K.S. School of Engineering & Management

15, Mallasandra, Off Kanakapura Road
Bangalore 560109

Department of Civil Engineering

IV Semester

Transportation Engineering

(Code: BCVL403)

Academic Year: 2024-25

Laboratory Manual/Observation Book

Name of the Student :

University Seat No :

K S SCHOOL OF ENGINEERING AND MANAGEMENT

Holiday Village Road, Vajarahalli Village, Mallasandra, off, Kanakapura Rd, Bengaluru, Karnataka 560109

VISION

To impart quality education in engineering and management to meet technological business and societal needs through holistic education and research.

MISSION

K. S. School of Engineering and Management shall,

- Establish state-of-art infrastructure to facilitate effective dissemination of technical and managerial knowledge.
- Provide comprehensive educational experience through a combination of curricular and experiential learning, strengthened by industry-institute interaction.
- Pursue socially relevant research and disseminate knowledge.
- Inculcate leadership skills and foster entrepreneurial spirit among students.

DEPARTMENT OF CIVIL ENGINEERING

VISION

- To emerge as one of the leading Civil Engineering Department by producing competent and quality ethical engineers with strong foot hold in the areas of Infrastructure development and research.

MISSION

- Provide industry oriented academic training with strong fundamentals and applied skills.
- Engage in research activities in Civil Engineering and allied fields and inculcate the desired perception and value system in the students.

K S S E M
Department of Civil Engineering
Semester = IV
Subject: Transportation Engineering (BCV403)

Table of contents

Experiment No: 01 Date:

AGGREGATE IMPACT TEST

Aim: To determine the aggregate impact value for the coarse aggregate.

Apparatus: Impact Testing Machine, Cylindrical measure, Tamping rod (10mm dia.), Sieves of size 12.5mm, 10mm, 2.36mm, Balance, Oven.

Brief Theory: Toughness is the property of a material to resists impact. The test is designed to evaluate the toughness of stones, i.e. the resistance of the stones to fracture under repeated impact may be called as impact test for good stones.

Procedure:

1. Oven dried aggregate passing 12.5mm IS sieve and retained on 10mm IS sieve is selected for the test.
2. Determine the mass of empty cylindrical measure cup =W1___________ gm.
3. The sample aggregates are placed in three layers of approximately equal depth in the cylindrical measure cup with each layer being tamped 25 times by the rounded end of the tamping rod and the top surface is leveled using the tamping rod as straight edge and determine its mass = W2 _________ gm.
4. The mass of the coarse aggregate sample W3 = (W2-W1) = ____________gm.
5. The coarse aggregate sample is transferred to base cylindrical mold in three layers, with each layer compacted by 25 times using tamping rod and the top surface is leveled.
6. The hammer is raised until its lower face is 380mm above the upper surface of the aggregate in the base mold, and allowed to fall freely on aggregates for 15 times at an interval of one second.
7. The crushed aggregate is then removed from the base mold and whole of it is sieved through 2.36mm IS sieve until no further significant amount passes. The mass of the disintegrated fraction passing through the sieve is weighed accurately and let it be referred as = W4 ___________ gm.
8. Determine the Aggregate Impact Value for the given sample as:

$$\text{Aggregate Impact Value} = \frac{W4}{W3} \text{X}100$$

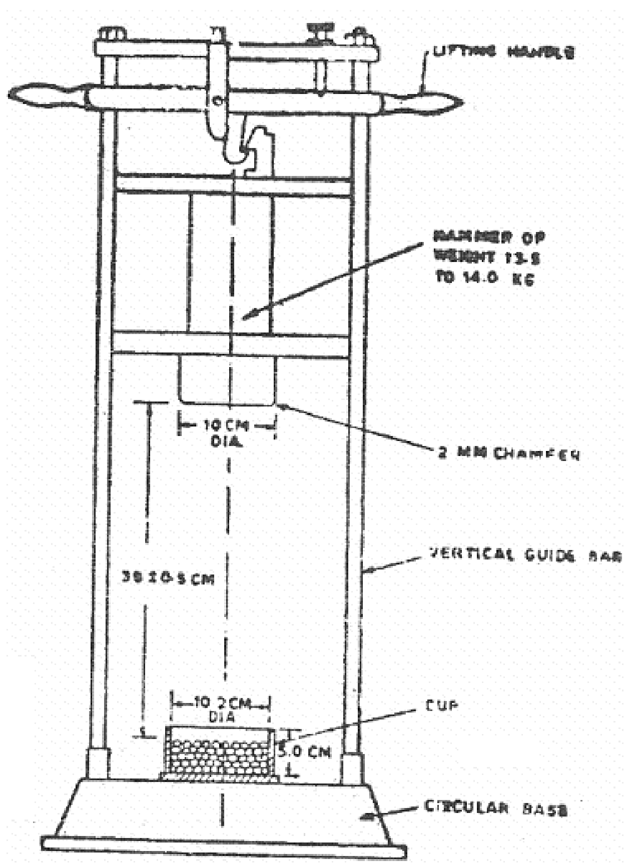
9. Observations & Calculations:

Tabular Column

Particulars	W1 gm.	W2 gm.	W3 gm.	W4 gm.	Aggregate Impact Value %
Trial-1					
Trial-2					
Trial-3					

Average Aggregate Impact value = _____________%

Sketch of the experimental setup:



Aggregate Impact Testing Machine

Result: The average aggregate Impact Value for the given coarse aggregate sample was found to be = ... %.

IS Specification: Aggregate Impact value is to classify the stones in respect of their toughness property as indicated below.

Aggregate impact value:
< 10 % → exceptionally strong
10 - 20 %→Strong
20 - 30 %→Satisfactory for road surfacing
➢ 35 % →weak for road surfacing.
Conclusion:

Reference Code:
IS 2386 Part IV Indian standard methods of test for concrete)

IS 383 Indian Standard specifications for Coarse and fine aggregate

IRC 15 – 1970 Standard specification and code of practice for construction of concrete roads

Viva Questions

1. What is the significance of the impact test?

2. What is allowable impact values of aggregate used in (a) concrete (b) wearing course?

3. In what aspect impact test is superior than crushing value of aggregate?

4. List various factors which affect the aggregate impact value.

5. What are the requirements of impact testing machine?

EXPERIMENT NO:2 **DATE:**

AGGREGATE CRUSHING TEST

Aim: To determine the aggregate crushing value for the coarse aggregate.

Apparatus: The following apparatus are required for the test.

1. Steel cylinder (diameter-15.2cm, height-13to 14cm)
2. Cylindrical measure (diameter-11.5cm, height-18cm)
3. Steel tamping rod (diameter-1.6cm, length 45 to 60cm)
4. Balance
5. Compression testing machine (capacity-3000kN, load to be applied-40t, rate of loading-4t/m)
6. IS Sieves of sizes 12.5mm, 10mm, and 2.36mm

Brief Theory: The stone used as road aggregate should have resistance to crushing under traffic wheel loads. If the aggregates are weak the stability of the pavement structure is adversely affected. Aggregates possessing low aggregate crushing value should be preferred.

Procedure:

1. Oven dried aggregate passing 12.5mm IS sieve and retained on 10mm IS sieve is selected for the test.

2. Determine the mass of empty cylindrical measure =W1____________gm.

3. The sample aggregates are filled in cylindrical measure in three layers of approximately equal depth with each layer being tamped 25 times by the rounded end of the tamping rod and the top surface is leveled using the tamping rod as straight edge and determine the mass of cylindrical measure + coarse aggregates =W2____________gm.

4. Determine the mass of the coarse aggregate sample present in the cylindrical measure as W3 = (W2-W1)= _____________gm.

5. The coarse aggregate sample is then transferred to cylindrical base mold in three layers, with each layer compacted by 25 times using tamping rod.

6. The surface of the aggregate is leveled and the plunger inserted on the top of the aggregates.

7. The Cylindrical base mold with the test sample and plunger in position in CTM.

8. Load is then applied through the plunger at a uniform rate of 39.20 kN/minute until the total load of 392 kN is being applied after which the load is released.

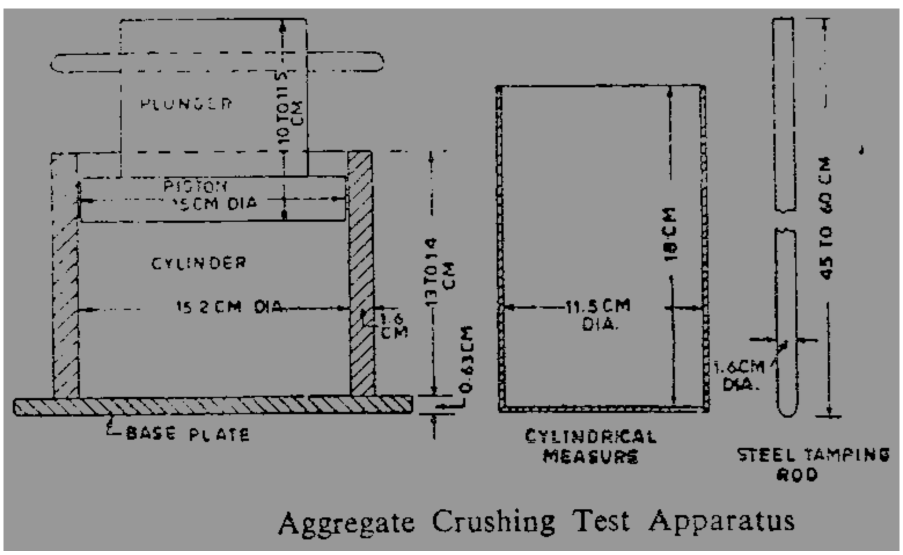
9. Crushed aggregates are removed from the cylindrical base mold and sieved through a 2.36 mm IS sieve.

10. The mass of the disintegrated aggregate particle which has passed through 2.36 mm sieve is determined and let it be = W4 __________ gm.

