LABORATORY MANUAL

TRANSPORTATION ENGINEERING-I LABORATORY

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Experiment No.1

Aim: To determine the combined Flakiness and Elongation Index of Coarse Aggregates. (According to MORTH)

Apparatus required: Thickness gauge, Length gauge, IS sieves of sizes 63, 50 40, 31.5, 25, 2a 16, 12.5,10 and 6.3mm, Weighing Balance

Material required: Coarse Aggregate.

Learning objective: The students will learn how to check the quality of aggregates at site and how to segregate them.

Theory

Aggregates that fall within a specific size range can exhibit various shapes, including rounded, cubical, angular, flaky, or elongated particles. It is clear that flaky and elongated particles possess less strength and durability compared to cubical, rounded, or angular particles of the same stone. Therefore, it is advisable to minimize the presence of excessively flaky or elongated aggregates. The shape of the aggregate mass is influenced by the percentage of elongated and flaky particles, while its angularity significantly impacts mix design and ultimate strength.

The shape of particles is assessed using the flakiness index, elongation index, and angularity number. Elongated and flaky aggregates tend to be less workable and are more prone to breaking under lighter loads compared to spherical or cubical aggregates. This test outlines the procedure for determining both the flakiness index and elongation index.

The flakiness index of aggregates refers to the percentage by weight of particles whose least dimension (thickness) is less than three-fifths (0.6 times) of their

mean dimension. This test does not apply to sizes smaller than 6.3 mm. In contrast, the elongation index measures the percentage by weight of particles whose greatest dimension (length) exceeds nine-fifths (1.8 times) their mean dimension, also with a minimum size limit of 6.3 mm. The permissible limit for the combined flakiness and elongation index of aggregates is 30% of the total weight.

Fig 1.1 : Flakiness and Elongation Gauges

Procedure

1. Sieve the sample through the IS sieves (as specified in the table).
2. Take a minimum of 200 pieces of each fraction to be tested and weigh them
3. In order to separate the flaky materials, gauge each fraction for thickness on a thickness gauge. The width of the slot used should be of the dimensions specified in column (4) of the table for the appropriate size of the material.

4. Weigh the flaky material passing the gauge to an accuracy of at least 0.1 percent of the test sample.
5. In order to separate elongated particle, now the elongated particle is separated from remaining non flaky material byusing length gauge.
6. Separation of Elongated Material- each fraction shall be gauged individually for length on a metal length gauge.
7. Weighing of Elongated Material - the total amount retained by the length gauge shall be weighed to an accuracy of at least 0.1 percent of the weight of the test sample.

Formulas

Flakiness Index = (X1+ X2+…..) / (W1 + W2 + ….) X 100

Elongation Index = (Y1 + Y2 + …) / (W1 + W2 + ….) X 100

Table 1.1 Sample Sheet

Size of aggregates		Weight fraction consisting of atleast 200 pieces,g	Thickness gauge size,mm	Weight of aggregates in each fraction passing thickness gauge,mm	Length gauge size, mm	Weight of aggregates in each fraction retained on length gauge,mm
Passing through IS Sieve,mm	Retained on IS sieve, mm					
1	**2**	**3**	**4**	**5**	**6**	**7**
63	50	W1	23.9	X1		
50	40	W2	27	X2	81	Y1
40	31.5	W3	19.5	X3	58	Y2
31.5	25	W4	16.95	X4		
25	20	W5	13.5	X5	40.5	Y3
20	16	W6	10.8	X6	32.4	Y4
16	12.5	W7	8.55	X7	25.5	Y5
12.5	10	W8	6.75	X8	20.2	Y6
10	6.3	W9	4.89	X9	14.7	Y7
Total		**W=**		**X=**		**Y=**

Precautions

1. Weigh the aggregate carefully.
2. Sieving of aggregates needs to be done uniformly.

Calculations

Results and Discussion

Learning outcome:

Experiment No. 2

Aim: To determine the aggregate crushing value of coarse aggregates as per IS: 2386 (Part IV) - 1963.

Apparatus Required: Cylindrical measure and plunger**,** Compression testing machine, IS Sieves of sizes - 2.5mm, 10mm and 2.36mm.

Material required: Coarse Aggregate.

