LABORATORY MANUAL

TRANSPORTATION ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

JORHAT ENGINEERING COLLEGE

NAME:

ROLL NO.:

SEMESTER:

ACADEMIC YEAR:

Group no.:

SEMESTER:

NAME OF PROJECT:

GUIDED BY:

SL. NO.	**NAME OF STUDENT**	**ROLL NO.**
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CONTENTS

LIST OF EXPERIMENTS

The following are the list of experiments that have been included in this manual:-

1. CBR test.
2. Aggregate crushing value test.
3. Los Angeles abrasion value test of aggregates.
4. Aggregate impact value test.
5. Shape test of aggregates
6. Specific gravity and water absorption test for coarse aggregates.
7. Softening point (Ring and ball test) of bitumen.
8. Penetration value test of bitumen.
9. Marshall Stability test.
10. Sieve analysis.

Preparation and transportation of test samples:

Sample preparation: Many samples will require some preparation before being sent to the laboratory for testing, particularly if their large sizes make them difficult to handle or because they require special protection.

Sample reduction: If the sample is delivered in larger than required for a particular testing programme, it must be divided to obtain a sample of the required size. In order to ensure the test sample represents the original material, it is necessary to divide the original sample either by quartering or by using a sample divider (Riffle box).

Sample transportation:

All samples should be carefully packed and labelled before transporting them to the laboratory. Sample bags must be strong enough to withstand rough handling and be of a type which prevents loss of fines or moisture from the sample, e.g. thick polythene bags inside jute bags. The use of steel drums for large bulk samples could also be considered. Water samples in glass or plastic containers will require particular care in handling. Undisturbed samples should be placed in wooden boxes and packed in sawdust or similar material to provide added protection. Collision between tubes in transit can easily damage sensitive samples.

Storage:

Storage of all samples should be in an orderly and systematic manner so that they can be subsequently located easily. The storage facility itself should be a secure area, free from the risk of contamination or other harmful influences. Undisturbed samples may be damaged by vibration or corrosion of tubes and should be stored with especial care. Tubes containing wet sandy or silty soils should be stored upright (suitably protected against being knocked over), to prevent possible slumping and segregation of water. The end caps of tube samples which are to be stored for long periods should be sealed with wax, in addition to the wax seal next to the sample itself. Samples which have been tested should not be disposed of without the authority of the laboratory section head.

Sample Drying: Many tests require the material to be drier at the start of the test than the sample as obtained from the field. Some means of drying the sample must, therefore, be utilised. In the case of liquid and plastic limit tests, it is essential that

the material is air dried and, as a general rule, it is preferable to dry samples in the air as opposed to drying in size of the sample and in general should not be smaller than 1.5 times the maximum particle size of the sample If the sample is still too large, one of the containers may be put aside and the material from the other container is passed through the sample divider again.

Air drying: This is essential for liquid and plastic limit tests and is the preferred procedure for all other tests. The sample should be spread out in a thin layer on a hard clean floor or on a suitable metal sheet. Ordinary corrugated galvanised roofing sheets are perfectly satisfactory for this purpose. The material should be exposed to the sunlight and should be in a layer not more than 20 mm thick. Cohesive materials such as clays, require breaking by hand or with a rubber mallet into small pieces, to allow drying to take place without too much delay. The soil should periodically be turned over and a careful check should be made to ensure the material is removed to a sheltered place if it starts to rain. In the case of soft stone or gravels, care should be taken to ensure only lumps of cohesive fines are broken up and that the actual stone particles are not destroyed. In the case of fine-grained materials, it is generally beneficial to the later stages of testing to pass the dried particles through a No. 4 sieve. Air drying should not normally take longer than 2 to 3 days if carried out correctly.

Oven drying. Oven drying should only be employed where air drying is not possible. Oven drying will not normally have any detrimental effect on the results for sound granular materials such as sand and gravel, but may change the structure of clay soils and thus lead to incorrect test results. Oven drying must never be used in the case of liquid and plastic limit tests. In oven drying the temperature should not exceed 1100C and the material should be dried as quickly as possible by spreading in thin layers on metal trays. Periodically, the material should be allowed to cool before testing is commenced.

Sand-bath drying: In certain cases an oven may not be available but the sample must be dried quickly; sand bath drying may then be utilised. The sand-bath consists simply of a strong metal tray or dish which is filled with clean coarse sand. The sand bath is placed on some form of heater such as a kerosene stove, a gas ring or an electric ring. The sample to be dried is placed in a heatproof dish which is embedded in the surface of the sand. A low heat should be applied so that the sand becomes heated without causing damage to the bath. The sample should be stirred and turned frequently to ensure the material at the base does not become too hot. The material should be allowed to cool before testing is commenced.

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EXPERIMENT NO. 1: DETERMINATION OF CALIFORNIA BEARING RATIO (CBR) VALUE

Aim: To determine the CBR value of a given soil sample.

Theory:

The California Bearing Ratio (CBR) test is a penetration test which was developed by the California State Highway Department, USA for the evaluation of soil-subgrade strength and base course materials strength base course materials strength for flexible pavements.

The CBR is a measure of resistance of a material to penetration of a standard plunger under controlled density and moisture conditions at standard rate. CBR value as defined by IS: 2720 (Part XVI)-1979 is the ratio of the force per unit area required to penetrate a soil mass with a circular plunger of 50 mm diameter at the rate of 1.25 mm/minute, to that required corresponding penetration of a standard material. The CBR test may be controlled in remoulded or undisturbed specimen in the laboratory. The test procedure should be strictly adhered if high degree of reproducibility is desired. Many methods exists today which utilise mainly CBR test values for designing pavements structure. The test is empirical and results cannot be related accurately with any fundamental property of the material. But the test is simple and has been extensively investigated for field correlations of flexible pavement thickness requirement.

Equipment/Apparatus: The apparatus as per IS:2720 (part XVI)-1979 comprises of the following:

1. *Loading machine*: Any compression machine with a capacity of at least 5000 kg which can operate at constant rate of 1.25mm per minute can be used for this purpose. A plunger of diameter 50mm, proving ring, deflection dial etc.
2. *Cylindrical moulds*: moulds of 150mm diameter and 175mmn height provided with a collar of about 50mm length and a detachable perforated base are used for this purpose. A spacer disk of 148mm and 47.7mm thickness is used to obtain a specimen of exactly 127.3mm height.
3. *Spacer disc*: A metal disc of 148 mm diameter and 47.7 mm height.
4. *Compaction rammer*: The material is compacted as specified for the work, either by dynamic compaction or static compaction. The details for dynamic compaction suggested by the ISI are given below:

Type of compaction	Number of layers	Weight of hammer, kg	Free fall, cm	Number of blows
Light compaction	3	2.6	31	56
Heavy compaction	5	4.89	45	56

5. *Adjustable stem, perforated plate, tripod and dial gauge*: The standard procedure requires that the soil sample before testing should be soaked in water to measure swelling. For these purpose these accessories are required.
6. *Surcharge weights*: In order to simulate the effect of over lying pavement weight, one annular metal weights each of 2.5 kg and 147mm diameter are placed on top of the specimen, both at the time of soaking and testing the samples, as surcharge.
7. *Penetration plunger*: A metallic plunger having a diameter of 50 mm and at least 100 mm long.
8. IS sieve of sizes 20mm and 4.75mm, oven, balance, coarse filter etc. equipments are required.

Line diagram:

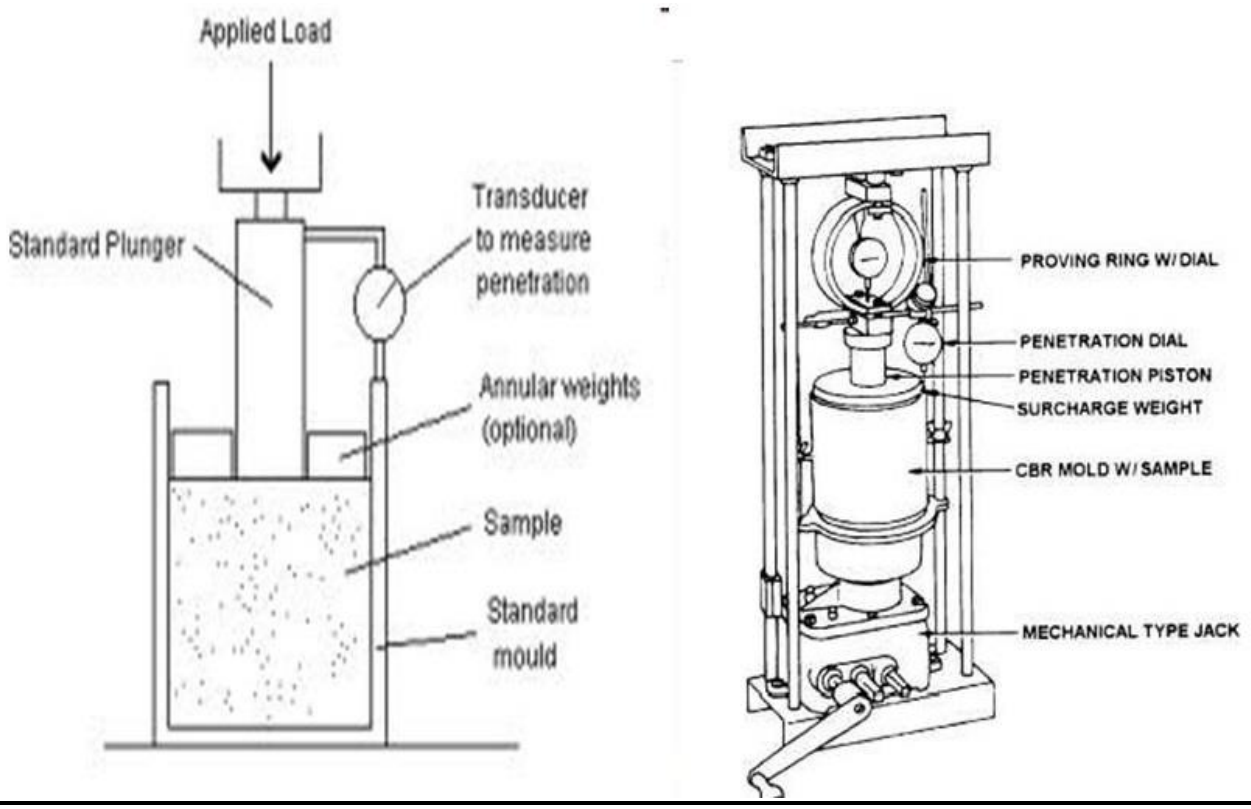

Fig 1.1: Line diagram of CBR test apparatus

Pictorial Image:

Fig.1.2: CBR test machine

Procedure:

1. *Preparation of test specimen*: As per the ISI, the CBR test may be performed on undisturbed soil specimen obtained by fitting a cutting edge to the mould or on remoulded specimens. The material used in the remoulded specimen shall pass a 20-mm IS sieve. About 20 to 45kg of material is sieved and dried through 20mm sieve. If there is noteworthy proportion of material retained on 20mm sieve, allowance for larger materials is made by replacing it by an equal weight of material passing 20mm sieve and 4.75mm sieve. The optimum moisture content and maximum dry density of soil are determined by adopting either IS light compaction (Proctor Compaction) or IS heavy compaction (Modified Proctor

Compaction) as per the requirement. In case the most of the sample pass through 4.75mm sieve, then the dry pulverised sample is sieved through 4.75mm sieve and the portion passing this sieve is only used for this test. Remoulded soil specimen may be compacted either by static compaction or by dynamic compaction.

Statically Compacted Specimen: The batch of soil is mixed with water to give the required moisture content. The correct weight of moist soil to obtain the desired density is placed in the mould and compaction is attained by pressing the spacer disc using a compaction or jack.

The preparation of a soil specimen by dynamic compaction or ramming is more commonly adopted and is explained below:

Dynamically Compacted Specimen: A representative sample of the soil weighing approximately 5.5kg for granular soil and 4.5 to 5kg weight for fine grained soils is taken and mixed thoroughly with water up to the optimum moisture content or field moisture content if specified so. The spacer disc is placed at the bottom of the mould over the base plate and a coarse filter paper is placed over the spacer discs. The moist soil is to be compacted over this in the mould by compacting either the IS light compaction or the heavy IS compaction.

a) For IS light compaction, the soil to be compacted is divided into three equal parts, the soil is compacted into three equal layers, each of compacted thickness about 44mm by applying 56 evenly distributed blows of the 2.6kg rammer.
b) For IS heavy compaction, the soil is divided into five equal parts. The soil is compacted in five equal layers, each of compacted thickness about 26.5mm by applying 56 evenly distributed blows of the 4.89kg rammer. After compacting the last layer, the collar is removed and the excess soil above the top of the mould is evenly trimmed off by means of the straight edge. It is important to see if the excess soil is to be trimmed off while preparing each specimen is of thickness about 5mm; If not the weight of soil taken for compacting each specimen is suitably adjusted for repeat tests so that the thickness of the excess layer to be trimmed off is about 5mm. Any hole that develops on the surface due to removal of coarse particles during trimming may be patched up with smaller size materials. Three such compacted specimens are prepared for the CBR tests. About 100gm of soil samples are collected from each mould for moisture content determination from trimmed off portions.

2. The clamps are removed and the mould with the compacted soil is lifted leaving below the perforated base plate and spacer disc which is removed. The mould with the compacted soil is weighed. A filter paper is placed on the perforated base plate, the mould with compacted soil is inverted and placed in position over the base plate (such that the top of the soil sample is now placed over the base plate) and the clamps of the base plate are tightened. Another filter paper is placed on the top surface of the soil sample and the perforated plate with adjustable stem over it. Surcharge weight of 2.5 or 5kg weight are placed over the perforated plate and the whole mould with the weights is placed in a water for soaking such that water can enter specimen from both top and bottom. The swell measuring device consisting of the tripod and the dial gauge are placed on the top edge of the mould and the spindle of the dial gauge is placed touching the top of the adjustable

stem of the perforated plate (see fig.2). The initial dial gauge reading is recorded and the test is kept undisturbed in the water tank to allow soaking of the soil specimen for four full days or 96 hours. The final dial gauge reading is noted to measure the expansion or swelling of the specimen due to soaking.

3. The swell measuring assembly is removed, the mould is taken out of the water tank and the sample is allowed to drain in a vertical position for 15 minutes. The surcharge weights, the perforated plate with stem and the filter paper are removed. The mould with the soil sample is removed from the base plate and is weighed again to determine the weight of the water absorbed.
4. The mould with the specimen is clamped over the base plate and the same surcharge weights are placed on the specimen such that the penetration test could be conducted. The mould with the base [plate is placed under the penetration plunger of the loading machine. The penetration plunger is seated at the centre of the specimen and is brought in contact with the top surface of the soil sample by applying a seated load of 4kg.
5. The dial gauge of the proving ring (for load reading) and the penetration dial gauge reading are set to zero.
6. The load is applied through the penetration plunger at a uniform rate of 1.25mm per-minute by setting the gear at constant rate of 1.25mm/min.
7. The load reading are recorded at penetration readings of 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 5.0, 7.5, 10.0 and 12.5mm. In case the load readings start decreasing before 12.5mm penetration, the maximum load value and the corresponding penetration value are recorded. After the final reading, the load is released and the mould is removed from the loading machine.
8. The proving ring calibration factor is noted so that the load dial values can be converted into load in kg also find the least count of penetration dial gauge reading to convert into mm.(The present our laboratory machine, the proving ring calibration factor =0.99kg/div., the deflection dial gauge L.C=0.01mm/div.)
9. About 50gm of soil is collected from the top three cm depth of the soil sample for the full determination of moisture content (w). Also weigh the mould with full soil and empty and determine dry density (γ_d).

Formula used in determination of $\gamma_d = \gamma_m$ / (1+w/100) g/cc

Where, = wet density

$=W-W_m/ V_m$,g/cc

W= Weight of mould with moist compacted soil in gm.

W_m= Weight of empty mould in gm.

V_m= Volume of the mould in cc.

N.B. - In case of unsoaked test, (i) and (ii) are performed.

Precautions:

i) The holes of the base plate of the mould should not be blocked.

ii) The surcharge weight should be aligned with the plunger so that the plunger penetrates freely into the soil.

Formulae to calculate the expansion ratio and CBR value:

The swelling or expansion ratio is calculated from observation during the swelling test using this formula:

Expansion ratio= 100(df-dt)/h

Where df= Final dial gauge after soaking in mm.

dt = initial dial gauge reading before soaking in mm

h= Initial height of the specimen in mm.

The CBR value is calculated from this formula,

CBR% = [Load carried by soil sample at 2.5 or 5mm penetration / Load carried by standard crushed stone at 2.5 or 5mm penetration] x 100

Results:

The expansion ratio of soil due to soaking and other details of the test may be reported as given in the observation sheet. The CBR values at 2.5 and 5mm penetrations are calculated for each specimen from the corresponding graphs as shown in Fig.1.2. Generally the CBR value at 2.5mm penetration is higher and this value is adopted. However if the CBR value is obtained at 5mm penetration, the test is to be repeated to verify the results. If the value at 5mm is again higher than it is adopted as the CBR value of the soil sample. The average CBR value of three specimens is reported to the first decimal place.

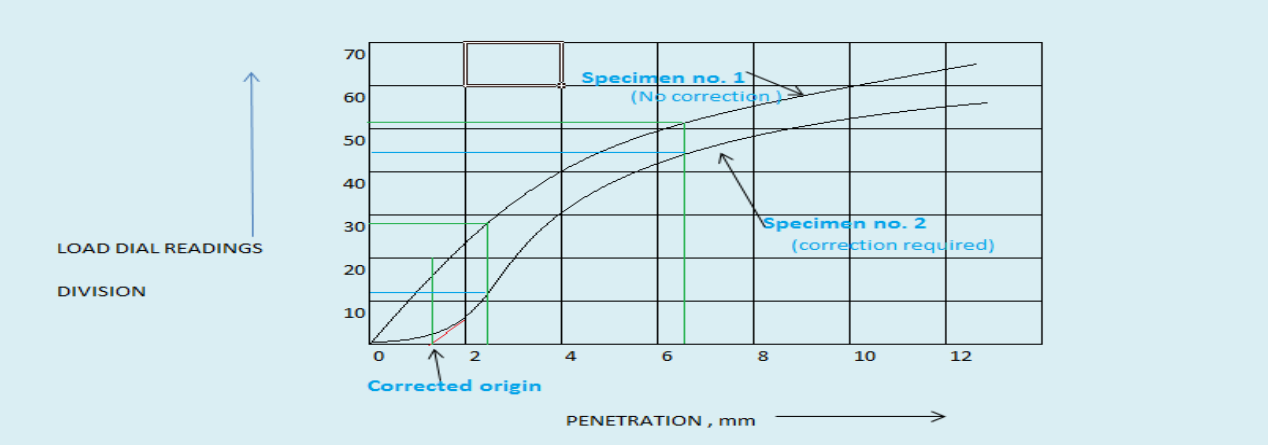

Fig.1.2: Typical load penetration curve

According to the Indian Road Congress, if the maximum variation in laboratory in CBR values between the three specimens exceed the value given below for the different ranges, the CBR test should be repeated on additional three specimens and the average value of six specimens is adopted.

