. Spacer disc.
3. Compaction Hammer (4.5 kg).
4. 20mm sieve and No. 4 (4.75 mm).
5. Expansion apparatus consisting of a perforated aluminum plate with adjustable stem and a tripod with a dial gauge for measuring the expansion of the soil sample during the period when the compacted soil is soaked in water.
6. Surcharge weights.
7. Apparatus for measuring the load on the piston and the movement of the piston during penetration.
8. A jack for applying a load to the piston.
9. Course filter paper, wire screen and cellophane.

Figure 1.3.2: CBR machine

➢ Procedure:-

A. Preparation of Sample in CBR Mold:-

1. Prepare 35kg of an air-dried soil sample to pass the 20mm sieve and retained on sieve No.4.
2. Oven dry 500g (approx.) of this soil and determine the natural moisture content.
3. Assemble the 150mm mold, extension collar and perforated base plate by clamping the mold fitted with extension collar to the base plate.
4. Insert the spacer disc over the base plate and position a 150mm diameter course filter paper on top of the disc.
5. Compact the sample in five layers by 55 blows per layer of the 4.5kg hammer.
6. Remove the extension ring and strike off excess soil with a straight edge. Lift the mold to remove the base plate and the spacer disc.
7. Determine the density of the soil by weighing the weight of the mold and dividing by the volume of the mold ($2305cm^3$).
8. Invert the mold after placing a filter paper on the base plate. Place another filter paper on top of the soil in the mold.

B. Penetration Load Measurement of the Sample:-

1. Place one 2.5kg annular surcharge disc on the soil surface and place the mold in the loading frame.
2. Seat the penetration piston with a 4.5kg load and set the dial gauges for load and strain to zero.
3. Place further surcharge weights on the sample until this surcharge weight equals the seeking surcharge.
4. Apply the load to the piston at a uniform rate of 1.25mm per minute of penetration. Note the load readings for every 0.5mm of penetration until 7.5mm of penetration.
5. On completion of the penetration release the load and remove the mold from the testing machine.
6. Remove the specimen from the mold and determine the moisture content for the entire depth of the sample.

C. Soaking of the Sample and Measurement of Swell:-

1. Place the perforated aluminum plate with adjustable stem attached to the filter paper on top of the soil.
2. Apply a surcharge weight to the aluminum plate appropriate for the thickness and weight of construct that it is anticipated the subgrade will have to bear. In any event, this should not be less than 4.5kg.
3. Place the mold in a water bath so that the water levee of water should be allowed to the bottom of the moil and the water levels inside and outside the mold should be equal.
4. Place the expansion apparatus on the mold and take the initial dial gauge readings for the swelling measurements.

5. Allow the specimen to soak for 4 days and maintain the constant water level inside and outside the mold.
6. At the end of the soaking period take a final dial gauge reading and calculate the swell as a percentage of the height of the specimen (125 mm).
7. Remove the expansion apparatus and surcharge weights and lift the mold out of the water bath. Allow the mold to drain for 15 minutes.
8. Weigh the specimen and determine the density.

➢ Classification of CBR:-

CBR	Layer	Status	Remark
0-3	Subgrade	Very poor	Replacement
3-7	Subgrade	Poor	Stabilization
7-20	Subgrade	Fair	(10-15)% subgrade
20-50	Sub-base	Good	(30-35)%
50-80	Base	Very good	Light traffic
80-100	Base	Excellent	Medium & heavy traffic
>100	Base	More than Crushed stone	Airport

➢ Calculations:-

- Swelling Percentage:-

  Percentage of the height of the specimen.

$$\% \, Swell = \frac{Swell \; (final \; readiing - initail \; reading)}{Height \; of \; specimen \; (125mm)} * 100\%$$

- Penetration Load Measurement:-
  - Plot the readings of load against the reading of penetration and draw a smooth curve through the points.
  - The curve is mainly convex upwards, although the initial portion of the curve may be concave upwards; the concavity is assumed to be due to surface irregularities. In this case, a correction is applied by drawing a tangent to the curve at the point of greatest slope. The corrected curve is then this tangent plus the convex portion of the original of the load at the corrected penetration of 2.5mm and 5.0mm. The obtained values (in pounds) are expressed as percentages of the standard loads of 30001b and 4500Ib, respectively. These standard loads were obtained from tests on a crushed stone that was defined as having a California bearing ratio of 100 percent, using a 3-in square plunger.

- Calculate CBR as follows:

$$I_{2.5mm\ (0.1-in)} = \frac{load\ at\ 2.5mm\ penetration}{3000Ib.} * 100\%$$

$$I_{5mm\ (0.2-in)} = \frac{load\ at\ 5mm\ penetration}{4500Ib.} * 100\%$$

- Usually the value at 2.5mm is greater than that a 5.0mm penetration and the former is taken as the CBR.
- If the C.B.R at 2.5mm is less than C.B.R at 5mm repeat the test on another soil sample. In the case, that the second test gives C.B.R at 2.5mm is less than C.B.R at 5mm, assume 5mm as CBR.

- Expected Curves Results:-

A. Smooth curve test (do not need a correction):

B. Concave at the beginning and in this case we need to draw a tangent, then find shift figure and do a correction, this happened due as to:

1. The area of the piston (3-in^2) not touch the surface completely which give resistance and the value is lower than it supposed to be.
2. The surface is not completely straight and contain some rocks (surface irregularity).

C. When the sample is stronger than crush stone the curve and we do a tangent and shift.

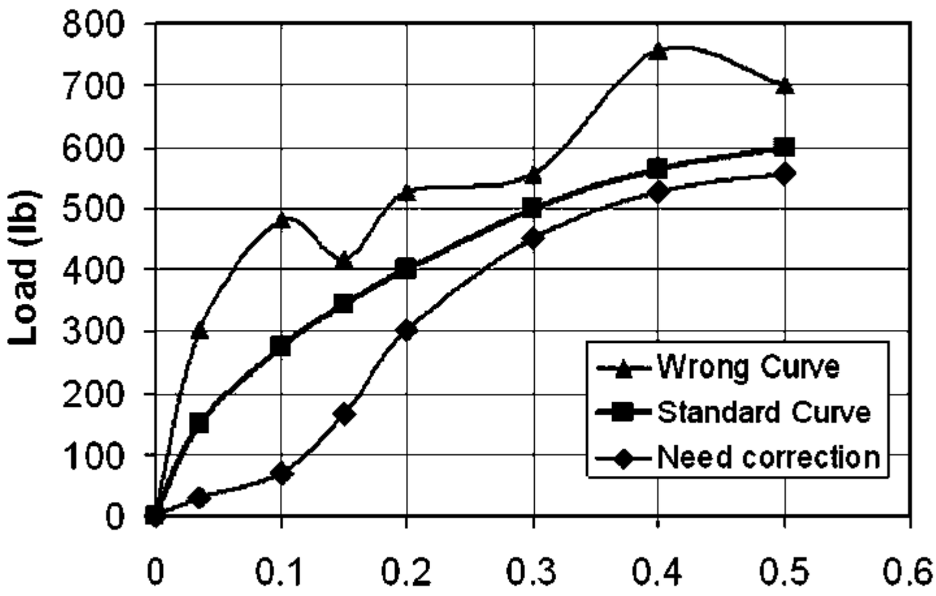


Figure 1.3.3: CBR curves

➤ Flexible Pavement Design by CBR method:-

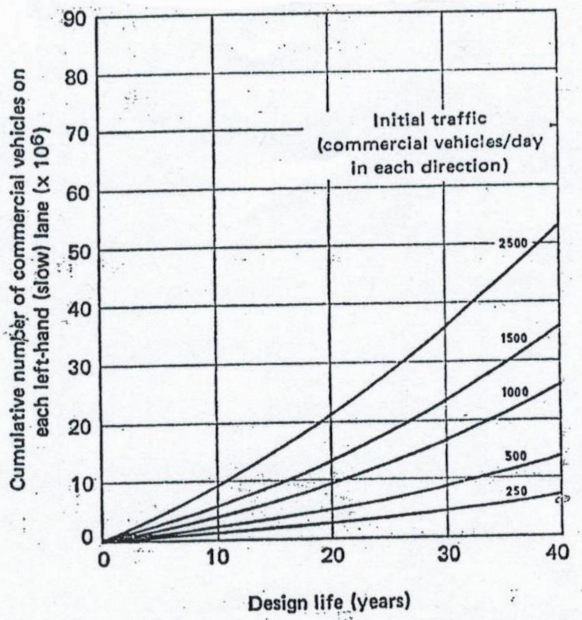


Fig. 19.4. Relationship between cumulative number of commercial vehicles carried by each left-hand (slow) lane and design life: growth rate 3 per cent.

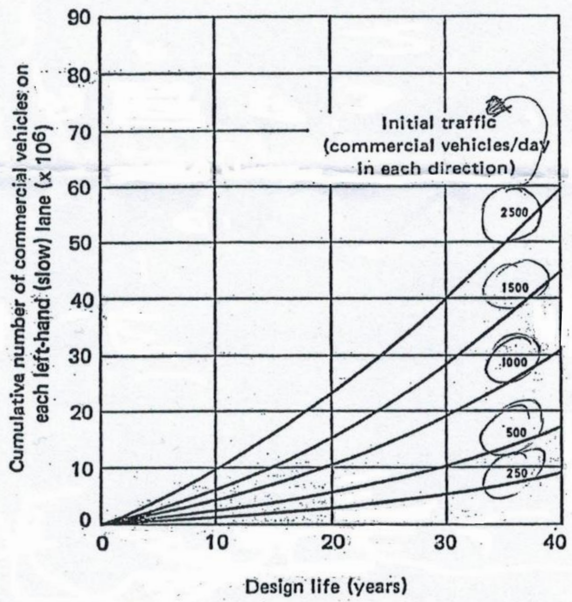


Fig. 19.5. Relationship between cumulative number of commercial vehicles carried by each left-hand (slow) lane and design life: growth rate 4 per cent.

TABLE 19.2

Conversion factors to be used to obtain the equivalent number of standard axles from the number of commercial vehicles

Type of road	Number of axles per commercial vehicle (see para 19.10) (a)	Number of standard axles per commercial axle (b)	Number of standard axles per commercial vehicle (a) × (b)
Motorways and Trunk Roads designed to carry over 1000 commercial vehicles per day in each direction at the time of construction	2.7	0.4	1.08
Roads designed to carry between 250 and 1000 commercial vehicles per day in each direction at the			

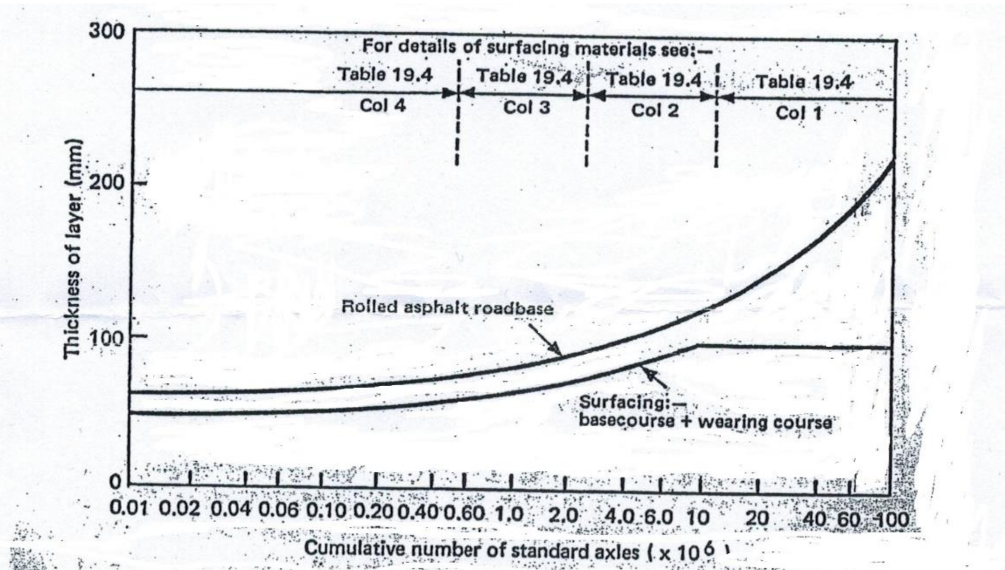


Fig. 19.10. Rolled asphalt roadbase: minimum thickness of surfacing and roadbase.

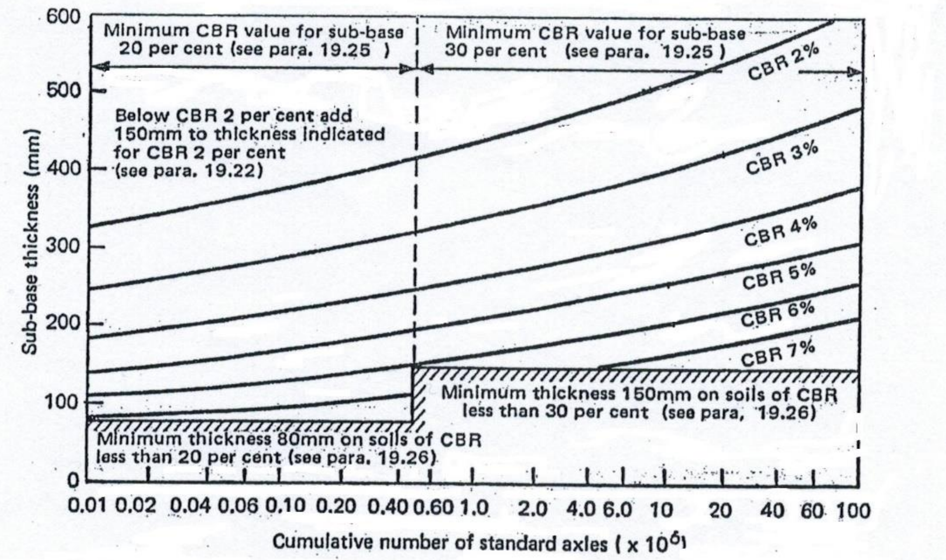


Fig. 19.9. Thickness of sub-base.