11. Determine the aggregate crushing value as:

$$\text{Aggregate Crushing Value} = \frac{W4}{W3} \text{ X } 100$$

Sketch:



Tabular COLUMN

Particulars	W1 gm.	W2 gm.	W3 gm.	W4 gm.	Aggregate Crushing Value %
Trial-1					
Trial-2					
Trial-3					

The average aggregate crushing valve = ____________________%

Result: The average aggregate crushing value for the given coarse aggregate sample was found to be = ... %

IS Specification:

Indian road congress and ISI have specified that the aggregate crushing value of the coarse aggregate used for the cement concrete pavement at surface should not exceed 30%. For aggregates used for concrete other than wearing surfaces the aggregate crushing value should not exceed 45%.

Conclusion:

Reference Code: -

I.S. 2386 Part IV Indian standard methods of test for concrete

I.S. 383 Indian Standard specifications for Coarse and fine aggregate

IRC 15 – 1970 Standard specification and code of practice for construction of concrete roads

Viva Questions

1. List out various sizes of Coarse Aggregate used in Concrete.
2. Give the general classification of aggregates and the IS specifications.
3. Define crushing value of aggregate and state its significance.

EXPERIMENT NO 3 **DATE:**

LOS ANGELES ABRASION TEST

Aim: To determine the coarse aggregate abrasive value. (Hardness of aggregate)

Apparatus:

1. Los-Angeles machine (diameter-70cm, length-50cm).
2. Steel balls (diameter-48cm, weight-390 to 445g).
3. Balance.
4. Sieves.

Brief Theory: Due to movement of traffic the aggregates used in the surfacing course are subjected to wearing action at top. Resistance to wear and tear is hence an essential property for road aggregates. To determine abrasion value Los-Angeles abrasion test is commonly adopted.

Procedure:

1. Clean dry aggregate, confirming to any one of the grading A to G is used for the test. Aggregates weighing 5Kg for grading A, B, C or D and 10Kg for grading E, for G may be taken as test specimen and placed in the cylinder and is noted as W_1 gms.
2. The abrasive charge is also chosen depending upon the aggregate and is placed in the cylinder of the machine; the cover is then fixed dust tight.
3. The machine is rotated for 500 revolutions for grading A, B, C and D for grading E, F, G it shall be rotated for 1,000 revolutions.
4. 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.
5. Using 1.7mm IS sieve the material is sieved and the coarser material is retained on the sieve is taken as W_2 g.

TABLE II GRADINGS OF TEST SAMPLES

(*Clause* 5.3.3)

Sieve Size (Square Hole)		Weight in g of Test Sample for Grade						
Passing mm	Retained on mm	A	B	C	D	E	F	G
80	63	—	—	—	—	2 500*	—	—
63	50	—	—	—	—	2 500*	—	—
50	40	—	—	—	—	5 000*	5 000*	—
40	25	1 250	—	—	—	—	5 000*	5 000*
25	20	1 250	—	—	—	—	—	5 000*
20	12·5	1 250	2 500	—	—	—	—	—
12·5	10	1 250	2 500	—	—	—	—	—
10	6·3	—	—	2 500	—	—	—	—
6·3	4·75	—	—	2 500	—	—	—	—
4.75	2·36	—	—	—	5 000	—	—	—

*Tolerance of ±2 percent permitted.

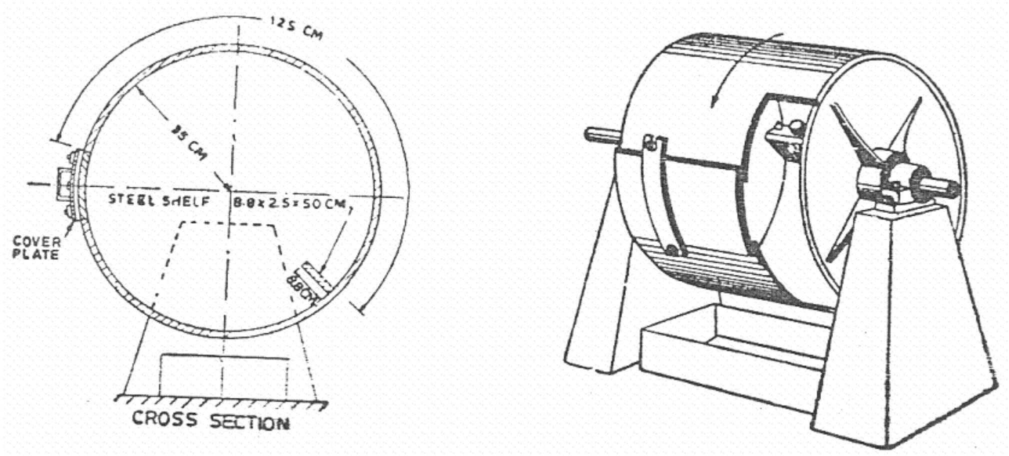
Observations & Calculations: -

1. Type of aggregate = 20 mm and down size
2. Grading = B
3. Coarse aggregate sample (20mm to 12.5 mm) = 2500 g

   (12.5 mm to 10 mm)= 2500 g
4. Number of spheres used = 11
5. Weight of charge = 4590 g
6. Number of revolutions = 500

Particulars	Trial. No (1)	Trial. No (2)	Trial. No (3)	Average
Weight of coarse aggregate sample=W_1 g				
Weight of specimen after abrasion test, coarser than 1.70mm = W_2 g				
Los-Angeles Abrasion Value = $\{(W_1-W_2) / W_1\}\times 100$ %				

Sketch: -



Los Angeles Machine

Result: Los-Angeles abrasive value = **...................................** %

IS Specification: - This test condition is considered more representative of field condition. The maximum allowable Los-Angeles abrasion value of aggregates as specified by IRC for different methods of construction are as shown in the table.

Sl. No.	Type of pavement layer	Los-Angeles abrasion value maximum%
01	Water bound macadam sub base course	60
02	WBM base course with bituminous surfacing	50
03	WBM surfacing course	40

Conclusion:

Reference Code:

IS 2386 - Part IV Indian standard methods of test for concrete
IS 383 - Indian Standard specification for Coarse and fine aggregate
IRC 15 – 1970 Standard specification and code of practice for construction of concrete roads

Viva Questions

1. What is significance of the abrasion test?

2. Which property of aggregate is measured by this test?

3. State the mechanical properties of aggregates.

EXPERIMENT NO:4 **DATE:**

SHAPE TEST ON AGGREGATES

(A) FLAKINESS INDEX TEST

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

IS Standards used: IS: 2386(Part-I)-1963 (Reaffirmed 2007)

Theory:

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 63 mm sieve.

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 50 mm sieve.

Equipment's:

1. Weighing Balance: A Balance of suitable capacity accurate to 0.1% of the mass of the weight of the test sample.
2. Elongation and Flakiness index gauges.

3. 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.

Experimental procedure:

1) For obtaining the combined flakiness and elongation index, flakiness test is conducted first and the non-flaky particles of the sample will be used for conducting elongation index

2) Sieve analysis is carried out on the sample of aggregate using sieves listed above(1)

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.

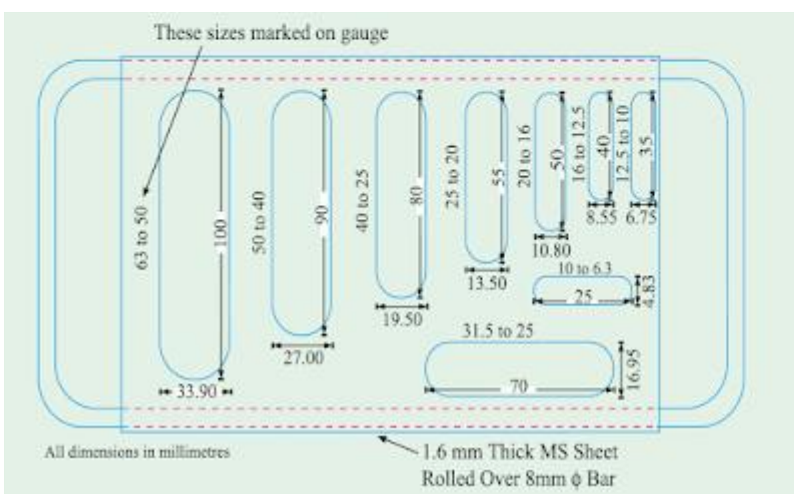
5) The sum of the weights of each fraction of aggregates gives the weight of the aggregate sample. (Say, W_1).

6) The particles belonging to a particular size group (ex: 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 and let it be W_2.

8) The particles retained through the specified slot of the length gauge are "elongated" and will be weighed to an accuracy of at least 0.1% of the weight of the test sample and let it be W_3.

Observations and calculations: Flakiness index



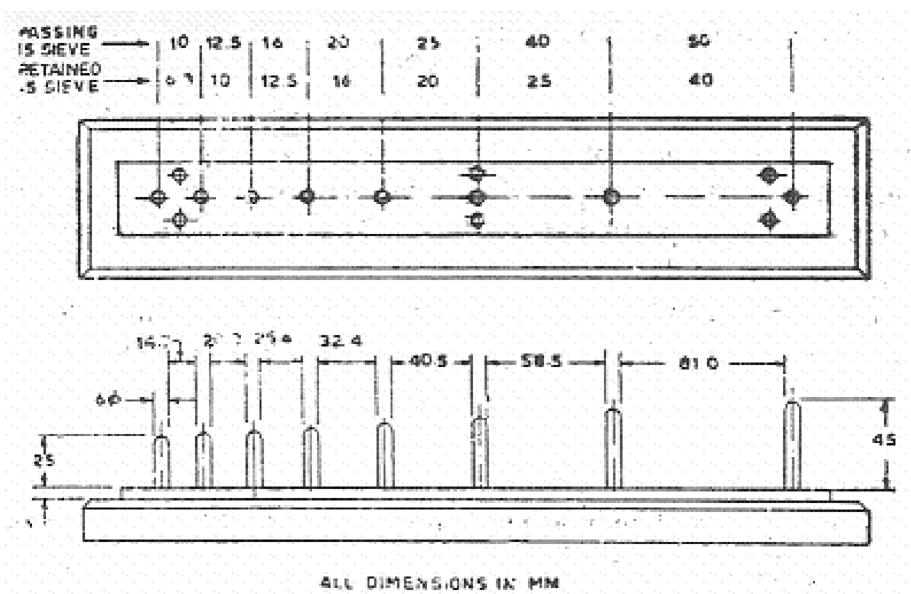
Thickness gauge

Aggregates particles present between the sieve sizes (mm)		Weight of 200 aggregate particles present between each sieve size. (W_1 gm.)	Weight of aggregate particles which has passed through the slot of thickness gauge. (W_2 gm.)
63	50		
50	40		
40	31.50		
31.50	25		
25	20		
20	16		
16	12.5		
12.5	10		
10	6.30		
		Σ W$_1$=	**Σ W$_2$=**

Flakiness index (%) = (Σ W_2/ Σ W_1) *100

Flakiness Index of the coarse aggregate =__________________%

(B) ELONGATION INDEX TEST



Length Gauge

Observation and calculations:

Aggregates particles present between the sieve sizes (mm)		Weight of 200 aggregate particles present between each sieve size. (W_1 gm.)	Weight of aggregate particles which has retained through the slot of length gauge. (W_3 gm.)
50	40		
40	31.50		
31.50	25		
25	20		
20	16		
16	12.5		
12.5	10		
10	6.30		
		ΣW_1=	**ΣW_3=**

Elongation index (%) = $(\Sigma W_3 / \Sigma W_1) * 100$

Elongation Index of the coarse aggregate =___________________%

Significance of shape test of aggregates:

Generally aggregates having elongation index values greater than 15% are generally not considered suitable for pavement construction. Flakiness index of aggregates should not be greater than 25% for use in road construction.