Maximum permissible variation in CBR values, %	Range of CBR values, %
3.0	Up to 10
5.0	10 to 30
10.0	30 to 60
Not significant	Above 60

Record of Observations:

Compaction moisture content =

Dry density =

Condition of test specimen: soaked/unsoaked

Moisture content: a) At top 3cm layer after soaking =

b) Average after soaking =

Proving ring calibration factor =

Surcharge weight =

Period of soaking =

Expansion ratio =

Sample no. (1)	Dial gauge reading in div. (2)	Penetration in mm (3)	Proving ring dial gauge reading in div. (4)	Load on plunger in kg (5)	CBR value at 2.5 and 5mm from graph (6)
1	0 50 100 150 200 250 300 400 500 750 1000 1250	0 0.5 1.0 1.5 2.0 2.5 3.0 4.0 5.0 7.5 10.0 12.5			CBR at 2.5mm= CBR at 5mm=

(Table for sample 2):

(Table for sample 3):

Average CBR value at penetration 2.5 mm = %

Average CBR value at penetration 5 mm = %

CBR of the sample (to be adopted for design) = %

Results: The mean CBR value of the three samples is the CBR value of the subgrade.

Questions for Discussion

i) What is the CBR value ?
ii) What is the significance of surcharge weight ?
iii) Under what conditions would you recommend to conduct CBR test on soaked specimen ?
iv) What are the field applications of CBR test results ?
v) When is it necessary to apply correction to CBR value ? What are the reasons for the concavity of load -penetration curve ?

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EXPERIMENT NO. 2: DETERMINATION OF AGGREGATE CRUSHING VALUE

Objective:

To determine crushing value of given road aggregates with the help of a compression testing machine .

Theory:

The principal mechanical properties required in road stones are- (a) satisfactory resistance to crushing under the roller during construction and (b)adequate resistance to surface abrasion under traffic.

Aggregates used in road construction should be strong enough to resist crushing under traffic wheel loads. If the aggregates are weak, the stability of the pavement structure is likely to be adversely affected. The strength of coarse aggregates is assessed by aggregate crushing test. The aggregate crushing value provides a relative measure of resistance to crushing under a gradually applied compressive load. To achieve a high quality of pavement, aggregate possessing low aggregate crushing value should be preferred.

Apparatus:

The apparatus for the standard aggregate crushing test as per IS: 2386- 1963 (Part IV) consists of the following:

1. Steel cylinder with open ends, internal diameter 152mm, square base plate, plunger having a piston of diameter 150mm, with a hole provided across the stem of the plunger so that rod could be inserted for lifting or placing the plunger in the cylinder.
2. A cylindrical measure having internal diameter of 115mm and a height of 180mm.
3. A straight steel tamping rod with one rounded end, having a diameter of 16mm and length 450 to 600mm.
4. Balance of capacity 3kg with accuracy up to 1gm.
5. Compression testing machine capable of applying load of 40tonnes at a uniform rate of loading of 4 tonnes per minute.
6. IS sieves of sizes 12.5mm, 10mm and 2.36 mm.

LINE DIAGRAM:

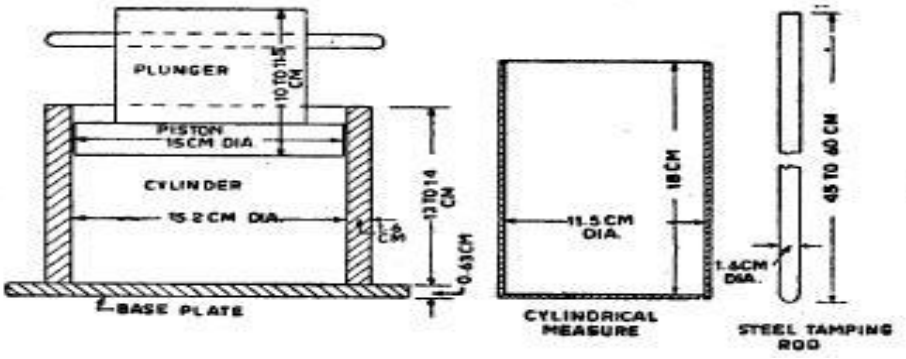

Fig. 2.1: Line diagram of Aggregate crushing value test apparatus

Pictorial image:

Fig.2.2: Aggregate crushing value testing machine

Procedure:

1. The aggregate passing 12.5mm IS sieve and retained on 10mm IS sieve is selected for the test. The aggregate should be in surface dry condition before testing. The aggregate may be dried by heating at a temperature of 100^0C to 110^0C for a period of 4 hours and is tested after being cooled to room temperature.
2. Take about 3.25 kg of this material.
3. The cylindrical measure is filled by the test sample of aggregates in three layers of approximately equal depth, each layer being tamped 25 times by the rounded end of the tamping rod. After the third layer is tamped, using the tamping rod as a straight edge, level off the aggregate at the top cylindrical measure. The test sample is then weighed. The same weight of the sample is taken in the successive test.

4. The cylinder of the test apparatus is placed in position on the base plate; one third of the test sample is placed in this cylinder and tamped 25 times by the tamping rod. Similarly, the other two layers are placed. The surface of the aggregates is levelled and the plunger is inserted so that it rests on the surface in level position. The cylinder with the test sample and the plunger is then placed on the compression testing machine. A load of 40 tonnes is then applied through the plunger at a uniform rate of 4 tonnes per minute, and then the load is released. Aggregates including the crushed portion are removed from the cylinder and sieved on a 2.36mm IS sieve. The material which passes this sieve is the weighed.
5. The above procedure is repeated on the second sample.

Precautions:

1. The plunger should be placed centrally and rest directly on the aggregates. Care should be taken that it doesn't touch the walls of the cylinder so as to ensure that the entire load s transferred onto the aggregates.
2. In the operation of sieving the aggregates through 2.36 mm sieve and weighing care should be taken to avoid loss of fines. The sum of weights of fractions retained and passing the sieve should not differ from the original weight of the specimen by more than 1 gm.
3. The temping should be done properly by gently dropping the tamping rod and not by hammering action. Also temping should be uniform over the surface of the aggregates taking care that the temping rod doesn't frequently strike against the wall of the mould.

Record of Observations: The aggregate crushing value is given by:

Aggregate crushing value = $W_2/W_1 * (100)$

Where, W_1 = Total weight of dry sample.

W_2 = weight of sample passing 2.36mm IS sieve.

	Sample I	Sample II
Total weight of dry sample taken, W_1 (gm.)		
Weight of portion passing 2.36 mm sieve, W_2 (gm.)		
Aggregate crushing value (percent)		

Mean =

Aggregate crushing value =

Results: The mean of the two results to the nearest whole number is reported as the "*Aggregate crushing value*" of the material.

Limits:

For strong aggregates, this value should be low. For bituminous pavements, the value shall not exceed 30% for surface courses and it shall not exceed 45% for base courses.

For cement concrete pavement, the value shall not exceed 30% for surface or wearing course and it shall not exceed 45% for other than wearing course.

Questions for discussion:

i) Which property of aggregate is measured by this test ?
ii) How is aggregate crushing value expressed ?
iii) Should the aggregates having high aggregate crushing value be considered good for road construction ?
iv) What are the uses of determining aggregate crushing value ?

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EXPERIMENT NO. 3: DETERMINATION OF LOS ANGELES ABRASION VALUE

Objective:

To determine the abrasion value of given coarse aggregates sample.

Theory:

Due to the movement of traffic, the road stones used in the surfacing course are subjected to wearing action at the top. Resistance to wear or hardness is hence an essential property for road aggregates, especially when used in wearing course. Thus road stones should be hard enough to resist the abrasion due to traffic. When fast moving traffic fitted with pneumatic types move on the road, the soil particles present between the wheel and road surface causes abrasion on the road stone. Steel tires of animal drawn vehicles, which rub against the stones, can cause considerable abrasion of the stones on the road surface. Hence in order to test the suitability of road stones to resist the abrasion action due to traffic, tests are carried out in the laboratory.

The principle of Los Angeles abrasion test is to produce the abrasive action by use of standard steel balls which when mixed with the aggregates and rotated in a drum for specific number of revolutions also cause impact on aggregates. The percentage wear of the aggregates due to with steel balls is determined and is known as Los Angeles Abrasion Value.

Apparatus:

The apparatus as per IS 2386 (Part IV) – 1963 consists of:

i) *Los Angles abrasion testing machine*: It consists of a hollow steel cylinder, closed at both the ends with an internal diameter of 700 mm and length 500 mm (see Fig.3.2) and capable of rotating about its horizontal axis. A removable cover for introducing sample is provided which when clamped is dust tight. A removable steel shaft projecting radially 88 mm into cylinder and extending full length is mounted firmly on the interior of the cylinder. The self is placed at a distance 1250 mm minimum from the opening in the direction of rotation.

ii) *Abrasive charge*: Cast iron or steel balls , approximately 48 mm in diameter and each weighing between 390 to 445 g; six to twelve balls are required.

iii) IS Sieve of size 1.7 mm.

iv) Balance of capacity 5 kg or 10 kg.

v) Drying oven.