Theory

The Aggregate Crushing Value (ACV) test is a measure of the resistance of coarse aggregates to crushing under a gradually applied compressive load. This property is crucial for assessing the quality of aggregates used in construction, particularly in concrete and asphalt.

Purpose of the Test: The test evaluates the mechanical properties of aggregates, which are essential for ensuring the durability and strength of concrete. It helps determine whether the aggregates can withstand the loads and stresses they will encounter in structural applications.

Principle: The principle behind the aggregate crushing value test is that aggregates subjected to compressive forces will experience deformation or fracture. The test quantifies the amount of crushed material produced when a specified load is applied. The resulting crushing value is expressed as a percentage of the weight of the original aggregate sample.

Key Concepts

1. Load Application: A gradually applied compressive load mimics the forces aggregates will experience in real-world conditions.

2. Resistance to Crushing: Aggregates with high crushing values are considered weak and less durable, while those with lower crushing values are seen as more robust.

3. Aggregate Types: The test can be performed on various types of aggregates, including gravel, crushed stone, and recycled materials, providing insight into their performance characteristics.

Procedure

1. The aggregates passing through 12.5mm and retained on 10mm IS Sieve are oven-dried at a temperature of 100 to 110 C for 3 to 4 hrs.
2. The cylinder of the apparatus is filled in 3 layers, each layer tamped with 25 strokes of a tamping rod.
3. The weight of aggregates is measured (Weight 'A').
4. The surface of the aggregates is then levelled and the plunger inserted.
5. The apparatus is then placed in the compression testing machine and loaded at a uniform rate so as to achieve 40T load in 10 minutes. After this, the load is released.
6. The sample is then sieved through a 2.36mm IS Sieve and the fraction passing through the sieve is weighed (Weight 'B').
7. Two tests should be conducted.

Result

Aggregate crushing value = (B/A) x 100%

The result should be recorded to the first decimal place and the mean of the two results reported.

Observation Tables

Observation	A	B	(B/A) x 100%	Aggregate crushing value

Attach Graph: (if applicable)

Calculation

Result and Discussion

The Aggregate crushing value obtained is : _____

Limits

The aggregate crushing value for cement concrete pavement shall not exceed 30%.

The aggregate crushing value for wearing surfaces shall not exceed 45%.

Learning Outcomes (what I have learnt): to be written by the students in 50-70 words.

Experiment No. 3

Aim: To determine the Los Angeles abrasion value for a given aggregate sample (IS 2386 (part iv) - 1963, AASHTO T 96, ASTM C 131).

Apparatus Required: Los Angeles Abrasion Testing Machine, Abrasive Charge – Cast iron or steel balls, Test sieve – 1.70 mm IS sieve, Balance of capacity 10 kg, Oven, Tray

Theory

The aggregates utilized in the surface course of highway pavements face wear from traffic movement. As vehicles travel on the road, soil particles between the pneumatic tires and the road surface contribute to the abrasion of road aggregates. Additionally, the steel-shod wheels of animal-driven vehicles also cause significant wear on the road surface. Consequently, it is essential for road aggregates to possess sufficient hardness to withstand abrasion. In the laboratory, the resistance of aggregates to abrasion is assessed using the Los Angeles test machine.

The Los Angeles abrasion test operates on the principle of generating abrasive action through the use of standard steel balls. When these balls are mixed with aggregates and rotated in a drum for a specified number of revolutions, they also impart an impact on the aggregates. The resulting percentage wear of the aggregates from their contact with the steel balls is measured and referred to as the Los Angeles Abrasion Value.

Procedure

The test sample consists of clean aggregates dried in oven at 105 – 110°C. The sample should conform to any of the grading shown in Table 6.1.

Select the grading to be used in the test such that it conforms to the grading being used in the construction, to the maximum extent possible.

