LABORATORY MANUAL FOR **Transportation Engineering**

Subject Code: **CEL 1601**

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY MIZORAM

LIST OF EXPERIMENTS

EXPERIMENT NO. I - Test on aggregate: Aggregate shape test

AIM: To determine the combined flakiness and elongation Index of the given coarse aggregate sample.

THEORY:

1. **Flakiness Index:** The flakiness index of an aggregate sample is the percentage by weight of particles in it with least dimension (thickness) less than three-fifth of their mean dimension. The flakiness index of an aggregate sample is determined by sieving the sample of aggregates through specified sieves to separate the aggregates into fractions of different sizes. Sizes of the sieves used for this purpose are: 63 mm, 50 mm, 40 mm, 31.5 mm, 25 mm, 20 mm, 16 mm, 12.5 mm, 10 mm, and 6.3 mm. The test is not applicable to material passing a 6.30 mm test sieve and also for aggregates retained on a 63 mm sieve.
2. **Elongation Index:** The elongation index of aggregate is the percentage by weight of particles, whose greatest dimension (length) is greater than one and four-fifth times (1.8) their mean dimension. The elongation index of an aggregate sample is determined by sieving the sample of aggregates through specified sieves to separate the aggregates into fractions of different sizes. Sizes of the sieves used for this purpose are: 50 mm, 40 mm, 31.5 mm, 25 mm, 20 mm, 16 mm, 12.5 mm, 10 mm, and 6.3 mm. The test is not applicable to material passing a 6.30 mm test sieve and for aggregates retained on a 50 mm sieve.

It may be noted that for determining the combined flakiness and elongation index, the elongation test is conducted after removing the flaky particles. For a regular elongation test, the complete sample will be evaluated.

APPARATUS:

a) Weighing Balance: A Balance of suitable capacity accurate to 0.1% of the mass of the weight of the test sample.
b) Elongation and Flakiness index gauges
c) Test Sieves: IS Sieves of the sizes and apertures appropriate to the specification of the material to be tested with square holes with appropriate sizes of lids and receivers

PROCEDURE:

1. For obtaining the combined flakiness and elongation index, the flakiness test is conducted first, and the non-flaky particles of the sample will be used for conducting the elongation index.
2. Sieve analysis is carried out on the sample of aggregate using sieves listed above.
3. A minimum of 200 pieces is taken for each fraction and weighed.
4. Weigh each of the individual size fractions retained on the test sieves, other than the 63.0 mm test sieve, and store them in separate trays with their sizes marked on the trays.
5. The sum of the weights of each fraction of aggregates gives the weight of the aggregate sample (Say, W1).
6. The particles belonging to a particular size group (e.g., passing through 50 mm and retained on 40 mm) are passed through the corresponding slot (for 50 mm – 40 mm fraction, the width of the slot is 27 mm) of the thickness gauge (flakiness index gauge) shown in Figure 1.
7. The particles passing through the specified slot of the thickness gauge are "flaky" and will be weighed to an accuracy of at least 0.1% of the weight of the test sample.
8. The sum of the weights of aggregates passing through different slots of the gauge is W2.
9. Flakiness index (%) = 100 * (W2 / W1)
10. For the purpose of determining the combined flakiness and elongation index value, the elongation index test will be conducted on the non-flaky aggregates identified in the flakiness test. Aggregates retained on the 50 mm sieve will be discarded for this test. Let the total weight of aggregates considered for the elongation test be W3.
11. Effort will be made to pass the particles belonging to a particular size group (e.g., passing through 50 mm and retained on 40 mm), when held length-wise through appropriate gaps (for 50 mm – 40 mm fraction, the gap is 81 mm) as shown in Figure 2. The aggregates that do not pass are elongated. These particles are weighed.
12. The sum of the weights of aggregates not passing through different gaps of the gauge is W4. Elongation index (%) = 100 * (W4 / W3)
13. The combined flakiness and elongation index will be the sum of the two indices (determined as described in the preceding steps).

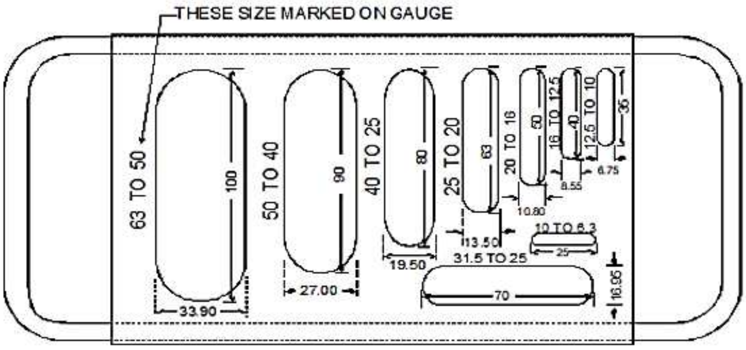


Figure 1: Thickness gauge

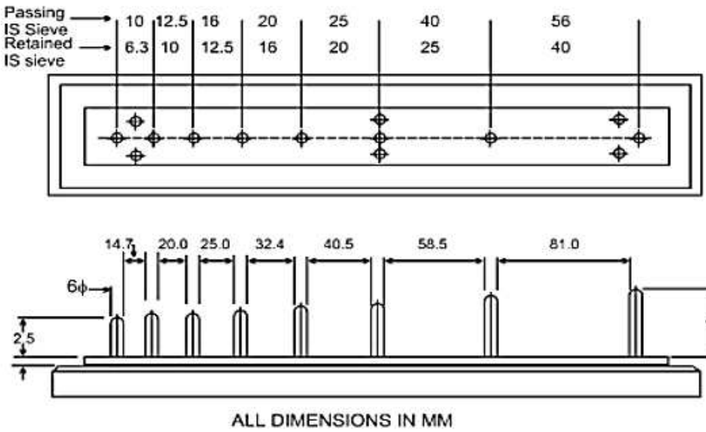


Figure 2: Length gauge

OBSERVATIONS AND CALCULATION:

Table 1. Flakiness Index

Size of Aggregates		Thickness gauge slot used (0.6* average size) (mm)	Weight of aggregate of this size group (gm)	Weight of aggregate fraction passing through the slot (gm)	Flakiness Index of each fraction of aggregate (%)
Passing through sieve of size (mm)	Retained on sieve of size (mm)				
63	50				
50	40				
40	31.5				
31.5	25				
25	20				
20	16				
16	12.5				
12.5	10				
10	6.3				
FI= $(W_2/W_1)*100$			W_1	W_2	FI=……. %

Table 2. Elongation Index

Size of Aggregates		Length gauge gap used (1.8* average size) (mm)	Weight of aggregate of this size group (gm)	Weight of aggregate fraction retained on the gauge (gm)	Elongation Index of each fraction of aggregate (%)
Passing through sieve of size (mm)	Retained on sieve of size (mm)				
50	40				
40	25				
25	20				
20	16				
16	12.5				
12.5	10				
10	6.3				
EI= $(W_4/W_3)*100$			W_3	W_4	EI=……. %

- Flakiness index (%), x = 100*(W2/W1) =
- Elongation index of non-flaky particles (%), y = 100*(W4/W3) =
- Combined flakiness and elongation index (%) = x + y =

RESULTS:

1. Flakiness index =
2. Elongation index of non-flaky particles =
3. Combined flakiness and elongation index =

QUESTIONS:

1. What is the significance of shape of aggregate in pavement construction?
2. Discuss the effects of flaky and elongated aggregate in road construction.
3. Discuss the advantages and limitations of rounded and angular aggregates in different types of pavements.

EXPERIMENT NO. II - Test on aggregate: Aggregate impact value test

AIM: To estimate the aggregate impact value of given sample.

THEORY: The 'Aggregate Impact Value' gives a relative measure of the resistance of an aggregate to sudden shock or impact, which in some aggregates differs from its resistance to a slow compressive load. The property of a material to resist impact is known as toughness. Due to movement of vehicles on the road the aggregates are subjected to impact resulting in their breaking down into smaller pieces. The aggregates should therefore have sufficient toughness to resist their disintegration due to impact. This Characteristic is measured by impact value test. The aggregate impact value is a measure of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load.

APPARATUS:

1. Impact Testing Machine: Impact testing machine conforming to IS: 2386 (Part IV) - 1963, as shown in Figure 1.
2. Metal Cylinder: cylindrical metal measure of 75 mm dia. and 50 mm depth.
3. Test Sieves: IS Sieves of the sizes and apertures appropriate to the specification of the material to be tested, (Sieves of sizes–12.5 mm, 10 mm and 2.36 mm).
4. A tamping rod of 10mm circular cross section and 230mm length, rounded at one end and Oven.
5. Balance: A balance of capacity not less than 500 g, readable and accurate to 0.1g.
6. Oven: A well-ventilated oven thermostatically controlled to maintain a temperature of 100 to 110ºC.