Line diagram:

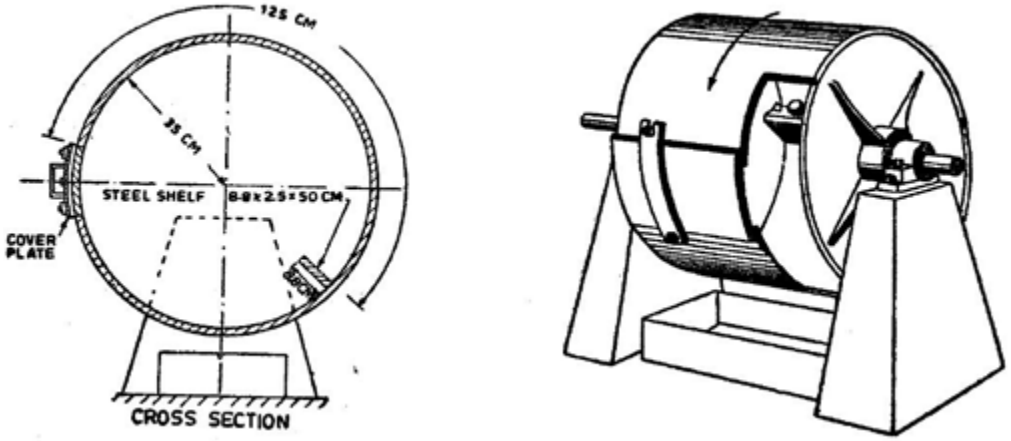

Fig. 3.1: Line diagram of Los Angeles Abrasion Machine

Pictorial image:

Fig.3.2: Los Angeles Abrasion testing machine

Procedure:

Test sample: It consists of clean aggregates dried in oven at 105°C to 110°C and are coarser than 1.70 mm sieve size. The sample should conform to any of the gradings shown in table.

Grading of test samples

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

1. Select the grading to be used in the test. It should be chosen such that it conforms to the grading to be used in construction, to the maximum extent possible.
2. Take 5 kg of sample for gradings A, B, C or D and 10 kg for gradings E, F and G.
3. Choose the abrasive charge as per Table 3.1.

Table 3.1: Selection of Abrasive Carge

Grading	No. of steel balls	Weight of charge, g
A	12	5000 ± 25
B	11	4584 ± 25
C	8	3330 ± 20
D	6	2500 ± 15
E	12	5000 ± 25
F	12	5000 ± 25
G	12	5000 ± 25

4. Open the cover and feed the aggregates and steel balls in the cylinder. Replace the cover tightly.
5. Rotate the machine at a uniform speed of 30 to 33 revolutions per minute (rpm).
6. Allow the machine to run for 500 revolutions for gradings A,B, C or D and 1000 revolutions for grading E, F or G
7. Stop the machine after desired number of revolutions.
8. Remove the dust cover and take out materials.
9. Separate the steel balls and sieve the material on 1.70 mm IS sieve.
10. Wash the material coarser than 1.70 mm size.
11. Dry it in the oven to a constant weight and weigh to an accuracy of 1 g.
12. Calculate the percentage loss of material.
13. Take another sample and repeat the experiment. Find the mean of two values and report it as Los Angeles Abrasion value.

Precautions:

1. The cover should be fixed tightly before rotating the machine.
2. All materials should be discharged from the cylinder after the conduct of the test.

Record of observations:

Grading selected:	Sample I	Sample II
Original weight of the sample, W_1 (g.)		
Weight of aggregates retained on 1.70 mm IS sieve, W_2 (g.)		
Loss of weight, (W_1 - W_2)		
Abrasion value ,$(W_1 - W_2) / W_1 X\ 100$		

Mean =

Los Angeles Abrasion Value =

Results: The mean of the two results to the nearest whole number is reported as the "*Los Angeles Abrasion value*" of the material.

Limits: .

For bituminous pavements, the value shall not exceed 30% for bituminous surface courses and it shall not exceed 40% for granular base courses (WBM and WMM).

For cement concrete pavement and dense bituminous Macadam (DBM) binder course the maximum acceptable value is 35 %.

Questions for Discussion:

i) What properties of aggregates are determined by Los angles test ?
ii) How does impact occur in the test ?
iii) What is the purpose of providing the self inside the cylinder ?
iv) Sample A and B have LA abrasion values 15 and 30 respectively which sample is harder?

v) How do you select the grading ?
vi) An aggregate sample is found to be having LA abrasion value 37. For which type of road construction it may be used.

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EXPERIMENT NO. 4: DETERMINATION OF AGGREGATE IMPACT VALUE

Objective:

To determine the aggregate impact value of road aggregates.

Theory:

Toughness is the property of a material to resist impact. Due to traffic loads, the road stones are subjected to the pounding action or impact and there is possibility of stones breaking into smaller pieces. The road stones should therefore be tough enough to resist fracture under impact. A test designed to evaluate the toughness of stones i.e., the resistance of the stones to fracture under repeated impacts may be called an impact test for road stones impact test may either be carried out on cylindrical stone specimens as in Page Impact test or on stone aggregates as in aggregate impact test. The Page Impact test is not carried out now-a-days and has also been omitted from the revised British Standards for testing mineral aggregates. The aggregate impact test has been standardized by the British standards institution and the Indian Standards Institution.

The aggregate impact value indicates a relative measure of the resistance of an aggregate to a sudden shock or an impact, which in some aggregates differs from its resistance to a slow compressive load. The method of test covers the procedure for determining the aggregate impact value of coarse aggregates.

Apparatus:

The apparatus of the aggregate impact value test as per IS: 2386 (Part IV)- 1963 consists of:

i) An impact testing machine weighing 45 to 60 kg and having a metal base with a plane lower surface of not less than 30 cm in diameter. It is supported on level and plane concrete floor of minimum 45 cm thickness. The machine should also have provisions for fixing its base.

ii) A cylindrical steel cup of internal diameter 102 mm, depth 50 mm and minimum thickness 6.3 mm.
iii) A metal hammer weighing 13.5 to 14.0 kg the lower end is cylindrical in shape, is 50 mm long, 100 mm in diameter.
iv) A cylindrical metal measure having internal diameter of 75 mm and depth 50 mm for measuring aggregates.
v) IS Sieves of sizes - 12.5mm, 10mm and 2.36mm
vi) A tamping rod of 10mm circular cross section and 230mm length, rounded at one end
vii) Oven

Line diagram:

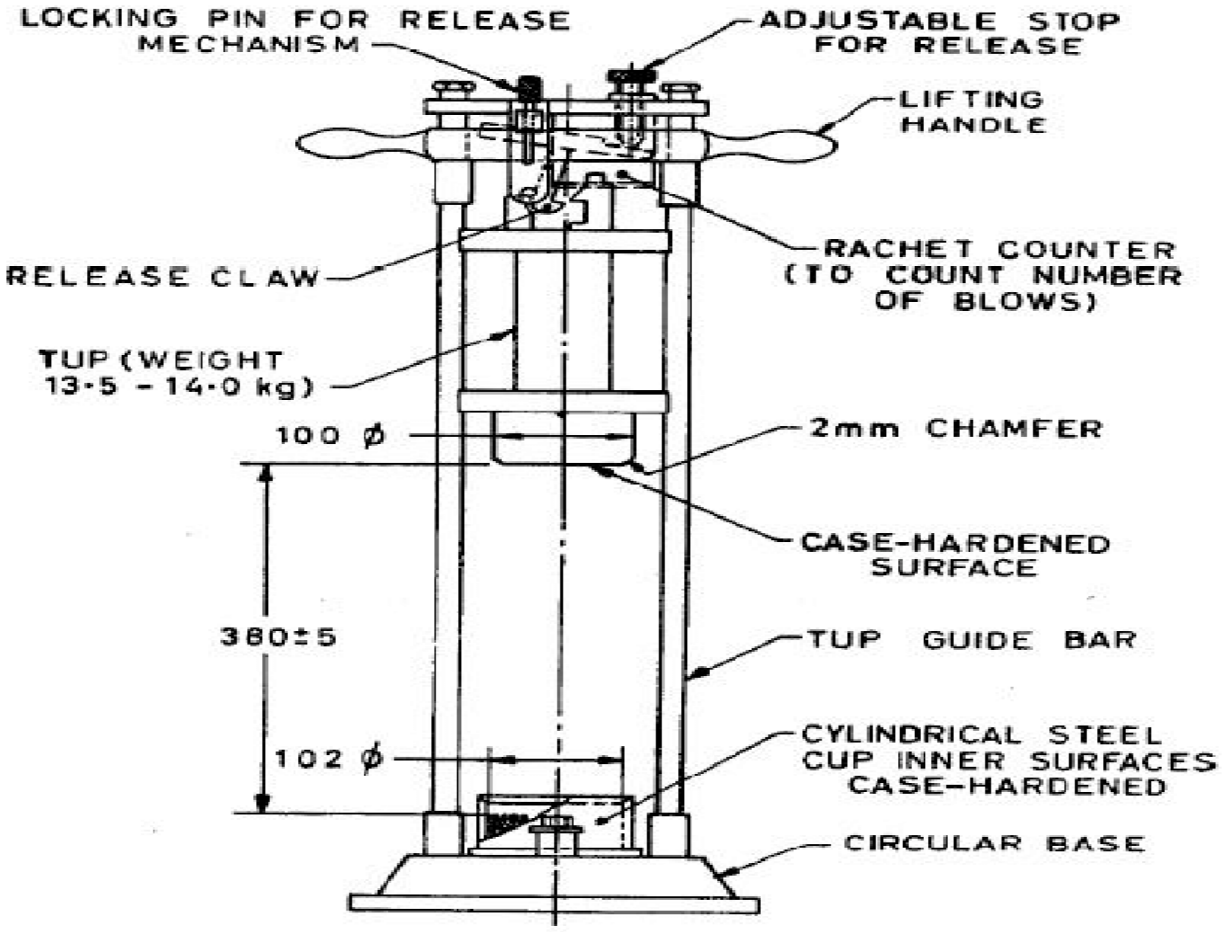

Fig.4.1: Aggregate impact test set up

Pictorial image:

Fig.4.2: Impact testing machine

Procedure:

The test sample: It consists of aggregates sized 10 mm to 12.5 mm. The aggregates should be dried by heating at 100°C-110°C for a periods of 4 hours and cooled.