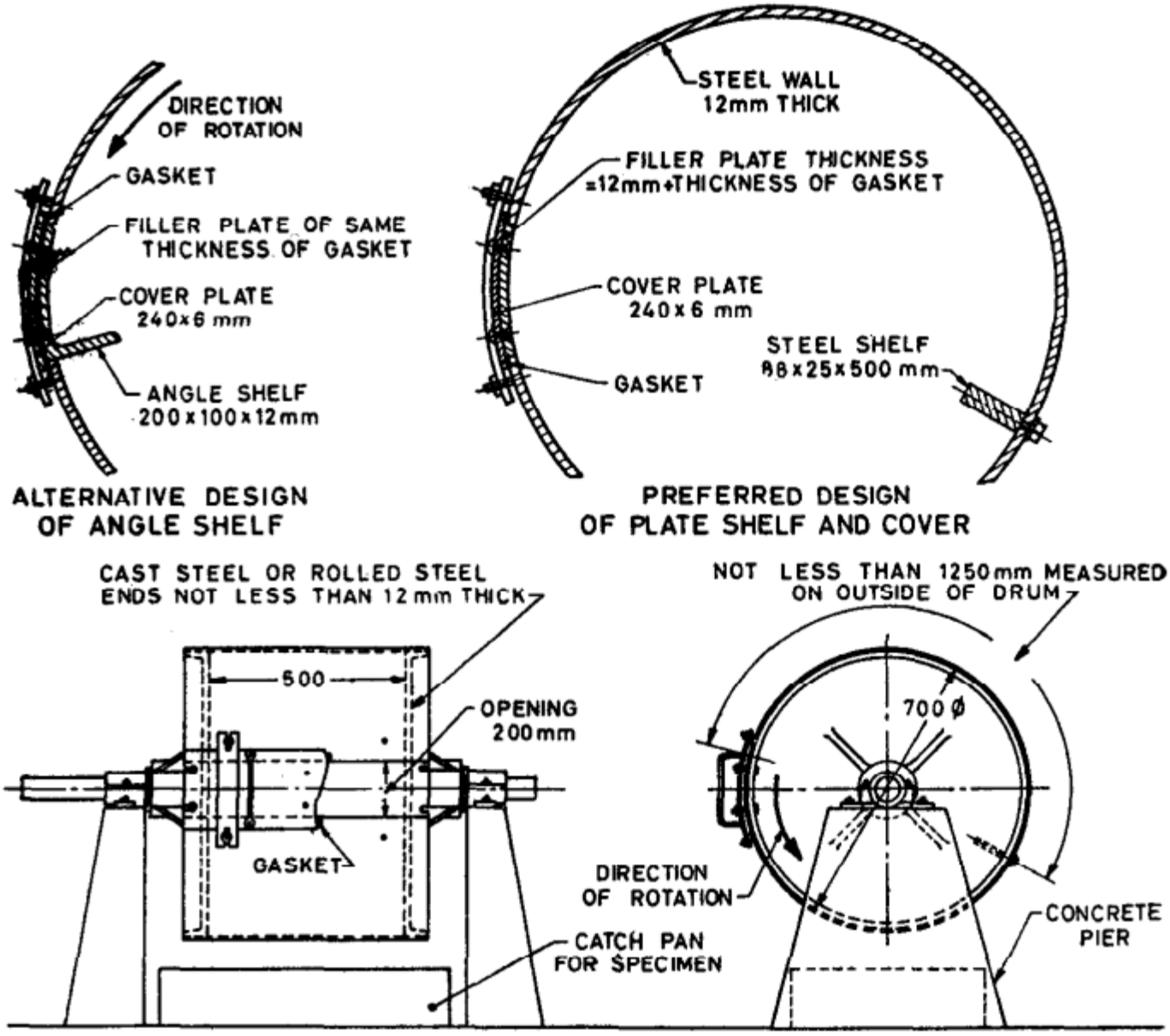
Take 5 kg of sample for grading A, B, C & D and 10 kg for grading E, F & G.

Choose the abrasive charge as per Table 6.2 depending on the grading of aggregates.

Place the aggregates and abrasive charge in the cylinder and fix the cover.

Rotate the machine at a speed of 30 – 33 revolutions per minute. The number of revolutions is 500 for grading A, B, C & D and 1000 for grading E, F & G. The machine should be balanced and driven such that there is uniform peripheral speed. Stop the machine after the desired number of revolutions and discharge material to a tray.

Sieve the entire material on the tray through 1.70 mm IS sieve. Weigh the material retained on 1.70 mm IS sieve correct to one gram.



NOTE 1 — Shaft bearing will be mounted on concrete piers or other rigid supports.

NOTE 2 — Suggested horse power for motor is not less than one.

All dimensions in millimetres.