EXPERIMENT NO: 5 **DATE:**

ANGULARITY NUMBER OF COARSE AGGREGATES

Aim: To determine the angularity number of coarse aggregates.

Apparatus: The apparatus shall consist of the following:

a) Metal Cylinder- A metal cylinder closed at one end and of about 3 liters capacity, the diameter and height of which shall be approximately equal, for example 15 cm and 15 cm respectiely. The cylinder shall be made from metal of thickness not less than 3 mm and shall be of sufficient rigidity to retain its shape under rough usage.
b) Tamping Rod - A straight metal tamping rod of circular cross section of 16 mm diameter and 60 cm long, rounded at one end.
c) Balance -Balance or scale of capacity 10 kg readable to one gram.
d) Scoop - A metal scoop approximately 20 x 12 x 5 cm, that is, about 1-litre heaped capacity.

Calibration of the Cylinder:

The cylinder shall be calibrated by determining to the nearest gram the weight of water at 27°C required to fill it, so that no meniscus is present above the rim of the container.

Preparation of the Test Sample:

The test sample shall consist of aggregate retained between the appropriate pair of IS Sieves (square mesh) from the following sets:

20-mm and 16-mm

16-mm and 12.5-mm

12.5-mm and l0-mm

10-mm and 6.3-mm

6.3-mm and 4.75-mm

The aggregate to be tested shall be dried for at least 24 hours in shallow trays in a well-ventilated oven at a temperature of 100^0 to 110^0 C, cooled in an air-tight container and tested.

Test Procedure:

The scoop shall be filled and heaped to over flowing with the aggregate, which shall be placed in the cylinder by allowing it to slide gently off the scoop from the least height possible.

The aggregate in the cylinder shall be subjected to 100 blows of the tamping rod at a rate of about 2 blows per second. Each blow shall be applied by holding the rod vertical with its rounded end 5 cm above the surface of the aggregate and releasing it so that it falls freely. No force shall be applied to the rod. The 100 blows shall he evenly distributed over the surface of the aggregate.

The process of filling and tamping shall be repeated exactly as described above with a second and third layer of aggregates; the third layer shall contain just sufficient aggregate to fill the cylinder level with the top edge before tamping.

After the third layer has been tamped, the cylinder shall be filled to overflowing, and the aggregate struck off level with the top using the tamping rod as a straight edge.

Individual pieces shall then be added and 'rolled-in' to the surface by rolling the tamping rod across the upper edge of the cylinder, and this finishing process shall be continued as long as the aggregate does not lift the rod off the edge of the cylinder on either side. The aggregate shall not be pushed in or otherwise forced down, and no downward pressure shall be applied to the tamping rod, which shall roll in contact with the metal on both sides of the cylinder.

The aggregate in the cylinder shall then be weighed to the nearest 5 grams.

Three separate determinations shall be made, and the mean weight of aggregate in the cylinder calculated. If the result of any one determination differs from the mean by more than 25 grams, three additional determinations shall immediately be made on the same material and the mean of all the six determinations is calculated.

Calculation:

The angularity number shall be calculated from the formula:

$$= 67 - \frac{100\,W}{C\ \ Ga}$$

Where

W = mean weight in g of the aggregate in the cylinder,

C = weight of water in g required to fill the cylinder, and

Ga = specific gravity of aggregate. G_a

Reporting of Results:

The angularity number of the given coarse aggregate is found to be __________ (shall be expressed to the nearest whole ember).

Significance of angularity number:

The angularity number indicates the angularity or roundedness of particles, which affects properties like workability. It is calculated by measuring the volume of voids when aggregates of a single size are densely packed in a cylinder. More angular are the particles there will be better interlocking, inter friction and greater mechanical stability, hence better pavement distress resistance. The value of angularity number generally lies between 0 & 11. In road construction, angularity number of 7 – 10 is generally preferred (IS:2386 (part-1) 1963).

Viva questions:

1. What is coarse aggregate Angularity?
2. What is the range of Angularity number?
3. Why angular aggregate is used?

EXPERIMENT NO:6 **DATE:**

SOFTENING TEST ON BITUMEN

Aim: To determine the softening point of bitumen.

Apparatus: It consists of ring and ball apparatus.

1. Steel Balls
2. Brass Rings
3. Constant temperature water bath
4. Beaker mounted on thermostat heating coil system with stirrer
5. Temperature measuring sensor

Theory: The softening point is the temperature at which the substance attains particular degree of softening under specified condition of test. For bitumen it is usually determined by ring and ball test.

Procedure:

1. Sample material is heated to a temperature between 75°C and 100°C above the approximate softening point until it is completely fluid and is poured in rings and placed on metal plates.
2. The ring arrangement is kept for half an hour air cooling.
3. Then ring arrangement is kept in water bath for 30 minutes at a temperature of 27^0C, and then mounted with in stand, which is kept inside beaker, after which the balls are placed in position and water is filled inside the beaker.
4. The thermostat is controlled such that the temperature of water is raised at uniform rate of 5°C per minute with a controlled heating unit, until the bitumen softens and touches the bottom plate by sinking of balls.
5. The temperature is noted down at this stage.

Test Property	Sample No 1		Sample No 2		Mean Value of Softening Temperature
	Ball 1	Ball 2	Ball 1	Ball 2	
Temperature at which sample touches bottom plate in _____^{0}C					

Result: The softening point of the sample = ...

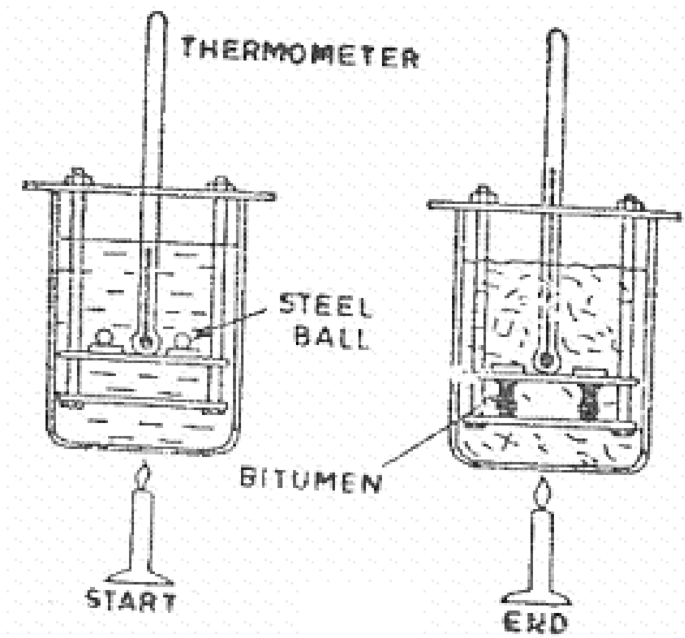
IS specification: The softening point gives an idea of the temperature at which the bituminous material attains a certain viscosity. Bitumen with higher softening may be preferred in warmer place.

Bitumen Grades	Softening point ^{0} c
A 25 & A 35	55 to 70
S35	50 to 65
S65	40 to 55

Conclusion: The mean softening temperature of the bitumen sample is ______^{0}C.

Reference Code: - IS 1205, Indian standards institution, Determination of softening point

Sketch:



SOFTENING POINT TEST SET – UP

Viva Questions

1. Define softening point of bitumen.
2. Explain the significance of softening point test.
3. What is the reference code used for softening point test?

EXPERIMENT NO: 7 DATE:

DUCTILITY TEST ON BITUMEN

Aim: To determine the ductility value for bitumen.

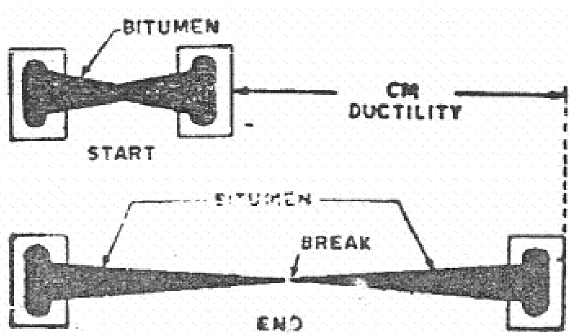
Apparatus Required: Ductility test apparatus consists of item like sample moulds (briquette) water bath, trowel and ductility machine.

Brief Theory: A certain minimum ductility is necessary for a bitumen binder. This is because of the temperature changes in the bituminous mixes and the repeated deformation that occurs in flexible pavement due to the traffic loads. If the bituminous has low ductility value, the bituminous pavement may crack especially in cold weather.