1. Sieve the material through 12.5 mm and 10 mm IS sieves. The aggregates passing through 12.5 mm sieve and retained on 10 mm sieve comprises the test materials.
2. Pour the aggregates to fill about just $1/3^{rd}$ depth of measuring cylinder.
3. Compact the material by giving 25 gentle blows with the rounded end of the tamping rod.
4. Add two more layers in similar manner, so that cylinder is full.
5. Strike off the surplus aggregates.
6. Determine the net weight of the aggregates to the nearest gram (W_1).
7. Bring the impact machine to rest without wedging or packing upon the level plate, block or floor, so that it is rigid and the hammer guide columns are vertical.
8. Fix the cup firmly in position on the base of machine and place whole of the test sample in it and compact by giving 25 gentle strokes with tamping rod.

9. Raise the hammer until its lower face is 380 mm above the surface of the aggregate sample in the cup and allow it to fall freely on the aggregate sample. Give 15 such blows at an interval of not less than one second between successive falls.
10. Remove the crushed aggregates from the cup and sieve it through 2.36 mm IS sieve and weight the fraction retained in the sieve.
11. Note down the observations in the table and compute the aggregate impact value.

Precautions:

1. Place the plunger centrally so that it falls directly on the aggregates sample and does not touch the walls of the cylinder in order to ensure that the entire load is transmitted on to the aggregates.
2. In the operation of sieving the aggregates trough 2.36 mm sieve the sum of weights of fractions retained and passing the sieve should not differ from the original weight of the specimen by more than 1 gm.
3. The tamping is to be done properly by gently dropping the tamping rod and not by hammering action. Also the tampering should be uniform over the surface of the aggregate taking care that the tamping rod does not frequently strike against the walls of the mould.

Record of Observations:

	Sample I	Sample II
Total weight of dry sample taken, W_1 (gm.)		
Weight of portion passing 2.36 mm sieve, W_2 (gm.)		
Aggregate impact value, $(W_2/W_1)*100$		

Aggregate impact mean value =

Results: The mean of the two results to the nearest whole number is reported as the "*Aggregate Impact value*" of the material.

Limits: The value shall not exceed 30% for bituminous surface courses and cement concrete wearing courses.

The maximum permissible value is 35 % for bituminous macadam ,40 % for water bound macadam base courses and 45 % for cement concrete base courses

Questions for Discussion:

i) What is meant by toughness of the aggregates ?
ii) How does toughness differ from compressive strength ?
iii) Which test simulates the field conditions better aggregate crushing value test or impact value test ?
iv) What are uses of determining impact value ?
v) Should a good quality road aggregate give higher impact value

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EXPERIMENT NO. 5: SHAPE TEST ON COARSE AGGREGATES

Objective:

Determine the Flakiness and elongation index of coarse aggregates.

Theory:

The particle shape of the aggregate mass is determined by the percentage of flaky and elongated particles in it. Aggregates which are flaky or elongated are detrimental to higher workability and stability of mixes.

- Shape of crushed aggregates determined by the percentage of flaky and elongated particles.
- Shape of gravel determined by its angularity number.
- Flaky and elongated aggregate particles tend to break under heavy traffic loads.
- Rounded aggregates preferred in cement concrete pavements as more workability at less water cement ratio.
- Angular shape preferred for granular courses/flexible pavement layers due to better interlocking and hence more stability.
- Flakiness Index is the percentage by weight of particles in it, whose least dimension (Thickness) is less than three-fifths of its mean dimension. The test is not applicable to particles Smaller than 6.3 mm in size.
- Elongation Index is the percentage by weight of particles in it, who's largest dimension (Length) is greater than one and four-fifths times its mean dimension. The test is not applicable to particles smaller than 6.3 mm in size.

Apparatus:

1. A standard thickness gauge
2. A standard length gauge
3. Tray, a balance of capacity 5 kg, readable and accurate up to 1 gm.
4. IS sieves of sizes 63, 50, 40, 31.5, 25, 20, 16, 12.5, 10 and 6.3 mm.

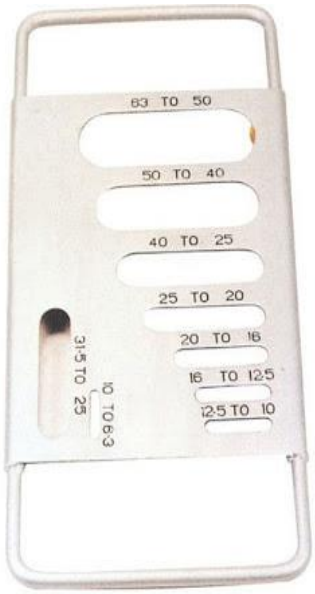

Fig.5.1: Thickness gauge

Procedure for using Gauge for Flakiness Index:

1. The sample is sieved through IS sieve sizes 63, 50, 40, 31.5, 25, 20, 16, 12.5, 10 and 6.3 mm.
2. Minimum 200 pieces of each fraction to be tested are taken and weighed (W1 gm).
3. Separate the flaky material by using the standard thickness gauge.
4. Weigh the flaky material passing the respective gauge to an accuracy of at least 0.1 percent of the test sample.

Flakiness Index

The amount of flaky material is weighed to an accuracy of 0.1 percent of the test sample If W1, W2… Wi are the total weights of each size of aggregates taken; If X1, X2, X3…….Xi are the weights of material passing the different thickness gauges then:

Record of observation (Flakiness Index):

Passing through I.S. Sieve, (mm)	Retained on I.S. Sieve, (mm)	Wt. Of the fraction consisting of at least 200 pieces (gm.)	Thickness gauge size, (0.6 times the mean sieve) (mm)	Weight of aggregate in each fraction passing thickness gauge (gms)

25	20	W1	13.5	X1
20	16	W2	10.8	X2
16	12.5	W3	8.55	X3
12.5	10	W4	6.75	X4
10	6.3	W5	4.89	X5
		W total=		X total=

Flakiness Index = $(X_1 + X_2 + \ldots.) / (W_1 + W_2 + \ldots..) \times 100$

Test for Elongation Index:

Fig.5.2: Length gauge

Procedure for using Gauge Elongation index:

1. The sample is sieved through sieve sizes, 50, 40, 25, 20,16, 12.5, 10 and 6.3
2. Minimum 200 pieces of each fraction to be tested are taken and weighed (W1 gm
3. Separate the elongate material by using the standard length gauge.
4. Weigh the elongated material retained on the respective gauge to an accuracy of at least 0.1 percent of test sample.

Elongation Index

The amount of elongated material is weighed to an accuracy of 0.1 percent of the test sample If W1, W2… Wi are the total weights of each size of aggregates taken. If X1, X2… Xi are the weights of material retained on different length gauges then:

Passing through I.S. Sieve, (mm	**Retained on I.S. Sieve, (mm)**	**Wt. Of the fraction consisting of at least 200 pieces (gm.)**	**Length gauge size, (1.8 times the mean** sieve) (mm**)**	**Weight of aggregate in each fraction retained on length gauge gms**
25	20	W_1	40.5	X_1
20	16	W_2	32.4	X_2
16	12.5	W_3	25.5	X_3
12.5	10	W_4	20.2	X_4
10	6.3	W_5	14.7	X_5
		Total W=		**Total X=**

Elongation Index = $(X_1+ X_2+….) / (W_1+ W_2+…..) X 100$

Result:

Flakiness Index =

Elongation Index =

Limits:

i) Flakiness index for bituminous concrete and surface dressing = max. 25%
ii) Flakiness index for water bound Macadam and bituminous Macadam = max. 15%
iii) Elongation index for bituminous or non-bituminous mixes. = max. 15%
iv) Flakiness index for concrete mix = max. 15%

Questions for Discussion

i) How are flakiness index and elongation index value expressed ?
ii) What is angularity number ?
iii) What shape of aggregate is preferred in road construction and why ?
iv) What are the uses of determining flakiness index and elongation index ?

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EXPERIMENT NO. 5: DETERMINATION OF SPECIFIC GRAVITY AND WATER ABSORPTION FOR COARSE AGGREGATES

Objective:

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

Theory:

The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. Aggregates having low specific gravity are generally weaker than those with high specific gravity. This property helps in a general identification of aggregates.

Water absorption also gives an idea on the internal structure of aggregate. Aggregates having more absorption are more porous in nature and are generally considered unsuitable, unless found to be acceptable based on strength, impact and hardness tests.

Apparatus:

The apparatus required for these tests are:

i) A balance of at least 3 kg capacity, with a accuracy to 0.5 g.

ii) An oven to maintain a temperature range of 100 to 110^0 C.

iii) A wire basket of not more than 6.3 mm mesh or a perforated container of convenient size with thin wire hangers for suspending it from the balance.

iv) A container for filling water and suspending the wire basket in it.

v) An airtight container of capacity similar to that of basket, a shallow tray and two dry absorbent clothes.

vi) Pycnometer of 100ml for aggregates finer than 6.3 mm and Specific gravity bottle.

