DEPARTMENT OF CIVIL ENGINEERING

CONCRETE LABORATORY

MANUAL

(B.E. IV/IV FIRST SEMESTER)
OSMANIA UNIVERSITY SYLLABUS - REF. NO - CE 431

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Experiment # 1

SPECIFIC GRAVITY OF CEMENT

1. **Objective:** - To determine the specific gravity of the given cement sample.

2. **Apparatus:** - Specific gravity bottle of 50 ml, Physical balance upto 1 mg accuracy, weights box (from 1 mg to 200 gms.) etc.

3. **Materials:** - Cement, kerosene, distilled water, cotton waste etc.

4. **Theory:** - Specific gravity is defined as the ratio between the weight or mass of a given volume of material and weight or mass of an equal volume of water.

$$\text{Sp. Gravity of cement (G)} = \frac{\text{Weight of cement sample}}{\text{Wt. Of equal vol. of water}}$$

5. **Procedure:** -

   i) Weigh the dry specific gravity bottle with lid. Let the weight of the empty bottle be W1 gms.

   ii) Fill the specific gravity bottle fully with distilled water and weigh it. Let this weight be W2 gms.

   iii) Wipe dry the specific gravity bottle and fill it to the top with Kerosene and weigh it. Let this weight be W3 gms.

   iv) Pour some of the kerosene out and introduce a weighed quantity of cement (about 50 gms) or weighted cement of about 2/3 of the volume of specific gravity bottle into the bottle. Rolled the bottle gently in inclined position until no further air bubbles rise to surface. Fill the bottle to top with kerosene and weigh it. Let this weight be W4 gms.

   v) Let the mass or weight of cement be W5 gms = 50 gms or weighted cement of about 2/3 of the volume of specific gravity bottle.

6. **Observations and Calculations: -**

S.No	Observations & Calculations	Trial Nos.		
		I	II	III
1.	Wt. Of dry empty bottle (W1) gm	52	52	
2.	Wt. Of bottle + full water with lid (W2) gm	145	145	
3.	Wt. Of bottle + full kerosene with lid (W3) gm	125	125	
4.	Wt. Of the bottle + cement + kerosene with lid (W4) gm	157	180	
5.	Wt. or mass of cement (W5) gm	50	52	
6.	Sp. Gr. Of kerosene (s) = $\frac{(W3 - W1)}{(W2 - W1)}$	0.78	0.78	
7.	Sp. Gr. Of cement (S) = $\frac{W5 \times (W3 - W1)}{(W5 + W3 - W4) \times (W2 - W1)}$	2.18	2.40	

Average Specific Gravity = $\frac{2.18 + 2.40 +}{2}$ = 2.29

7. **Result-** The specific gravity (Sp.Gr) of the given cement sample is 2.29

8. **Precautions**

i) Kerosene used should be free from water.3

ii) All air bubbles shall be eliminated in filling the apparatus and inserting the lid (or stopper)

iii) Duplicate determination of specific gravity should agree within 0.01

iv) While introducing cement care should be taken to avoid splashing and cement should not adhere to inside of flask above the liquid

v) Specific gravity bottle should be held in a constant temperature water bath to ensure same temperature before each weighing is made.

(Ref: - IS269 – 1989 & IS: 4031 – 1988)

FINENESS OF CEMENT

1. **Objective:** - To determine the fineness of the given cement sample by sieving through a 90 micron I.S. Sieve.

2. **Apparatus:** - 90 microns I.S Sieve with mesh opening of 0.087 mm, weighing balance sensitive to 0.1 mg accuracy, weights box, nylon bristle brush etc.

3. **Material-** Cement

4. **Theory-** The degree of fineness of cement is a measure of the mean size of particles of cement. It is expressed in term of either percent of residue by weight, after sieving on IS sieve of size 90 microns or specific surface by Air permeability method.

   By fineness method,

$$\text{Fineness of cement} = \frac{\text{Wt. Of sample retained on the sieve}}{\text{Total Wt. Of the cement sample}} \times 100$$

   The rate of hydration and hydrolysis and consequent development of strength in cement mortar depends upon the fineness of cement. To have the same rate of hardening in different brands of cement, the fineness has been standardized. The finer cement has quicker action with water and gains early strength though its ultimate strength remains unaffected. The shrinkage and cracking of cement will increase with fineness of cement.