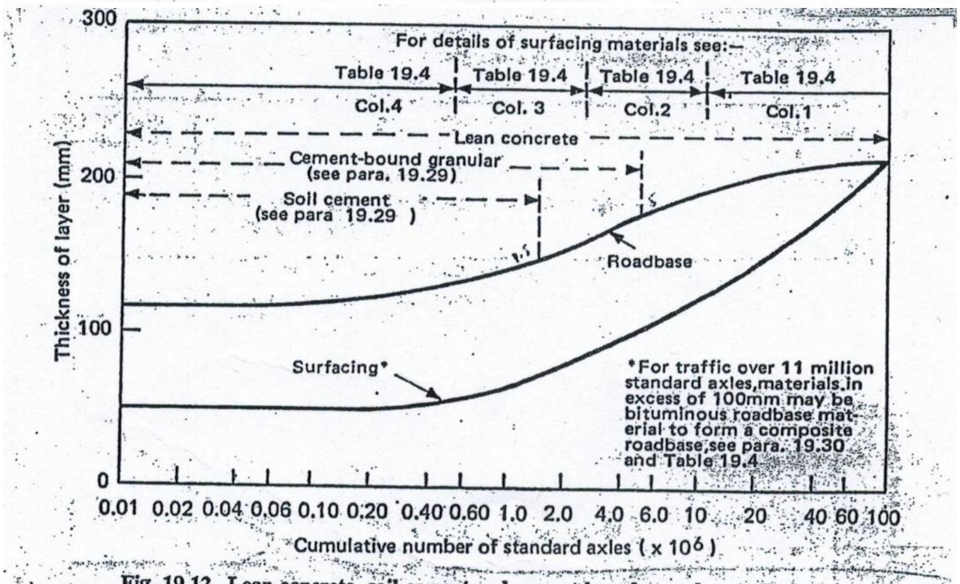
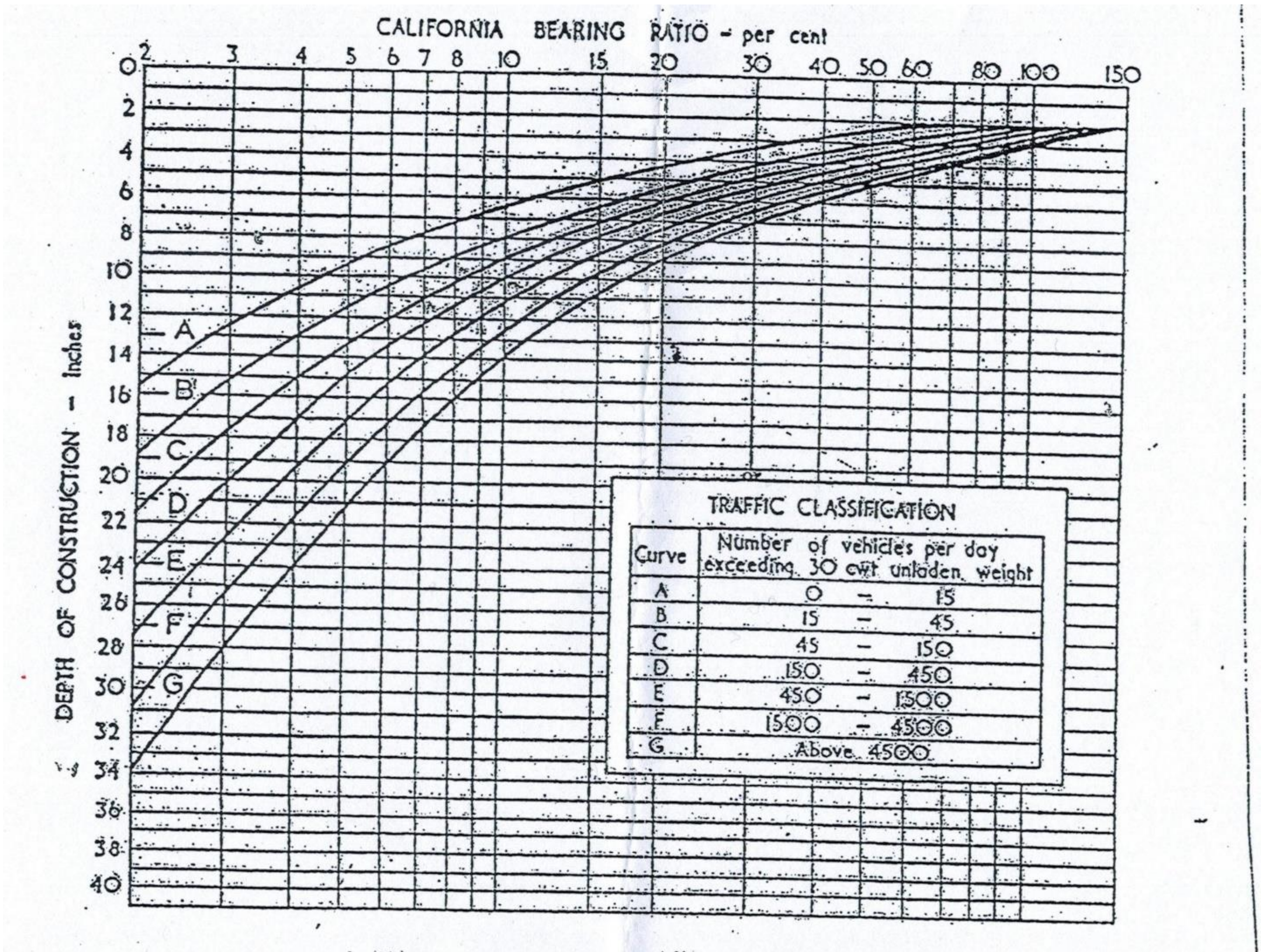


Fig. 19.12. Lean concrete, soil-cement and cement-bound granular roadbases: minimum thickness of surfacing and roadbase.



C.B.R. design curves for different classes of road.

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California Bearing Ratio Test

Date:	Location:			Site:	No.
Soil type:	Tin No.	Moisture Content	Mean moisture content	Dearing value at 2.5 mm &5.0 mm	
Dry density:				Top %	
				Bottom %	

Penetration of plunger (mm)	Load (Digit)		Load (kg)		Loads (Ib.)	
	Top	Bottom	Top	Bottom	Top	Bottom
0.00						
0.25						
0.50						
0.75						
1.00						
1.50						
2.00						
2.50						
3.00						
3.50						
4.00						
4.50						
5.00						
5.50						
6.00						
6.50						
7.00						
7.50						

Remarks:____

Tested by:	Checked by:

SECTION 2: Aggregate Tests

Introduction

Knowledge of current aggregate tests and applicable testing methods and factors affecting variability of these tests and methods was needed in order to conduct an efficient research project that would be applicable to the needs of those who provided funds for this research. Two main aggregate qualities must be evaluated from aggregate tests: the susceptibility to impact and the susceptibility to weathering, or durability (Hudec, 1983). To evaluate these qualities aggregate tests must be able to: provide correlations with field performance; be suitable for aggregates from different sources; results in reasonable variability of aggregate from a single source; and give the results representative of the whole sample (Shergold, 1948). The following is a review of the literature pertinent to this study.

EXPERIMENT No.1

B.S. 882

1.1: Sieve Analysis & Fineness Modules

➢ Objective:-

To determine the grading or the size distribution of the aggregates.

➢ Theory:-

- Sieve analysis is the process of dividing a sample of aggregate into a fraction of the same size. The purpose of doing this analysis is to determine the grading or the size distribution of the aggregate which is important to find out whether the aggregate pile we are studying is good for the mix or not. The grading of the aggregate, usually effects on the workability of the fresh concrete.
- The aggregate of interest is thrown into a series of sieves nested in order with the smallest at the bottom, and after shaking, the mass of retained aggregate in each sieve is calculated.
- The aggregate we use in our experiment should be represented to the pile we obtained it from, so we cannot just take the mass we need for the experiment arbitrary because this arbitrary specimen might not contain a certain size of the aggregate. For that reason the Quartering Method is used, this method involves taking a big amount of aggregate from the pile of interest (more than the amount we need) and then divide them into quarters or halves till we gain the amount we need for the experiment.
- After sieving the specimen, we calculate the retained mass in each sieve, a table is made, and the grade curve is drawn.
- The sieve analysis can be done in two methods, a wet method and a dry method, but as the wet method takes more time, we have made the dry method.
- Fineness Modulus is a measure to the grading of an aggregate pile, and it is used to compare aggregate that is gained from the same source. It can be defined as the sum of the Cumulative percentage retained on the sieves of the standard series divided by 100.

➢ Apparatus:-

1. Set of sieves.
2. A dried specimen of aggregate.
3. Trays.
4. Electronic weighting machine.
5. Mechanical shaker.
6. Riffle box.

Figure 2.2.1.1: Electronic sieving machine

➢ Procedure:-

1. We put the dried aggregate specimen into the sample splitter and reduce the amount until we get 2kg of the specimen.
2. After nesting the sieves in order (starting from the smaller at the bottom), the aggregate specimen is thrown into the sieves.
3. The nested sieves are then moved to the mechanical shaker and left there for 15 minutes.
4. Then the weight of the retained aggregate in each sieve is calculated using the Electronic weighting machine.
5. Table of the results is established and the Grading curve is drawn.

➢ Standard Sieve Sizes:-

US Standard Sieve	Clear Opening (mm)
3-in	75
2.5-in	63
2-in	53
1.5-in	37.5
1.0-in	25.4
3/4-in	19
1/2-in	12.7
3/8-in	9.5
No.4	4.75
No.8	2.36
No.10	2.00
No.16	1.18
No.20	0.85
No.30	0.6
No.40	0.425
No.50	0.3
No.80	0.18
No.100	0.15
No.200	0.75

➢ Calculations:-

$$Fineness\ Modulus = \frac{1}{100} * total\ of\ percetage\ retained\ on\ designeted\ sieve$$

By Order of	
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Sample	
Initial weight	

US Standard Sieve	Cumulative weight Retained	Cumulative percent Retained	Specifications limits	Fineness Modulus
3-in				
2.5-in				
2-in				
1.5-in				
1.0-in				
3/4-in				
1/2-in				
3/8-in				
No.4				
No.8				
No.10				
No.16				
No.20				
No.30				
No.40				
No.50				
No.80				
No.100				
No.200				

Remarks:____
____
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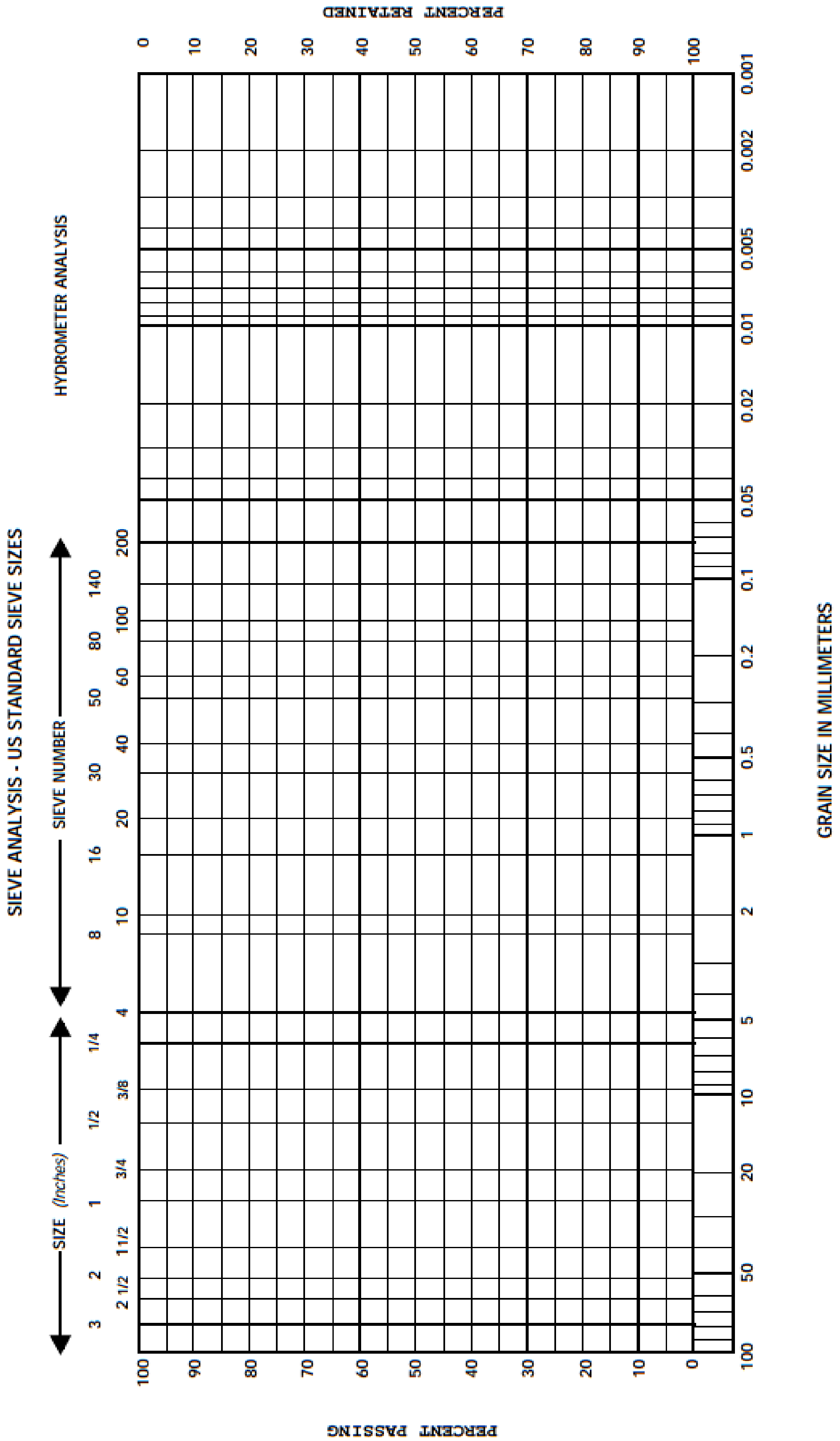
Date of test:	Tested by:	Checked by:


PERCENT RETAINED
0
10
20
30
40
50
60
70
80
90
100
SIEVE ANALYSIS - US STANDARD SIEVE SIZES
SIZE (Inches)
SIEVE NUMBER
HYDROMETER ANALYSIS
3
2
2 1/2
1 1/2
1
3/4
1/2
3/8
1/4
4
8
10
16
20
30
40
50
60
80
100
140
200
100
90
80
70
60
50
40
30
20
10
0
100
50
20
10
5
2
1
0.5
0.2
0.1
0.05
0.02
0.01
0.005
0.002
0.001
GRAIN SIZE IN MILLIMETERS
PERCENT PASSING

1.2: Selection and Combining of Aggregates

➢ Objective:-

To select and combine aggregates suitable for the Marshall bituminous mix design.

➢ Theory:-

It is normal for aggregates to be sorted into closely graded sizes that can at any time be remixed in particular proportions to conform to a gradation specification. The blending of aggregates to meet a specification eventually becomes a trial and error exercise, but initially there is a mathematical method that gives a guideline as to where to commence.

➢ Apparatus:-

1. Set of test sieves of suitable sizes.
2. Mechanical sieve shaker.
3. A balance accurate to 0.5g
4. Trays, scoops, and sieve brushes.
5. Sample divider (riffle box).
6. Drying oven.

Figure 2.2.2.1: Riffle box

➢ Procedure:-

1. Take representative samples from each aggregate stockpile.
2. Dry all the aggregate to constant weight at 105°C.
3. Perform a sieve analysis on each sample using suitable sieve sizes.
4. Calculate the percentage passing each sieve size.
5. Decide the aggregate grading specification that is appropriate.
6. Now it is necessary to combine the fine, intermediate, and coarse aggregate to obtain the required grading appropriates proportions of these aggregate fractions may be determined from the following equation:

$$aA + bB + cC = P$$

Where:

A, B, C, etc.: Percentage of material passing a given sieve for aggregate A, B, C.

a, b, c, etc.: proportions of aggregates A, B, C, etc.
Used in the combination where the total = 1.0.
P: percentage of material passing a given size for aggregates A, B, C.

7. Blend the aggregate in the proportions determined by the Calculations carried out according to step six then prepare 2kg of the blended aggregate.
8. Carry out a grading analysis of the 2kg of blended aggregate to check its compliance with the specification.