Procedure for aggregate coarser than 6.3 mm:

1. About 2 kg of aggregate sample is taken, washed to remove fines and then placed in the wire basket. The wire basket is then immersed in water, which is at a temperature of 22^0 C to 32^0 C.
2. Immediately after immersion the entrapped air is removed from the sample by lifting the basket 25 mm above the base of the tank and allowing it to drop, 25 times at a rate of about one drop per second.
3. The basket, with aggregate are kept completely immersed in water for a period of 24 ± 0.5 hour.
4. The basket and aggregate are weighed while suspended in water, which is at a temperature of 22^0 C to 32^0 C.
5. The basket and aggregates are removed from water and dried with dry absorbent cloth.
6. The empty basket is suspended back in water tank and weighed.
7. The surface dried aggregates are also weighed.
8. The aggregate is placed in a shallow tray and heated to about 110 ^{0}C in the oven for 24 hours. Later, it is cooled in an airtight container and weighed.

Procedure for specific gravity determination of aggregate finer than 6.3 mm :

1. A clean, dry Pycnometer is taken and its empty weight is determined.
2. About 1000g of clean sample is taken into the Pycnometer, and it is weighed.
3. Water at 27 ^{0}C is filled up in the Pycnometer with aggregate sample, to just immerse sample.
4. Immediately after immersion the entrapped air is removed from the sample by shaking Pycnometer, placing a finger on the hole at the top of the sealed Pycnometer.
5. Now the Pycnometer is completely filled up with water till the hole at the top, and after confirming that there is no more entrapped air in it, it is weighed.
6. The contents of the pycnometer are discharged, and it is cleaned.
7. Water is filled up to the top of the pycnometer, without any entrapped air. It is then weighed.

For mineral filler, specific gravity bottle is used and the material is filled upto one-third of the capacity of bottle. The rest of the process of determining specific gravity is similar to the one described for aggregate finer than 6.3 mm.

Precautions:

1. If the aggregate is not oven-dried before soaking, specific gravity values may be significantly higher. This is because in the normal procedure the water may not be able to penetrate the pores to the center of the aggregate particle during the soaking time. If the aggregate is not oven-dry to start, the existing water in the aggregate pore structure may be able to penetrate further into the pores.
2. Make sure to use cloth and not paper towels. Paper towels may absorb water in the aggregate pores.

Record of Observations:

1. Aggregate coarser than 6.3 mm:

SL. NO.	DETAILS	OBSERVED VALUES
1.	Weight of saturated aggregate and basket in water, W_1 (gm.)	
2.	Weight of basket in water, W_2 (gm.)	
3.	Weight of saturated aggregate in air, W_3 (gm.)	
4.	Weight of oven dry aggregate, W_4 (gm.)	
5.	Apparent specific gravity: $W_4/[W_4-(W_1-W_2)]$	
6.	Bulk specific gravity: $W_4/[W_3-(W_1-W_2)]$	
7.	Water absorption: $[(W_3- W_4)x\ 100]/ W_4$	

Results:

Bulk Specific Gravity =

Apparent Specific Gravity =

Water Absorption = %

2. Aggregate of size finer than 6.3 mm:

SL. NO.	DETAILS	OBSERVED VALUE
1.	Weight of pycnometer in air, W_1	
2.	Weight of aggregates and Pycnometer, W_2	
3.	Weight of aggregates, Pycnometer and water, W_3	
4.	Weight of water and pycnometer in air, W_4	
5.	Apparent specific gravity: $(W_2 - W_1) / [(W_2 - W_1) – (W_3 - W_4)]$	

Results: Apparent specific gravity =

Limits:

i) The specific gravity of coarse aggregates ranges from 2.5 to 3.0.
ii) The water absorption of aggregates ranges from 0.1 to 2 %.

Questions for Discussion:

i) What is the difference between specific gravity and density ?
ii) Why specific gravity of aggregate is important ?
iii) What are the factors affecting specific gravity test ?
iv) How water absorption will affect mix design ?
v) What will happen if water absorption of aggregates is more ?

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EXPERIMENT NO. 7: DETERMINATION OF SOFTENING POINT OF BITUMINOUS MATERIAL

Objective:

To determine the softening point of bitumen/tar as per IS: 1205 - 1978.

Theory:

Bitumen does not suddenly change from solid to liquid state ,but as the temperature increases it gradually becomes softer until it flows readily .A semi solid state bitumen grades need sufficient fluidity before they are used for application with the aggregate mix .For this purpose bitumen is sometimes cut back with a solvent like kerosene .The common procedure however is to liquefy the bitumen by heating .The softening point is the temperature at which the substance attains particular degree of softening under specified condition of test . For bitumen it usually determined by Ring and Ball test. Brass ring test containing the test sample of bitumen is suspended in liquid like water or glycerine at a given temperature. A steel ball is placed upon the bitumen and liquid medium is then heated at a specified distance below the ring is recorded as the softening point of a particular bitumen. The apparatus and test procedure are standardized by ISI. It obvious but harder grade bitumen possess higher softening point than softer grade bitumen.

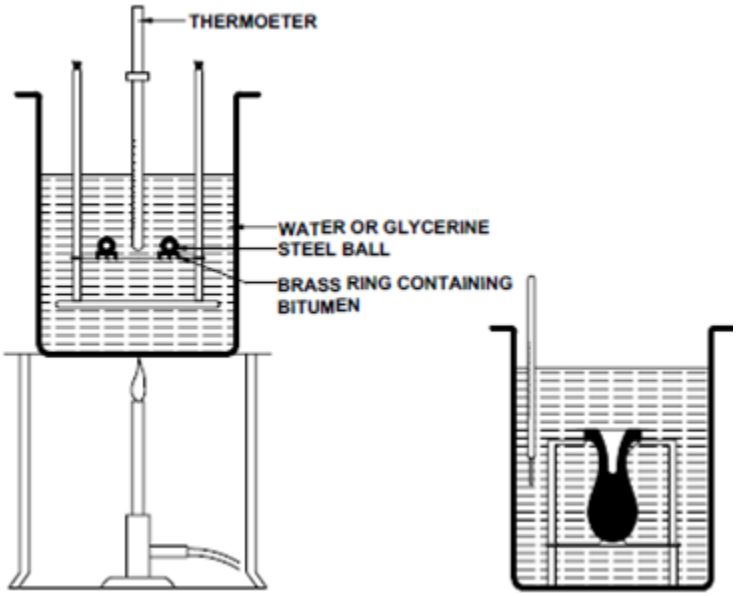
Apparatus:

i) *Ring and ball apparatus*: It consists of the following:

a) Steel balls - two numbers each of 9.5 mm diameter and weighing 3.5 ± 0.05 g.
b) Brass rings – two numbers each having depth of 6.4 mm. The inside diameter at bottom and top is 15.9 mm and 17.5 mm respectively.
c) Ball guides to guide the movement of steel balls centrally.
d) Support – that can hold rings in position and also allows for suspension of a thermometer. The distance between the bottom of the rings and the top surface of the bottom plate of the support is 25 mm.

ii) *Thermometer* that can read upto 100° C with an accuracy of 0.2° C.
iii) *Bath*: a heat resistant glass breaker not less than 85 mm in diameter and 1220 mm in depth.
iv) *Stirrer*

Line Diagram:



Pictorial Image:

Fig. 7.2: Ring and ball apparatus

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. Place the rings, previously heated to a temperature approximating to that of the molten material, 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 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 50 mm 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 ball sinks through the ring, carrying a portion of the material with it.
6. Note down the temperature when any of the steel ball with bituminous coating touches the bottom plate.
7. Record the temperature when the second ball also touches the bottom plate. The average of the two readings to the nearest 0.5 ° C is reported as the softening point.

Precautions:

1. Distilled water should be used as the heating medium.
2. During the conduct of the test the apparatus should not be subjected to vibrations.
3. The bulb of the thermometer should be at about the same level as the rings.

Record of Observations:

	1	2
Temperature when the ball touches the bottom, ° C		

Average =

Softening point of bitumen/tar =

Questions for Discussion:

i) What is the importance of determination of softening point in road construction operation?
ii) What is the concept of determination of softening point by ring and ball apparatus ?
iii) What is the criteria of selection of medium used for heating the specimen ?
iv) What will happen to softening point if:
    a. Aluminium balls are used in place of steel balls ?
    b. The distance rings and the bottom place is increased ?

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EXPERIMENT NO. 7: DETERMINATON OF PENETRATON VALUE OF BITUMEN

Objective:

To determine consistency or the grade (mean penetration value) of bituminous material.

Theory:

Penetration is a measurement of hardness or consistency of bituminous material. The penetration of a bituminous material is the distance in tenths of a mm, that a standard needle would penetrate vertically, into a sample of the material under standard conditions of temperature load and time. This test is used for evaluating consistency of bituminous materials.

Apparatus:

i) *Containe*r: A flat bottomed cylindrical metallic dish 55 mm in diameter and 35 mm in depth is required. If the penetration is of the order of 225 or more deeper dish of 70 mm dia. And 45 mm depth is required.
ii) *Needle*: A straight, highly polished, cylindrical hard steel rod with standard dimension.
iii) *Water bath*: A water bath maintained at 25.0°C ± 0.1 °C containing not less than 10 litres of water, the sample being immersed to a depth not less than 100 mm from the top and supported on a perforated shelf not less than 0 mm from the bottom of the bath.
iv) *Transfer dish or tray*: It should provide support to the container and should not block the container.
v) *Penetration apparatus*: It should be such that will allow the needle to penetrate without much friction and is accurately calibrated to give results in one tenth of a millimetre.
vi) Bath thermometer - Range 0 to 44°C, Graduation 0.2°C
vii) *Time measuring device*: With an accuracy of ± 0.1 s.