5. **Procedure:**

   i) Weigh accurately 100 gms of cement in a plate and transfer it to a clean dry IS Sieve 90 microns and break down any air set lumps with fingers.

   ii) Hold the sieve and pan in both hands, sieve with gentle wrist motion until most of the fine material has passed through and the residue looks fairly clean. This usually requires 3 to 4 minutes.

   iii) Place the cover on the sieve and remove the pan. With sieve and cover held firmly in one hand, the other side of the sieve is tapped with the handle of the brush, which is used for cleaning the sieve. Sweep clean the under side of the sieve.

   iv) Empty the pan to wipe clean with a cloth. Replace the sieve in the pan and remove the cover carefully. Return any coarse material that had been caught in cover during tapping the sieve.

   v) Continuously sieve the sample for 15 minutes, rotating the sieve continuously throughout the sieving operation without spilling the cement.

   vi) Weigh the residue left on the sieve.

6. **Observation and Calculations: -**

S.No	Wt. Of cement sample taken	Wt. Of residue (gms)	Fineness of cement (Wt. Of residue) = (mass of residue in gms ± C) x100 / Wt of cement sample
1.	100 gms	8	8
2.	100 gms	7	7
3.	100 gms	9	9

C (correction factor): The difference between the percentage residue on the sieve and that assigned to the standard sample is the amount of correction and shall be added or subtracted as necessary.

Average Fineness = 8

7. **Result:** - The fineness (percentage weight of residue) of the given cement sample is 8

8. **Precautions: -**

i) The sieve must be cleaned thoroughly before the experiment.

ii) Any air set lumps in the sample should be broken down with fingers, but do not rub on the sieve.

iii) The care should be taken to ensure that no cement is spilled. After sieving, all residues must be taken out carefully and weighed.

iv) The underside of the sieve shall be lightly brushed with a 25 or 40mm bristle brush after every five minutes of sieving.

(Ref: - I.S: 269 – 1976 and I.S. 460 – 1978)

Experiment # 3

NORMAL (STANDARD) CONSISTENCY OF CEMENT

1. **Objective:** - To determine the normal consistency of a given cement sample.

2. **Apparatus:** - Vicat apparatus with Vicat plunger, vicat needle and vicat mould, conforming to IS: 5513 – 1976, weighing balance (accuracy 0.05 % of weight of cement), weight box, rubber gloves, water measuring jar (100 ml to 200 ml capacity), trowel, non porous glass plate, 850 micron I.S. Sieve. The vicat apparatus as shown in figure consists of a frame bearing a movable rod with a cap at one end and detachable needle or plunger at the other end. The movable rod carries an indicator, which moves over a graduated scale having graduations in mm from zero to 40 on either direction to measure the vertical movement of the plunger. The scale is attached to the frame. The movable part with all the attachments (cap, rod with needle or plunger) weighs 300 gm.

   The plunger A, required for determining the consistency is of polished brass10 mm in diameter and 50 mm long with the lower end flat and small projection at upper end for insertion into the movable rod.

   The vicat mould for cement paste consists of a split ring 80 mm in diameter and 40 mm in height and rest on a non-porous plate (glass plate). The gauging trowel weighs 210 gm.

3. **Material-** Cement, clean water.

4. **Theory-** Normal consistency of cement is defined as the percentage of water required to get a cement paste.

   This amount of water is expressed as percentage of water by weight of dry cement, which will permit the Vicat plunger to penetrate to a height of 5 mm to 7 mm from the bottom of the Vicat mould when cement paste is tested.

   The object of conducting this test is to find out the amount of water to be added to the dry cement to get a paste of normal consistency i.e. the paste of certain standard solidity, which is used to fix the quantity of water to be mixed in dry cement before performing tests for setting time, soundness of cement, and compressive strength of cement.

5. **Procedure:**

   i) Take about 400 gms of cement passing 850 micron I.S. Sieve and prepare a paste with a weighed quantity of water (say 24% by weight of cement) for the first trial, taking care that the gauging time (time of mixing) is between 3 to 5 minutes, The gauging time is counted from the time of adding water to the dry cement until commencing to fill the mould.

   ii) Fill the vicat mould resting upon non-porous plate (glass plate) with the mixed cement paste. After completely filling the mould, slightly shake the mould to expel air. Then smooth off the surface of the paste making it level with the top of the mould with the help of a trowel.

iii) Place the test block in mould with the non-porous resting plate under the rod attached with the plunger 'A'. Lower the plunger gently to touch the surface of the test block and release it quickly, allowing it to sink into the paste by its own weight. Take the reading by noting the depth of penetration of the plunger.

iv) Repeat the above procedure for various of percentages of water with an interval of 2% until the amount of water necessary for the standard consistency is obtained i.e., the depth of penetration of plunger is 5 mm to 7 mm from the bottom of the scale.

v) Draw a graph between percentage of water by weight of cement on Y-axis and penetration of plunger in millimeters on X-axis.