EXPERIMENT No.2: Los Angeles Abrasion Test

ASTM C 131 - 69

➢ Objective:-

Measuring the hardness of coarse aggregate, i.e. the resistance of wear using Los Angeles method to determine the Los Angeles Abrasion Value (L.A.A.V).

➢ Theory:-

- The Los Angeles Rattler test is a measure of degradation of mineral aggregates of standard grading's resulting from a combination of actions including abrasion or attrition, impact, and grinding in a rotating steel drum containing a specified number of steel spheres (dependent upon the test sample's grading). As the drum rotates, a shelf plate picks up the sample and the steel spheres, carrying them around until they are dropped to the opposite side of the drum, causing an impact-crushing effect. The contents then roll within the drum with an abrading and grinding action until the shelf plate impacts and the cycle is repeated. After the prescribed number of revolutions, the contents are removed from the drum and the aggregate portion is sieved to measure the degradation as percent loss.
- Los Angeles abrasion test studies all possible reasons causing wear. In the L.A. abrasion machine Attrition, Abrasion, and crushing are all present as follows:
  1. Attrition: By the friction between the aggregate particles.
  2. Abrasion: By the friction between the steel balls and the aggregates.
  3. Crushing: By hitting the walls of the testing machine.
- Los Angeles abrasion test is suitable for coarse aggregate of different sizes and it is not used for fine aggregate.

➢ Apparatus:-

1. It consists from:
   A. A steel drum, 28 inches in diameter and 20 inches in length. This drum rotates with its axis set horizontally at a speed of approximately 33 R.P.M.
   B. A door closed by bolts and nuts, and an internal steel shelf that extend along the steel drum and it guarantees that the balls and aggregate will hit and so abrasion and attrition are done.
   C. Automatic counter switch, the number of wanted revolutions is set at the beginning of the test so that the machine will stop automatically when revolving the set number of revolutions.
2. Steel Balls.
3. Weighing machine.
4. Sieves (19mm, 12.5mm and 9.5mm).

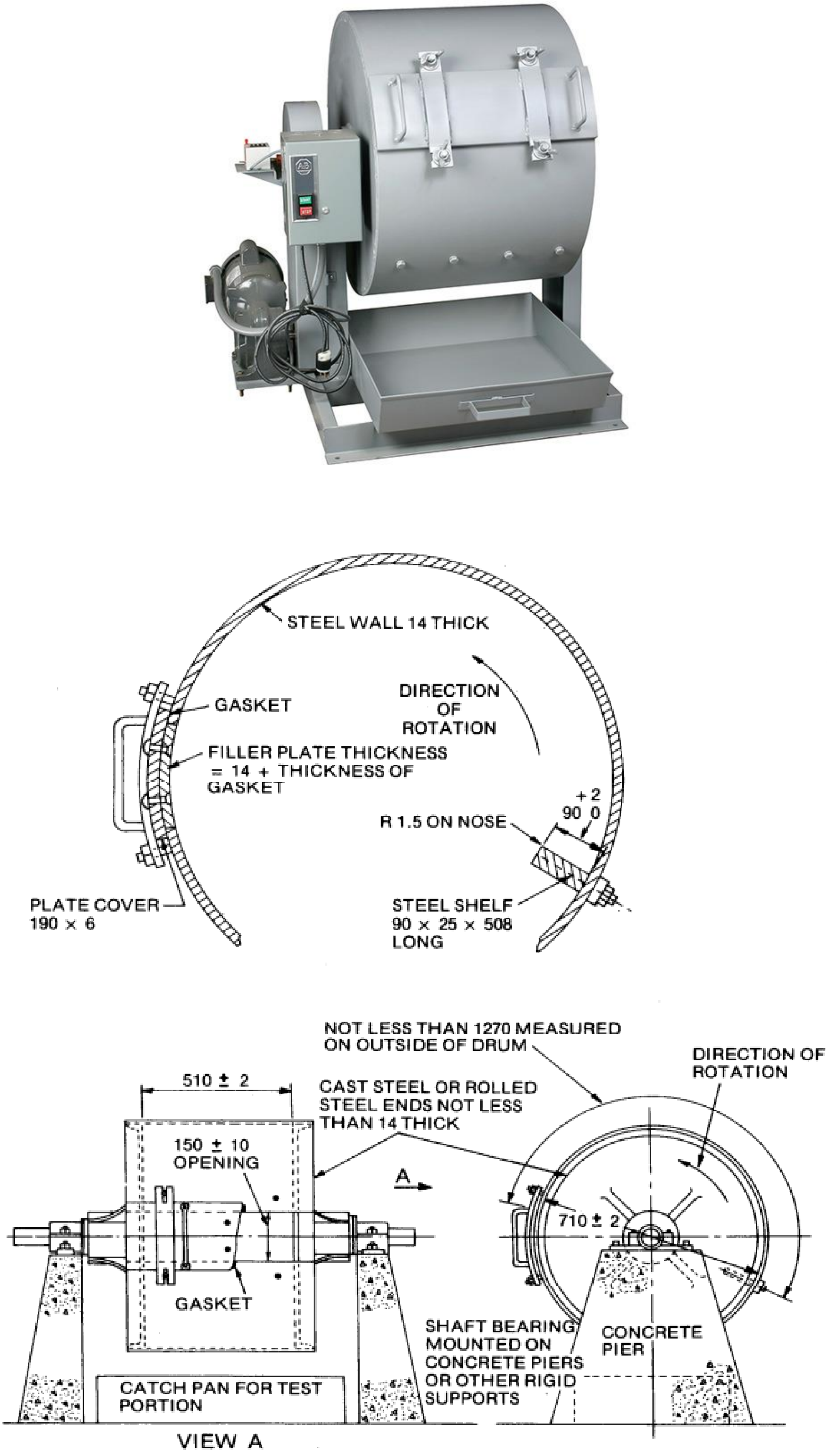


Figure 2.3.1: Apparatus

➢ Procedure:-

1. Check and record the mass of the test portion to the nearest gram.
2. Select and make up the appropriate steel ball charge and check the mass of total charge by this table:

Nominal Material Size (mm)		Mass and Grading of Test Portion (g)					
Passing	**Retained**	**A**	**B**	**C**	**D**	**E**	**F**
75.0	63.0					2500±50	
63.0	50.0					2500±50	
50.0	37.5					5000±50	5000±50
37.5	25.0	1250±25					5000±50
25.0	19.0	1250±25					
19.0	12.5	1250±25	2500±10				
12.5	9.5	1250±25	2500±10				
9.5	6.3			2500±10			
6.3	4.75			2500±10			
4.75	2.36				5000±10		
Total mass of sample		5000±10	5000±10	5000±10	5000±10	10000±100	10000±100
Number of revolutions		500	500	500	500	1000	1000
Number of balls		12	11	8	6	12	12

3. Inspect the Los Angeles abrasion-testing machine for cleanliness and brush out if necessary.
4. Place the test portion and steel ball charge in the machine, place the cover plate into position and tighten the cover plate clamp-nuts evenly and securely.
5. Set the revolution counter to 500 and allow the machine to operate continuously for 500 revolutions.
6. On completion, remove the cover plate, turn the drum until the aperture is at the bottom and then remove the test portion and charge of steel balls from the drum into the tray by hitting the drum with a rubber mallet and then cleaning the interior thoroughly with a soft brush. Take special care to avoid loss of material.
7. Remove the steel ball charge from the sample. Assemble the 300mm diameter sieves in order 75.0, 53.0, 37.5, 26.5, 19.0, 9.50, 6.75, 4.75 and 1.70mm and pan, and sieve the test portion by hand or in a mechanical sieve shaker.
   Determine the mass of the material passing the 1.70mm sieve and record. Combine all material coarser than the 1.70mm sieve and weigh and record. If the difference between the sum of the masses and the original mass of the test portion exceeds 0.5 percent of the original mass of the test portion, disregard the test and repeat completely using a fresh test portion.
8. Wash all material coarser than 1.70mm in a 300mm diameter 1.70mm sieve with water until the water remains clear.

9. Transfer the washed material to a suitable container and oven-dry at 105°C to 110°C until constant mass is achieved.
10. Cool the material for a minimum period of 1 hour, to 23 ± 2°C and re-sieve as in Procedure.

➢ **Calculations:-**

$$LAV\% = \frac{W_T - W_R}{W_T} * 100$$

Where:

W_T = Total mass of the washed and dried material before abrasion, in grams.
W_R = Mass of material retained on the 1.70mm sieve after abrasion, washing, drying and re-sieving, in grams

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Aggregate gradation type	g
Original weight of sample	g
Weight of sample retained on sieve No.12	g
Weight of sample retained on sieve No.12 after washing	g
$LAV = \frac{W_T - W_R}{W_T} * 100$	g

Remarks:____

Date of test:	Tested by:	Checked by:

Bituminous Material in Road Construction

- Mobility is a basic human need. Transportation also plays a major role in the development of the human civilization.
- Effective pavement design is one of the more important aspects of project design. The pavement is the portion of the highway that is most obvious to the motorist.
- The pavement is substantially affected by the number of heavy load repetitions applied, such as a single tandem tried and quad axial trucks, buses, tractor-trailers and equipment.
- A complete description of soil, binder and bituminous mixtures testing is provided.
- The pavement should meet the following requirements:
  1. Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil.
  2. Structurally strong to withstand all types of stresses imposed upon it.
  3. Adequate coefficient of friction to prevent skidding of vehicles.
  4. Smooth surface to provide comfort to road users even at high speed.
  5. Produce least noise from moving vehicles.
  6. Dust proof surface so that traffic safety is not impaired by reducing visibility.
  7. Impervious surface, so that sub-grade soil is well protected.
  8. Long design life with low maintenance cost.

➢ Pavement Types:-

- The pavements can be classified based on the structural performance into two, flexible pavements and rigid pavements.
- The flexible pavement, having less flexural strength, acts like a flexible sheet (e.g. bituminous road). On the contrary, in rigid pavements, wheel loads are transferred to sub-grade soil by flexural strength of the pavement and the pavement acts like a rigid plate (e.g. cement concrete roads). In addition to these, composite pavements are also available. A thin layer of flexible pavement over rigid pavement is an ideal pavement with most desirable characteristics. However, such pavements are rarely used in new construction because of high cost and complex analysis required.
- In this LAB is concerned mostly with Flexible pavement.

➢ Flexible Pavement:-

The following types of construction have been used in flexible pavement:

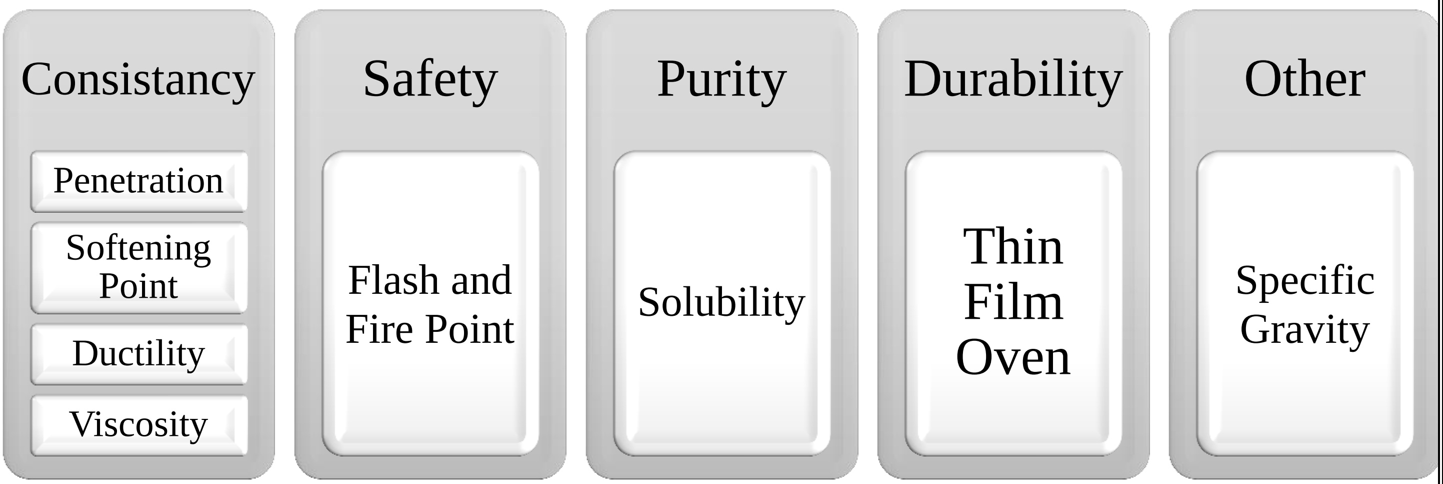
1. Conventional layered flexible pavement.
2. Full - depth asphalt concrete (AC) pavement.
3. Thin asphalt concrete (AC) pavement (membrane).
4. Surface treatments.

Layer	Definition
Seal Coat	Seal coat is a thin surface treatment used to waterproof the surface and to provide skid resistance.
Tack Coat	Tack coat is a very light application of asphalt, usually asphalt emulsion diluted with water. It provides proper bonding between two layers of binder course and must be thin, uniformly cover the entire surface, and set very fast.
Prime Coat	A primer coat is an application of low viscous cutback bitumen to an absorbent surface like granular bases on which binder layer is placed. It provides bonding between two layers. Unlike a tack coat, prime coat penetrates into the layer below, plugs the voids, and forms a watertight surface.
Surface Course	• Surface course is the layer directly in contact with traffic loads and generally contains superior quality materials, particularly bituminous materials such as hot mixed asphalt (HMA). • They are usually constructed with dense graded asphalt concrete (AC). The functions and requirements of this layer are: 1. It provides characteristics such as friction, smoothness, drainage, etc. In addition, it will prevent the entrance of excessive quantities of surface water into the underlying base, sub-base and sub-grade. 2. It must be tough to resist the distortion under traffic and provide a smooth and skid- resistant riding surface. 3. It must be waterproof to protect the entire base and sub-grade from the weakening effect of water.
Binder Course	This layer provides the bulk of the asphalt concrete structure. Its chief purpose is to distribute the load to the base course the binder course generally consists of aggregates having less asphalt and does not require quality as high as the surface course, so replacing a part of the surface course by the binder course results in more economical design
Base Course	The base course is the layer of material immediately beneath the surface of binder course and it provides additional load distribution and contributes to the sub-surface drainage. It may be composed of bituminous materials (such as rolled asphalt) with lower quality than that used in surfacing or may be composed of lean concrete, crushed stone, crushed slag, soil cement, cement-bound granular, dense macadam and other untreated or stabilized materials for low volume roadways (<2,000 vehicles per day) depending upon loading and other design considerations.
Sub-Base Course	• The sub-base course is the layer of material beneath the base course and the primary functions are to provide structural support, improve drainage and reduce the intrusion of fines from the sub-grade in the pavement structure If the base course is open graded, then the sub-base course with more fines can serve as a filler between sub-grade and the base course. A sub-base course is not always needed or used. For example, a pavement constructed over a high quality, stiff sub-grade may not need the additional features offered by a sub-base course. In such situations, the sub-base course may not be provided • The sub-base consists of granular material - gravel, crushed stone, reclaimed material or stabilized soil.
Sub-grade	The top soil or sub-grade is a layer of natural soil prepared to receive the stresses from the layers above. It is essential that at no time soil sub-grade is overstressed. It should be compacted to the desirable density, near the optimum moisture content.