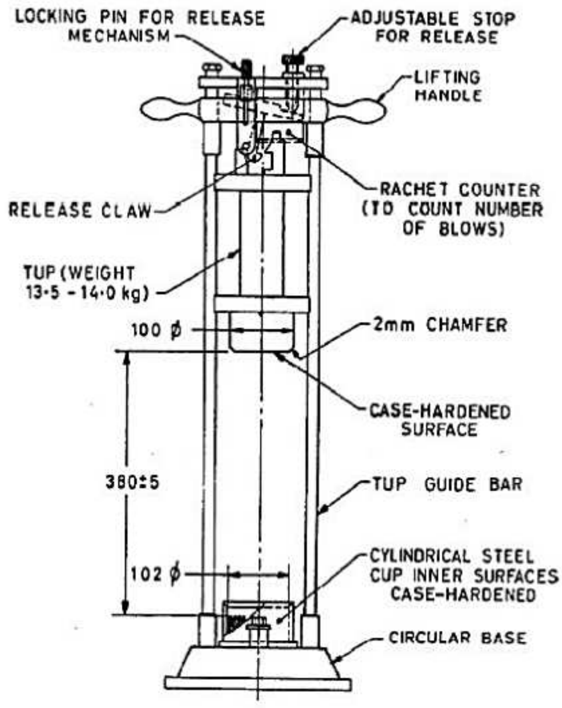


Figure 1: Impact Test Apparatus

PROCEDURE:

<u>Preparation of test sample:</u>

1. The test sample shall consist of aggregate the whole of which passes a 12.5 mm IS Sieve and is retained on a 10 mm IS Sieve. The aggregate comprising the test sample shall be dried in an oven for a period of four hours at a temperature of 100 to 110 ºC and cooled.
2. The measure shall be filled about one-third full with the aggregate and tamped with 25 strokes of the rounded end of the tamping rod.
3. Further similar quantity of aggregate shall be added and a further tamping of 25 strokes given. The measure shall finally be filled to overflowing, tamped 25 times and the surplus aggregate struck off, using the tamping rod as a straight-edge.
4. The net weight of aggregate in the measure shall be determined to the nearest gram (Weight A) and this weight of aggregate shall be used for the duplicate test on the same material.

<u>Experimental Procedure:</u>

1. The impact machine shall rest without wedging or packing upon the level plate, block or floor, so that it is rigid and the hammer guide columns are vertical.
2. The cup shall be fixed firmly in position on the base of the machine and the whole of the test sample placed in it and compacted by a single tamping of 25 strokes of the tamping rod.
3. The hammer shall be raised until its lower face is 380 mm above the upper surface of the aggregate in the cup, and allowed to fall freely on to the aggregate. The test sample shall be subjected to a total of 15 such blows each being delivered at an interval of not less than one second.
4. The crushed aggregate shall then be removed from the cup and the whole of it sieved on the 2.36 mm IS Sieve until no further significant amount passes in one minute.
5. The fraction passing the sieve shall be weighed to an accuracy of 0.1 g (Weight B). The fraction retained on the sieve shall also be weighed (Weight C) and, if the total weight (B+C) is less than the initial weight (Weight A) by more than one gram, the result shall be discarded, and a fresh test made.
6. Two tests shall be conducted.

OBSERVATIONS AND CALCULATION:

Sample No.	Weight *A*	Weight *B*	Aggregate impact value	Avg. Aggregate impact value
1				
2				

The ratio of the weight of fines formed to the total sample weight in each test shall be expressed as a percentage, the result being recorded to the first decimal place:

$$Aggregate\ impact\ value\ = \frac{B}{A} \times 100$$

Where, B = weight of fraction passing 2.36 mm IS Sieve, and A = weight of oven-dried sample.

The mean of the two results shall be reported to the nearest whole number as the aggregate impact value of the tested material.

RESULTS:

1. Average Aggregate impact value of aggregate sample 1 (%) =

2. Average Aggregate impact value of aggregate sample 2 (%) =

QUESTIONS:

1. How aggregate impact value is expressed?
2. How does toughness differ from compressive strength?
3. Aggregate impact value material A is 20 and that of B is 45. Which one is better surface course and why?
4. Which test simulates the field conditions better, aggregate crushing value test or impact value test?

EXPERIMENT NO. III - Test on aggregate: Los Angeles abrasion test

AIM: To determine the abrasion value of given aggregate sample by conducting Los Angeles abrasion test.

THEORY: Abrasion is a measure of resistance to wear or hardness. It is an essentially property for road aggregates especially when used in wearing coarse. Due to the movements of traffic, the road stones used in the surfacing course are subjected to wearing actions at the top. When traffic moves on the road the soil particle (sand) which comes between the wheel and road surface causes abrasion on the road stone. The abrasion test on aggregate is found as per I.S.-2386 part IV.

Abrasion tests on aggregates are generally carried out by any one of the following methods- (i). Los Angeles abrasion test. (ii). Deval abrasion test. (iii). Dorry abrasion test.

Los Angeles Abrasion Test: The principle of Los Angeles abrasion test is to find the percentage wear due to the relative rubbing action between the aggregates and steel balls used as abrasive charge pounding action of these balls also exist while conducting the test. Maximum Allowable Los Angeles Abrasion Values of Aggregates in Different types of pavement layers as per Indian Road Congress (IRC) are: -

1. For sub-base course a value of 60%. For base course such as WBM, Bituminous Macadam (B.M.), Built – Up spray grout base course and etc. value of 50%.
2. For surface course such as WBM, BM, Bituminous Penetration Macadam, Built-Up spray grout binder course and etc. a value of 40%.
3. If aggregates are used in surface course as bituminous carpet, bituminous surface dressing, single or two coats, cement concrete surface course and etc. a value of 35%.
4. If aggregates are used for bituminous concrete, Cement concrete pavement as surface coarse than aggregate abrasion value of 30% maximum.

APPARATUS:

1. Los Angeles machine with inside diameter 70cm and inside length of 50cm.
2. Abrasive charges having diameter 4.8cm and weight 390 to 445 gm.
3. I.S Sieve with 1.7 mm opening.
4. Weighting Balance of 0.1gm accuracy.
5. Metallic Tray

PROCEDURE:

1. Clean and dry aggregate sample confirming to one of the grading A to G is used for the test. (Refer Table 1).
2. Aggregates weighing 5 kg for grading A, B, C or D and 10 kg for grading E, F or G may be taken as test specimen and placed in the cylinder.
3. The abrasive charge is also chosen in accordance with table no.1 and placed in the cylinder of the machine, and cover is fixed to make dust tight.
4. The machine is rotated at a speed of 30 to 33 revolutions per minute.
5. The machine is rotated for 500 revolutions for grading A, B, C and D, for grading E, F and G, it shall be rotated for 1000 revolutions.
6. After the desired number of revolutions, the machine is stopped, and the material is discharged from the machine taking care to take out entire stone dust.
7. Using a sieve of size larger than 1.70 mm I.S sieve, the material is first separated into two parts and the finer position is taken out and sieved further on a 1.7 mm I.S sieve.
8. Let the original weight of aggregate be *W1* g, weight of aggregate retained on 1.70 mm I.S sieve after the test be *W2* g.

OBSERVATIONS AND CALCULATION:

Table 1. Aggregate Gradation and corresponding abrasive charge

Grading	Weight in grams of each test sample in the size range, mm (Passing and retained on square holes)										Abrasive Charge	
	80-63	63-40	50-40	40-25	25-20	20-12.5	12.5-10	10-6.3	6.3-4.75	4.75-2.36	No. of spheres	Weight of charge
A				1250	1250	1250	1250				12	5000+/-25
B						2500	2500				11	4584+/-25
C								2500	2500		8	3330+/-20
D										5000	6	2500+/-15
E	2500	2500	5000								12	5000+/-25
F			5000	5000							12	5000+/-25
G				5000	5000						12	5000+/-25

Sl.No	Details of sample	Observations	
		1	2
1	Weight of specimen= W_1 g		
2	Weight of specimen retain on 1.7 mm IS Sieve after abrasion test = W_2 g		
3	Los Angeles abrasion value		
4	Mean value		

$$\text{Los Angeles abrasion value } \% = \frac{W1 - W2}{W1} \times 100$$

RESULTS:

Los Angeles abrasion value (%) =

QUESTIONS:

1. How does impact occur in Los Angeles abrasion test?
2. How is Los Angeles abrasion value expressed?
3. Sample A and B have Los Angeles abrasion value is 15 and 30 respectively which sample is harder?