Fig 3.1 LOS ANGELES ABRASION TESTING MACHINE

Results

Original weight of aggregate

sample = W1 g Weight of aggregate sample retained = W2 g Weight passing 1.7mm IS sieve = W1 - W2 g

Los Angeles Abrasion Value = [(W1 - W2) / W1] X 100

Table 3.1 Grading of test sample

Sieve size		Weight of test sample (g)						
Passing (mm)	Retained on (mm)	A	B	C	D	E	F	G
80	63					2500*		
63	50					2500*		
50	40					5000*	5000*	
40	25	1250					5000*	5000*
25	20	1250						5000*
20	12.5	1250	2500					
12.5	10	1250	2500					
10	6.3			2500				
6.3	4.75			2500				
4.75	2.36				5000			

*Tolerance of ±12 percent permitted.

The abrasive charge, depending upon the grading of the test sample as described shall be as follows :

Table 3.2: Selection of Abrasive Charge

Grading	No. of Steel balls	Weight of charge (g)
A	12	5000 ± 25

B	11	4584 ±25
C	8	3330 ± 20
D	6	2500 ± 15
E	12	5000 ± 25
F	12	5000 ± 25
G	12	5000 ± 25

Observation Table

Observation	W1 g	W2 g	W1 - W2	[(W1 - W2) / W1] X 100	Abrasion Value

Attach Graph: (if applicable)

Calculations

Result and Discussion

The Los Angeles Abrasion Value is : _____

Recommended value

Los Angeles test is commonly used to evaluate the hardness of aggregates. The test has more acceptability because the resistance to abrasion and impact is determined simultaneously.

Depending upon the value, the suitability of aggregates for different road constructions can be judged as per IRC specifications as given:

Table 3.4: Recommended values of Abrasion as per IRC

S.No.	Type of Pavement	Max. Permissible Abrasion Value in %
1	Water Bound Macadam sub base course	60
2	WBM base course with bituminous surfacing	50
3	Bituminous bound macadam	50
4	WBM surfacing course	40
5	Bituminous Penetration Macadam	40
6	Bituminous surfacing dressing, Cement concrete surface course	35
7	Bituminous concrete surface course	30

Learning Outcomes (what I have learnt): to be written by the students in 50-70 words

Experiment No. 4

Aim: To determine the aggregate impact value of coarse aggregates as per IS: 2386 (Part IV) - 1963.

Apparatus required: Impact testing machine conforming to IS: 2386 (Part IV) - 1963, IS Sieves of sizes - 12.5mm, 10mm and 2.36mm, A cylindrical metal measure of 75mm dia. and 50mm depth, A tamping rod of 10mm circular cross section and 230mm length, rounded at one end, Oven

Preparation of Sample

i) The test sample should conform to the following grading: Passing through 12.5mm IS

- Sieve 100 %
- Retention on 10mm IS Sieve 100 %

ii) The sample should be oven-dried for 4hrs. at a temperature of 100 to 110 C and cooled.

iii) The measure should be about one-third full with the prepared aggregates and tamped with 25 strokes of the tamping rod. A further similar quantity of aggregates should be added and a further tamping of 25 strokes given. The measure should finally be filled to overflow, tamped 25 times and the surplus aggregates struck off, using a tamping rod as a straight edge. The net weight of the aggregates in the measure should be determined to the nearest gram (Weight 'A')

Procedure

1. The cup of the impact testing machine should be fixed firmly in position on the base of the machine and the whole of the test sample

placed in it and compacted by 25 strokes of the tamping rod.

2. The hammer should be raised to 380mm above the upper surface of the aggregates in the cup and allowed to fall freely onto the aggregates. The test sample should be subjected to a total of 15 such blows, each being delivered at an interval of not less than one second.