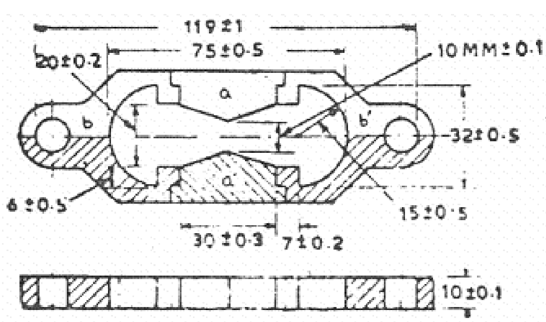
Procedure:

1. The bitumen sample is melted to a temperature of 75^0C to 100^0C above the approximate softening point until it is fluid.
2. Thirty to forty minutes after the sample is poured into the moulds, the plate assembly along with the sample is placed in the water bath maintained at 27^0C for 30 minutes.
3. The pointer is set at the zero position and the machine is started. The two grips are pulled apart horizontally while the test is in operation, and precaution must be taken such that the stretching bituminous thread is immersed in water at a depth of at least 10 mm.
4. The distance, at which the bituminous thread snaps or breaks, is recorded in cm to report as ductility value.

Sketch:



Ductility Test Concept



Briquette Mould

Result: The ductility value = ... cm.

IS Specification: The ductility value of bitumen varies from 50 to 100 cm. The minimum ductility value of 50 cm is specified for bituminous construction.

Reference Code: - IS 1203 – 1978 Indian standard methods for tar & Bitumen

<u>Viva Questions</u>

1. What do you understand by ductility of bitumen?
2. Why ductility of bitumen needs to be determined?
3. Explain the significance of ductility test.
4. How is ductility value expressed?
5. Give the dimension of the standard briquette mould.
6. What is the necessity of water usage in the experiment?
7. What is the test temperature and standard rate of pull?
8. What are the factors which affect the ductility of test specimen?

EXPERIMENT NO: 8 **DATE:**

PENETRATION TEST ON BITUMEN

Aim: To find the penetration value of bitumen

Apparatus Required: Container, needle, water bath, penetrometer and stop watch

Brief Theory: The penetration value of bituminous materials vary depending upon several factors such as constituents, temperature etc. At temperature ranging between 25 and 50 degree centigrade most of the paving bitumen grades remain in semi-solid or in plastic states. Penetration test is commonly adopted test on bitumen to grade the material in terms of hardness. Depending upon the climatic conditions and type of construction, bitumen of different penetration grades are used.

Procedure:

1. The bitumen is softened to a pouring consistency between 75 and 100^0C above the atmospheric temperature at which bitumen attains pouring consistency.
2. Pour the melt into the container to a depth at least 10 mm in excess of the expected penetration. Protect the sample from dust and allow it to cool in an atmosphere at a temperature between 15 to 30°C for l/2 to 2 h for 45 mm deep container and 1 to l/2 h when the container of 35 mm depth is used. Then place it along with the transfer dish in the water bath at 25.0 ± 0.1°C and allow it to remain for 1 1/2 to 2 h and 1 to 1 1/2 h for 45 mm and 35 mm deep container respectively.
3. The weight of the needle, shaft and additional weights are checked. The total weight of the assembly should be 100 gm.
4. The needle assembly is lowered and the tip of the needle is made to touch the top surface of the sample.
5. The initial reading of the penetrometer dial is either adjusted to zero or the initial reading is taken before releasing the needle.
6. The needle is released exactly for a period of 5 seconds by pressing the needle release knob and final reading is taken on the dial.
7. The difference between the readings gives the penetration value of bitumen.

Observations:

Reading	Trial 1	Trial 2	Trial 3
Initial penetration value			
Final penetration value			
Penetration value =(Final – Initial)			

Sketch:

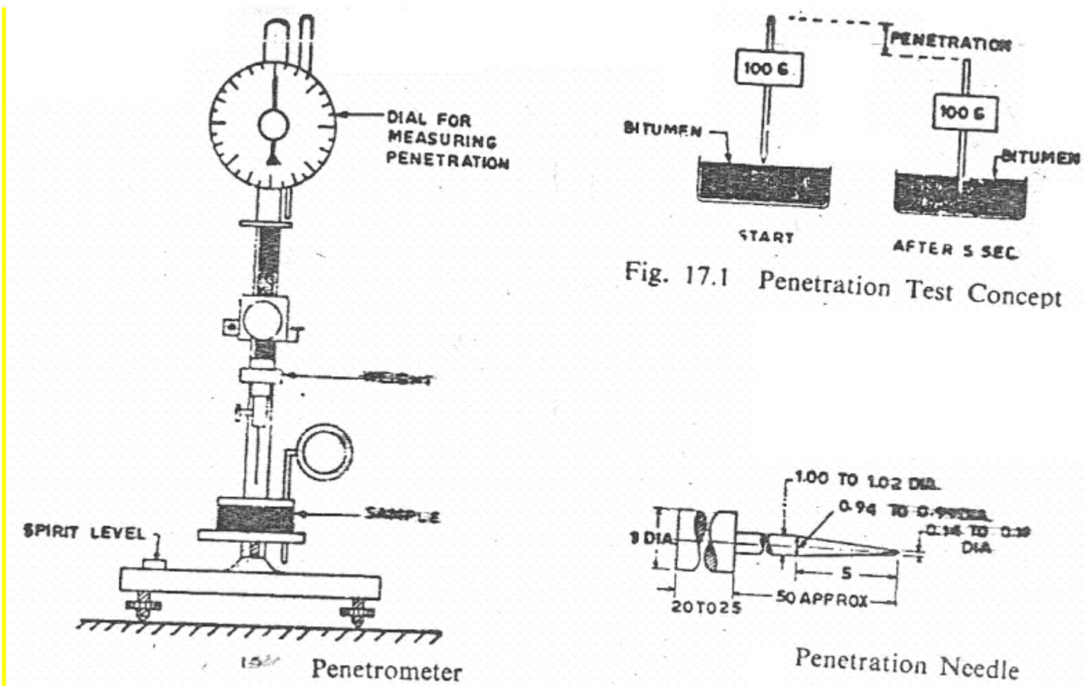


Fig. 17.1 Penetration Test Concept

Penetrometer

Penetration Needle

Result: The mean penetration value of bitumen = **............................**

IS Specification: IRC suggests bitumen grades 30/40, 60/70, & 80/100. In warmer region lower penetration grades is used are preferred and in colder region bitumen with higher penetration are used.

Reference Code: - IS 1203– 1978 Indian standard methods for testing Tar & Bitumen

IS: 73 – 1961 Indian standard specifications for paving bitumen

<u>Viva Questions</u>

1. Define penetration value of bitumen and give the IS specifications.
2. Define grade of bitumen.
3. Which property of bitumen is related to penetration value?
4. What is meant by the term 40/50 bitumen?
5. What are the applications of penetration test?
6. What does 90-grade bitumen indicate?
8. Which bitumen grades are commonly used in warmer region?

EXPERIMENT NO: 9 DATE:

SPECIFIC GRAVITY TEST ON BITUMEN

Aim: Determine the specific gravity for bitumen.

Apparatus: Specific gravity bottle, distilled water, bitumen.

Brief Theory: The specific gravity is defined as the ratio of the mass of a given volume of the material to the mass of an equal volume of water.

Procedure:

1. The specific gravity bottle is cleaned, dried and its mass is determined along with the stopper. (w1)
2. The mass of the specific gravity bottle about half filled with bituminous material. (w2)
3. Mass of the specific gravity bottle half filled with bituminous material and rest with distilled water. (w3)
4. The mass of the specific gravity bottle filled with distilled water. (w4)
5. Specific gravity = $\frac{(w2-w1)}{(w2-w1)-(w3-w4)}$

Observations & Calculations:

Mass of the specific gravity bottle (w1) =

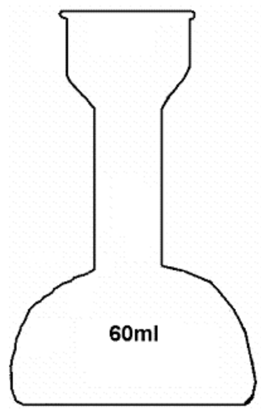
Mass of the specific gravity bottle about half filled with bituminous material (w2) =

Mass of the specific gravity bottle half filled with bituminous material and rest with distilled water (w3) =

Mass of the specific gravity bottle filled with distilled water (w4) =

Specific gravity = $\frac{(w2-w1)}{(w2-w1)-(w3-w4)}$

Sketch:



IS Specification: Knowledge of correct specific gravity of bituminous materials is necessary to convert the specified bitumen content by weight to volume basis when the binder is measured by volume. The specific gravity of bitumen ranges from 0.95 to 0.99.

Result: The specific gravity of bitumen **................................**

Reference Code: - IS 1202– 1978

<u>Viva Questions</u>

1. Define specific gravity.
2. What is the significance of specific gravity?
3. Is it permissible to use kerosene in the specific gravity experiment? If not, why?
4. What are the sources of errors in the experiment?

EXPERIMENT NO: 10 **DATE:**

FLASH AND FIRE POINT TRST ON BITUMINOUS MATERIAL

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

IS Standards used: IS: 1209-1978 Need and Scope:

Theory of the test:

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 -350^0 C) with sensitivity of 0.1^0 C.

Experimental 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 5^0 C to 6^0 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 17^0 C below the actual flash point and then at interval every 1^0C to 3^0C.

8. The stirring is discontinued during the application of the test flame.

Observations and Calculation:

Sl. No.	Description	Test-1	Test-2	Test-3	Mean Value
1	Flash point ^{0}C				
2	Fire point ^{0}C				

Result:

Flash point of the given bituminous sample was found to be ___________^{0}C

Fire point of the given bituminous sample was found to be ___________^{0}C

Viva 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: 11 **DATE:**

WET SIEVE ANALYSIS OF SUBGRADE SOIL

Theory:

Soil gradation (sieve analysis) is the distribution of particle sizes expressed as a percent of the total dry weight. Gradation is determined by passing the material through a series of sieves stacked with progressively smaller openings from top to bottom and weighing the material retained on each sieve.

Need and scope:

The results of testing will reflect the condition and characteristics of the aggregate from which the sample is obtained. Therefore, when sampling, it is important to obtain a disturbed representative sample that is representative of the source being tested because the distribution of different grain sizes affects the engineering properties of soil. Wet and dry sieve analysis IS: 2720 (Part 4) – 1985 (Reaffirmed-2006).