EXPERIMENT NO. IV - Test on aggregate: Specific gravity test

AIM: To determine the specific gravity of a given aggregate sample.

THEORY: Specific gravity is defined as the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. It is a measure of the density of the aggregate compared to the density of water. Specific gravity is an important property of aggregates used in construction, as it provides information about the quality and strength of the material. The specific gravity test on aggregate is found as per I.S.-2386 part III.

APPARATUS:

a) Balance, sensitive to 0.01 g
b) Pycnometer
c) Funnel
d) Graduated jar
e) Water tank
f) Tray
g) Cloth for drying the sample

PROCEDURE:

1. Take a clean, dry pycnometer and determine its weight (W1).
2. Fill the pycnometer about one-third full with the dry aggregate sample.
3. Weigh the pycnometer with the aggregate (W2).
4. Fill the pycnometer with water up to the calibration mark, ensuring no air bubbles are present.
5. Weigh the pycnometer with the aggregate and water (W3).
6. Empty the pycnometer and fill it completely with water up to the calibration mark. Weigh it (W4).
7. Calculate the specific gravity using the formula.

OBSERVATIONS AND CALCULATION:

Description	Weight (g)
Weight of pycnometer (W1)	
Weight of pycnometer + aggregate (W2)	

Weight of pycnometer + aggregate + water (W3)	
Weight of pycnometer + water (W4)	

$$Specific\ Gravity = \frac{(W2 - W1)}{(W2 - W1) - (W3 - W4)}$$

RESULTS:

The specific gravity of the given aggregate sample is ________.

QUESTIONS:

1. Why is specific gravity an important property for aggregates in construction?
2. How does the presence of air bubbles affect the specific gravity test?
3. What is the significance of using a specific gravity bottle in this test?

EXPERIMENT NO. V - Test on aggregate: Water absorption test

AIM: To determine the water absorption of coarse aggregates as per IS: 2386 (Part III) - 1963.

THEORY: Water absorption is the measure of the amount of water that an aggregate can absorb. It is an essential property of aggregates used in construction, as it provides information about the porosity and durability of the material. Water absorption is expressed as a percentage of the dry weight of the aggregate.

APPARATUS:

a) Wire basket - perforated, electroplated, or plastic coated with wire hangers for suspending it from the balance
b) Water-tight container for suspending the basket
c) Dry soft absorbent cloth - 75 cm x 45 cm (2 nos.)
d) Shallow tray of minimum 650 sq.cm area
e) Air-tight container of a capacity similar to the basket
f) Oven

PROCEDURE:

1. A sample not less than 2000 g should be used.
2. Thoroughly wash the sample to remove finer particles and dust, drain it, and then place it in the wire basket.
3. Immerse the wire basket with the aggregate in distilled water at a temperature between 22°C and 32°C.
4. After immersion, remove the entrapped air by lifting the basket and allowing it to drop 25 times in 25 seconds.
5. Keep the basket and sample immersed for a period of 24 ± ½ hours.
6. Remove the basket and aggregates from the water, allow it to drain for a few minutes, then gently empty the aggregates onto one of the dry cloths and gently surface-dry them with the cloth, transferring them to a second dry cloth when the first one removes no further moisture.
7. Spread the aggregates on the second cloth and expose them to the atmosphere away from direct sunlight until they appear to be completely surface-dry.
8. Weigh the aggregates (Weight 'A').

9. Place the aggregates in an oven at a temperature of 100°C to 110°C for 24 hours.
10. Remove the aggregates from the oven, cool them, and weigh them again (Weight 'B').

OBSERVATIONS AND CALCULATION:

Sl No	Determination No	I	II	III
1	Weight of saturated surface-dried sample in g (A)			
2	Weight of oven dried sample is g (B)			
3	Water absorption $= \frac{A-B}{B} \times 100\%$			
Average value				

$$Water\ absorption = \frac{A-B}{B} \times 100\%$$

RESULTS:

Water absorption of the given aggregate sample = ________%

QUESTIONS:

1. Why is water absorption an important property for aggregates in construction?
2. How does the presence of finer particles affect the water absorption test?
3. What is the significance of using distilled water and maintaining a specific temperature range during the test?

EXPERIMENT NO. VI - Tests on bitumen: Penetration test.

AIM: To determine the penetration value of the given bitumen sample.

THEORY: Various types and grades of bituminous materials are available for use in road making. One of the ways of grading bitumen is in terms of its penetration value. Penetration grading system of bitumen has been replaced in India by viscosity grading. However, penetration test remains to be an important test which is retained in many binder specifications. The penetration test determines the consistency of bituminous binders for the purpose of grading them and for the purpose of giving an indication of the expected performance. Penetration is determined by measuring the depth (in units of one tenth of a millimetre) to which a standard needle with the needle assembly weighing 100 gm will penetrate vertically at 25 ˚C standard temperature in 5 seconds of standard duration. The softer the bitumen, the larger will be the penetration. The penetration grades of bitumen are generally designated as 80/100, 60/70, or 30/40 grade bitumen. 80/100 bitumen indicates that the penetration value of binder ranges from 8 mm to 10 mm.

APPARATUS:

1. Penetrometer
2. Sample cup
3. Water bath for maintaining a temperature of 25˚C.
4. Thermometer
5. Specified needle
6. Stop watch

PROCEDURE:

1. Pour the bitumen sample into the container of 35 mm depth.
2. Cool in atmosphere at a temperature between 15-30 ˚C for 60 to 90 minutes.
3. Place the container in the water bath maintained at a temperature of 25 ˚C for 60 to 90 minutes.
4. Place the sample under the penetrometer and adjust the screw so that the tip of needle just touches the surface of the bitumen sample.
5. Take the initial reading and press the knob for 5 seconds. Take the final reading.
6. Make at least three such measurements.

OBSERVATIONS AND CALCULATION:

Observations	Sample A			Sample B		
	Initial Reading	Final Reading	Penetration	Initial Reading	Final Reading	Penetration
1						
2						
3						
4						
5						
6						
Average	For Sample A			For Sample B		

RESULTS:

1. The average penetration value of Sample A =
2. The average penetration value of Sample B =

QUESTIONS:

1. Which property of bitumen is related to penetration value?
2. The penetration value of binder is 65; what is the distance in mm which the needle has penetrated through?
3. What does an 80/100 grade bitumen indicate?
4. Which bitumen grades are commonly used in warmer regions and why?

EXPERIMENT NO. VII - Tests on bitumen: Ductility test

AIM: To determine the ductility value of the given bitumen sample.

THEORY: In the flexible pavement construction where bitumen binders are used, it is of significance that the binders form ductile film around the aggregate. The binder material which does not possess sufficient ductility would crack when flexed or elongated. Ductility is expressed as the distance in centimetres to which a standard briquette of bitumen can be stretched before the thread breaks. The test is conducted at 27 º C +/- 0.5 º C at a rate of pull of 50 +/- 2.5 mm per minute.

APPARATUS:

1. Ductility machine
2. Briquette mould
3. Knife

PROCEDURE:

Sample Preparation:

1. Apply grease on the glass plate.
2. Arrange the end pieces and side pieces of the briquette mold on the glass plate. Apply grease on the insides of the side pieces of the mold.
3. Heat the bitumen sample to a pouring consistency and carefully pour it into the mold.

Experimental Procedure:

1. Allow the sample to cool in air for about 30 to 40 minutes.
2. Immerse the mold with the plate in a water bath maintained at 27°C for 30 minutes.
3. Take out the mold and cut off excess bitumen, if any, with a sharp hot knife.
4. Replace the mold back in water for 85 to 90 minutes at 27°C.
5. With the help of a hot knife, remove the side pieces of the mold and separate the sample from the plate.
6. Carefully place the sample in the ductility machine on the plate provided. Fix the ends of the mold to the plate.
7. Note the initial reading on the scale provided on the machine. It should be 0 (zero).

8. Start the ductility machine. The sample stretches and a thread is formed in the middle. The sample stretches at a uniform rate of 50 ± 2.5 mm per minute.
9. The thread formed in the middle breaks after some distance. The distance up to which the sample stretches before the thread breaks is recorded as the ductility value.