SECTION 3: Physical Properties of Bitumen

Introduction

- **<u>Physical Priorities can be classified as follow:-</u>**
  1. Consistency.
  2. Safety.
  3. Purity.
  4. Durability.
  5. Other.



- **<u>Properties Required of a Road Binder:-</u>**

  The function of a bituminous mixes is to bind the aggregate particles together to enable a coherent layer to be formed capable of withstanding the action of traffic for as long as possible. To achieve this end, it requires appropriate theological, and adhesive properties and resistance to weathering. These are governed by its chemical composition and purity. The material must also meet miscellaneous requirements for its handling and storage.

  1. Rheological Properties:

     The flow properties must be such that the coating of aggregate particles during mixing can be achieved and that the mix can be compacted efficiently. They must also be such that the mix does not deform at the highest road temperature and is sufficiently flexible at low temperatures to resist fretting and cracking. Bitumen should be consistent in their theological properties so that engineers can make use of recommended application and service temperatures with confidence.

2. Adhesive Properties:

The bitumen must be able to bind stone particles together and therefore no better bond between bitumen and aggregate is essential.

3. Miscellaneous Properties:

It is sometimes advisable to determine the density of the bitumen in order to make accurate mass to volume conversion, and vice versa, for ordering and storage purposes. It is also necessary to ensure than the risk of fire during storing and handling is minimized

4. Durability:

The bitumen must be able to retain the necessary theological properties after exposure to weathering agencies during mix prepared and in service. Temperature is an important weathering agency and the highest temperature to which the bitumen will be subjected occurs during mixing. This temperature has to be sufficient to dry the aggregate and permit efficient coating by the bitumen. Therefore, it is essential that the durability of the bitumen is such that the theological and adhesive properties are not detrimentally affected al typical mixing temperatures.

5. Chemical Composition and Purity:

Bitumen is having a particle balance of chemical components achieve appropriate theological, adhesive and durability properties. It is important to establish that the proportion of components that may lead to poor performance, particularly as regards durability, are appropriate. It is also necessary on occasions to determine whether bitumen’s may have been degraded during manufacture or contaminated during storage or handling.

EXPERIMENT No.1: Penetration Test

ASTM D5 – 78

➢ Objective:-

This test is done to determine the hardness or softness of bitumen by measuring the penetration of a standard loaded needle as per IS 1203 – 1978.

➢ Theory:-

- Penetration: Distance in tenth millimeter that a standard needle penetrates vertically into a sample of the asphalt under known conditions of load time and temperature. It measures the hardness or softness of bituminous martial under a given set of condition.
- The principle is that the penetration of a bituminous material is the distance in tenths of a mm that a standard needle would penetrate vertically, into a sample of the material under standard conditions of temperature, load and time.
- Standard penetration conditions:
  1. The load is equal to 100g (surcharge weight + needle holder + needle).
  2. Temperature at 25ºC.
  3. Applied for 5second.
- But the standard penetration conditions are changing when the weather is changing, for example for cold climate:
  1. The load is equal to 200g.
  2. Temperature at 5ºC.
  3. Applied for 60second.

➢ Apparatus:

1. A penetration device with scale to measure the travel of the needle in a tenth of a millimeter.
2. Standard penetration needle.
3. Sample container.
4. Water bath.
5. Transfer dish.
6. Timing device.
7. Thermometers.

Figure 3.1.1: Penetrometer

➢ Procedure:-

1. Soften the bitumen above the softening point (between 75 and 100ºC). Stir it thoroughly to remove air bubbles and water.
2. Pour it into a container to a depth of at least 15mm in excess of the expected penetration.
3. Cool it at an atmospheric temperature of 15 to 30ºC for 11/2 hours. Then place it in a transfer dish in the water bath at 25.0 + 0.1ºC for 11/2 hrs.
4. Keep the container on the stand of the penetration apparatus.
5. Adjust the needle to make contact with the surface of the sample.
6. Adjust the dial reading to zero.
7. With the help of the timer, release the needle for exactly five seconds.
8. Record the dial reading.
9. Repeat the above procedure thrice.

➢ Penetration Grade:-

Grade	Uses
AC 20-30	Isolation the inclined surfaces
AC 40-50	1. Isolation of retaining wall & foundations. 2. Maintenance and filling the cracks in rods.
AC 60-70	Hot mix asphalt in hot climate
AC 85-100	Hot mix asphalt in moderate climate
AC 120-150	Hot mix asphalt in cold climate
AC 200-300	Preparing the Emulsion Asphalt

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Reading	Penetration (0.1 mm)
1	
2	
3	
4	
5	
6	

Type of bathe:	
Average Penetration (0.1mm):	
Penetration Grade:	

Remarks:____

____

____

Date of test:	Tested by:	Checked by:

EXPERIMENT No.2: Softening Point Test

ASTM D36 – 76

➤ Objective:-

- This test is done to determine the softening point of asphaltic bitumen and fluxed native asphalt, road tar, coal tar pitch and blown type bitumen as per IS: 1205 – 1978.
- The principle behind this test is that softening point is the temperature at which the substance attains a particular degree of softening under specified condition of the test.

➤ Theory:-

- Bituminous materials do not have a definite melting point, as many pure compounds have, but instead the transition from solid to liquid is slow and covers rather a wide range of temperature. Generally, the higher the softening point, the less the temperature susceptibility. The most commonly used softening point of asphalt and tar pitches (ring and ball apparatus). This test has endured since its adoption by ASTM in 1919 and has become a valuable consistency test for control in refining operations, particularly in the production of air blown asphalts. It is also a means of identification for determining methods of production and source of crudes.
- In the softening – point test, heat is applied in such a manner that the temperature of the water is raised from 5±1ºC (41ºF) at a rate of 5ºC 9ºF/min. The temperature is read from the thermometer at the instant the asphalt sample touches the bottom of the reference plate. If the difference in value obtained from the two samples runs at one time exceeds 2ºF (1ºC), then the test must be repeated. The mean of the two determinations is reported to the nearest 0.5oF (0.2ºC) and is called the softening point. Duplicate softening points by the same operator should not be considered suspect unless they differ by more than 3ºF (1.7ºC). The softening point value has particular significance for materials that are to be used as thick films, such as joints and crack fillers and roofing cements. A high softening point ensures that they will not flow in service.
- The importance of knowing softening point:
  1. Put the suitable AC in the right place.
  2. Knowing the best temperature for storage the Asphalt cement

➤ Apparatus:-

1. A brass shoulder ring.
2. A steel ball 9.53mm in diameter 3.5g in weight.
3. A guide for centering the ball.
4. A ring holder for supporting the brass ring.
5. Thermometers.
6. A water bath (800ml beaker is adequate).
7. A brass pouring plate.

Figure 3.2.1: Ring & ball apparatus

➢ Significance of Softening Point test:-

1. The softening point is not a melting point; bituminous binders do not melt, but instead gradually change from semi-solid to liquids on the application of heat. The method of testing is entirely arbitrary and must be exactly carried out if the results are to be of value. As the practical significance of the test is limited, the specifications of many binders for particular purposes are now often written without softening point requirements.
2. The test is also useful for determining the temperature susceptibilities of bitumen's which are to be used in thick films, such as in crack fillers. When two bitumen's have the same penetration value, the one with the higher softening point is normally less susceptible to temperature changes.

➢ Procedure:-

A. Preparation of Sample:-

1. The sample should be just sufficient to fill the ring. A knife should cut off the excess sample.
2. Heat the material 110ºC above the expected softening point. Stir it to remove air bubbles and water, and filter it through IS Sieve 50, if necessary.
3. Heat the rings and apply glycerin. Fill the material in it and cool it for 30 minutes.
4. Remove excess material with the help of a warmed, sharp knife.

B. Materials of Softening Point below 80ºC:-

1. Assemble the apparatus with the rings, thermometer and ball guides in position.
2. Fill the beaker with distilled water at a temperature 5.0 ± 0.5ºC per minute.
3. With the help of a stirrer, stir the liquid and apply heat to the beaker at a temperature of 5.0 ± 0.5ºC per minute.
4. Apply heat until the material softens and allow the ball to pass through the ring.
5. Record the temperature at which the ball touches the bottom, which is nothing but the softening point of that material, then take the average of two record results.

C. Materials of Softening Point above 80ºC:-

The procedure is the same as described above. The only difference is that instead of water bath, glycerin bath is used and the starting temperature of the test is 32ºC.

By Order of	
Order Number	
Project / Site	
Lab.	

	Temperature
Ball1-Asphalt sample touches the bottom	
Ball2-Asphalt sample touches the bottom	

Type of bathe:	
Average Temperature (softening Point):	

Remarks:____

____

____

Date of test:	Tested by:	Checked by:

EXPERIMENT No.3: Specific Gravity Test

ASTM Designation D70

➢ Objective:-

To determine the specific gravity of asphalt cement.

➢ Theory:-

Specific gravity: Ratio of a given weight of asphalt cement to at 25ºC to that of an equal volume of water at the same temperature.

➢ Apparatus:-

Glass Pycnometer, consisting of a cylindrical or conical vessel ground to receive an accurately fitting glass stopper.
Approximately 22 to 26mm in diameter.

Figure 3.3.1: Glass Pycnometer

➢ Procedure:-

1. Through clean, dry and weight the Pycnometer and stopper.
2. Fill the Pycnometer with freshly boiled distilled water, firmly insert the stopper and completely immerse the Pycnometer for 30 minutes in a bath of distilled water, maintained at 25ºC.
3. Carefully remove the Pycnometer from the constant temperature bath. Wipe the top of the stopper so that it is dry and the meniscus of water in the bore is flashy with the top of the stopper. Wipe all moisture from the outer surface of the Pycnometer with a clean cloth.
4. Immediately weight the Pycnometer and water. Dry and slightly warm the Pycnometer.
5. Pour the Pycnometer about half full with previously heated asphalt. Take care that no asphalt touches the slides of the Pycnometer above the final level of the asphalt and that there are no air bubbles.
6. Cool the Pycnometer and asphalt to the room temperature and weight the stopper.
7. Fill the Pycnometer with distilled water and firmly insert the stopper. Completely immerse the Pycnometer again in the 25ºC (77ºF) constant temperature bath for 30 minutes.
8. Repeat step No.3 after removal of the Pycnometer from the constant temperature bath.
9. Weight the Pycnometer and content immediately.
10. All weights should be to the nearest thousands of grams.
11. Carefully clean the Pycnometer after the test by placing it upside down in the oven it less than 100ºC (212ºF) until most of the asphalt has flowed out into some crucible or other disk. Swab the inside with a piece of soft cloth, cool, rise clean with a suitable solvent, and wipe clean

By Order of	
Order Number	
Project / Site	
Lab.	

Sample type:	
Temperature (ºC):	

A=	
B=	
C=	
D=	
$S.G = \frac{C - A}{B - A - D + C}$	

Remarks:____

____

____

Date of test:	Tested by:	Checked by:

EXPERIMENT No.4: Ductility Test

AASHO T51
ASTM D113

➢ Objective:-

- This test is done to:
  1. To measure the ductility of the distillation residue of cutback bitumen, blown type bitumen and other bituminous products as per IS: 1208 – 1978.
  2. To determine the suitability of bitumen for its use in road construction
- The test is also believed to measure the adhesiveness and elasticity of the bitumen.

➢ Theory:-

- Ductility: The distance which the bitumen (AC) elongate before the thread of material breaks
- The principle is: The ductility of a bituminous material is measured by the distance in cm to which it will elongate before breaking when a standard briquette specimen of the material is pulled apart at a specified speed and a specified temperature.
- Ductility is one of the important characteristics of asphalt cements. The presence or absence of ductility however, is usually of more significance than the actual degree of ductility. Asphalt cement possessing ductility is normally more adhesive than asphalt cements lacking this characteristic. However, asphalt cements having an exceedingly high degree of ductility are usually more temperature susceptible.

➢ Apparatus:-

1. A mold that will form a briqu8tte of approximately 75mm overall length and a minimum cross sectional width of 10mm.
2. A water bath that can be adjusted to the test temperature and has a volume in excess of ten liters.
3. A testing machine that is capable of pulling the briquette apart, while it is immersed in water, at the specified rate.
4. A thermometer.

Figure 3.4.1: Ductilometer

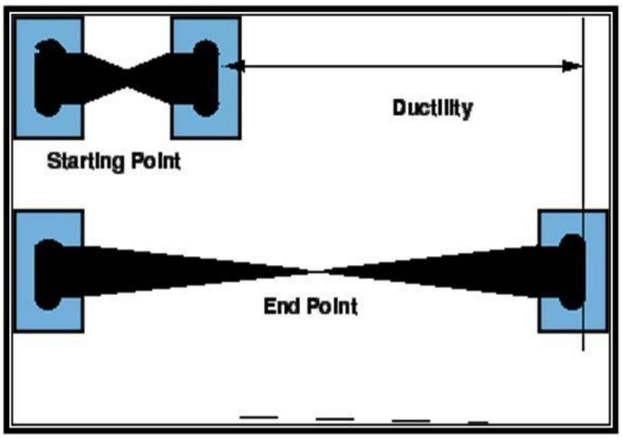


Figure 3.4.2: Sample

➢ **Significance of Ductility test:-**

- This test method provides one measure of tensile properties of bituminous materials. The test is actually a measure of the internal cohesion of a bitumen. The binder material that does not possess sufficient ductility would crack and thus provide pervious pavement surface.
- Since bitumen possessing high ductility normally adhere well to aggregates, the test is best used as a measure of whether or not ductility is present in the material, rather than as a means of determining the exact degree of ductility available. Thus, a bitumen with 100-cm ductility might will be considered a better road-surfacing constituent than one with 10-cm ductility, but a binder with 80-cm ductility is not necessarily better than a 60cm one.
- Bitumen possessing high ductility are also usually highly susceptible to temperature changes, while the lower ones are not. The lack of ductility does not necessarily indicate poor quality; indeed, bitumen of low susceptibility and low ductility are highly desirable as crack fillers in roadways.

➢ **Procedure:-**

1. Heat the sample carefully and when it has become fluid strain it through a No. 50 (300 micron) sieve (why?).
2. Stir the sample well and assemble the mold on six level brass plate, having treated the surfaces to prevent the bitumen sticking to them.
3. Pour the material into the mold in a thin stream back and forth from end to and until the mold is more than level full.
4. Cool the material to room temperature for approximately 30 minutes, and then place it in the water bath at 25ºC for another 30 minutes.
5. Cut off the excess bitumen in the mold with a hot knife, leveling the surface.
6. Place the specimen in the mold complete with brass plate in the water bath, and maintain the temperature at 25ºC for 85 – 95 minutes.
7. Remove the sample from the plate and detach the side pieces of the mold.
8. Attach each of the mold to the pins in the testing machine and pull the two ends apart at the specified rate (50mm per minute). The water in the tank of the testing machine should be maintained at 25ºC for the duration of the test. There should be 2.5cm of water both above and below the sample. If the thread sags, the specific gravity of the water should be increased by addition of salt such that the required depth of water below the thread is maintained.
9. The bitumen are pulled into a Thread, and the distance in millimeters at which any rupture of the thread occurs is recorded.
10. The average of the three tests is normally reported as the ductility in the sample. If no rupture occurs at the maximum extension (1000mm) the ductility should be reported as (+ 1000mm).