Apparatus required:

1. A series of sieve sets ranging from 4.75mm to 75µm (4.75mm, 2.00mm, 1.00mm, 425µm, 212µm, 150µm, 75µm)
2. Balance sensitive to ± 0.01g

Procedure:

Soil passing 4.75mm I.S. Sieve and retained on 75micron I.S. Sieve contains no fines. Those soils can be directly dry sieved rather than wet sieving.

Dry Sieving:

1. Take 500gm of the soil sample from disturbed representative sample.
2. Conduct sieve analysis using a set of standard sieves as given in the data sheet.
3. The sieving may be done either by hand or by mechanical sieve shaker for 10 minutes.
4. Weigh the material retained on each sieve.
5. The percentage retained on each sieve is calculated on the basis of the total weight of the soil sample taken.
6. From these results the percentage passing through each of the sieves is calculated.
7. Draw the grain size curve for the soil in the semi-logarithmic graph provided.

Wet Sieving:

If the soil contains a substantial quantity (say more than 5%) of fine particles, a wet sieve analysis is required. All lumps are broken into individual particles.

1. Take 500gm of oven dried soil sample and soaked in water.
2. For heavy clays if de-flocculation is required, 2% calgon solution is used instead of water.
3. The sample is stirred and left for soaking period of at least 10 minutes.
4. The material is sieved through 75 micron sieve.
5. The material is washed until the water filtered becomes clear.
6. The soil retained on 75 micron sieve is collected and dried in oven.
7. It is then sieved through the sieve shaker for ten minutes and retained material on each sieve is collected and weighed.
8. The material that would have been retained on pan is equal to the total mass of soil taken for dry sieve analysis minus the sum of the masses of material retained on all sieves.
9. Draw the grain size distribution curve for the soil in a semi-logarithmic graph.

Presentation of data:

Sieve analysis

Sample Details: ____________________

Weight of Sample taken for Sieve Analysis = ______ gms.

Location: _______________________________

Sl.No.	I S Sieve No:	Mass retained in gms	Cumulative mass retained in gms	Percent mass(%) retained	Percent (%) mass passing
1	4.75 mm				
2	2.00 mm				
3	1.00 mm				
4	425 microns				
5	212 microns				
6	150 microns				
7	75 microns				
8	Pan				

Result: Draw the grain size distribution curve for the soil in a semi-logarithmic graph.

EXPERIMENT NO: 12 **DATE:**

C B R TEST ON SOIL

Aim: To determine the CBR value of the highway subgrade soil.

Theory:

CBR is the ratio expressed in percentage of force per unit area required to penetrate a soil mass with a standard circular plunger of 50 mm diameter at the rate of 1.25 mm/min to that required for corresponding penetration in a standard material. The ratio is usually determined for penetration of 2.5 and 5 mm. When the ratio at 5 mm is consistently higher than that at 2.5 mm, the ratio at 5 mm is used. The following table gives the standard loads adopted for different penetrations for the standard material with a C.B.R. value of 100%.

Penetration of Plunger (mm)	Standard load (Kg
2.50	1370
5.00	2055

Apparatus Required:

CBR loading unit

CBR Test Apparatus Consists of loading machine with capacity of at least 5000 kg and equipped with a movable head or base which enables Plunger of 50 mm dia. To penetrate into the specimen at a rate of 1.25 mm/ minute.

CBR Mould with Base Plate, Stay Rod and Wing Nut

Cylindrical mould:

Inside dia. 150mm and height 175mm with a detachable perforated base plate of 235mm dia. and 10mm thickness. Net capacity - 2250 ml; conforming to IS-9669:1980 (Reaffirmed-2016).

Collar:

A detachable extension collar of 60 mm height.

Spacer Disc:

148 mm in diameter and 47.7 mm in height along with handle.

Weights:

One annular metal weight and several slotted weights weighing 2.5 kg each, 147 mm in diameter, with a central hole of 53 mm in diameter.

Compaction Rammer

Compaction Rammer of weight - 4.89 kg with a drop 450 mm.

Reference:

IS 2720(Part 16):1987 Methods of test for soils: Laboratory determination of CBR (second revision). Reaffirmed- Dec 2021.

Procedure:

Preparation of Test Specimen:

1. Remoulded specimens are prepared in the laboratory by compaction. The material used in the remoulded specimen shall pass 19 mm I.S. sieve. Allowance for large material shall be made by replacing it by an equal amount of material which passes a 19mm I.S. Sieve but is retained on 4.75 mm sieve.
2. The dry density for a remolding shall be either the field density or the value of the maximum dry density estimated by the compaction test. The water content used for compaction shall be the optimum water content or the field moisture as the case may be.
3. Dynamic Compaction: A representative sample of the soil weighing approximately 4.5 kg or more for fine grained soil and 5.5 kg or more for granular soil shall be taken and mixed thoroughly with water. If the soil is to be compacted to the maximum dry density at the optimum moisture content, the exact mass of the soil required shall be taken and the necessary quantity of water added so that the water content of the soil sample is equal to the determined optimum moisture content.
4. Fix the extension collar and the base plate to the mold. Insert the spacer disc over the base. Place the filter paper on the top of the spacer disc.
5. Apply Lubricating Oil to the inner side of the mold. Compact the mix soil in the mold using heavy compaction. i.e. compact the soil in 5 layers with 55 blows to each layer by the 4.89 kg rammer.
6. Remove the extension collar and trim the compacted soil carefully at the level of top of mold, by means of a straight edge. Any holes developed on the surface of the compacted soil by removal of the coarse material, shall be patched with the smaller size material. Remove the perforated base plate, Spacer disc and filter paper and record the mass of the mold and compacted soil specimen. Place a disc of coarse filter paper on the perforated base plate, invert

the mold and compacted soil and clamp the perforated base plate to the mold with the compacted soil in contact with the filter paper.

7. Place a filter paper over the specimen and place perforated plate on the compacted soil specimen in the mold. Put annular weights to produce a surcharge equal to weight of base material and pavement, to the nearest 2.5 kg.

8. Immerse the mold assembly and weights in a tank of water and soak it for 96 hours. Mount the tripod for expansion measuring device on the edge of the mold and record initial dial gauge reading. Note down the readings every day against time of reading. A constant water level shall be maintained in the tank throughout the period.

9. At the end of soaking period, note down the final reading of the dial gauge and take the mold out of water tank.

10. Remove the perforated plate and the top filter paper. Weigh the soaked soil sample and record the weight.

Procedure for Penetration Test:

1. Place the mold assembly with test specimen on the lower plate of penetration testing machine. To prevent upheaval of soil into the hole of the surcharge weights, 2.5 kg annular weight shall be placed on the soil surface prior to seating the penetration plunger after which the remainder of the surcharge weights shall be placed.

2. Seat the penetration piston at the center of the specimen with the smallest possible load, but in no case in excess of 4 kg so that full contact of the piston on the sample is established.

3. Set the load and deformation gauges to read zero. Apply the load on the piston so that the penetration rate is about 1.25 mm/min.

4. Record the load readings at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 4.0, 5.0, 7.5, 10 and 12.5 mm.

5. Raise the plunger and detach the mold from the loading equipment. Take about 20 to 50 g of soil from the top 30 mm layer and determine the moisture content.

Observation and Recording:

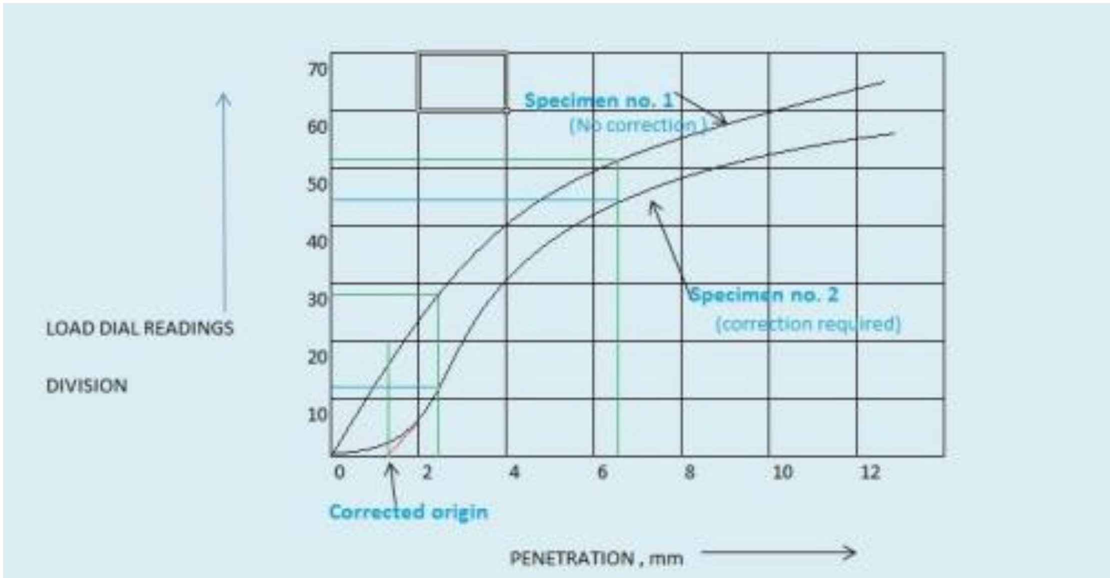
Penetration in mm	Applied load (kg)
0.50	
1.00	
1.50	
2.00	
2.50	
4.00	
5.00	
7.50	
10.00	
12.50	

Calculation

1. If the initial portion of the curve is concave upwards, apply correction by drawing a tangent to the curve at the point of greatest slope and shift the origin. Find and record the correct load reading corresponding to each penetration. C.B.R. = (PT/PS) X 100 Where PT = Corrected test load corresponding to the chosen penetration from the load penetration curve. PS = Standard load for the same penetration taken from the table above.
2. C.B.R. of specimen at 2.5 mm penetration =
3. C.B.R. of specimen at 5.0 mm penetration =
4. The C.B.R. values are usually calculated for penetration of 2.5 mm and 5 mm. Generally the C.B.R. value at 2.5 mm will be greater than at 5 mm and in such a case/the former shall be taken as C.B.R. for design purpose. If C.B.R. for 5 mm exceeds that for 2.5 mm, the test should be repeated. If identical results follow, the C.B.R. corresponding to 5 mm penetration should be taken for design.