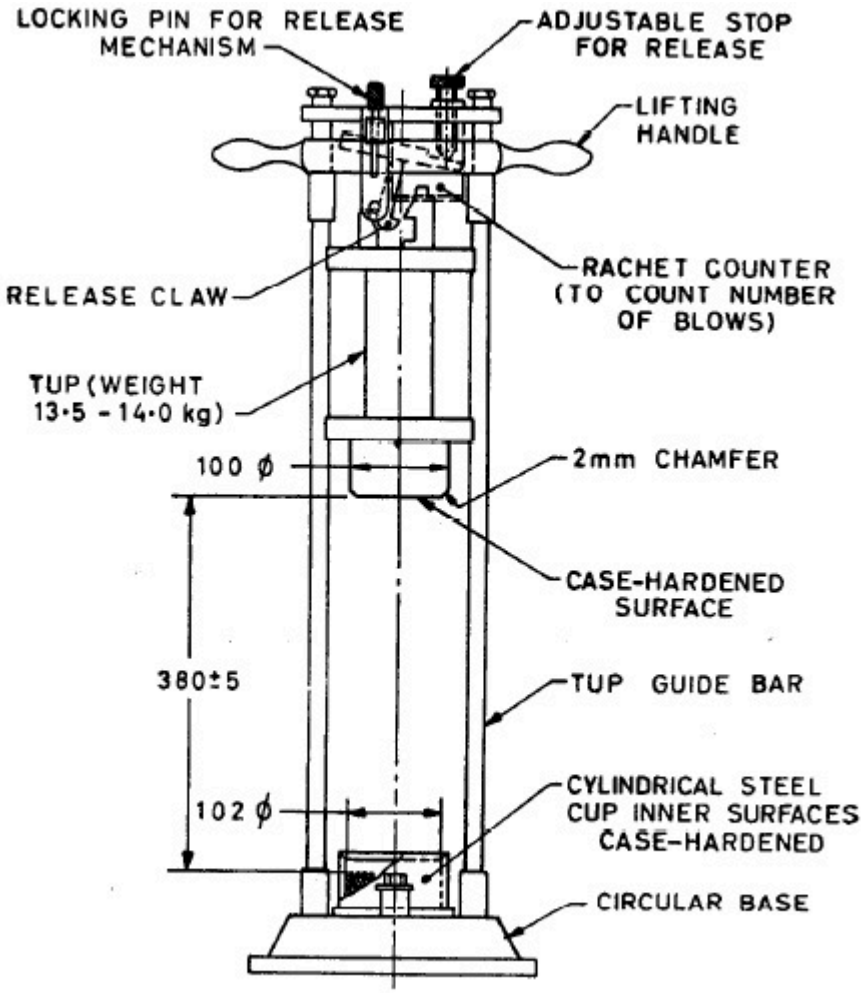


Fig 4.1 Impact Value test apparatus for aggregates

Reporting of Results

1. The sample should be removed and sieved through a 2.36 mm IS Sieve. The fraction passing through should be weighed (Weight 'B'). The

fraction retained on the sieve should also be weighed (Weight 'C') and if the total weight (B+C) is less than the initial weight (A) by more than one gram, the result should be discarded and a fresh test done.

2. The ratio of the weight of the fines formed to the total sample weight should be expressed as a percentage.
3. Aggregate impact value = (B/A) x 100%
4. Two such tests should be carried out and the mean of the results should be reported.

Observation table

Observation	A	B	B/A	B/A*100	Impact Value

Attach Graph: (if applicable

Calculations

Result and Discussion

The Aggregate Impact Value is : _____

Limits: Aggregate Impact Values, (AIV's), below 10 are regarded as strong, and AIV's above 35 would normally be regarded as too weak for use in road surfaces

Learning Outcomes (what I have learnt): to be written by the students in 50-70 words

Experiment No. 5

Aim: Determination of specific gravity and water absorption of coarse aggregate. (BIS 2386-3 (1963), ASTM-C127 – 12)

Apparatus required: Balance, wire basket, 4.75mm IS sieve.

Material required: sand, water.

Learning Objective: Students will learn how to find specific gravity and water absorption of coarse aggregate and check the results with prescribed limits.

Theory:-The specific gravity of an aggregate is defined as the ratio of the mass of a given volume of sample to the mass of an equal amount of water at the sample temperature.

Absorption influences the behaviour of aggregate in concrete in several important aspects. A highly absorptive aggregate, if used in dry condition, will reduce effective water cement ratio to an appreciable extent and may even make the concrete unworkable unless a suitable allowance is made. Hence determination of absorption of aggregate is necessary to determine the net water content.

Limits:

The specific gravity of aggregates ranges from 2.5 to 3.0 The water absorption of aggregates ranges from 0.1 to 2.0 %

Outline of Procedure:

1. Take about 5 Kg of aggregate by method of quartering; rejecting all material passing the 10mm IS sieve.

2. Wash thoroughly to remove dust etc. from the surface of the particles. Dry to constant mass at temperature of 105 C.

3. Immerse the sample in water at 22 – 32 C for a period of 24 hours.

4. Remove the aggregate from the water and roll the same in a large piece of cloth until all visible films of the water are removed, although

the surface of the particles will still appear to be damp.