By Order of	
Order Number	
Project / Site	
Lab.	

Sample type	
Temperature (ºC)	
Ductility	

Remarks:____

____

____

Date of test:	Tested by:	Checked by:

EXPERIMENT No.5: Flash & Fire Point Test

ASTM D92

➢ Objective:-

This test is done to determine the flash point and the fire point of asphaltic bitumen and fluxed native asphalt, cutback bitumen and blown type bitumen as per IS: 1209 – 1978.

➢ Theory:-

The principle behind this test is given below:

- Flash Point – The flash point of a material is the lowest temperature at which the application of the test flame causes the vapors from the material to momentarily catch fire in the form of a flash under specified conditions of the test.
- Fire Point – The fire point is the lowest temperature at which the application of the test flame causes the material to ignite and burn at least for five seconds under specified conditions of the test.

➢ Apparatus:-

1. Cleveland open cup apparatus – this consists of a test cup, heating plate, test flame applicator, heater and supports.
2. A shield to protect the apparatus from drafts.
3. A thermometer with a range of 6 to 400ºC (ASTM 11C).

Figure 3.5.1: Cleveland open cup apparatus

➢ Procedure:-

A. Flash Point:-

1. Soften the AC bitumen at 110ºC above the expected softening point. Stir it thoroughly to remove air bubbles and water.
2. Fill the cup with the material to be tested up to the filling mark (AC or cutback asphalt). Place it in the bath. Fix the open clip. Insert the thermometer of high or low range as per the requirement and the stirrer, to stir it.
3. Light the test flame, adjust it. Supply heat at such a rate that the temperature increase, recorded by the thermometer is neither less than 5ºC nor more than 6ºC per minute.
4. Open flashpoint is taken as that temperature when a flash first appears at any point on the surface of the material in the cup. Take care that the bluish halo that sometimes surrounds the test flame is not confused with the true flash. Discontinue the stirring during the application of the test flame.
5. Flash point should be taken as the temperature read on the thermometer at the time the flash occurs.

B. Fire Point:-

1. After flash point, heating should be continued at such a rate that the increase in temperature recorded by the thermometer is neither less than 5ºC nor more than 6ºC per minute.
2. The test flame should be lighted and adjusted so that it is about the size of a bead 4mm in diameter.

➢ Classifications:-

Type	Rate of temperature rise (°C/min)
AC (245-235)°C	(14-17)°C/min when it reaches 56°C below expected the flash point Decrease the heat to (5-6)°C/min until the end of experiment
RC< 40°C	(5-6)°C/min
MC (40-110) °C	(5-6)°C/min
SC > 110°C	(5-6)°C/min

➢ Calculations:-

The temperature at which the flame applications cause a bright flash was 21°C, but as standardized in ASTM the flash point should be measured at sea level, so this temperature needs calibration using the following equation:

Corrected flash and fire point $= C + 0.03 * (760 - P)$

Where:

C: the recorded temperature.

P: the local atmosphere pressure.

By Order of	
Order Number	
Project / Site	
Lab.	

Flash Point temperature (ºC)	
Fire Point temperature (ºC)	

Remarks:____
____
____

Date of test:	Tested by:	Checked by:

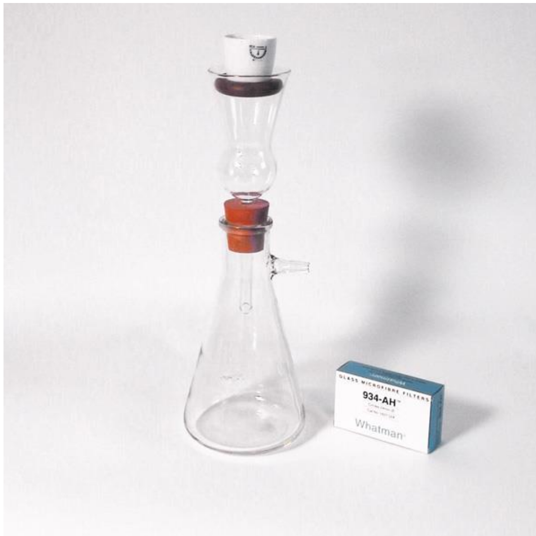
EXPERIMENT No.6: Solubility Test

ASTM D5546

➢ Objective:-

For the determination of the degree of the solubility of asphalt cement in trichloroethylene.

➢ Apparatus:-



➢ Theory:-

- Solubility: the quality or property of being soluble; relative capability of being dissolved
- Refined asphalt is almost pure bitumen and is usually more than 99% soluble in trichloroethylene.
- The degree of solubility is a process of dissolving about two grams of asphalt in 100ml of solvent and filtering the resultant solution through a glass micro filter pad, placed in a porcelain crucible. The amount of material retained on the filter pad is determined and expressed as a percentage of the original sample.
- The solubility of this test must be more than 99% if this is not happening, then we cannot use the asphalt in hot mixed asphalt.

➢ Procedure:-

1. Place the crucible plus one thinness of the glass fiber in an oven at 110°C for 15 minutes and allow cooling in a desiccator. Wight to the nearest 0.1g and store in the desiccator until it is ready to use.
2. Place approximately two grams of asphalt cement into a tarred Erlenmeyer flask or a 150ml. Beaker and weight to nearest mg. Then add 100ml of trichloroethylene to the beaker while continuously agitating until all of asphalt cement is uniformly dispersed in the solution. Cover the container and wait for 15 minutes.
3. Place the previously prepared and weighed crucible into the filtering flask. Wet the glass filter pad with a small amount of trichloroethylene.

➢ Calculations:-

$$\%\, Soluble = \frac{Original\ weight - Insoluble\ weight}{Original\ weight} * 100\%$$

EXPERIMENT No.7: Viscosity Test

➢ Objective:-

- The test aims to determine the viscosity of bitumen by:
  1. The Sybolt-Furol viscosity test
  2. The kinematic capillary viscosity test
- The purpose of the viscosity test is to determine the flow characteristics of asphalt in the range of temperature used during application.

➢ Theory:-

- Viscosity is defined as the ratio between the applied shear stress and induced shear rate of a fluid.
- The basis viscosity test is the measure of time required for a constant volume of material to flow under rigidly controlled test condition.
- The purpose of the viscosity test is to determine the flow characteristics of asphalt in the range of temperature used during application. Either the kinematic viscosity test or the Sybolt-Furol viscosity test, measures the viscosity or consistency of asphalt cement. In the Sybolt-Furol test, a specified volume of asphalt cement is placed in a standard tube closed with a cork stopper. Since the temperature of viscosity determination for the asphalt cement is often above 212°F (100°C), oil is used as a medium for the constant temperature bath of the Viscometer. After the asphalt reaches a specified temperature, the stopper is withdrawn and the time in seconds is measured in the flow of 60ml. of the material through Furol orifice. As the viscosity of the material increases, it takes a longer time to flow through the orifice and thus fill the 60ml. beaker.
- Kinematic viscosity of asphalt cement at higher temperature such as 275°F (135°C) is usually measured with gravity flow capillary Viscometers. For this test, and because of the wide range of asphalts, several calibrated Viscometers differing in the size of the capillary are necessary. The basis of this test is the measure of time required for the constant volume of material to flow under rigidly controlled test conditions, such as temperature and the head of flowing liquid. Using the measured time in seconds and the Viscometer calibration constant, it is possible to compute the viscosity of the material in the fundamental units, stokes and centistokes.

7.1: Saybolt-Furol Viscosity Test

ASTM DBB

➢ Theory:-

The type of Saybolt Viscosity:

1- Furol viscosity.
2- Universal viscosity.

	Diameter for Orifice	Calibration Temperature	Tested Material	Viscosity
Furol-Saybolt Viscometer	3.15mm	50°C	Heavy Oil Residual material	0.1 SUS
Universal Viscometer	1.75mm	37.5°C	Light Oil Distilled material	10 SFS

➢ Apparatus:-

1. Saybolt Viscometer with furol orifice and hath.
2. Withdrawal tube.
3. Filter funnel.
4. Receiving flask.
5. Viscosity Thermometer.
6. Timer.
7. Thermometer support.

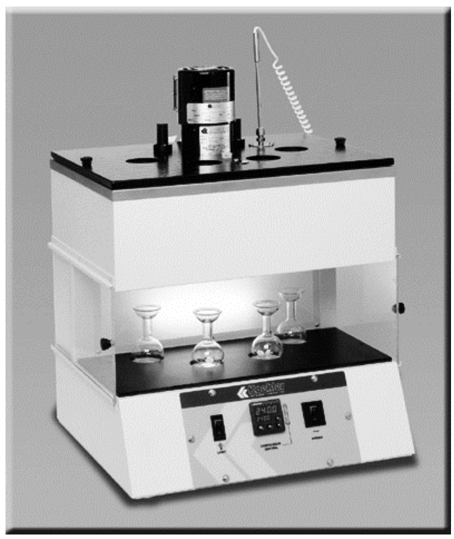


Figure 3.7.1.1: Saybolt viscometer with furol orifice and hath

➢ Procedure:-

1. Set up the apparatus in a draft free area. The room temperature should be kept between 68^{o}F and 86^{o}F and this temperature should be noted.
2. Fill the bath at least 6mm above the overflow rim of the Viscometer.
3. Calibrate the Saybolt–Furol Viscometer at 122°F using a viscosity standard with a minimum efflux time of 90 seconds.
4. If the efflux time differs from the standard by more than 0.2 percent calculate the correction factor from the equation:

$$F = \frac{V}{t}$$

Where:

V = Certified Saybolt Furol viscosity of the standard.

t = Efflux time at 122^{o}F in seconds.

5. Insert a tight fitting cork stopper with a cord attached into the air chamber at the bottom of the Viscometer.
6. Filter a sample through a 100-mesh screen into the Viscometer until the level is above the overflow rim.
7. Stir the sample with a thermometer, equipped with a thermometer support, in a circular motion at (30–50) R.P.M in a horizontal plane until the temperature remains constant.
8. Remove the thermometer and place the tip of the withdrawal tube at a point in the gallery. Then remove the oil from the gallery unit its level is below the overflow rim using suction on the tube.
9. Position the receiving flask where the stream of oil just strike the neck of the flask. The graduation mark on the flask should be between 100 and 130mm from the bottom of the Viscometer tube.
10. At the same time pull the cork from the Viscometer and start the timer. Stop the timer the moment the bottom of the manicure reaches the graduation mark. Record the efflux time in seconds.

➢ Classifications:-

The classifications of Asphalt cement.

Type	Range	Poise
AC 2.5	250 ± 50	200-300
AC 5.0	500 ± 100	400-600
AC 10	1000 ± 200	800-1200
AC 20	2000 ± 400	1600-2400
AC 40	4000 ± 800	3200-4800

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Efflux time (second)			
Saybolt – Furol viscosity (seconds)			
Kinematic viscosity			
Bitumen Grade			

Remarks:____

Date of test:	Tested by:	Checked by:

7.2: Kinematic Viscosity Test

ASTM DBB

➢ Apparatus:-

1. Zeitfuchs cross – arm viscometer.
2. Thermometers having a range from 137.5 to 142.5°F (58.5 to 61.5°C) and 272.5 to 277.5°F (133.5 to 136.5°C).
3. Water bath.
4. Timer.

Figure 3.7.2.1: Zeitfuchs cross – arm viscometer

➢ Procedure:-

1. Allow sealed samples, as received, to reach room temperature.
2. Open the sample container and mix the sample thoroughly by stirring for 30 seconds, taking care to avoid the entrapment of air. If the sample is too viscous for such stirring, place the sample in the tightly sealed container in a bath or oven maintained at 145 ± 5°F (63 ± 3°C) until it becomes sufficiently liquid for stirring.
3. Place the Viscometer, with axis vertical, in the water hath which has already been brought to the required temperature (140°F or 257°F) (60°C or 135°C).
4. Pour the sample to be tested into the large tube, being careful not to wet the sidewalls, until it reaches a point about 5 to 6mm from the top of the siphon positioned beneath the horizontal tube.
5. Leave the set for about 20 – 30 minutes.
6. Apply light suction to the small tube so that the sample fills the siphon. Discontinue suction when the sample has reached a distance of about 30mm below the horizontal tube.
7. Measure the time in seconds and tenth of a second for the sample to run between the graduation marks at each end of the small bulb at the bottom of the capillary tube.
8. Multiply this time by the constant "C" of the Viscometer to get the viscosity in centistokes (mm^2/Sec).

➢ Classifications:-

The classifications at 60°C	
Cutback Type	Use
MC (30-60)	-
RC, MC, SC (70-140)	Prime coat
RC, MC, SC (250-500)	Tack coat
RC, MC, SC (800-1600)	Seal coat
RC, MC, SC (3000-6000)	Cold mix asphalt

The classifications at 135°C
AC Type (Cst)
AC 80
AC 110
AC 150
AC 210
AC 300

By Order of	
Order Number	
Project / Site	
Lab.	

Time (seconds) for the sample to run between graduation marks	
Viscometer constant (c)	
Viscosity in centistokes	

Remarks:____

____

____

Date of test:	Tested by:	Checked by:

EXPERIMENT No.8: Loss on Heat Test

➢ Objective:-

To study the effect of heat on the physical properties on asphalt.

➢ Procedure:-

Put a known weight sample in the oven at temperature 165°C you can put five or four samples, then this oven will rotate (5-6) R.P.M for 5 hours the Volatility martial will evaporate.

➢ Calculations:-

$$\% \, Loss\ on\ Heat = \frac{Initial\ Weight - final\ Weight}{Initial\ Weight} * 100\%$$

➢ Results:-

The effect of continuous heating for the physical proprieties of bitumen as shown in table.

Physical Proprieties	Effect
Penetration	Decrease
Softening Point	Increase
Specific Gravity	Till same
Ductility	Decrease
Flash & Fire Point	Increase
Viscosity	Increase
Weight	Decrease
Density	Increase

SECTION 4: Mix Design

Introduction

- Asphaltic concrete is a particular form of rolled asphalt that has found extensive use in the United States for the surfacing of major flexible highways. In the United Kingdom, however rolled asphalt was the surfacing material used for heavily trafficked routes. Asphaltic concrete differs from hot rolled asphalt (as specified in BS 594) by having a continuous aggregate grading whereas rolled asphalt has a gap graded aggregate.
- The blending of aggregates with asphalt should produce asphalt mixes with the following desirable properties:
  1. Workability to facilitate easy placement of bituminous materials without experiencing segregation;
  2. Sufficient stability (resistance to permanent deformation) so that under traffic loads the pavement without distortion and displacement;
  3. Durability by having sufficient asphalt to ensure an adequate film thickness around the aggregate particles.
  4. Sufficient air voids
  5. Skid resistant
  6. Low noise and good drainage properties
- In asphalt mix design, high durability is usually obtained at the expense of low stability. Hence, a balance has to be stricken between the durability and stability requirements.
- The main objective of an asphalt concrete mix design method is to determine the proper proportions of aggregates and asphalt in order to produce an economical mix that meets the performance requirements of the pavement.