Graph:

Draw graph between Load versus Penetration.


LOAD DIAL READINGS
DIVISION
70
60
50
40
30
20
10
0
2
4
6
8
10
12
Specimen no. 1
(No correction)
Specimen no. 2
(correction required)
Corrected origin
PENETRATION , mm

EXPERIMENT NO: 13 **DATE:**

BITUMINOUS MIX DESIGN BY MARSHALL METHOD (DEMO)

The Marshall Mix Design method consists mainly of the following steps:

(i) Determination of physical properties, size and gradation of aggregates.

(ii) Selection of types of asphalt binder.

(iii)Prepare initial samples, each with different asphalt binder content. For example, three samples are made each at 4.5, 5.0, 5.5, 6.0 and 6.5 percent asphalt by dry weight for a total of 15 samples. There should be at least two samples above and two below the estimated optimum asphalt content.

(iv) Plot the following graphs:

(a) Asphalt binder content vs. density

(b) Asphalt binder content vs. Marshall stability

(c) Asphalt binder content vs. flow

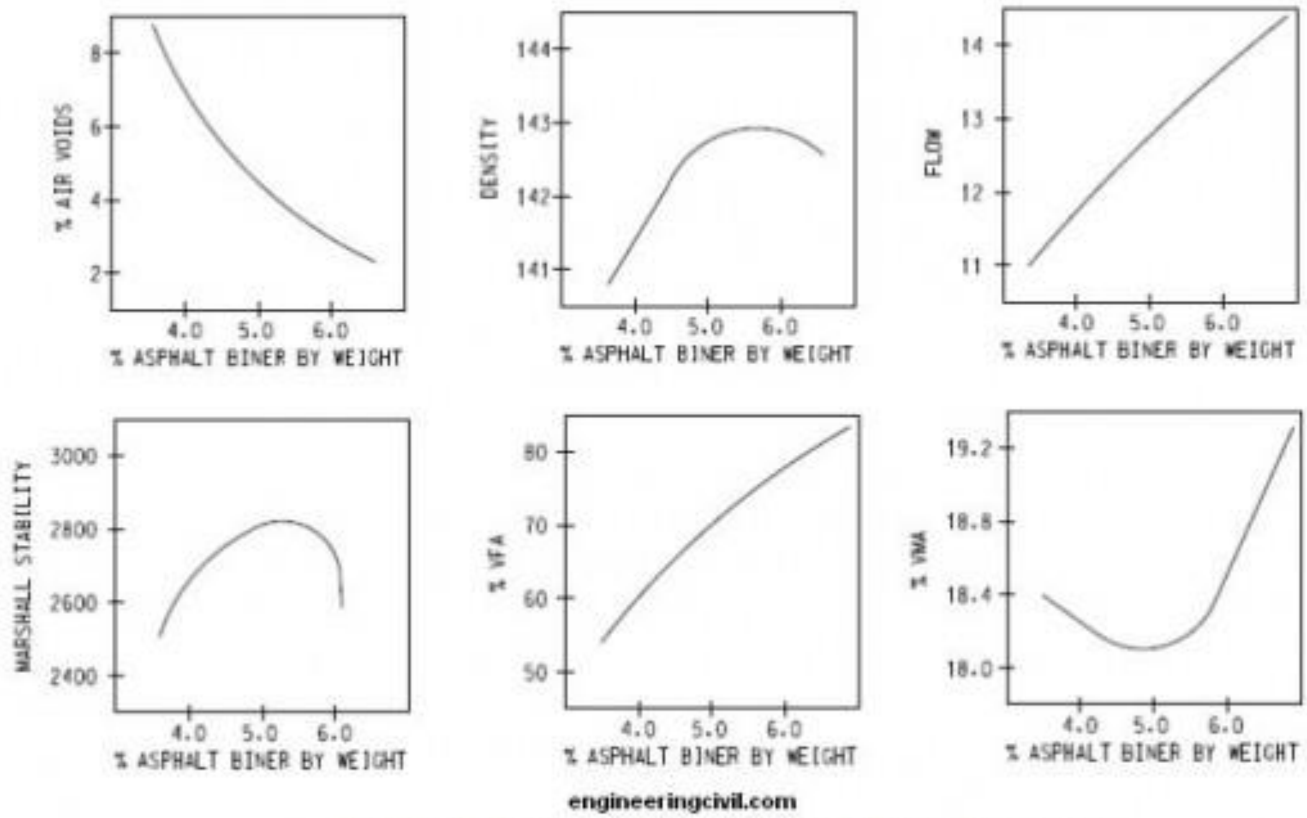
(d) Asphalt binder content vs. air voids

(e) Asphalt binder content vs. voids in mineral aggregates

(f) Asphalt binder content vs voids filled with asphalt

(v) Determine the asphalt binder content which corresponds to the air void content of 4 percent

(vi) Determine properties at this optimum asphalt binder content by reference with the graphs. Compare each of these values against design requirements and if all comply with design requirements, then the selected optimum asphalt binder content is acceptable. Otherwise, the mixture should be redesigned.

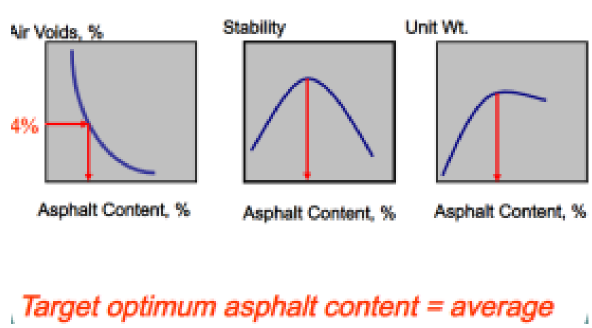


Design graphs for Marshall Mix Design

8. Determining Optimum Binder Content

Determine the optimum binder content for the mix design by taking average value of the following three bitumen contents found form the graphs obtained in the previous step.

1. Binder content corresponding to maximum stability
2. Binder content corresponding to maximum bulk specific gravity (G_m)
3. Binder content corresponding to the median of designed limits of percent air voids (V_v) in the total mix (i.e. 4%)



EXPERIMENT NO: 14 **DATE:**

DESIGN OF FLEXIBLE PAVEMENT-IRC 37-2018

Design the pavement for construction of a new bypass with the following data:

1. Two lane carriage way
2. Initial traffic in the year of completion of construction = 400 CVPD (sum of both directions)
3. Traffic growth rate = 7.5 %
4. Design life = 15 years
5. Vehicle damage factor based on axle load survey = 2.5 standard axle per commercial vehicle
6. Design CBR of subgrade soil = 4%.

Solution:

1. Distribution factor = 0.75

2.

$$N = \frac{365 \times [(1 + 0.075)15 - 1)]}{0.075} \times 400 \times 0.75 \times 2.5$$

$$= 7200000$$

$$= 7.2 \text{ msa}$$

3. Total pavement thickness for CBR 4% and traffic 7.2 msa from IRC:37 2001 chart1 = 660 mm

4. Pavement composition can be obtained by interpolation from Pavement Design Catalogue (IRC: 37 2001).

(a) Bituminous surfacing = 25 mm SDBC + 70 mm DBM

(b) Road-base = 250 mm WBM

(c) sub-base = 315 mm granular material of CBR not less than 30 %

Summary

The design procedure given by IRC makes use of the CBR value, million standard axle concept, and vehicle damage factor. Traffic distributions along the lanes are taken into account. The design is meant for design traffic which is arrived at using a growth rate.

EXPERIMENT NO: 15 DATE:

DESIGN OF RIGID PAVEMENT-IRC 58-2015

Recommended Procedure for slab design;

Step 1: Stipulate design values for the various parameters.

Step 2: Select a trial design thickness of pavement slab.

Step 3: Compute the repetitions of axle loads of different magnitudes and different categories during the design life.

Step 4: Find the proportions of axle load repetitions operating during the day and night periods.

Step 5: Estimate the axle load repetitions in the six-hour-period during the day time. The maximum temperature differential is assumed to remain constant during the 6 hours for analysis of bottom-up cracking

Step 6: Estimate the axle load repetitions in the six-hour period during the night time. The maximum negative temperature differential during night is taken as half of day-time maximum temperature differential. Built in negative temperature differential of 5ºC developed during the setting of the concrete is to be added to the temperature differential for the analysis of top-down cracking. Only those vehicles with spacing between the front (steering) axle and the first rear axle less than the transverse joint spacing need to be considered for top-down cracking analysis.

Step 7: Compute the flexural stresses at the edge due to the single and tandem axle loads for the combined effect of axle loads and positive temperature differential during the day time. Determine the stress ratio (Flexural stress/Modulus of Rupture) and evaluate the Cumulative Fatigue Damage (CFD) for single and tandem axle loads.

Step 8: Compute the maximum flexural stress in the top surface of the pavement slab with the front axle near the approaching transverse joint and the rear axle close to the following joint in the same panel under negative temperature differential. Determine the stress ratio and evaluate the CFD for different axle loads for the analysis of top-down cracking.

Step 9: Sum of CFD for the BUC and TDC. If the sum is less than 1.0, the pavement slab is safe against fatigue cracking.

Illustrative examples of thickness design

A cement concrete pavement is to be designed for a four-lane divided National Highway with two lanes in each direction in the state of Bihar. Design the pavement for a period of 30 years.

Lane width = 3.5 m;

Transverse joint spacing = 4.5 m.

It is expected that the road will carry, in the year of completion of construction, about 3000 commercial vehicles per day in each direction. Axle load survey of commercial vehicles indicated that the percentages of front single (steering) axle, rear single axle, rear tandem axle and rear tridem axle are 45%, 15%, 25% and 15% respectively. The percentage of commercial vehicles with spacing between the front axle and the first rear axle less than 4.5 m is 55%. Traffic count indicates that 60% of the commercial vehicles travel during night hours (6 PM to 6 AM).