Line Diagram:

Pictorial Diagram:

Procedure:

i) The bitumen above the softening point (between 75 and 100^{o}C) is softened. It is stirred thoroughly to remove air bubbles and water.

ii) It is poured into a container to a depth of at least 15mm in excess of the expected penetration.

iii) It is cooled at an atmospheric temperature of 15 to 30^{o}C for 1 hrs. Then it is placed in a transfer dish in the water bath at 25.0 ± 0.1^{o}C for 1 to 1.5 hrs.

iv) The container is kept on the stand of the penetration apparatus.

v) The needle is adjusted to make contact with the surface of the sample.

vi) Make the pointer of the dial gauge to read zero or note the initial dial reading.

vii) With the help of the timer, the needle is released for exactly 5 seconds.

viii) The dial reading is recorded.

ix) Make at least 3 readings at points on the surface of the sample not less than 10 mm apart and not less than 10 mm from side of the dish.

Precautions:

i) There should be no movement of the container while needle is penetrating into the sample.
ii) The sample should be free from any extraneous matter.
iii) The needle should be cleaned with benzene and dried before penetration.

Record of Observations:

Actual Test temperature = ° C

	Test 1	Test 2	Test 3
Penetration dial reading a) Initial			
b) Final			
Penetration value			

Mean penetration value =

Interpretations of results:

Penetration test is a commonly adopted test to grade material in terms of its hardness. A 80/100 grade bitumen indicates that its penetration value lies in between 80 and 100. The grading of bitumen helps to assess its suitability for use in different climatic conditions and types of construction.

Questions for Discussion:

i) Which property of bitumen is related to penetration value ?
ii) The penetration value of a binder is 65; what is the distance in mm which the needle has penetrated through ?
iii) What variations are expected in the test results if:
    a) The time of penetration is increased ?
    b) The actual test temperature is below the test temperature ?
iv) What does a 80/100 grade bitumen indicate ?

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EXPERIMENT NO. 9: MARSHALL STABILITY TEST FOR BITUMEN MIX DESIGN

Objective:

To find out optimum bitumen content of given bituminous mix.

Theory:

Bruce Marshall, formerly bituminous engineer with Mississippi state highway department, USA formulated Marshall's method for designing bituminous mixes. Marshall's test procedure was later modified and improved upon by U.S.corps of engineers through their extensive research and correlation studies .ASTM and other agencies have standardized the test procedure. Generally, this stability test is applicable to hot-mix design using bitumen and aggregates with maximum size of 25mm.

In this method, the resistance to plastic deformations of cylindrical specimen of bituminous mixture is measured when the same is loaded at the periphery at 5 cm per minute. This test procedure is used in designing and evaluating bituminous paving mixes. The test procedure is extensively used in routine test program for the paving jobs. There are two major features of the Marshall method of designing mixes namely, (i) Density-voids analysis, (ii) stability-flow tests. The Marshall stability of the mix is defined as a maximum load carried by a compacted specimen at a standard test temperature at 60^0C. The flow value is a deformation the Marshall Test specimen undergoes during the loading up to the maximum load in 0.25 mm units. In this test an attempt is made to obtain optimum binder content for the type of aggregate mix and traffic intensity. The proposed designed steps for the design of bituminous mix are given below:

i) Select grading to be used.

ii) Select aggregates to be employed in the mix.

iii) Determine the proportion of each aggregate required to produce design grading.

iv) Determine the specific gravity of the aggregate combination and of the asphalt cement.

v) Make up trail specimens with varying asphalt contents.

vi) Determine the specific gravity of each component specimen.

vii) Make stability tests on the specimens.

viii) Calculate the percentage of voids, VMA and the percent voids filled with bitumen each specimen.

ix) Select the optimum bitumen content with design requirements. The design may be required if necessary after altering the gradation so as to fulfil the design requirements.

Apparatus:

1. *Mould assembly:* Cylindrical moulds of 10cm diameter and 7.5cm height are required. It further consist of a base plate and collar extension. They are designed to be interchangeable with either end of cylindrical mould.

2. *Sample Extractor*: For extruding the compacted specimen from the mould, an extractor suitably fitted with a jack or compression machine.

3. *Compaction pedestal and hammer*: It consist of a wooden block capped with M.S. plate to hold the mould assembly in position during compaction. The compaction hammer consist of a flat circular tamping face 8.8 cm diameter and equipped with a 4.5 kg. Weight constructed to provide a free fall of 47.5cm. Mould holder is provided consisting of spring tension device designed to hold compaction mould in place on the compaction pedestal.

4. *Breaking head*: It consist of upper and lower cylindrical segments or test heads having an inside radius of curvature of 5cm. The lower segment is mounted on a base having two vertical guide rods which facilitate insertion in the holes of upper test head.

E) *Loading machine*: See Fig. 9.1. The loading machine is provided with a gear system to lift the base in upward direction. On the upper end of the machine, a pre-calibrated proving ring of 5 tonne capacity is fixed. In between the base and the proving ring, the specimen contained in test head is placed. The loading machine produces a movement at the rate of 5cm per minute. Machine is capable of reversing its movement downward also. This facilitates adequate space for placing test head system after one specimen has been tested.

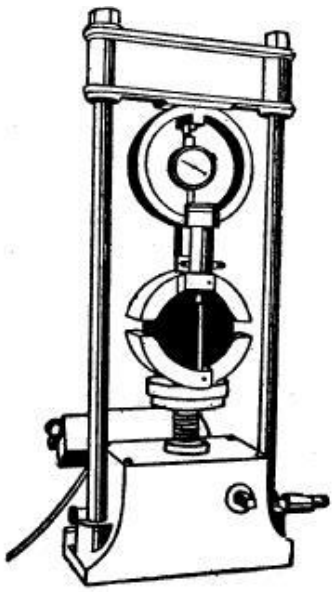

Fig.9.1: Loading machine set up

F) *Flow Meter*: One dial gauge fixed to the guide rods of a testing machine can serve the purpose. Least count of 0.025 mm is adequate. The flow value refers to the total vertical upward movement from the initial position at zero load to a value at maximum load.

The dial gauge or the flow meter should be able to measure accurately the total vertical movement upward.

Besides the above equipment, the following are also required.,

i) Ovens on hot plate,

ii) Mixing apparatus,

iii) Water bath, thermometers of range up to 200^0C with sensitivity of 2.5^0C. Balance with an accuracy of 0.1 gm.

Pictorial Image:

Procedure:

In the Marshall method each compacted test in specimen is subjected to the following tests and analysis in the order listed below:

Bulk density determination,

Stability and flow test,

Density and voids analysis,

At least three samples are prepared for each binder content.

Preparation of test specimens:

The coarse aggregates, fine aggregates and the filter material should be proportioned and mixed in such a way that final mix after blending has the gradation within the specified Range. The specified gradation of mineral aggregates and the bitumen binder as per IRC:

29-1968 are given in table 10.1.

Table 10.1: Composition of dense graded bituminous macadam

Sieve size	**Percentage passing by weight grade 1**	**Percentage passing by weight grade 2**
20mm	-	100
12.5mm	100	80-100
10mm	80-100	70-90
4.75mm	55-75	50-70
2.36mm	35-50	35-50
600µ	18-29	18-29
300 µ	13-23	13-23
150 µ	8-16	8-16
75 µ	4-10	4-10
Binder content percent by weight of mix	5-7.5	5-7.5

The aggregates and filter are mixed together in the desired proportion as per the design requirements are fulfilling the specified gradation. The required quantity of mix is taken so as to produce a compacted bituminous mix specimen of thickness 63.5mm approximately.

Approximately 1200g of aggregates and filter are taken and heated to a temperature of 175 to 190^{0}C. The compaction mould assembly and rammer are cleaned and kept pre heated to a temperature of 100 to 145^{0}C. The bitumen is heated to temperature of 121 to 138^{0}C and the required quantity of first trail percentage of bitumen (say 3.5% by weight of mineral aggregates) is added to the heated aggregate and thoroughly mixed using a mechanical mixer or by hand mixing with trowel. The mixing temperature for 80/100 grade bitumen may be around 154^{0}C and that for 60/70 grade about 160^{0}C. The mix is placed in a mould and compacted by rammer, with 75 blows on either side. The compacting temperatures may be about 138^{0}C for 80/100 grade bitumen and 149^{0}C for 60/70 grade. The compacted specimen should have a thickness of 63.5 mm. The weight of the aggregate taken may be suitably altered to obtain a thickness of 63.5 $\pm$ 3.0 mm. At least two specimens, but preferably three or four specimens should be prepared at each trail bitumen content which may be varied at 0.5 percent increments up to about 6.0 or 6.5 percent. The compacted specimens are allowed to cool to room temperature, the sample height and weight is determined, theoretical density is calculated. The specimen is then weighed in air and then in water for determining volume and later bulk density. The specimens are then transferred into a water bath, kept at 60^0 C for 30

to 40 minutes. They are then removed, dried and placed in Marshall Test head. Their Stability and flow values are noted. They are corrected for variation from average height.