OBSERVATIONS AND CALCULATION:

Test Parameter	Sample No.			Average (cm)
	1	2	3	
Ductility (cm)				

RESULTS:

The average ductility value of the given sample of bitumen = _____cm

QUESTIONS:

1. How is ductility value expressed?
2. How will be the ductility value affected if the test temperature is more than the specified one?
3. What are the precautions to be taken while finding ductility value?

EXPERIMENT NO. VIII - Tests on bitumen: Stripping test

AIM: To determine the stripping value of aggregates used in road construction; ascertain the suitability of road aggregates for bituminous road construction.

THEORY: This test is conducted to determine the effects of moisture upon adhesion of the bituminous film to the surface particles of the aggregate. This test is of significant value to ascertain the suitability of the two materials i.e., bitumen and aggregates, because one particular aggregate may be satisfactory with one binder and unsatisfactory with another: and the same being true for the binders. The specifications of ministry of the transport and shipping recommend the determination of stripping value by the static immersion method.

APPARATUS:

1. Thermostatically controlled water bath
2. Beakers of capacity 500 ml

PROCEDURE:

1. Obtain the material that passes through 25mm sieve and is retained on 12.5mm sieve.
2. Dry, clean and heat the binder and aggregates to 150 to 175 0C and 120-150 0C respectively and mix with 5 percent binder by weight of aggregate.
3. After complete coating, allow the mixture to cool at room temperature in a clean dry beaker.
4. Add distilled water to immerse the coated aggregates.
5. Cover the beaker and keep it undisturbed in a thermostatic water bath at a temperature of 40 C for a period for 24 hrs.
6. Estimate the extent of stripping by visual examination while the specimen is still under water and express as the average percent area of aggregate surface uncoated.

OBSERVATIONS AND CALCULATION:

Observation and calculations:

	Sample 1	Sample 2	Sample 3
Percentage of area of aggregate uncoated by immersion in water			
Average Stripping value			

PRECAUTIONS:

1. The aggregates should be thoroughly dried before mixing the binder.
2. Distilled water should be used for the test. 3. Mix – up of the two separate samples should be uniform.

RESULTS:

Stripping value of the given sample =

QUESTIONS:

1. Two aggregates A and B have stripping value of 20% and 30 % when used with the same bitumen; which is preferable and why?
2. How will the stripping value be effected in case the aggregate are not fully dried?

EXPERIMENT NO. IX - Tests on bitumen: Softening point test

AIM: To determine the softening point of the given bitumen sample.

THEORY: The Softening Point of bitumen or tar is the temperature at which the substance attains particular degree of softening. As per IS: 334-2002, it is the temperature in ºC at which a standard ball passes through a sample of bitumen in a mould and falls through a height of 2.5 cm, when heated under water or glycerine at specified conditions of test. The binder should have sufficient fluidity before its applications in road uses. The determination of softening point helps to know the temperature up to which a bituminous binder should be heated for various road use applications. Softening point is determined by ring and ball apparatus.

APPARATUS:

1. Ring & Ball apparatus
2. Water bath
3. Stirrer
4. Thermometer
5. Beaker
6. Heating device etc.

PROCEDURE:

1. Preparation of test sample: Heat the material to a temperature between 75-100 ° C above its softening point; stir until it is completely fluid and free from air bubbles and water. If necessary, filter it through IS sieve 30. Place the rings on a metal plate which has been coated with a mixture of equal parts of glycerine and dextrin. After cooling for 30 minutes in air, level the material in the ring by removing the excess material with a warmed, sharp knife.
2. Assemble the apparatus with the rings, thermometer and ball guides in position.
3. Fill the bath with distilled water to a height of 50mm above the upper surface of the rings. The starting temperature should be 5 °C.
4. Apply heat to the bath and stir the liquid so that the temperature rises at a uniform rate of 5 ± 0.5 °C per minute.
5. As the temperature increases the bituminous material softens and the balls sink through the rings carrying a portion of the material with it.

6. Note the temperature when any of the steel balls with bituminous coating touches the bottom plate.

OBSERVATIONS AND CALCULATION:

Observations and Calculation:

Bitumen Sample	Identification of Sample (Grade of bitumen)	Temperature (^{0}C)		
		Ball 1	Ball 2	Average
A				
B				

RESULTS:

The Softening Point Temperatures of the given samples of Bitumen are: -

(a) Sample A =

(b) Sample B =

QUESTIONS:

1. What is the importance of determination of softening point in road construction operations?

2. What are the criteria of selection of medium used for heating the specimen?

3. What are the factors, which may affect the ring and ball test results.

EXPERIMENT NO. X - Tests on bitumen: Flash and fire point test

AIM: To determine the flash and fire point of given bitumen samples by Pensky-Martens closed tester.

THEORY: Need and Scope: Bituminous materials leave out volatiles at high temperatures depending upon their grade. These volatile catch fire causing a flash. This condition is very hazardous, and it is therefore essential to qualify this temperature for each bitumen grade.

FLASH POINT: the flash point of a material is the lowest temperature at which the vapour of the substance momentarily takes fire in the form of flash under specified condition of test.

FIRE POINT: The fire point is the lowest temperature at which the material gets ignited and burns under specified condition of test.

APPARATUS:

1. Pensky-Martens closed tester consisting of cup, lid, stirrer, shutter, flame exposure device.
2. Thermometer (0-350o C) with sensitivity of 0.1o C.

PROCEDURE:

1. The material is filled in the cup up to a filling mark.
2. The lid is placed to close the cup in a closed system. All accessories including thermometer of the specified range are suitably fixed.
3. The bitumen sample is then heated. The flame is lit and adjusted in such a way that the size of a bleed is of 4mm diameter.
4. The heating is done at the rate of 5o C to 6o C per minute.
5. The stirring is done at the rate of approximately 60 revolutions per minute.
6. The test flame is applied at intervals depending upon the expected flash and fire points.
7. First application is made at least 17o C below the actual flash point and then at every 1 o C to 3o C.
8. The stirring is discontinued during the application of the test flame.

OBSERVATIONS AND CALCULATION:

Observations and Calculation:

Sl. No	Description	Test-01	Test-02	Test-03	Test-04	Mean value
1	Grade of bitumen					
2	Rate of heating time (min)					
3	Temperature					
4	Flash point					
5	Fire Point					

RESULTS:

Flash point of the sample =

Fire point of the sample =

QUESTIONS:

1. What is the utility of determination of flash point?
2. Should a good binder possess higher flash point?
3. What are the flash and fire points?

EXPERIMENT NO. XI - Tests on bitumen: Viscosity test

AIM: To determine the viscosity of given bitumen sample by Tar Viscometer.

THEORY: Viscosity is defined as inverse of fluidity. Viscosity thus defines the fluid property of bituminous material. The degree of fluidity at the application temperature greatly influences the ability of bituminous material to spread, penetrate into the voids and also coat the aggregates and hence affects the strength characteristics of the resulting paving mixes.

APPARATUS:

Tar Viscometer with 4mm and 10mm orifices – The apparatus consists of main parts like cup, valve, water bath, sleeves, stirrer, receiver, and thermometer etc.

PROCEDURE:

1. The tar cup is properly levelled and water in the bath is heated to the temperature specified for the test and is maintained throughout the test. Stirring is also continued.
2. The sample material is heated at the temperature 200C above the specified test temperature, and the material is allowed to cool. During this the material is continuously, stirred.
3. When material reaches slightly above test temperature, the same is poured in tar cup, until the levelling peg on the valve rod is just immersed. In the graduated receiver (cylinder), 25ml of mineral or one percent by weight solution of soft soap is poured. The receiver is placed under the orifice.
4. When the sample material reaches the specified testing temperature within +/- 0.10C and is maintained for five minutes, the valve is opened.
5. The stopwatch is started, when cylinder records 25ml. The time is recorded for flow up to a mark of 75ml (i.e., 50ml of test sample to flow through the orifice).

OBSERVATIONS AND CALCULATION:

Sl. No.	Description	Test - 1	Test - 2	Mean value
1.	Specified Test Temp. ^{0}C	60 ^{0}C	60 ^{0}C	
2.	Size of Orifice in mm			
3.	Viscosity in Seconds			

RESULTS:

The average viscosity value of the given sample of bitumen:

QUESTIONS:

1. What do you understand by viscosity?

2. How is strength of bituminous road affected by the viscosity of binder?

EXPERIMENT NO. XII - Test on soil: California Bearing Ratio of soil

AIM: To determine the California Berating Ratio (CBR) of the given soil sample.