5. Now weigh 3 kg of the sample in the saturated surface dry condition and note down the mass as W1, gram.

6. Place the weighted aggregate immediately in the wire basket and dip it in the water. Weigh this basket with aggregate, while keeping it in water with the help of the balance; note its mass as W3, grams.

7. Dry the sample to the constant weight at the temperature of 100 – 110 C for 24 hours.

Precaution:

1. The mass of the sample should be accurate at all stages

2. The sample should be free from the foreign material.

3. The large fragments should be wiped individually.

4. Avoid evaporation during surface drying operation.

Observation Tables:

Observation	Reading	
Material		
Mass of saturated surface dry sample, W1, gm		
Mass of basket suspended in water, W2, gm		
Mass of material + basket suspended in water, W3, gm		
Mass of aggregate suspended in water, (W3 – W2), gm		
Mass of oven dry aggregate in air, W4, gm		
Bulk specific gravity,		
Absorption percentage		
Bulk specific gravity		

Calculations:

Specific gravity = W4 / [W4 – (W3 – W2)]

Water absorption = mass of moisture / mass of oven dry sample * 100

Result and Discussion

Learning Outcomes (what I have learnt): to be written by the students in 50-70 words

Experiment No. 6

Aim: To determine the penetration of a given sample of bitumen. (IS: 1203: 1978, BS 1426: 2000, ASTM D5 – 97, 1997)

Apparatus required: Standard Penetrometer, Water bath, Bath thermometer – Range 0 to 44oC, Graduation 0.2oC

Theory:

The penetration test is a key procedure used to assess the consistency and hardness of bitumen. This test measures the depth (in tenths of a millimeter) that a standardized needle penetrates vertically into a sample of bitumen under specific conditions.

The primary aim of the penetration test is to provide a quantitative measure of the hardness or softness of bitumen, which is critical for determining its suitability for various applications in road construction and maintenance.

The penetration test is based on the principle that the viscosity and hardness of bitumen vary with temperature and composition. By subjecting a bitumen sample to a controlled force and temperature, the depth of penetration of a needle into the material indicates its relative consistency.

Key Concepts

1. Standardized Needle: A standardized needle with a specified weight (usually 100 grams) is used to ensure consistent results.
2. Temperature Control: The bitumen sample is typically conditioned at 25°C (77°F) to standardize the testing conditions.
3. Measurement of Penetration: The depth of penetration is measured after a specified time (usually 5 seconds), providing a direct indication of the bitumen's

consistency.

Importance in Bitumen Testing

Quality Control: The test helps manufacturers and construction engineers ensure that the bitumen meets specified performance standards for various applications.

Specification Compliance: Different grades of bitumen are defined by their penetration values, guiding material selection for specific road or paving projects.

Performance Prediction: The penetration value correlates with the performance characteristics of the bitumen, including its ability to withstand traffic loads and temperature variations.

Procedure

1. Soften the bitumen above the softening point by heating it between 75 and 100 °C.

2. Remove air bubbles and water by stirring the softened sample thoroughly.

3. Make sure bitumen should be just sufficient to fill the container to a depth of at least 15mm in excess of the expected penetration.

4. Cool the bitumen sample at an atmospheric temperature of 15 to 30 °C for 1.5 hours.

5. After that place it in a transfer dish in the water bath at 25 + 0.1 °C for 1.5 hours.

6. Keep the container on the stand of the penetration apparatus and adjust the needle such that it makes contact with the surface of the sample.

7. Adjust the dial gauge reading to zero.

8. Release the needle for exactly 5 seconds and then record the dial gauge reading expressed in tenths of a millimeter.

9. Repeat the above procedure three times.

Observation table:

Grade of bitumen

No.	Dial gauge reading	Penetration value
1		
2		
3		

Calculations:

Result and Discussion

The mean value is not less than three consistent penetration measurements (which do not differ by more than the values specified below) is reported as penetration value.