EXPERIMENT No.1: Marshall Test

ASTM Designation D 1559

➢ Objective:-

To determine the stability and resistance to plastic flow of bituminous mixtures using the Marshall apparatus.

➢ Theory:-

- The design of asphalt paving mixes is largely a matter of selecting and proportioning materials to obtain the desired properties in the finished construction. The overall objective for the design of asphalt paving mixes is to determine an economical blend and gradation of aggregates (within the limits of the project specifications) and asphalt that yields a mix having:
  1. Sufficient asphalt to ensure a durable pavement.
  2. Sufficient mix stability to satisfy the demands of traffic without distortion or displacement.
  3. Sufficient voids in the total compacted mix allow for a slight amount of additional compaction under traffic loading without flushing, bleeding and loss of stability, yet low enough to keep out harmful air and moisture.
  4. Sufficient workability to permit efficient placement of the mix without segregation.
- The Marshall method of mix design has been widely used with satisfactory results. Developed by the corps of engineers (USA) during World War II, the test is relatively a simple one and uses simple equipment's. In the test, a sample specimen 4-in. in diameter by 2.5-in. in high is prepared by compacting in a mold with a compacting hammer that weighs 10Ib and has a free fall of 18-in. Depending upon the design traffic, either 35* 50 or 75blows.
- After overnight curing, the density and voids are determined and the specimen is heated to 140°F (60°C) from the marshal stability and flow tests. The specimen is then placed in a cylindrical shaped split breaking head and is loaded at a rate of 2-in /min. The maximum load registered during the test in Newton's or pound is designated as the marshal stability of the specimen. The amount of movement, or strain, occurring between no load and the maximum load, in units of 0.01-in., is the flow value of the specimen. The specimens are prepared in a range of asphalt contents. Figure 33 shows typical test results plotted in a routine form. Measurements made on the specimens before testing for stability are used for the unit – weigh and void Calculations. The stability value obtained for each individual specimen is modified if the specimen thickness is greater or less than the normal height of 2.5-in. (Table 1).

- Table (2) shows asphalt institute design criteria applies to curves to get a suitable asphalt percentage. A common procedure of doing this is to take the most desirable asphalt percentages for stability, unit weight, and percentage voids and then average them. This average value should satisfy the required criteria and if it does not, it should be adjusted until a value is found that will satisfy all criteria. If no such asphalt percent exists, there a different aggregate gradation must be selected.

Table (1): Stability Correction			
Volume of Specimen, cm^3	Approximate Thickness of Specimen		Correlation Ratio
	In.	mm	
200 to 213	1	25.4	5.56
214 to 225	1 1/16	27.0	5.00
226 to 237	1 1/8	28.6	4.55
238 to 250	1 3/16	30.2	4.17
251 to 264	1 1/4	31.8	3.85
265 to 276	1 5/16	33.3	3.57
277 to 289	1 3/8	34.9	3.33
290 to 301	1 7/16	36.5	3.03
302 to 316	1 1/2	38.1	2.78
317 to 328	1 9/16	39.7	2.50
329 to 340	1 5/8	41.3	2.27
341 to 353	1 11/16	42.9	2.08
354 to 367	1 3/4	44.4	1.92
368 to 379	1 13/16	46.0	1.79
380 to 392	1 7/8	47.6	1.67
393 to 405	1 15/16	49.2	1.56
406 to 420	2	50.8	1.47
421 to 431	2 1/16	52.4	1.39
432 to 443	2 1/8	54.0	1.32
444 to 456	2 3/16	55.6	1.25
457 to 482	2 1/4	57.2	1.19
471 to 482	2 5/16	58.7	1.14
483 to 482	2 3/8	60.3	1.09
496 to 508	2 7/16	61.9	1.04
509 to 522	2 1/2	63.5	1.00
523 to 535	2 9/16	64.0	0.96
536 to 546	2 5/8	65.1	0.93
547 to 559	2 11/16	66.7	0.89
560 to 559	2 3/4	68.3	0.86
574 to 585	2 13/16	71.4	0.83
586 to 598	2 7/8	73.0	0.81
599 to 610	2 15/16	74.6	0.78
611 to 625	3	76.2	0.76

Table (2): Marshall Design Criteria						
Traffic category No. of compaction blows each end of specimen	Heavy 75 blows		Medium 50 blows		Light 35 blows	
Test property	Min	Max	Min	Max	Min	Max
Stability all mixtures	750		500		350	
Flow, all mixtures	8	16	8	18	8	20
% Air voids						
Surfacing of leveling	3	5	3	5	3	5
Sand or stone sheet	3	5	3	5	3	5
Sand asphalt	5	8	5	8	5	8
Binder or base	3	8	3	8	3	8

➢ Significance of Marshall test:-

Marshall Stability measures the maximum load sustained by the bituminous material at a loading rate of 50.8mm/minute. Marshall Stability is related to the resistance of bituminous materials to distortion, displacement, rutting and shearing stresses. The stability is derived mainly from internal friction and cohesion. Cohesion is the binding force of binder material while internal friction is the interlocking and frictional resistance of aggregates. As bituminous pavement is subjected to severe traffic loads from time to time, it is necessary to adopt bituminous material with good stability and flow.

➢ Apparatus:-

1. Specimen mold assembly. The cylindrical mold are 101mm. In diameter and 76.2mm in height.
2. Specimen extractor.
3. Compaction hammer weighing 4.54kg and having a free fall of 457mm.
4. Compaction pedestal.
5. Specimen mold holder.
6. Breaking head.
7. Loading jack.
8. Ring dynamometer assembly.
9. Flow meter.
10. Oven and /or hot plate.
11. Mixing apparatus
12. Water bath.
13. Air bath (for cutback asphalt mixes only).
14. Containers, thermometers, balance, mixing tools, spoons, heat proof gloves etc.

Figure 4.1.1: Compaction hummer

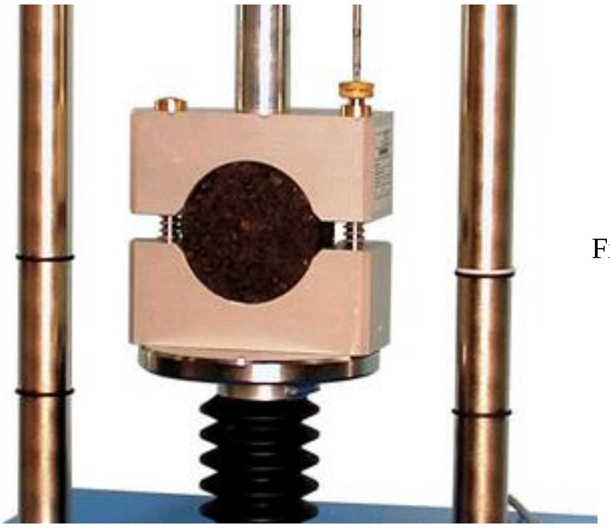


Figure 4.1.2: Breaking head

Figure 4.1.3: Marshall Apparatus

➢ **Procedure:-**

1. Prepare aggregates to a particular grading specification. Dry the aggregates to constant weight at 105°C.
2. Determine the mixing temperature from the charts for the particular grade of bitumen being used.
3. Weigh into the pan an amount of the prepared aggregate (about 1200g) that will produce a specimen having a height of about 63.5mm.
4. Heat the aggregate to the specified mixing temperature.

5. Place the heated aggregates into the heated mixing bowl and dry mix them thoroughly.
6. Form a crater in the middle of the aggregate and pour in the bitumen that has been heated to the correct temperature.
7. Mix the bitumen with the aggregates thoroughly and quickly so that all the aggregate particles are coated.
8. Place a filter paper on top of the mold base – plate.
9. Place the mixture into the compaction mold having previously heated all the apparatus – mold, hammer etc. to the required temperature.
10. Spread the mixture completely in the mold with a heated trowel or knife, 15 times around the perimeter and ten times in the center.
11. Remove the collar and smooth the surface of the mix with a trowel to a slightly rounded shape. The temperature of the mix should be checked to confirm it is at the specified temperature.
12. Replace the collar, place the mold assembly on the pedestal and apply 50 blows (or any other specified number of blows) of the 4.54kg hammer, falling through 457mm.
13. Remove the base plate and collar and reverse and re-assemble the mold, and then apply the same number of blows to the reverse side of the sample.
14. Extrude the sample from the mold and allow it to cool before removing it from the mold.
15. Place the specimen on a flat surface and allow it to stand overnight at room temperature.
16. Weigh and measure the sample. The height of the sample should be 63.5mm ± 1.27mm.
17. Now carry out a bulk specific gravity determination on the sample. The test described in ASTM D1188-71.
18. Weigh the sample in air after it has stood at room temperature for at least 1 hour. This weight is A.
19. Coat the briquette completely with paraffin was sealing all surface voids in addition, allow it to cool for 30 minutes. Then weigh the briquette, this weight is D.
20. Weigh the sample in the water bath at 25°C. This weight is E.
21. Immerse the sample in a water bath at 60°C for 30 – 40 minutes.
22. Heat the testing head of the Marshall machine to a temperature of between 21 and 37.8^{o}C.
23. Place the sample, having dried the surface, in the testing head and zero the gauges for stability and flow.
24. Apply the load at a rate of 51mm per minute until failure i.e. maximum land reading. This load at failure is recorded as the Marshall Stability value for the specimen.
25. Take the value of the deformation or flow of the sample at failure. The entire flow – stability test should be completed within 30 seconds.
26. Having completed the stability and flow bests for the series of samples it is now necessary to make a density and void analysis of the specimens.

➢ Calculations:-

Prepare separate graphical plots for each of the following:

1. Asphalt binder content versus density (unit weight).
2. Asphalt binder content versus corrected Marshall Stability.
3. Asphalt binder content versus Marshall Flow.
4. Asphalt binder content versus percentage of air voids in the total mix.
5. Asphalt binder content versus percentage of voids filled with asphalt.
6. Asphalt binder content versus percentage of voids in mineral aggregate with asphalt.

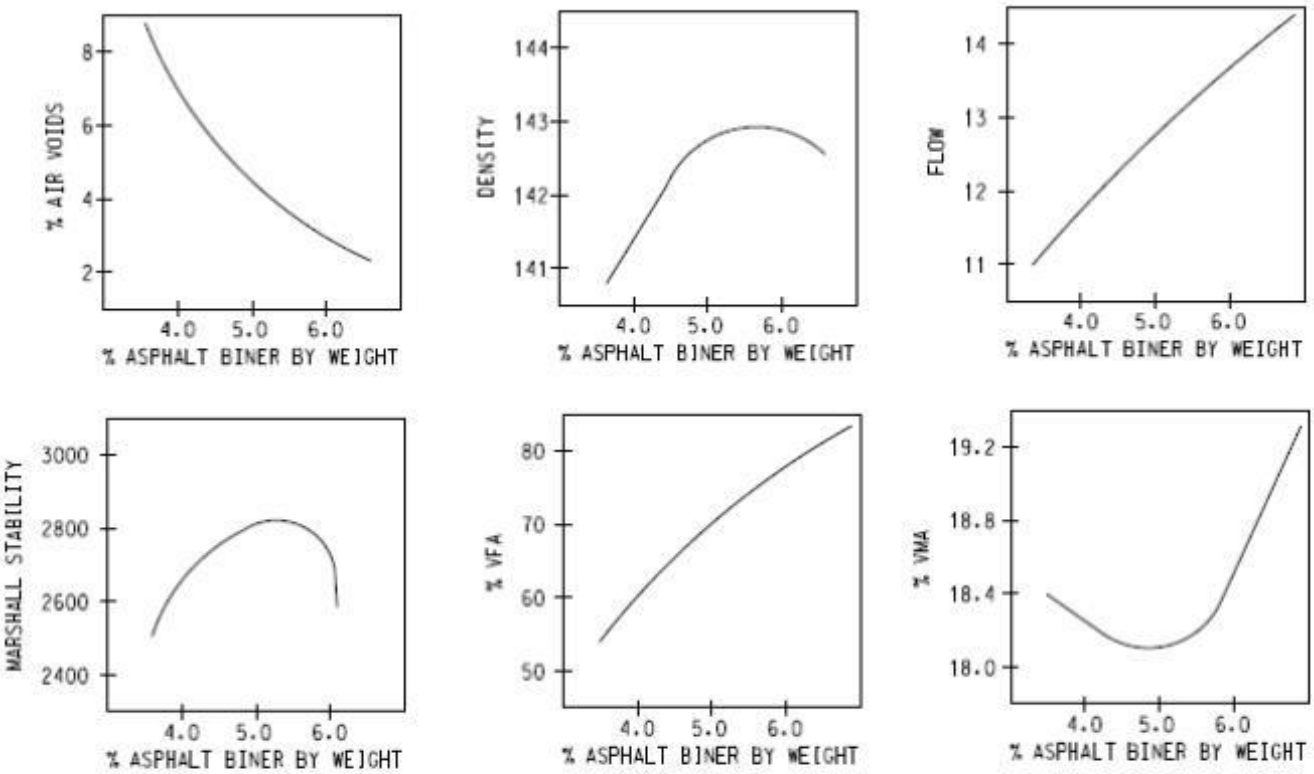


Figure 4.1.4: Standard graphs

➢ Sample of Calculations:-

For $PHA\% = 6\%$

$$AC\% = \frac{PHA}{PHA + 100} * 100\% = \frac{6}{6 + 100} * 100\% = 5.66\%$$

$Height = 65.1mm$

$Wight\ in\ Air = 1165gm$

$Wight\ in\ Water = 638.6gm$

$SSD = 1170$

THEN:

$$Total\ Volume = SSD - Weight\ in\ Water = 1170 - 638.6 = 531.4cm^3$$

$$Bituman\ Volume = \frac{AC\% * Weight\ in\ Air}{100} = \frac{5.66 * 1165}{100} = 65.94cm^3$$

$$Aggregate\ Volume = \frac{(1 - AC\%) * Weight\ in\ Air}{Specific\ Gravity} = \frac{(1 - 0.04306) * 1116}{2.5} = 439.6cm^3$$

$$Density = \frac{Weight\ in\ Air}{Total\ Volume} = \frac{1165}{531.4} = 2.19g/cm^3$$

$$Air\ Voids\% = \frac{Total\ Volume - Bitumen\ Volume - Aggregate\ Volume}{Total\ Volume} * 100\%$$
$$= \frac{531.4 - 65.94 - 439.6}{531.4} * 100\% = 4.87\%$$

$$VMA\% = \frac{Total\ Volume - Aggregate\ Volume}{Total\ Volume} * 100\% = \frac{531.4 - 439.6}{531.4} * 100\%$$
$$= 17.275\%$$

$$VFA\% = \frac{VMA\% - Air\ Voids\%}{VMA\%} = \frac{17.275 - 4.87}{17.275} = 71.81\%$$

$$Flow = 4mm * 100/25.4 = 15.75\ \frac{1}{100} in$$

$$Stability = 6kN * 1000/9.81 = 611.62kg$$

$$Correction\ factor = 0.93$$

$$Correction\ Stability = Correction\ Factor * Stability = 0.93 * 611.62 = 568.81kg$$

➢ Selection of Optimum Binder Content:-

Method 1:-

Using the plots of figure in standard graphs above, let the binder contents corresponding to maximum density be B_1, corresponding to maximum stability be B_2 and that corresponding to the specified voids content (at 4.0%) be B_3.