Calculation of Specific gravity of compacted specimens:

The specific gravity values of the different aggregates, filler, and bitumen used are determined first. The theoretical specific gravity G_t of the mix is given by;

$$G_t = (W_1 + W_2 + W_3 + W_b) / \left(\frac{W1}{G1} + \frac{W2}{G2} + \frac{W3}{G3} + \frac{Wb}{Gb} \right)$$

Where, W_1 = weight of coarse aggregates in the total mix

W_2 = weight of fine aggregates in the total mix

W_3 = weight of filler in the total mix

W_b = weight of bitumen in the total mix

G_1 = apparent specific gravity of coarse aggregate

G_2 = apparent specific gravity of fine aggregate

G_3 = apparent specific gravity of filler material

G_b = apparent specific gravity of bitumen

Bulk specific gravity, $G_m = W_m / (W_m - W_w)$

Where,

W_m = weight of mix in air

W_w = weight of mix in water

Density and void analysis:

Soon after the compacted bituminous mix specimens have cooled to room temperature, the weight, average thickness and diameter of the specimen are noted. The specimens are to be weight in air and then in water. The bulk density value G_b of the specimen if calculated from the weight and volume. The voids analysis is made as given below:

Air voids percent, $V_v = [(G_t - G_m) / G_t] \times 100$

Percent volume of bitumen, $V_b = \left[\frac{Wb}{Gb} / \left(\frac{W1 + W2 + W3 + Wb}{Gm} \right) \right] \times 100$

Voids in mineral aggregate, $VMA = V_v + V_b$

Voids filled with bitumen, $VFB = (V_b / VMA) \times 100$

<u>Loading Test:</u>

Determination of Marshall Stability and flow values:

The specimens to be tested are kept immersed under water in a thermostatically controlled water bath maintained at 60^0C for 30 to 40 minutes. Remove the specimen from the water bath, and place in the lower segment of the breaking head. Place the upper segment of the breaking head on the specimen, and place the complete assembly in position on the testing

machine . Place the flow meter over one of the post and adjust it to read zero. Apply a load at a rate of 51 mm/minute until the maximum load reading is obtained. Record the maximum load and the indicated flow. The corrected Marshall Stability value of each specimen is determined by applying the approximate correction factor, if the average height of the specimen is not exactly 63.5mm the correction factors are given in table 10.2.

Volume of specimen in cubic centimetre	**Approximate thickness of specimen in mm**	**Correction factors**
457-470	57.1	1.19
471-482	58.7	1.14
483-495	60.3	1.09
496-508	61.9	1.04
509-522	63.5	1.00
523-535	65.1	0.96
536-546	66.7	0.93
547-559	68.3	0.89
560-573	69.9	0.86

Table 10.2: Correction factors value for Marshall stability test

Notes:

1. The measured stability of a specimen multiplied by the ratio for the thickness of specimen is equal to the corrected stability for a 63.5 mm specimen.
2. Volume thickness relationship is based on a specimen diameter of 10cm.

Determination of optimum bitumen content

Five graphs are plotted with values of bitumen content against the value of:

i) Density G_b, g/cm^3,

ii) Marshall stability S, kg,

iii) Voids in total mix V_v %,

iv) Flow value ,F (0.25mm units)

v) Voids filled with bitumen , VFB %,

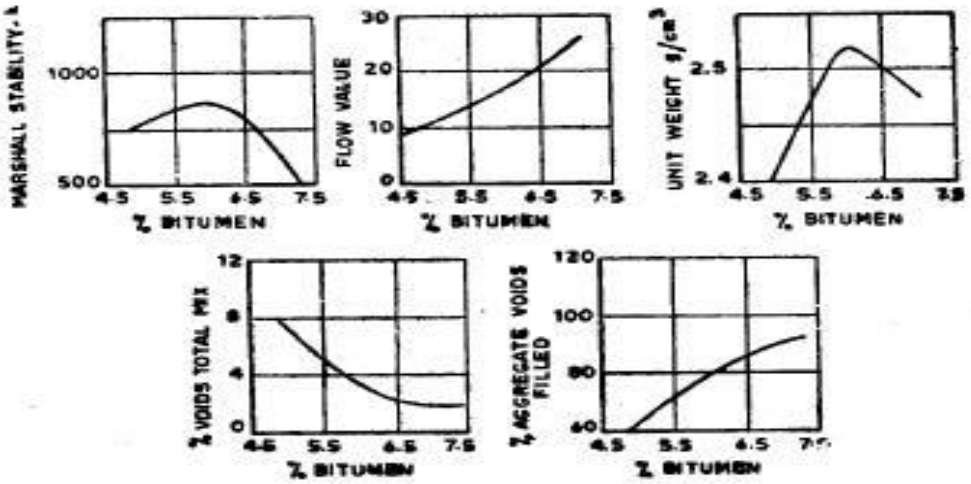

Fig. 10.2 Graphs for Marshall Test

Let the bitumen content corresponding to maximum density be B_1, corresponding to maximum stability be B_2 and that corresponding to the specified voids content Vv (4.0% in the case of dense AC mix) to B_3. Then the optimum bitumen content for deign mix is given by

$B_0 = (B_1+B_2+B_3)/3$.

The value of flow and VFB are found from the graphs, corresponding to the bitumen content B_0. All the design values of Marshall Stability, flow, voids and VFB are checked at the optimum bitumen content B_0, with the specified design requirements of the mix.

Design requirements of the mix:

As per IRC: 29-1968, when the specimens are compacted with 50 blows on either face of the designed AC mix should fulfil the following requirements.

- Marshall stability value Kg(minimum) =340
- Marshall flow value , 0.25mm units = 8 to 16
- Voids in total mix, Vv% =3 to 5

Voids in mineral aggregates filled With bitumen,VFB %=75 to 85

The highest possible Marshall Stability values in the mix should be aimed at consistent with the other three requirements mentioned above. In case the mix designed does not fulfil any one or more of the designed requirements, the gradation of the aggregates or filter content or bitumen content or combination of these are altered and the design tests are repeated till all the requirements are simultaneously fulfilled.

Record of Observations:

Stability and flow value determination

Type of grading of aggregate:

Mixing temperature:

Number of blows on either side:

Grade of bitumen:

Compaction temperature:

Providing ring calibration factor:

Flow value dial, 1 division:

Observation table for density and voids:

Sample no	**Bitumen content, %**	**Height of sample, mm**	**Weight (g)**		**Bulk density**	**G_b**	V_v	**V_b**	**VMA**	**VFB**
			W_m	**W_w**						
1										
2										
3										
Average										
1										
2										
3										
Avg.										
1										
2										
3										
Avg.										
1										
2										

3										
Avg.										

Observation table for Marshall Stability and flow value:

Sample no.	**Bitumen content %**	**Stability value** **Measured** **Corrected**	**Flow dial reading**	**Flow value of 0.25mm units**
1				
2				
3				
Average				
1				
2				
3				
Average				
1				
2				
3				
Average				
1				
2				
3				
Average				

1. Optimum bitumen content determination:

B_1 = Bitumen content corresponding to maximum density =

B_2 = Bitumen content corresponding to maximum Stability =

B_3 = Bitumen content corresponding to 4% air voids =

B_0 = Optimum bitumen content = $(B_1+B_2+B_3)/3$ =

In addition to these, graphs plotted between with bitumen content on x axis and:

1. Bulk density, G_b
2. Marshall Stability, M
3. %voids in total mix, V_v

4. Flow value, f
5. % voids filled with bitumen, VFB

Results:

Optimum bitumen content = %
Marshall Stability at optimum bitumen content = kg
Marshall Flow value at optimum bitumen content, 0.25mm units = mm
Voids in total mix at optimum bitumen content, V_v = %
Voids in mineral aggregate filled with bitumen, VFB = %

Questions for Discussions:

i) What is the significance of flow value in Marshall test ?
ii) What is filler ?
iii) What are the essential properties of bituminous mix ?
iv) What do you understand by VMA and VFB ?

DEPARTMENT OF CIVIL ENGINEERING, JORHAT ENGINEERING COLLEGE

TRANSPORTATION ENGINEERING LABORATORY

EXPERIMENT NO. 10: SIEVE ANALYSIS OF COARSE AGGREGATES

Objective: To determine the particle size distribution of coarse aggregates by means of sieve analysis.

Theory: Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. In this test, we use different sieves as standardized by the IS 2386 (Part I) - 1963 code and then pass aggregates through them and thus collect different sized particles retained over different sieves.

Apparatus/Equipment:

1. A set of IS Sieves of sizes – 80mm, 63mm, 50mm, 40mm,31.5mm, 25mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm,4.75mm, 3.35mm, 2.36mm, 1.18mm, 600µm, 300µm, 150µm and 75µm.
2. Balance or scale with an accuracy to measure 0.1 percent of the weight of the test sample.
3. Mechanical sieve shaker.

Procedure:

1. The test sample is dried to a constant weight at a temperature of 110°C ± 5 °C and weighed say W_1.
2. The IS sieves are arranged in the order 80mm, 63mm, 50mm, 40mm,31.5mm, 25mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm,4.75mm, 3.35mm, 2.36mm, 1.18mm, 600µm, 300µm, 150µm and 75µm with lid and pan on top and bottom respectively.
3. The sample is placed on the topmost sieve and after the lid is attached the whole sieve set is placed on a mechanical sieve shaker and sieved for about 15mins.
4. The weight of aggregates retained on each sieve is weighed and Cumulative weight passing through each sieve is calculated as a percentage of the total sample weight.

5. Fineness modulus is obtained by adding cumulative percentage of aggregates retained on each sieve and dividing the sum by 100.
6. The particle size distribution curve is plotted using the data obtained.

Observation table:

IS sieve size	Weight of aggregated retained			% of total weight retained	Cumulative % of total weight retained	% passing or % finer
	Sample no					
	I	II	Avg.			
80mm						
63mm						
40mm						
25mm						
20mm						
16mm						
12.5mm						
10mm						
6.3mm						
4.75mm						
2.36mm						

Results: Size of coarse aggregate: mm, single-sized / graded

Questions for Discussions:

i) What do you mean by gradation of aggregates ?
ii) Why gradation of aggregate is important in road construction ?
iii) What is single-sized and graded aggregates ?