Range of penetration value	Maximum difference
0-49	2
50-149	4
150-249	6

Final penetration value (mm):

Learning Outcomes (what I have learnt): to be written by the students in 50-70 words

Experiment No. 7

Aim: To determine the softening point of a given bitumen sample (IS: 1205, BS2000-58, ASTM D36-95, 1995, AASHTO T53-06, 2006)

Apparatus Required: Ring and ball apparatus, Thermometer -Low Range: -2 to 80°C, Graduation 0.2°C High Range: 30 to 200°C, Graduation 0.5°C

Theory

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

Procedure

Preparation of sample

1. Fill the ring with the sample. Cut off the excess sample by a knife.
2. Heat the material between 75 and 100°C. Remove air bubbles and water by stirring it and then, filter it through IS Sieve 30, if necessary.
3. Heat the rings and apply glycerin.
4. Now fill the material in rings and cool it for 30 minutes.
5. Use a warmed, sharp knife to remove the excess material.

For Materials of softening point below 80°C

1. Assemble the apparatus with the rings, thermometer and ball guides in position.
2. Fill the beaker with boiled distilled water at a temperature 5.0 ± 0.5 °C per minute.
3. With the help of a stirrer, stir the liquid and apply heat to the beaker at a temperature of
5.0 ± 0.5 °C 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.

For Materials of softening point above 80 °C

The procedure is the same as described above. The only difference is that instead of water, glycerin is used and the starting temperature of the test is 35 °C.

Results

Softening point (°C) = the temperature at which the ball touches the bottom

=

Result and Discussion

Table 7.1 The requirements of softening point for paving bitumen as per BIS.

Property	Paving Grades			
	VG10	VG20	VG30	VG40
Softening point ^{o}C, Min	40	45	47	50

Learning Outcomes (what I have learnt): to be written by the students in 50-70 words

Experiment No. 8

Aim: To determine the ductility of a given sample of bitumen (IS: 1208 – 1978; ASTM D113-07, 2007; AASHTO T51-08, 2008)

Apparatus Required: Standard briquette mould, Water bath,3 Testing machine, Thermometer – Range 0 to 44°C, Graduation 0.2°C

Learning Objectives:

This test is done to determine the ductility of distillation residue of cutback bitumen, blown type bitumen and other bituminous products as per IS: 1208 –1978. 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.

Procedure

1. Heat the bituminous material to be tested to a temperature of 75 to 100°C above the approximate softening point until it becomes thoroughly fluid.
2. Assemble the mould on a brass plate (Figure 9.2).
3. Thoroughly coat the surface of the plate and the interior surfaces of the sides of the mould with a mixture of equal parts of glycerin and dextrin to prevent the material under test from sticking to the surface.
4. Pour the material in a thin stream back and forth from end to end of the mould until it is more than level full.
5. Leave it to cool at room temperature for 30 to 40 minutes and then place it in a water bath maintained at the specified temperature for 30 minutes.
6. Now, remove the excess bitumen by means of a hot, straight-edged putty knife or spatula to make the mould just level full.
7. Place the brass plate and mould with briquette specimen in the water bath at the specified temperature for about 85 to 95 minutes.
8. Remove the briquette from the plate; detach the side pieces and the briquette immediately

9. Attach the rings at each end of the two clips to the pins or hooks in the testing machine and pull the two clips apart horizontally at a uniform speed, as specified, until the briquette ruptures.
10. AMeasure the distance in cm at which the rupture occurs.

Note: While the test is being done, make sure that the water in the tank of the testing machine covers the specimen both above and below by at least 25mm and the temperature is maintained continuously within ± 0.5°C of the specified temperature.

Observation Tables

Grade of bitumen	
No.	**Ductility**
1	
2	
3	

Calculation

Result and Discussion

Table 8.1 Requirements as per BIS for paving bitumen

Property	VG10	VG20	VG30	VG40
Ductility at $25^{o}C$, cm min. after thin film oven test	75	50	40	25

Note: A normal test is one in which the material between the two clips pulls out to a point or to a thread and rupture occurs where the cross-sectional area is minimum. Report the average of three normal tests as the ductility of the sample, provided the three determinations are within ± 0.5 percent of their mean value.

If the values of the three determinations do not lie within ± 0.5 percent of their mean, but the two higher values are within ± 0.5 percent of their mean, then record the mean of the two higher values as the test result.

Ductility (cm) = Average of the three reading

Learning Outcomes (what I have learnt): to be written by the students in 50-70 words.