THEORY: California Bearing Ratio (CBR) is defined as the ratio, expressed as a percentage, of the force per unit area required to penetrate a soil mass with a circular plunger of 50 mm diameter at a rate of 1.25 mm/min to that required for corresponding penetration in a standard material. Tests are performed on natural or compacted soils in water-soaked or unsoaked conditions, and the results obtained are compared with the curves of the standard test.

APPARATUS:

1. CBR mold with detachable perforated base plate
2. Spacer disc with a removable handle (to be placed inside the mold)
3. Collar of 50 mm high
4. Penetration plunger of 50 mm diameter
5. One annular and a few slotted surcharge masses of 2.5 kg each
6. Rammer (2.6 kg with 310 mm drop for standard Proctor results) and (4.89 kg with 450 mm drop for modified Proctor results)
7. Straight cutting edge
8. Loading machine of 50 kN capacity fitted with a calibrated proving ring to which the plunger has to be attached
9. Penetration measuring dial gauge of 0.01 mm accuracy
10. Soaking tank
11. Swelling gauge consisting of perforated plate with adjustable extension stem

Mold Specification:

Diameter of the mold: 150 mm

Height of the mold: 175 mm

Height of the CBR soil specimen: 125 mm

Soil Specification:

Particle size: should pass through a 19 mm sieve

Soil particles of size greater than 19 mm should be replaced by particles of size between 4.75 mm and 19 mm.

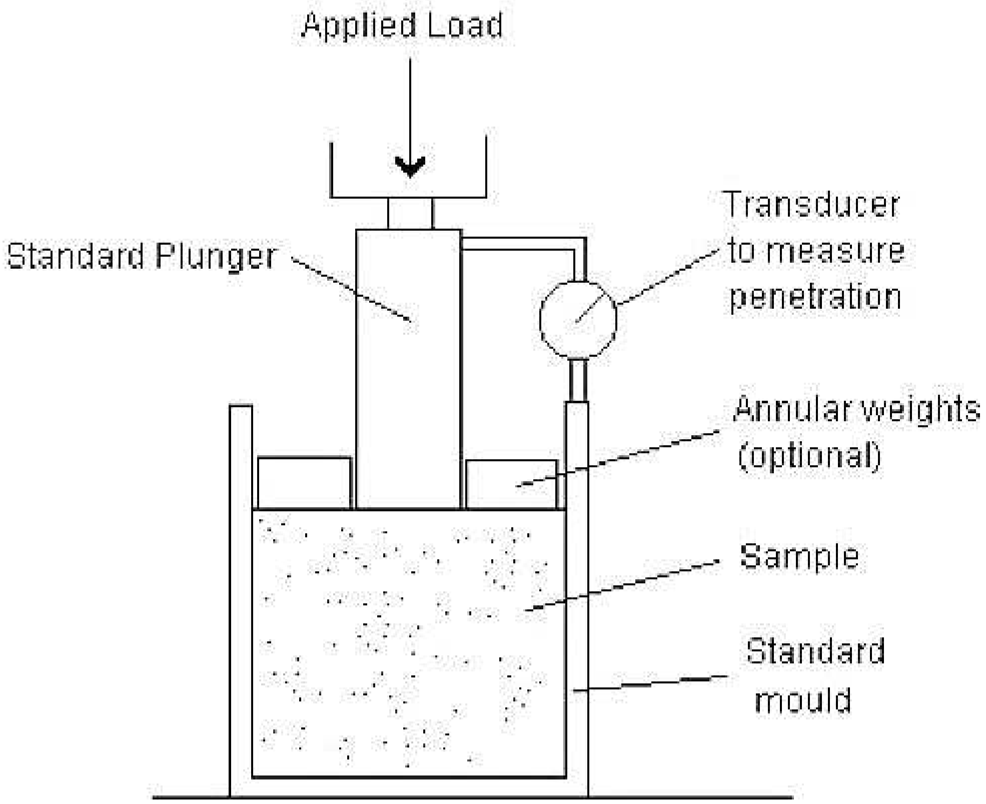


Figure: CBR Apparatus

PROCEDURE:

1. Take the weight of the empty mold.
2. Keep the spacer disc on the base plate and a filter paper on the disc and fix the mold to the base plate with the disc inside the mold. Attach the collar over the mold.
3. Add water to the specimen and compact it in accordance with the Standard Proctor test or Modified Proctor test.
4. After compaction, remove the collar and level the surface using a cutting edge.
5. Detach the base plate and remove the spacer disc.
6. Take the weight of the mold with the compacted specimen and determine the bulk density of the specimen.
7. Take a sample for moisture content determination and find the dry density.
8. Place a filter paper on the perforated base plate.

9. Fix the mold upside down to the base plate so that the surface of the specimen which was downwards in contact with the spacer disc during compaction is now turned upwards on which the penetration test is to be performed (for unsoaked condition).
10. For soaked condition, fix the adjustable stem and perforated plate on the compacted soil specimen in the mold along with a 2.5 kg surcharge load.
11. Place the above setup in the soaking tank for four days (ignore this step in the case of unsoaked CBR).
12. After four days, measure the swell reading and find the percentage swell with the help of the dial gauge reading.
13. Remove the mold from the tank and allow the water to drain.
14. Place the specimen under the penetration piston and place a total surcharge load of 4 kg (2.5 kg during soaking + 1.5 kg during testing).
15. Set the load and deformation gauges to zero.
16. Apply load to the plunger into the soil at a rate of 1.25 mm per minute.
17. Record the load readings at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 4.0, 5.0, 7.5, 10.0, and 12.5 mm.
18. Remove the plunger and determine the water content of the soil.
19. Plot the load versus deformation curve.

IRC-37 Specifications:

Subgrade: The CBR values for subgrade should range from 2% to 10%. Preferably, it should be greater than 2%. If the CBR value is less than 2%, a soil capping layer of 150 mm thickness, having a CBR value greater than or equal to 10%, should be provided between subgrade and sub-base. The subgrade should be compacted to 97% of the maximum dry density achieved with heavy (modified Proctor) compaction. The dry density obtained should not be less than 1.75 g/cc for expressways, national highways, state highways, major district roads, and other heavily trafficked roads. In other cases, the subgrade should be compacted to at least 97% of the standard Proctor density.

Sub-base: The sub-base soil should have a liquid limit of less than 25% and a plasticity index of less than 6%. For cumulative traffic up to 2 msa (million standard axles), the CBR value should not be less than 20%. For cumulative traffic greater than 2 msa, the CBR value should not be less than 30%.

Note: The CBR test is performed for both soaked and unsoaked soil specimens. Usually, the unsoaked CBR value will be greater than the CBR value for soaked conditions. The CBR values for unsoaked specimens are suitable for (i) arid regions, (ii) where comparatively thick bituminous surfacing of an impermeable nature is provided on top, and where the water table is very deep. For other cases, soaked CBR results are preferred.

OBSERVATIONS:

Table: Observations - Unsoaked condition

Maximum dry density of the specimen to be prepared		g/cc
Optimum moisture content to be taken		%
Weight of the empty mould		g
Weight of the soil specimen and mould before soaking		g
Volume of the soil specimen		cm^3
Bulk density of the specimen		g/cc
Water content of the specimen		%
Dry density of the specimen		g/cc
Diameter of plunger		cm
Area of plunger		sq.cm
Deformation rate		mm/minute
Proving ring constant		kN/division
Standard pressure for 2.5mm penetration		kg/cm^2
Standard pressure for 5mm penetration		kg/cm^2

Dial gauge reading in divisions	Penetration in mm	Load in division	Load in kN	Pressure in kg/cm^2	CBR (after correction)
0					
50					
100					
150					
200					
250					
400					
500					
750					
1000					
1250					

Table: Observations - Soaked condition

Maximum dry density of the specimen to be prepared		g/cc
Optimum moisture content to be taken		%
Weight of the empty mould		g
Weight of the soil specimen and mould before soaking		g
Volume of the soil specimen		cm^3
Bulk density of the specimen		g/cc
Water content of the specimen		%
Dry density of the specimen		g/cc
Weight of the soil specimen and mould after soaking for 96 hours		g
Weight gain due to absorption of water		g
Diameter of plunger		cm
Area of plunger		sq.cm
Deformation rate		mm/minute
Proving ring constant		kN/division
Standard pressure for 2.5mm penetration		kg/cm^2
Standard pressure for 5mm penetration		kg/cm^2

Dial gauge reading in divisions	Penetration in mm	Load in division	Load in kN	Pressure in kg/cm^2	CBR (after correction)
0					
50					
100					
150					
200					
250					
400					
500					
750					
1000					
1250					

CALCULATION:

<u>Expansion ratio</u>

$$Expansion\ ratio = \frac{df - ds}{h} \times 100$$

Where,

df=final dial gauge reading in mm(after 96 hrs),

ds=initial dial gauge reading in mm, and

h=initial height of the specimen in mm

California bearing Ratio (CBR):

$$CBR = \frac{PT}{PS} \times 100$$

Where,

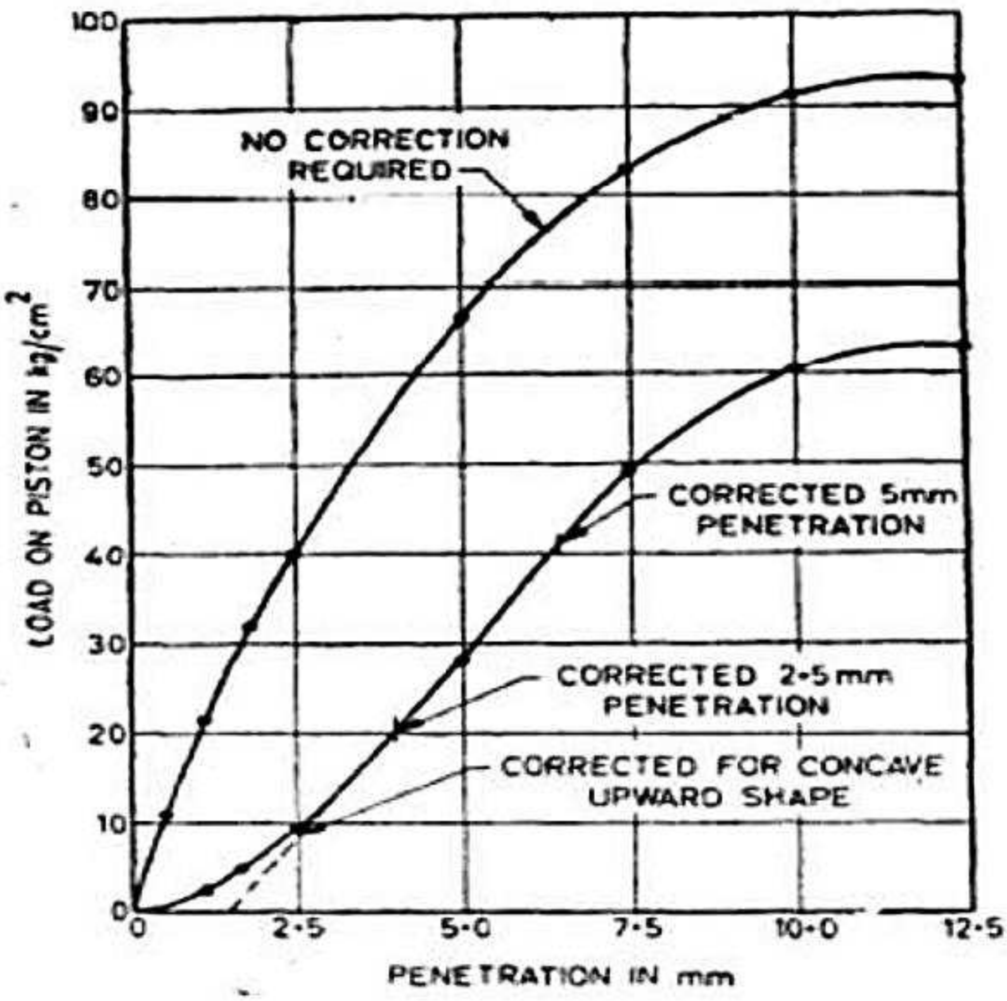
PT = corrected unit (or total) test load corresponding to the chosen penetration from the load penetration curve

PS = unit (or total) standard load for the same depth of penetration as for PT taken from the table given below.

Penetration depth (mm)	Unit standard load (kg/cm^2)	Total standard load (kgf)
2.5	70	1370
5.0	105	2055

Generally, the CBR value at 2.5 mm penetration will be greater than that at 5 mm penetration, and in such a case, the former shall be taken as the CBR value for design purposes. If the CBR value corresponding to a penetration of 5 mm exceeds that for 2.5 mm, the test shall be repeated. If identical results follow, the CBR corresponding to 5 mm penetration shall be taken for design.

Corrections in load vs. deformation curve: The curve plotted may be convex upwards, although the initial portion of the curve may be concave upwards due to surface irregularities. A correction shall then be applied by joining the tangent to the curve at the point of maximum slope. The corrected curve shall be taken to be this tangent, together with the convex portion of the original curve, with the origin of strains shifted to the point where the tangent cuts the horizontal axis for penetration.



RESULTS:

CBR of the given soil sample = _____%

QUESTIONS:

1. Why is it important to compact the soil specimen in accordance with the Standard Proctor test or Modified Proctor test before conducting the CBR test?
2. Explain the significance of soaking the compacted soil specimen for four days and how it affects the CBR value. What are the implications of using soaked versus unsoaked CBR values?
3. How do you determine the bulk density and dry density of the soil specimen, and why are these measurements important in the context of the CBR test?
4. Describe the procedure for conducting the penetration test on the soil specimen. What is the purpose of recording the load readings at various penetrations, and how do you use these readings to plot the load versus deformation curve?

EXPERIMENT NO. XIII - Traffic studies: Manual Method For Traffic Volume Study

AIM: To conduct a traffic volume study and to determine different volume statistics for a particular road section.

THEORY: In this method, vehicles are counted manually. There are two methods of manual counting:

1. Direct method
2. Indirect method

Direct Method: In this method, data is recorded using a hand tally on the observation sheets.

Advantages:

- Traffic volume, as well as vehicle classification, can be obtained.
- Data can be used immediately after collection.

Disadvantages:

- This method is not practical for long-duration counts and when the traffic flow is high.
- The counts cannot be cross-checked, increasing the probability of errors.
- This method is very difficult when the volume is high and/or there are three or more traffic lanes.
- The counts cannot be recorded in bad weather.

Indirect Method: In this method, data is collected using a video camera. The video is captured for a particular duration and data is retrieved and entered into the observation sheets later by rewinding.

Advantages:

- Besides traffic volume, several traffic parameters can be obtained from the recorded film.
- Data can be cross-checked and quality can be ensured.
- Applicable when the volume is high.
- Suitable for non-lane-based traffic operation.

Disadvantages:

- Data cannot be used immediately after collection.
- This process is time-consuming and tedious.
- Not suitable for very long-duration counts.

APPARATUS:

1. Observation sheets
2. A stopwatch
3. Video camera (in case of indirect methods)

PROCEDURE:

1. First, a section of the road is to be selected according to the guidelines, and all necessary lab preparations are to be completed in advance.
2. Traffic volume is a unidirectional study. Therefore, it is more desirable to record traffic in each direction of travel and keep separate observers for each direction.
3. The number of observers required to count the vehicles depends on the number of lanes and the type of information required.
4. The time slots and number of shifts could vary depending on the members of the field team. For example, for all-day counts, work in three shifts of 8 hours each could be organized.
5. Data is to be recorded on tally sheets/field data observation sheets. First, the observer records the date, location, weather condition, direction, and time of the study. One or more sheets may be required for observing and recording the traffic data.
6. The observer counts the vehicles and records observations in the respective vehicle-type column with the help of hand tallies called the Five-Dash system (vertical strokes for the first four vehicles followed by an oblique for the fifth vehicle, depicting a total of five) for each count interval, mostly 15 minutes.
7. Data is collected for each type of vehicle and filled in tally sheets for the whole time of the study.
8. Calculate the hourly volume (vehicles/hour). Volume can be expressed as Average Daily Traffic (ADT) and Annual Average Daily Traffic (AADT) depending on the data recorded.
9. Also, determine the peak rate of flow and Peak Hour Factor (PHF) during both peak and off-peak periods for data recorded in the field.