Details of axle load spectrum of rear single, tandem and tridem axles are given in table VII.1. Front (steering) axles are not included. The average number of axles per commercial vehicle is 2.35 (due to the presence of multi-axle vehicles).

Table VII.1 Axle load spectrum for example

Single Axle			Tandem Axle			Tridem Axle		
Axle Load Class (KN)	Mean Load (KN)	Frequency (% of Single Axle)	Axle Load Class (KN)	Mean Load (KN)	Frequency (% of Tandem Axle)	Axle Load Class (KN)	Mean Load (KN)	Frequency (% of Tridem Axle)
185-195	190	18.15	380-400	390	14.5	530-560	545	5.23
175-185	180	17.43	360-380	370	10.5	500-530	515	4.85
165-175	170	18.27	340-360	350	3.63	470-500	485	3.44
155-165	160	12.98	320-340	330	2.5	440-470	455	7.12
145-155	150	2.98	300-320	310	2.69	410-440	425	10.11
135-145	140	1.62	280-300	290	1.26	380-410	395	12.01
125-135	130	2.62	260-280	270	3.9	350-380	365	15.57
115-125	120	2.65	240-260	250	5.19	320-350	335	13.28
105-115	110	2.65	220-240	230	6.3	290-320	305	4.55
95-105	100	3.25	200-220	210	6.4	260-290	275	3.16
85-95	90	3.25	180-200	190	8.9	230-260	245	3.10
<85		14.15	<180		34.23	<230		17.58
		100			100			100

Effective CBR of compacted subgrade = 8 %.

Design a concrete pavement for the following options

(i) concrete pavement with tied concrete shoulder with doweled transverse joints

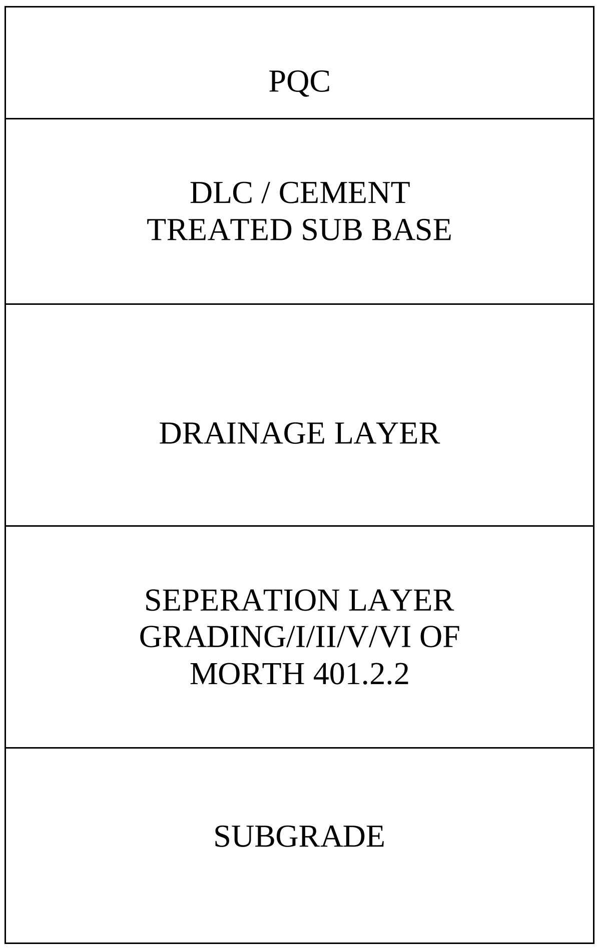
(ii) concrete pavement without tied concrete shoulder and without doweled transverse joints.

(iii) Concrete pavement with widened outer lane and.

(iv) Concrete pavement bonded to dry lean concrete layer

Solution for example:

Typical cross-section of a concrete pavement is shown in figure below.



Typical Cross-Section of Concrete Pavement

a) Selection of modulus of subgrade reaction :-

● Effective CBR of compacted subgrade = 8%. Modulus of subgrade reaction = 50.3 MPa/m (from table 2).

● Provide 150 mm thick granular subbase.

● Provide a DLC subbase of thickness 150 mm with a minimum 7 day compressive strength of 7 MPa.

● Effective modulus of subgrade reaction of combined foundation of subgrade + granular subbase and DLC subbase (from table 4 by interpolation) = 285 MPa/m.

● Provide a debonding layer of polythene sheet of 125 micron thickness between DLC and concrete slab.

b) Selection of Flexural Strength of Concrete :-

● 28-day compressive strength of cement concrete ≥ 40 MPa minimum

● 90-day compressive strength of cement concrete ≥ 48 MPa

● 28-day Flexural strength of cement concrete = 4.5 MPa (minimum)

● 90-day Flexural strength of cement concrete = 4.5 × 1.1 = 4.95 MPa

(c) Selection of Design Traffic for Fatigue Analysis :-

● Design period = 30 years.

● Annual rate of growth of commercial traffic (expressed in decimal) = 0.075 (assumed)

● Two-way commercial traffic volume per day = 6000 commercial vehicles/ day

● % of traffic in predominant direction = 50% (3000 CVs in each direction)

● Total two-way commercial vehicles during design period,

$$C = \frac{365\ X\ 6000\ \{(1+0.075)^{30}\}}{0.075}$$

● = 226,444,692 CVs

● Average number of axles (steering/single/tandem/tridem) per commercial vehicle = 2.35

● Total two-way axle load repetitions during the design period = 226,444,692 X 2.35 = 532,145,025 axles

● Number of axles in predominant direction = 532,145,025 X 0.5 = 266,072,513

● Design traffic after adjusting for lateral placement of axles (25% of predominant direction traffic for multi-lane highways) = 266,072,513 X 0.25 = 66,518,128

● Night time (12-hour) design axle repetitions = 66,518,128 * 0.6 (60% traffic during night time) = 39,910,877

● Day time (12-hour) design axle repetitions = 66,518,128 * (1-0.6) = 26,607,251

● Day-time Six-Hour axle load repetitions = 26,607,251 / 2 = 13,303,626

● Hence, design number of axle load repetitions for bottom-up cracking analysis = 13,303,626

● Night-time Six-Hour axle load repetitions = 39,910,877/2 = 19,955,439

● % of commercial vehicles having the spacing between the front (steering) axle and the first axle of the rear axle unit less than 4.50 m = 55%

● Hence, the Six-hour night-time design axle load repetitions for Top- down cracking analysis (wheel base < 4.5 m) = 19,955,439 X 0.55 = 10,975,491

● The axle load category-wise design axle load repetitions for bottom-up and top-down fatigue cracking analysis are given in the following table:

4. Category-wise design axle load repetition for bottom-up and top-down fatigue cracking analysis are as follows

design number of axle load repetition for bottom-up cracking analysis = 13,303,626

design axle load repetition for Top-down cracking analysis 10,975,491

Axle Load Category	Proportion of the Axle Category	Axle Repetition for Bottom-up Cracking Analysis (Day time)	Axle Repetition for Top-down Cracking Analysis (Night time)
Front (steering) single	0.45	5986632	4938971
Rear single	0.15	1995544	1646324
Tandem	0.25	3325906	2743873
Tridem	0.15	1995544	1646324

c) Cumulative Fatigue Damage (CFD) analysis for Bottom-Up Cracking (BUC) and Top-Down Cracking (TDC) and Selection of Slab Thickness :-

● Effective modulus of subgrade reaction of foundation, k = 285 MPa/m

● Elastic Modulus of concrete, E = 30,000 MPa

● Poisson’s ratio of concrete, μ = 0.15

● Unit weight of concrete, γ = 24 kN/m3

● Design flexural strength of concrete = 4.95 MPa

● Max. day-time Temperature Differential in slab (for bottom-up cracking) = 16.8ºC (for Bihar)

● Night-time Temperature Differential in slab (for top-down cracking) = day-time diff/2 + 5 = 13.4ºC

Pavement option I - Concrete pavement with tied concrete shoulder with dowel bars across transverse joints.

● Trial thickness of slab, h = 0.28 m

● Radius of relative stiffness, l = (Eh3/(12k(1-μ2))0.25 = 0.78758 m

● 'Beta' factor in the stress equations will be 0.66 for doweled transverse joints for carrying out TDC analysis.

Table VII.2 Cumulative Fatigue Damage Analysis for Bottom-up Cracking
(Mid Point of the Axle Load Class from Table VII-1 is Adopted for Stress Computation)

Bottom-up Cracking Fatigue Analysis for Day-time (6 hour) traffic and Positive Temperature Differential									
Rear Single Axles(as per Table VII-1, 1st col)					Rear Tandem Axles(as per Table VII-1, 3rd col)				
Expected Rep (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Rep. (Ni)	Fatigue Damage (ni/Ni)	Expected Rep. (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Rep. (Ni)	Fatigue Damage (ni/Ni)
362191	2.503	0.506	588331	0.616	482256	2.118	0.428	infinite	0.000
347823	2.422	0.489	1344185	0.259	349220	2.045	0.413	infinite	0.000
364586	2.341	0.473	4072762	0.090	120730	1.972	0.398	infinite	0.000
259022	2.260	0.457	22079767	0.012	83148	1.899	0.384	infinite	0.000
59467	2.179	0.440	infinite	0.000	89467	1.826	0.369	infinite	0.000
32328	2.099	0.424	infinite	0.000	41906	1.754	0.354	infinite	0.000
52283	2.018	0.408	infinite	0.000	129710	1.681	0.340	infinite	0.000
52882	1.937	0.391	infinite	0.000	172615	1.608	0.325	infinite	0.000
52882	1.856	0.375	infinite	0.000	209532	1.535	0.310	infinite	0.000
64855	1.775	0.359	infinite	0.000	212858	1.462	0.295	infinite	0.000
64855	1.695	0.342	infinite	0.000	296006	1.39	0.281	infinite	0.000
282369	1.614	0.326	infinite	0.000	1138458	1.317	0.266	infinite	0.000
1995544	**Fat Dam from Single Axles =**			**0.976**	**3325906**	**Fat Dam from Tandem Axles =**			**0.000**

Table VII.3 Cumulative Fatigue Damage Analysis for Top-Down Cracking
(Mid Point of the Axle Load Class from Table VII-1 is Adopted for Stress Computation)