Then the optimum binder content for mix design is given by:

$$B_o = \frac{B_1 + B_2 + B_3}{3}$$

Method 2:-

The optimum asphalt binder content is selected based on the combined results of Marshall Stability and flow, density analysis and void analysis (see standard graphs Figure Optimum Asphalt Binder content can be arrived at in the following procedure (Roberts et al., 1996):

1. Plot the following graphs:
   - Asphalt binder content vs. Density. Density will generally increase with increasing asphalt content, reach a maximum, and then decrease. The peak density usually occurs at a higher asphalt binder content than peak stability.
   - Asphalt binder content vs. Marshall Stability. This should follow one of two trends:
     - Stability increases with the increasing asphalt binder content, reaches a peak, then decreases.
     - Stability decreases with increasing asphalt binder content and does not show a peak. This curve is common for some recycled HMA mixtures.
   - Asphalt binder content vs. Flow.
   - Asphalt binder content vs. Air voids. Percent air voids should decrease with increasing asphalt binder content.
   - Asphalt binder content vs. VMA. Percent VMA should decrease with increasing asphalt binder content, reach a minimum, and then increase.
   - Asphalt binder content vs. VFA. Percent VFA increases with the increasing asphalt binder content.
2. Determine the asphalt binder content that corresponds to the specification median air void content (typically, this is four percent). This is the optimum asphalt binder content.

Determine properties of this Optimum Asphalt Binder content by referring to the plots. Compare each of these values against specification values and if all are within specification, then the preceding optimum asphalt binder content is satisfactory. Otherwise, if any of these properties is outside the specification range the mixture should be redesigned.

Method 3:-

- Before determining the optimum binder content, the design specifications must first be examined. To determine the O.B.C., the binder contents corresponding to maximum stability, maximum unit weight, and to appropriate percentages (guided by the design specifications) of voids in total mix and aggregate voids filled with binder are determined. The O.B.C. is then taken as the average of these four binder contents.
- The selected O.B.C. is checked to ensure that it gives a mixture that will still meet the specified criteria. This is done by re-entering the curves with the selected O.B.C. If the values obtained are found inadequate, then the mix requires redesigning, and the tests performed again, before it can be used in the pavement.

Report:-

Prepare graphs of:-

1. Unit weight versus binder content.
2. Air voids versus binder content.
3. Stability (N) versus binder content.
4. Flow (mm) versus binder content.
5. Voids in total mix versus binder content.
6. Voids in mineral aggregate versus binder content.

Use average values of the specimens at each binder content and omit any values that are obviously in error. In the case of unit weight and stability data smooth curves, showing, if possible clear maxima should be obtained.

7. Stiffness factor versus binder content.
8. Retained stability versus binder content.

➢ Form for Calculations:-

PHA%	Sample	AC%	Height (mm)	Weight in Air (g)	Weight in Water (g)	S.S.D	Total Volume (cm^3)	Bitumen Volume (cm^3)	Aggregate Volume (cm^3)
4.5	A								
4.5	B								
4.5	C								
4.5	D								
5	A								
5	B								
5	C								
5	D								
5.5	A								
5.5	B								
5.5	C								
5.5	D								
6	A								
6	B								
6	C								
6	D								
6.5	A								
6.5	B								
6.5	C								
6.5	D								

PHA%	Sample	Density (g/cm^3)	Air Voids %	V.M.A %	V.F.A %	Stability kN	Stability Kg	Correction Factor	Corrected Stability	Flow (mm)	Flow ($\frac{1}{100}in.$)
4.5	A										
4.5	B										
4.5	C										
4.5	D										
AVERAGE											
5	A										
5	B										
5	C										
5	D										
AVERAGE											
5.5	A										
5.5	B										
5.5	C										
5.5	D										
AVERAGE											
6	A										
6	B										
6	C										
6	D										
AVERAGE											
6.5	A										
6.5	B										
6.5	C										
6.5	D										
AVERAGE											

EXPERIMENT No.2: Maximum Theoretical Specific Gravity of Paving Mixture

ASTM Designation D 2041

➢ Objective:-

To determine the maximum theoretical specific gravity of a compacted bituminous paving mixture.

➢ Theory:-

- Specific gravity is defined as the mass of a given volume of asphalt concrete, with the air voids removed, to the mass of an equal volume of water at the same temperature.
- The theoretical maximum specific gravities and densities of hot-mix asphalt paving mixtures are intrinsic properties whose values are influenced by the composition of the mixtures in terms of types and amounts of aggregates and bituminous materials.

➢ Apparatus:-

Only one of several variations of apparatus and procedure will be described in this reference:

1. A metal bowl having a capacity of at least one liter.
2. Balance with the capacity of at least 1.5kg and sensitivity to 0.1g. The balance shall be equipped with a suitable suspension apparatus and holder to permit weighting the sample, both in air and in water, while suspended from the center of scale pan of the balance.
3. A consist temperature bath suitable to accept the suspended metal bowl.

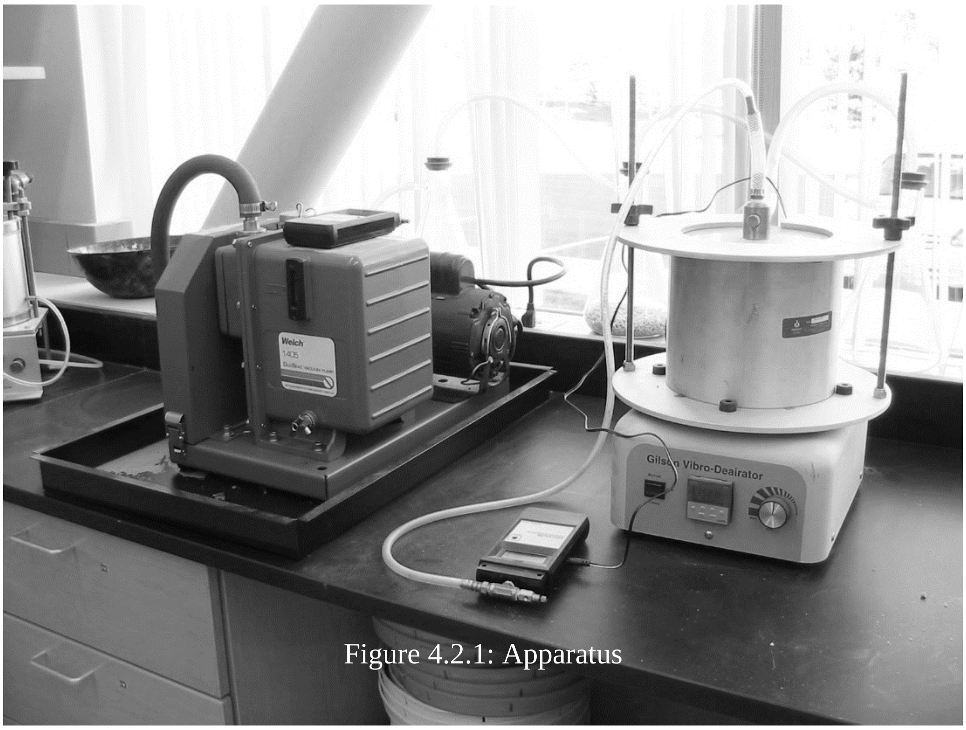


Figure 4.2.1: Apparatus

➢ Size of Sample Shall Conform to the following:-

Size of largest aggregate practice in mixture (inches)	Minimum sample size (g)
1	2500
¾	2000
½	1500
3/8	1000
No.4	

➢ Procedure:-

1. Surface the asphalt mixture by heating, so that the practice can be manually separated into individual pieces, while taking care not to fracture the individual aggregate.
2. Cool to room temperature and obtain the net weight in air. Make certain that the individual practice do not stick together and thereby trap air pockets. Weight and designate the net weight of the sample in air as (A).
3. Weight the Pycnometer full with water without voids, this weight is (B).
4. Weight the Pycnometer + sample + water without voids, this weight is (C).

➢ Calculations:-

- The specific gravity can be obtained by:

$$G_{mm} = \frac{A}{A + B - C}$$

Where:
A: Mass of dry sample in air.
B: Mass of Pycnometer filled with water.
C: Mass of Pycnometer filled water of sample.

- The air voids can be obtained by:

$$AV\% = \frac{G_{mm} - G_{mb}}{G_{mm}} * 100\%$$

Where:
G_{mm} = Maximum theoretical specific gravity.
G_{mb} = Bulk specific gravity.

EXPERIMENT No.3: Stripping Test

ASTM Designation D 1664-69

➢ Objective:-

To be acquainted with the stripping test performed on aggregate particles in bibulous material and surfaces.

➢ Theory:-

- The stripping value of aggregates is determined as the ratio of the uncovered area observed visually to the total area of aggregates, expressed as a percentage.
- It is know that there is a tendency for water to displace the film of bitumen, which coats the aggregate particles in most bitumen surface. This phenomenon, which results from pen trial wetting at the aggregate types than others. The former are known as hydrophilic, while the latter as hydrophilic.
- The stripping test supposed to be an indicate of low well an emulsion will stay coated to the stone if the job is hit by a rainstorm before the emulsion has set.

➢ Apparatus:-

1. Containers.
2. Scales.
3. Constant-temperature oven.
4. Sieve (1/4, 3/8).
5. Spatula.

➢ Procedure:-

1. Sieve the aggregate sample in order that the sample of such size that 100% passes 3/8-in (9.5mm) sieve and retained on a ¼-in (6.3mm) sieve.
2. Wash the aggregate in distilled water to remove all fines then dry the mat 275-300°F (135-149°C) to a constant weight and store in airtight containers until required for use.
3. Dry the aggregate for one hour in original containers at 275-300°F (135-149°C).
4. Heat the asphalt material separately at 275-300°F (135-149°C) and mix 5.5g ± 0.2g from the heated bitumen's with 100g from the dry aggregate with warm spatula blade for 2-3 minutes.
5. Transfer the coated aggregate to a 600ml glass container-cover immediately with 400ml of distilled water at room temperature. Allow the coated aggregate to remain immersed in water for 16-18 hours.
6. To estimate visually the coated area of stripping test, remove any film footing on the water surface.
7. Illuminates the specimen by a shaded lamp, fitted with a 75W electric bulb positioned to eliminate the surface of the water.

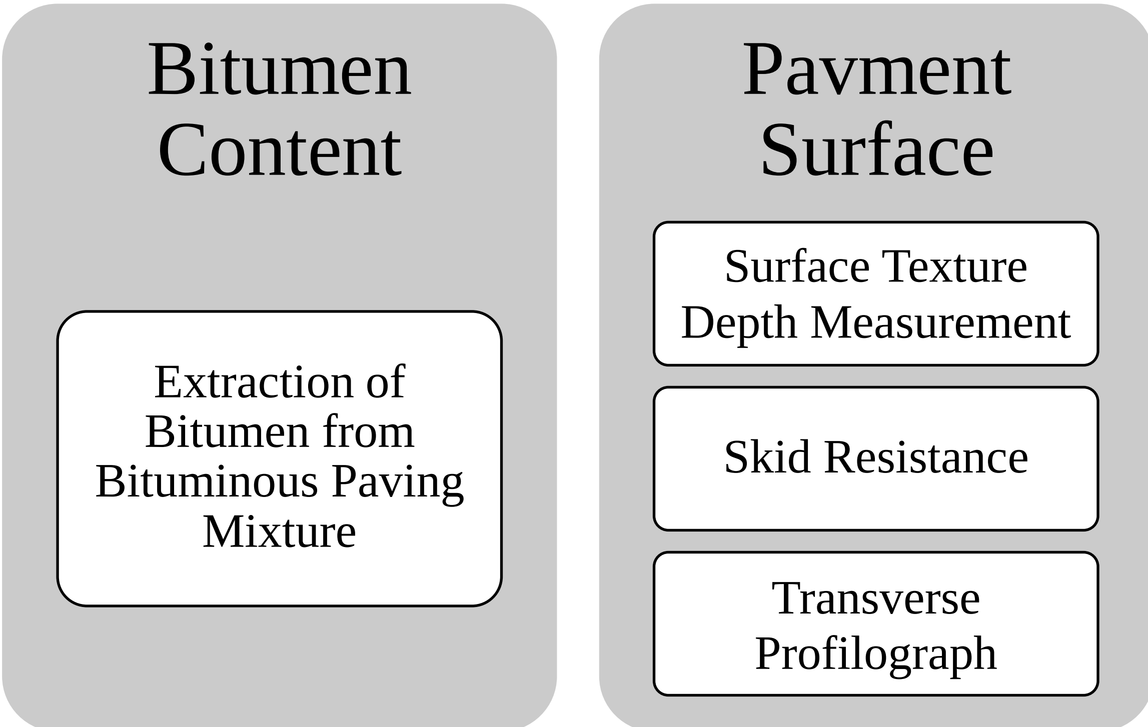
8. By the observation the water, from above, estimate the percentage of the total visible area of the aggregate that remains coated as above or below 95%. Any thin brownish, translucent areas are to be considered fully coated.

➢ Calculations:-

$$\% \, Stripping = \frac{Weight\ of\ stripping\ aggregate}{Total\ weight\ of\ aggregate} * 100\%$$

SECTION 5: Quality Control Tests

Introduction



The texture of a pavement surface and its ability to resist the polishing effect of traffic is of prime importance. In this section, a test is described which measures the skid resistance of a pavement surface using the British Pendulum Skid Tester. When this test is being carried out, it is also important to be able to describe the texture of the surface and the sand patch method for determining the average Surface Texture Depth is included. Finally, it is important to be able to measure the profile of a road pavement and the determine that it has been constructed to the specified camber or super elevation and subsequently to determine whether deformation occurs under traffic. These properties can be determined using the Transverse Profilograph.

EXPERIMENT No.1: Extraction of Bitumen from Bituminous Paving Mixture

ASTM Designation D 2172–79

➢ Objective:-

To determine the bitumen content of a sample of bituminous paving mix.

➢ Theory:-

- A sample of paving mixture is placed in a bowl that may be revolved at various speeds. A bitumen solvent is added to the sample that is allowed to stand for approximately one hour during which some disintegration occurs. The bowl is then revolved at high speed and the centrifugal force cases the extract to be removed via the drainpipe. More solvent is added to the sample and the cycle is repeated at least three times. Finally, the aggregate is collected from the bowl and dried. It can also be sieved to determine the grading of the aggregate in the mix. A sample extract is also taken and the mass of mineral matter in it is determined by evaporating the extracted sample and finally carrying out an ash determination. The percent bitumen content is then calculated.
- This method covers the quantitative determination of asphalt cement in a bituminous paving mixture. The paving mixture is extracted with trichloroethylene, or methylene chloride solvent.

➢ Apparatus:-

Figure 5.1.1: Oven / Muffle furnace

1. Oven / Muffle furnace.
2. Flat pan.
3. Balance.
4. Hot plat.
5. Graduated Cylinder.
6. Ignition Dish.
7. Desiccators.
8. Analytical Balance.
9. Extraction apparatus with a bowl that can be rotated at spent of up to 3600 R.P.M.
10. Filter Rings.
11. Solvent (Note: only trichloroethylene, methylene chloride, or other relatively non–toxic solvents should be used and only proper procedures for disposing of waste solvents should be carried out).