Observation Table

Classified Traffic Volume Count Study for Mid-Block Section

<table>
<tr><td colspan="9">Name of the Road:</td><td colspan="6">Day & date:</td></tr>
<tr><td colspan="9">Section from: to:</td><td colspan="6">Hour:</td></tr>
<tr><td colspan="9">Location:</td><td colspan="6">Weather:</td></tr>
<tr><td colspan="9">Direction: Sheet No.:</td><td colspan="6">Name of the observer(s):</td></tr>
<tr><td></td><td colspan="9">FAST MOVING VEHICLES</td><td colspan="5">SLOW MOVING VEHICLES</td></tr>
<tr><td rowspan="2">Vehicle Type / Time</td><td rowspan="2">Two-Wheeler</td><td rowspan="2">Three Wheeler</td><td rowspan="2">Four Wheeler</td><td colspan="2">Bus</td><td rowspan="2">LCV</td><td colspan="2">Truck</td><td rowspan="2">Cycle</td><td rowspan="2">Cycle Rickshaw</td><td colspan="2">Animal Drawn</td><td rowspan="2">Others</td></tr>
<tr><td>Mini</td><td>Full</td><td>2-Axle</td><td>Multi-Axle</td><td>Bullock cart</td><td>Horse</td></tr>
<tr><td>00-15</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>15-30</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>30-45</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>45-60</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>TOTAL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>PCU Factor</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>TOTAL PCU</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

OBSERVATIONS AND CALCULATION:

$$PCU, vehicles = Number\ of\ vehicles\ X\ PCU\ factor$$

$$volume = \frac{total\ no.of\ vehicles}{total\ time}\ PCU/hr$$

$$volume = \_\_\_\_\_\_\_\_ PCU/hr$$

$$Peak\ hour\ factor = \frac{total\ hourly\ voluem}{(4\ \times maximum\ 15\ minutevolume\ within\ the\ hour)}$$

$$Peak\ hour\ factor = \_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

RESULTS:

Traffic volume =

Peak hour factor =

Plot traffic volume in PCU vs Time in hours line graph.

QUESTIONS:

1. What are the key differences between the direct and indirect methods of manual vehicle counting?
2. How do you ensure the accuracy and reliability of the data collected using the Five-Dash system?
3. Why is it important to record traffic volume separately for each direction of travel?
4. How do you calculate the Average Daily Traffic (ADT) and Annual Average Daily Traffic (AADT) from the collected data?

EXPERIMENT NO. XIV - Traffic studies: Spot Speed Study by Pavement Marking Method

AIM: To conduct a spot speed study, develop a cumulative frequency speed distribution curve and calculate various statistical measures.

THEORY: The speed survey is done to determine the speed that drivers select, unaffected by the existence of congestion. This information is used to determine general speed trends, help determine reasonable speed limits, and assess safety. The speed of travel on the road is also used in classifying routes. The level of service based on speed is an indicator of the quality of traffic flow or mobility. The pavement marking method can be used to successfully complete a spot speed study using a small sample size taken over a relatively short period of time. It is a quick and inexpensive method for collecting speed data but a relatively inaccurate method. To calculate vehicle speed, we use the predetermined study length known as trap length and the elapsed time it takes for the vehicle to move through the test section in the following formula:

$$V = \frac{D}{T}$$

Where, V = speed (m/s), D = distance between two sections (m), and T = time elapsed between two sections (sec). Using the recommended study lengths based on the average speed of the traffic stream, the speed calculations become straightforward and less confusing.

Table: Recommended Trap length for spot speed studies

Traffic stream average speed (miles/hr)	Recommended study length (feet)
Below 25	88-100
25-40	176-200
Over 40	264-300

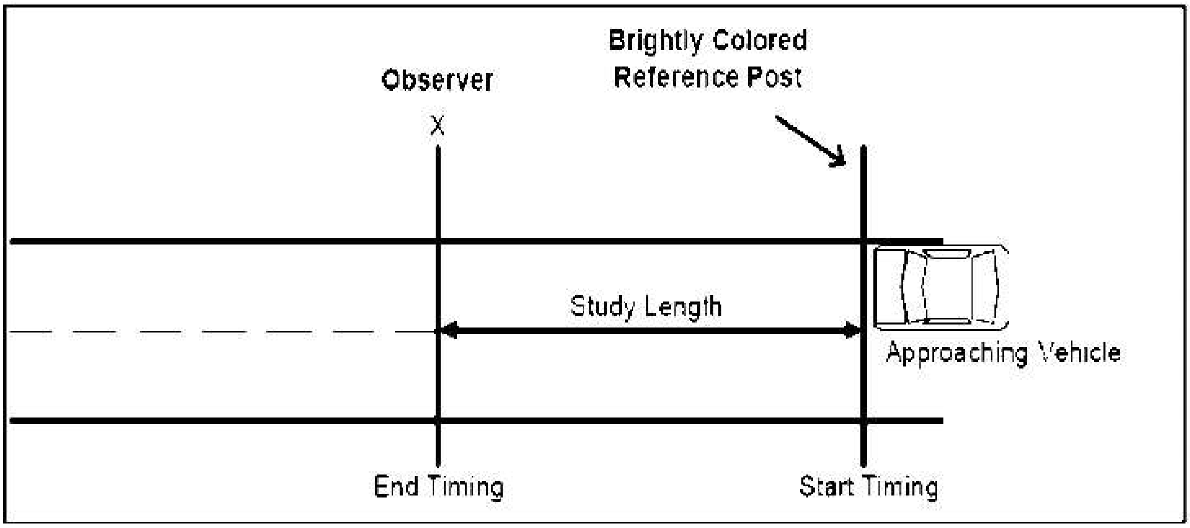


Figure: Trap length for conducting a speed study

Key parameters associated with roadway speeds:

1. **Time Mean Speed (TMS):** It is the average speed of all the vehicles passing a point on a highway or lane over some specified time period. It is taken as an arithmetic mean of all the speeds.

$$TMS = \frac{\sum_i \left(d/t_i \right)}{n}$$

2. **Space Mean Speed (SMS):** The average speed of all vehicles occupying a given section of highway or lane over some specified time period. Thus, it is the harmonic mean of speeds.

$$SMS = \frac{d}{\sum_i t_i / n}$$

where d *= distance traversed*

t_i *= time for "*i^{th}*" vehicle to traverse a particular section*

n *= number of observed vehicles*

3. **85th Percentile Speed:** The speed at or below which 85% of a sample of free-flowing vehicles are travelling.
4. **Median (50th Percentile Speed):** The speed that equally divides the distribution of spot speeds. 50% of observed speeds are higher than the median, whereas 50% of observed speeds are lower than the median.
5. **Design Speed:** 98th percentile speed is taken as design speed.

6. **Mode:** The mode is defined as the single value of speed that is most likely to occur, i.e. for which frequency is maximum.
7. **Pace:** It is defined as the 10 km/h increment in speed in which the highest percentage of drivers is observed. It is also found graphically using the frequency distribution curve. The pace is a traffic engineering measure not commonly used for other statistical analyses.

APPARATUS:

1. Measuring tape
2. Flags/ Road markers
3. A stopwatch
4. Observation sheets
5. Computer system with statistical software e.g. MS Excel

PROCEDURE:

1. Select the site as per guidelines and then obtain the appropriate trap length. Using the recommended study lengths based on the average speed of the traffic stream, the speed calculations become easy and less tedious.
2. Record observations on the spot speed study data entry form. On the spot speed data form, the observer records the date, location, weather conditions, start time, and end time. Spot speed study is a unidirectional study. First, choose one direction and then proceed to observations.
3. As the front of the vehicle (or only the lead vehicle in a group) crosses the starting section of the study length, the observer there signals the observer at the end section, who starts the stopwatch. The observer stops the stopwatch when the vehicle reaches the end station. Therefore, the time elapsed between the two sections is obtained.
4. Repeat the procedure for recording the time of vehicles moving in the opposite direction.
5. Calculate vehicle speeds by using the predetermined study length and the elapsed time it took the vehicle to move through the test section using the following formula:

$$V = \frac{D}{T}$$

Where, V = speed (m/s),

D = distance between two sections (m), and

T = time elapsed between two sections (sec).

6. Choose appropriate bin limits and generate a frequency distribution table.
7. Perform calculations using Table 3.2.
8. Generate a frequency distribution curve and cumulative frequency distribution curve either manually or using software such as MS Excel/Sigma Plot.
9. Compute various statistical metrics like mean, mode, standard deviation, etc., either using statistical formulae or using the generated graphs. Also, determine the speed percentiles such as 15th, 50th, 85th, and 98th percentile speeds.
10. Compute the confidence bounds with 95% and 99.7% confidence, respectively, and hence compute the sample size required to achieve a tolerance of "x km/hr" as an error.

OBSERVATIONS AND CALCULATION:

ANALYSIS OF DATA

Plot frequency distribution curve and cumulative frequency distribution curve and report the following results.