Top-Down Cracking Fatigue Analysis for Night-time (6 hour) traffic and Negative Temperature Differential														
Rear Single Axles(as per Table VII-1 1st col)					Rear Tandem Axles (as per Table VII-1 3rd col) (Stress computed for 50% of axle load)					Rear Tridem Axles (as per Table VII-1 5th col) (Stress computed for 33% of axle load)				
Expected Rep. (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Rep. (Ni)	Fat. Dam. (ni/Ni)	Expected Rep. (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Rep. (Ni)	Fat. Dam. (ni/Ni)	Expected Rep. (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Rep. (Ni)	Fat. Dam. (ni/Ni)
298808	2.399	0.485	1768731	0.169	397862	2.427	0.490	1267085	0.314	86103	2.353	0.475	3370878	0.026
286954	2.344	0.473	3899961	0.074	288107	2.371	0.479	2564487	0.112	79847	2.297	0.464	9089367	0.009
300783	2.288	0.462	11091781	0.027	99603	2.316	0.468	6308978	0.016	56634	2.242	0.453	38025932	0.001
213693	2.233	0.451	52048021	0.004	68597	2.26	0.457	21946523	0.003	117218	2.186	0.442	Infinite	0.000
49060	2.177	0.440	infinite	0.000	73810	2.205	0.445	infinite	0.000	166443	2.131	0.430	Infinite	0.000
26670	2.122	0.429	infinite	0.000	34573	2.149	0.434	infinite	0.000	197723	2.075	0.419	Infinite	0.000
43134	2.066	0.417	infinite	0.000	107011	2.094	0.423	infinite	0.000	256333	2.02	0.408	Infinite	0.000
43628	2.011	0.406	infinite	0.000	142407	2.038	0.412	infinite	0.000	218632	1.964	0.397	Infinite	0.000
43628	1.955	0.395	infinite	0.000	172864	1.983	0.401	infinite	0.000	74908	1.909	0.386	Infinite	0.000
53506	1.900	0.384	infinite	0.000	175608	1.927	0.389	infinite	0.000	52024	1.853	0.374	Infinite	0.000
53506	1.844	0.373	infinite	0.000	244205	1.872	0.378	infinite	0.000	51036	1.798	0.363	Infinite	0.000
232955	1.789	0.361	infinite	0.000	939228	1.816	0.367	infinite	0.000	289424	1.742	0.352	Infinite	0.000
1646324	**Fat Dam from Sing. Axles =**			**0.274**	**2743873**	**Fat Dam from Tand Axles =**			**0.445**	**1646324**	**Fat Dam from Tridem Axles =**			**0.036**

Table VII.4 Gives the Cumulative fatigue damage values for five trial thicknesses.

Table VII.4 Cumulative Fatigue Damage Values for Different Trial Thicknesses (for the Data Considered in the Example)

Slab Thickness, m	CFD for BUC Case			CFD for TDC Case					Remarks
	Due to Rear Single Axles	Due to Tandem Axles	Total CFD	Due to Rear Single Axles	Due to Tandem Axles	Due to Rear Tridem Axles	Total CFD	Sum of BUC and TDC CFD	
0.24	36.27	2.992	39.262	7.064	8.69	1.489	17.243	56.505	Unsafe
0.25	14.924	0.812	15.737	3.537	4.475	0.674	8.686	24.423	Unsafe
0.26	6.488	0.136	6.624	1.671	2.245	0.285	4.201	10.825	Unsafe
0.28	0.976	0.00	0.976	0.274	0.445	0.036	0.755	1.731	Unsafe
0.29	0.282	0.00	0.282	0.078	0.157	0.009	0.245	0.527	Safe

Pavement Option II - Concrete pavement with no concrete shoulder and without dowel bars across transverse joints. This is for illustration since dowel bar is essential for heavy traffic to prevent faulting, erosion and pumping at transverse joints.

- Trial thickness of slab, h = 0.33 m
- Radius of relative stiffness, l = (Eh3/(12k (1-µ2))0.25 = 0.75358 m
- 'Beta' factor in the stress equations will be 0.90 for transverse joints without dowel bars for carrying out TDC analysis.

The cumulative fatigue damage values obtained for bottom-up and top-down cracking analyses are given below.

Bottom-up cracking :-

(a) CFD due to rear single axles = 0.935

(b) CFD due to tandem axles = 0.000

(c) Total CFD = 0.935

Top-down cracking :-

(a) CFD due to rear single axles = 0.233

(b) CFD due to tandem axles = 0.390

(c) CFD due to tridem axles = 0.030

(d) Total CFD = 0.654

Total CFD for BUC and TDC=1.589 >1,0

Hence, the trial thickness of 330 mm is not adequate. A thickness of 340 mm is needed. This clearly shows that for heavy traffic, dowel bar is necessary to lower CFD for TDC. This also illustrates that CFD for BUC is large for pavement without concrete shoulder.

Pavement option III - Concrete pavement with widened outer lanes.

The reduction of flexural stress due to widening of the outer lane by 0.5 m to 0.6 m is of the same order as that of providing tied concrete shoulder. Hence, the thickness of the pavement will be the same as that obtained for Option I (with tied concrete shoulders). Hence, design thickness of concrete pavement slab = 290 mm. The thickness may be increased by 10 mm for two retexturing during the pavement's life time.

Pavement option IV- Concrete pavement bonded to dry lean concrete layer.

A 7 day strength of 10 MPa or higher for the DLC is necessary for a bonded pavement. There is no upper strength limit for DLC for bonded cases.

● Provide a granular subbase of 250 mm thickness above the subgrade

● Effective modulus of subgrade reaction of foundation consisting of subgrade (8% CBR) and granular subbase (from tables 2 and 3) = 72 MPa/m

● Assuming that doweled transverse joints and tied concrete shoulders will be provided, the thickness of slab required for the given traffic and other design data = 0.30 m.

● Referring to fig. 6, $E1 = 30000$ MPa, $E2 = 13600$ MPa, $\mu1 = 0.15$, $\mu2 = 0.20$

● Provide a DLC thickness of 0.15 m. For bonded condition, DLC of of 10 MPa strength at 7 days is considered. Higher strength DLC will give lower thickness of PQC slab

● Depth of neutral axis (computed using equation 11) = 0.16 m

● Assume a trial slab thickness (to be bonded to 0.15 m thick DLC layer) = 0.235 m

● Stiffness of the slab to be placed over DLC layer (Equation 12) = 46.65 MN.m

● Stiffness of the DLC layer (Equation 13) = 23.28 MN.m

● Combined stiffness of slab and DLC = 46.65 + 23.28 = 69.93 MN.m

● Stiffness of the design slab of 0.3 m thickness (Equation 10) = 69.05 MN.m

● Combined stiffness is more than the design stiffness requirement. Hence OK.

EXPERIMENT NO: 16 **DATE:**

TRAFFIC ENGINEERING STUDIES

Theory:

Traffic volume is the number of vehicles crossing a section of Highway per unit time at any selected period. It is used as a quantity measure of flow and the commonly used units are vehicles per day and vehicles per hour. A complete traffic volume study includes the classified volume study by recording the volume of various types and classes of traffic, their distribution by direction and turning movements and the distribution on different lanes per unit time. There are variations in traffic flow from time to time. Hourly traffic volume varies considerably during a day, the peak hourly volume may be much higher than the average hourly volume. Daily traffic volumes vary considerably in week and there are variations with season also. In classified traffic volume study, the traffic is classified and the volume of each class of traffic – busses, truck, passenger cars, other light vehicles, rickshaws, tongas, bullock carts, cycles and pedestrians is found separately. The direction of each class of traffic is also to be noted. At intersections the traffic flow in each direction of flow including turning movements are recorded.

COUNTING OF TRAFFIC VOLUME

Traffic volume counts can be done by either mechanical counters or manual. In mechanical counters, traffic count is recorded by electrically operated counters and recorders capable of recording the impulses. Other methods of working of mechanical detectors are by photo electric cells, magnetic detector and radar detectors. The main advantage of this type of counters is they can work round the clock for the desired period. The disadvantage of this method is that the impulses caused by the vehicles of light weight may not be enough in some cases to actuate the counter. Also it is not possible to record classified traffic volume data and details of turning movements along with pedestrian traffic. In manual counters, a field team is employed to record traffic volume on the prescribed record sheets by hand held counters. In this method it is possible to obtain data which cannot be obtained by mechanical counters such as vehicle classification, turning movements and the details regarding loading conditions and number of occupants. However it is not practicable to conduct manual counts round the clock and on all days round the year. Therefore it is necessary to resort to statistical sampling techniques so that we can cut down the manual hours involved in taking complete traffic counts.

First the fluctuations of traffic volume during the hours of the day and the daily variations are observed, than by selecting typical short count periods, the traffic volume study is made by manual counting after that by statistical analysis, the peak hourly traffic volumes as well as the average daily traffic volumes are calculated. This method is most commonly used because of the specific advantages over other methods. The prescribed record sheet for traffic volume counts is as below. The traffic volume count is done for every 15 minutes period.

Road details:					Location:					Date:		
Direction: ___________ to ____________ Weather condition:												
Time		Motorized Passenger vehicles					Motorized Goods vehicle			Human powered vehicles		Total PCU's
From	To	2 Wheelers	3 Wheelers	Cars / Jeeps	Van / Mini Buss	Busses	LCV's	2 Axle Trucks	Multi Axle Trucks	Cycles	Cycles Rickshaws	

The data collected from traffic volume count is utilized for designing the following elements of highway:

i) Design of flexible and rigid pavement.

ii) Design of traffic signals.

Questions on Traffic Studies

1. The traffic volume is usually expressed in __________

2. The number of vehicles that pass through a transverse line of road at a given time in a specified direction is called __________

3. Which method is more accurate for traffic analysis?

4. The 5 minute count at a traffic junction is 15 find the hourly count? 5. The traffic design in India is based on ________

6. How desire line is drawn

7. The PCU (passenger car unit) value for car on an urban road is

8. What is the first stage in traffic engineering studies?

9. The traffic flow is __________

10. The outgoing and incoming traffic are counted at?