Figure 5.1.2: centrifuge

➢ Procedure:-

1. Place the sample (650g approx.) in the bowl of the apparatus.
2. Cover it with the solvent and allow up to one hour (maximum) for solvent to disintegrate the sample.
3. Dry and determine the mass of the filter ring and fit it in position.
4. Clamp the cover of the bowl and place a graduated cylinder under the drainpipe to collect the extract.
5. Start the centrifuge revolving slowly and increase the speed up to 3600 R.P.M. (maximum), or until the solvent ceases to flow from the drainpipe.
6. Stop the machine, add a further 200ml of solvent and repeat the procedure.
7. Use sufficient 200ml additions of solvent (minimum of three) so that the extract is not darker than a light straw color.
8. Collect the extract and washings in a suitable vessel.
9. Remove the filter ring from the bowl and dry it in the air.
10. Remove all the contents of the bowl into a metal pan and dry them completely. The mass of the extracted aggregate is equal the mass of the aggregate in the pan plus the increase in the mass of the filter rings.
11. A sieve analysis can now be carried out on the dry extracted aggregates.

Determine the mass of the mineral matter in the extract as follows:

1. Record the volume of the total extract in the graduated cylinder.
2. Agitate the extract completely and immediately measure accurately about 100ml into an ignition dish of known mass.
3. Evaporate the sample to dryness on a hot plate or steam bath.
4. Ash the residue at a dull red heat (500–600°C), cool and add 5ml. of saturated ammonium carbonate solution per gram of ash. Allow this to digest at room temperature for one hour.
5. Dry the dish and contents in an oven at 100°C to constant mass; cool in a desiccator and then determine the mass.

➢ Calculations:-

- The mass of mineral matter in the total volume of extract (W4) is computed as follows:

$$W_4 = G * \left(\frac{W_1}{V_1 - V_2}\right)$$

Where:
G = Ash in a liquid (g).
V_1 = Total volume (ml).
V_2 = Volume after removing aliquot (ml).

- The bitumen content (percent) in the test portion can be calculated as follows:

$$\%\ Bitumen\ content = \frac{W_1 - W_2 - (W_3 + W_4)}{W_1 - W_2} * 100\%$$

Where:
W_1 = Mass of test portion.
W_2 = Mass of water in test portion.
W_3 = Mass of extracted mineral aggregate.
W_4 = Mass of mineral matter in the extract.

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Mass of test portion (W_1)				
Mass of water in test portion (W_2)				
Mass of extracted mineral aggregate (W_3)				
Mass of mineral water in extract (W_4)				
Ash in aliquot (G)				
Sample's total volume (V_1)				
Sample's volume after removing aliquot (V_2)				
$W_4 = G * \left(\frac{W_1}{V_1 - V_2}\right)$				
$\% \, Bitumen \; content = \frac{W_1 - W_2 - (W_3 + W_4)}{W_1 - W_2} * 100\%$				

Remarks:____

____

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Date of test:	Tested by:	Checked by:

EXPERIMENT No.2: Transverse Profilograph

ASTM Designation E 1318-94

➢ Objective:-

To record the transverse profile of a road pavement.

➢ Theory:-

The Profilograph records the profile of a surface on a chart and can indicate wheel path ruts and surface imperfections, as well as road camber and super elevation. It consists of a 4.25m straight reference beam along which a carriage, fitted with a sensor wheel in contact with the road surface, travels. The vertical displacement of the sensor wheel and the horizontal movement of the carriage along the beam are recorded on a rotating drum that is also attached to the carriage.

➢ Apparatus:-

1. Transverse Profilograph.
2. A brush for cleaning the road surface.
3. Recording charts (216mm x 356mm) either plain or with graph.

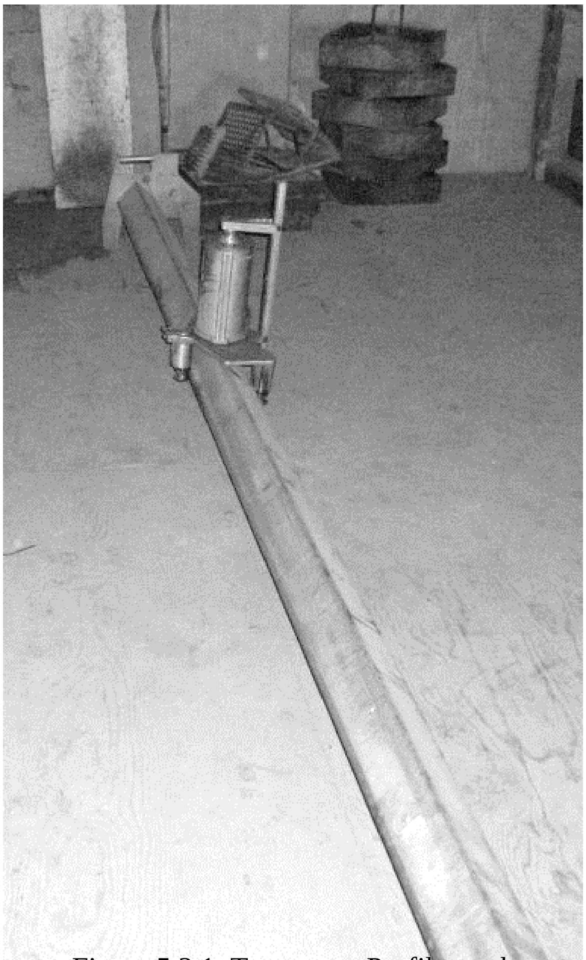

Figure 5.2.1: Transverse Profilograph

➢ **Procedure:-**

1. Block the roadway lane that is to be recorded in a safe manner.
2. Sweep the test strip clean.
3. Place the beam across the lane with the single leveling screw end at the curb side of the lane.
4. Level the beam using the leveling screw and bubble.
5. Install a chart on the drum by releasing the clamps and squaring the fresh chart on the flange on the bottom of the drum. Lock the clamps when the chart is in the correct positions.
6. Revolve the drum so that the paper clamps swing towards the middle of the beam and continue around as far as possible without touching the pen. This will make full use of the chart.
7. Lower the sensor wheel by retracting the bolt on the other arm and releasing its shaft. Gently rest the tracing wheel on the test surface.
8. Install and zero the pen. Set the pen height by sliding the holder vertically and locking it in the correct position. Fins bring the pen tip into contact with the chart.
9. Unlock the carriage by retracting the carriage barrel bolt and roll the recorder across the beam tracing the pavement profile.
10. At the end of the run, lock the recorder to the beam again.
11. If it is required to mark any road features (cracks etc.) on the chart, stop the sensor wheel at the point lift the wheel about 25mm so causing a mark on the chart, then continue recording.
12. On completion of recording, retract the pen and cap it, then retract the sensor wheel and remove the chart from the drum.

The recording displays the vertical pavement profile at full depth and horizontal distances are recorded at a ratio of 300mm = 25mm (i.e. 1/12 of the distance travelled).

EXPERIMENT No.3: Surface Frictional Properties of Aggregates and Pavements

ASTM E 303 – 74

➢ Objective:-

To determine the skid resistance of a surface using the British Pendulum tester.

➢ Theory:-

- The tester is a dynamic pendulum impact type tester that is based on the energy loss occurring when a rubber slider edge is propelled across a test surface. The apparatus may be used for both elaboration and field tests on flat surfaces, and for polished stone value measurements on curved laboratory specimens for accelerated polish wheel tests. The values measured are referred to as British Pendulum (tester) numbers (BPN) for flat surfaces, and polished stone values (PSV) for specimens subjected to accelerated polishing tests.
- The following terminology is applicable when the skid resistance is being determined for a performance based specification
    1. A test site is the position at which a single in situ test is performed.
    2. A measured lane is the trafficable lane within a pavement, for which measures of pavement conditions are taken.
    3. A segment is a variable length of the measured lane.
    4. A sub-segment is a selected portion of the segment

➢ Apparatus:-

1. British pendulum tester, this includes a pendulum with slider mount weighing 1500g. The device can be adjusted vertically to provide a slider contact path of 125mm for testing flat surfaces.
2. Rubber sliders complying with the requirements of Table 1. The striking edges of new sliders shall be square, clean cut and free from contamination. The wear on the striking edges of sliders in use should not exceed the dimensions. Avoid handling the surface of the sliders at all times. The sliders shall be bonded to a rigid backing plate as shown in Figure 2. The backing plate and slider shall have a combined mass of 35± g between uses the sliders shall be stored in talcum power in the dark at room temperature. The sliders should be discarded when they are more than twelve months old.
3. Contact path gauge which is a thin ruler which is marked for measuring the contact length on flat surfaces (125mm).
4. Thermometer - capable of determining surface temperature in the range of 0°C to 60°C, readable to at least 1°C.
5. Water container, surface thermometer and a brush.
6. Brush for sweeping road

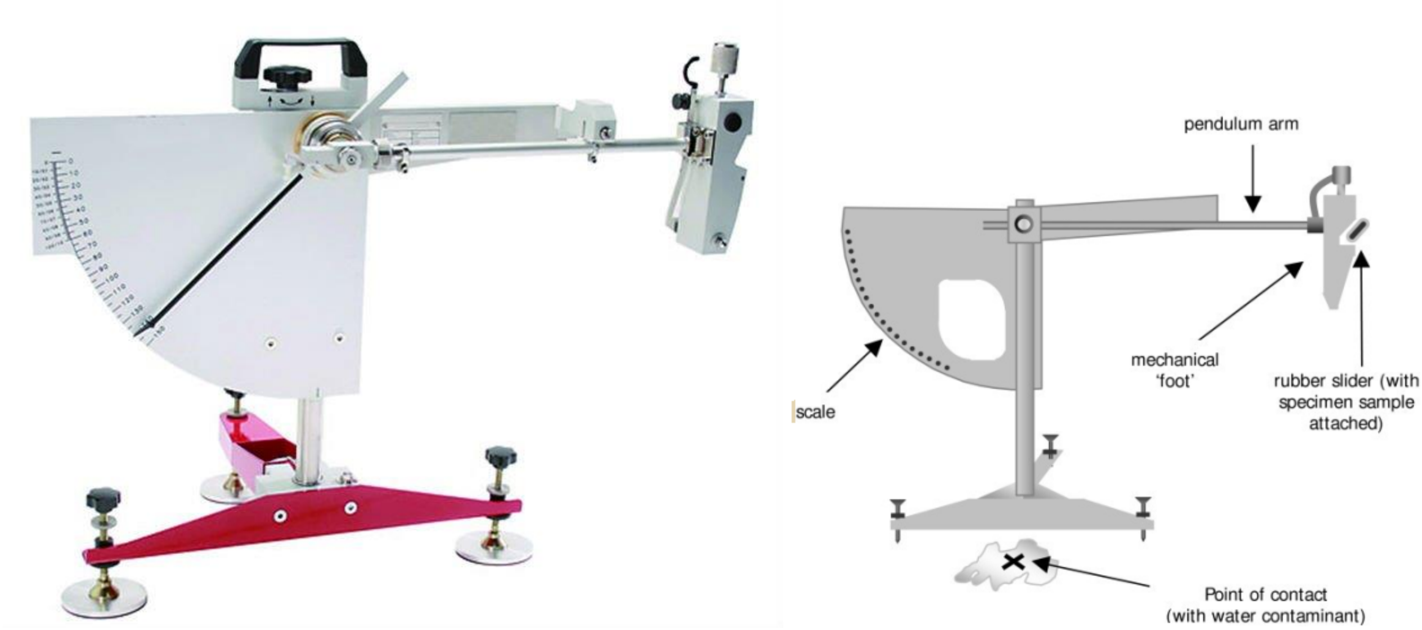

Figure 5.3.1: British pendulum tester

➢ Procedure:-

A. Preparation for test:-

1. The road surface to be tested is first cleaned free of loose particles and washed with clean water.
2. Level the apparatus using the leveling screws and the spirit level.
3. Raise the pendulum mechanism by loosening the locking knob and turning the head movement knobs at the center of the device. Adjust so that the slider can swing free of the test surface. Now tighten locking knob firmly.
4. Place the pendulum in release position and rotate the drag pointer counter clockwise until it comes to rest against the adjustment screw on the pendulum arm.
5. Now release the pendulum and note the pointer reading. If it is not zero loosen the locking ring and rotate the friction ring on the bearing spindle slightly and lock again.
6. Repeat the test and continue adjusting the friction ring until the pendulum swing carries the pointer to zero.
7. To adjust the slide length:
   I. Place the spacer under the adjusting screw of the lifting handle with the pendulum hanging free.
   II. Lower the pendulum so that the edge of the slider just touches the surface. Lock the pendulum head firmly, raise the lifting handle and remove the spacer.
   III. Raise the slider with the lifting handle, move the pendulum to the right of the lower slider and allow the pendulum to move slowly to the left until its edge touches the surface. Place the contact path gauge beside the slider and measure the length.

IV. If the contact length is not between 124 and 127mm on a flat surface measured from trailing edge to trailing edge of the rubber slider, adjust the contact length by raising or lowering the instrument with the front leveling screws. Readjust the level of the instrument if necessary.

8. Finally place the pendulum in the release position and rotate the drag pointer counter clockwise until it comes to rest against the adjustment screw on the pendulum arm.

B. Performing the test:-

1. Wet the test area thoroughly. Execute one swing but do not record the reading.
2. Always catch the pendulum on the early portion of its return swing. Lift the slider with its lifting handle to prevent it touching the test surface and return the pendulum to its starting position each time.
3. The pointer should be returned to its position resting against the adjustment screw before every swing.
4. Make six swings, rewetting the test area each time, and record the results.
5. Remove the higher and lower values then take the average for the rest of results.
6. Recheck the slide contact length on completion of the tests.

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BPN / first trial	
/ second trial	
/ third trial	
/ fourth trial	
BPN / Average	

Remarks:____

Date of test:	Tested by:	Checked by:

EXPERIMENT No.4: Surface Texture Depth Measurement

ASTM E1845

➢ Objective:-

To measure the surface texture depth.

➢ Theory:-

Pavement texture is defined as the vertical unevenness of the absolutely even pavement surface.

➢ Apparatus:-

1. Small cylindrical container.
2. Rubber Bung.
3. Steel Ruler or Meter Stick.
4. Fine sand.

➢ Procedure:-

1. Fill the small cylinder with the sand having previously determined the volume of sand contained by the cylinder.
2. Place this known volume of sand on the surface of the area to be tested.
3. Using the rubber bung rub the sand into the road surface using circular motion, and spreading it outwards over a circular area.
4. Continue spreading the sand in this manner until a circular area, in which all the indentations have been filled with sand, is obtained, and the sand is exhausted.

➢ Calculations:-

Using the ruler measure the diameter of the sanded area mean surface texture depth:

$$H(mm) = \frac{Volume\ (mm^3)}{Cross\ section\ Area\ of\ circle\ (mm^2)}$$

It is normal to carry out this test in the wheel track on the road. In this case, however carry out measurement both in the wheel tracks and in between the wheel tracks.

Student Notes

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