1. Median speed =________________km/hr

2. Modal speed = ________________km/hr

3. Pace = ___________________ km/hr
4. %Vehicles in pace =_______________

5. Mean Speed = $V_{mean} = \frac{\sum f_i \times V_i}{n}$ = ------------ =____________ km/hr

6. Standard Deviation, $\sigma_s = \sqrt{[\frac{f_i(V_i - V_m)^2}{n-1}]}$ =--------------=___________km/hr

7. Percentile Speeds: 15th Percentile Speed = __________________________

   50th Percentile Speed = __________________________

   85th Percentile Speed = _________________________

   98th Percentile Speed = __________________________

8. Confidence bounds, $\mu = V_{mean} \pm Z\sigma_s$

Note: For 95% confidence, Z=1.96 & for 99.7% confidence, Z=3.0

9. Sample size required for x% confidence with accepted error of S_e,

   $n_s = \frac{Z^2 \sigma_s^2}{S_e^2}$ =----------------- = __________

Table: Observation Table

Spot speed study data entry form

Date:	Day:	Weather:	Page:
Name of the road:			
Name of the observer(s):			
Study/trap length:			
Direction From:	Towards:		
Total number of vehicles observed:			
Vehicle No.	Time taken to cover study length (s)	Speed (m/s)	Speed (km/hr)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

NOTE: Different observers can observe different types of vehicles and thus we can have classified spot speeds.

Table: Calculation Table

Table 3.2 Cumulative Frequency Distribution Sheet

Date:	Day:	Weather:	Page:
Name of the road:			
Name of the observer(s):			
Study/trap length:			
Direction From:	Towards:		
Total number of vehicles observed:			

Speed interval (Km/hr)	Mid value of speed interval, V_i (km/hr)	Frequency, f_i	Cumulative frequency, $\sum f_i$	% Frequency, $\%f_i$	% Cumulative frequency $\%\sum f_i$	$f_i \times V_i$	$f_i(V_i - V_m)^2$

PRESENTATION OF DATA

Some graphical illustrations have been shown below. These graphs have been generated with the set of an example spot speed study using MS Excel.

Table 3.3 Frequency of speeds obtained from a sample survey

Speed Range, kmph	20-25	26-30	31-35	36-40	41-45	46-50	51-55
Frequency	0	2	6	18	25	19	16
Speed Range, kmph	56-60	61-65	66-70	71-75	76-80	81-85	Total
Frequency	17	12	7	4	3	1	130

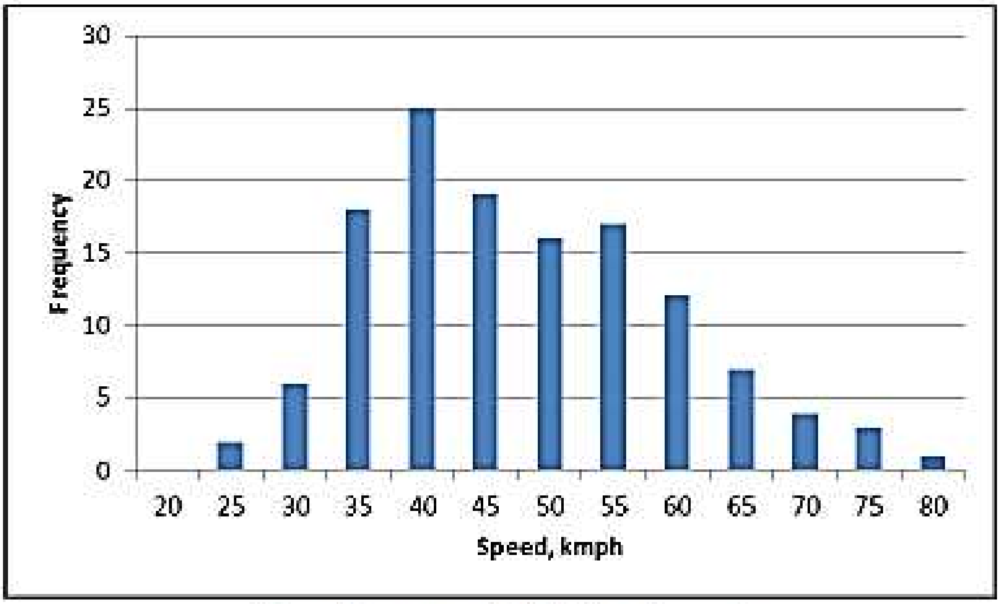


Fig Frequency distribution of speeds

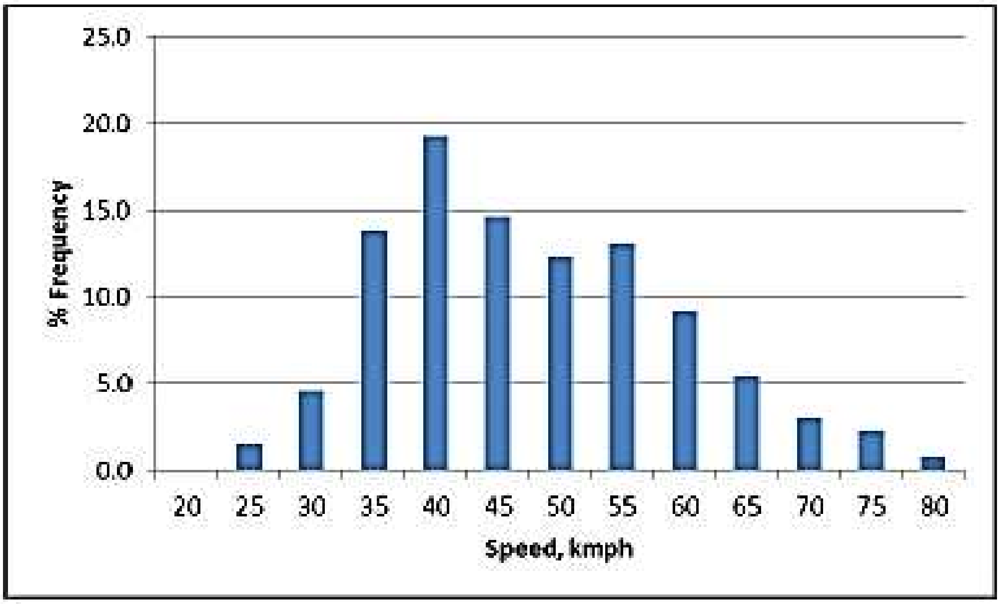


Fig Percent frequency distribution of speeds

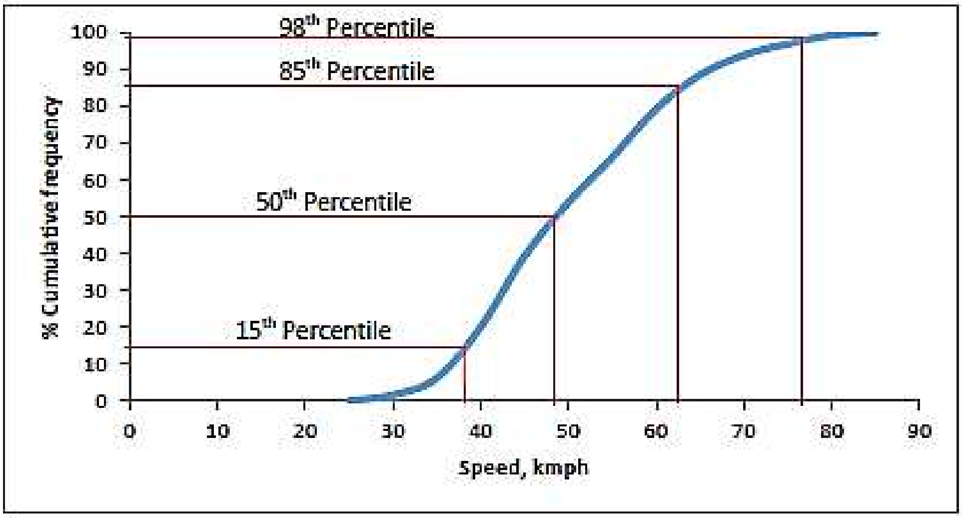


Fig 3.4 Percent Cumulative frequency distribution of speeds

RESULTS:

Students are expected to use the data collected during spot speed surveys. The data should be analysed and presented in both tabular as well as graphical forms using both the manual method and using the software. Hence inferences should be drawn from each.

QUESTIONS:

1. How do you determine the appropriate trap length for a spot speed study, and why is it important to use the recommended study lengths?
2. What is the significance of recording the date, location, weather conditions, and other details on the spot speed study data entry form?
3. Explain how you calculate the speed of a vehicle using the elapsed time and predetermined study length. Why is this method used in spot speed studies?
4. How do you generate and interpret frequency distribution curves and cumulative frequency distribution curves in the context of a spot speed study? What statistical metrics can you derive from these curves?