6. **Observation and Calculations: -**

S.No	Weight of Cement in grams (gms)	Percentage (%) of water added	Quantity of water in ml.	Depth of penetration from bottom in mm
1.	~~400~~ 300	24	72	38
2.	~~400~~ 300	28	84	35
3.	~~400~~ 300	30	90	26
4.	~~400~~ 300	31	~~93~~	19
5.	~~400~~ 300	32	96	12
6.	~~400~~ 300	33	99	6

Standard consistency of the given cement = 7 %

7. **Result:** - The normal (standard) consistency of the given cement sample is 7 % by weight.

8. **Precautions: -**

i) After half a minute from the instant of adding water, it should be mixed thoroughly with fingers for at least one minute. A ball of this paste is prepared and then it is pressed into the test mould, mounted on the non-porous plate.

ii) The plunger should be released quickly without pressure or jerk, after the rod is brought down to touch the surface of the test block.

iii) Plunger should be cleaned during every repetition and make sure that it move freely and that there are no vibrations.

iv) For each repetition of the experiment fresh cement is to be taken

v) The experiment should be conducted at a room temperature of 27 ± 2 ° C and at a relative humidity of 90 %.

(Ref: - IS269 – 1989 & IS: 4031 (Part 4)– 1988)

Experiment # 4 (a)

INITIAL SETTING TIME OF CEMENT

1. **Objective:** - To determine the initial setting time of a give cement sample.

2. **Apparatus:** - Vicat apparatus with vicat needle and vicat mould, conforming to IS: 5513 – 1976, weighing balance (accuracy 0.05 % of weight of cement), weight box, rubber gloves, water measuring jar (100 ml to 200 ml capacity), trowel, non porous glass plate, 850 micron I.S. Sieve. The vicat apparatus as shown in figure consists of a frame bearing a movable rod with a cap at one end and detachable needle or plunger at the other end. The movable rod carries an indicator, which moves over a graduated scale having graduations in mm from zero to 40 on either direction to measure the vertical movement of the plunger. The scale is attached to the frame. The movable part with all the attachments (cap, rod with needle or plunger) weighs 300 gm.

   The vicat needle required for determining the initial setting time is of polished brass1 mm square or 1. 13 mm in diameter and 50 mm long with the lower end flat and small projection at upper end for insertion into the movable rod.

   The vicat mould for cement paste consists of a split ring 80 mm in diameter and 40 mm in height and rest on a non-porous plate (glass plate). The gauging trowel weighs 210 gm.

3. **Material-** Cement, clean water.

4. **Theory:** - In order that the concrete may be placed in position conveniently, it is necessary that the initial setting time of cement is not too quick and after it has been laid hardening should be rapid so that the structure can be made use of as early as possible. The initial set is a stage in the process of hardening after which any crack that may appear will not reunite.

   Initial setting time: - Initial setting time is the time elapsed between the moment the water is added to the cement, to the time that the paste starts losing its plasticity.

5. **Procedure:**

   i) Take about 400 gms of cement and prepare a paste with a 0.85 times the water required to give or produce standard consistency i.e., 0.85 x P x 4 where P = Standard consistency. The gauging time (time of mixing) is kept between 3 to 5 minutes.

   Start the stopwatch at the instant when the water is added to the cement.

   ii) Completely fill the mould, which is resting upon non-porous plate, shake the mould to expel air. Then smooth off the surface of the paste making it level with the top of the mould with the help of a trowel.

   iii) Place the test mould with the non-porous resting plate under the rod attached with the Needle B. Lower the needle gently to touch the surface of the test block and release it quickly, allowing it to sink into the paste. Take the reading by noting the depth of penetration of the needle.

iv) Repeat this procedure until the needle fails to pierce the block for 5 mm measured from the bottom of the mould. The period elapsed between the time at which water is added to the cement and the time at which the needle fails to pierce the test block by 5 mm is the initial setting time of the given cement sample.

6. **Observation and Calculations: -**

S.No	Weight of Cement in grams	Added water 0.85 X P x 4 in ml	Time elapsed in minutes	Depth of penetration from bottom in mm
1.	~~400~~ 300	84.1	10	0
2.	300	84.1	20	0
3.	300	84.1	30	0
4.	300	84.1	40	1
5.	300	84.1	50	3
6.	300	84.1	55	5
7.			60	
8.			65	
9.			70	
10.			75	

7. **Result: -** The initial setting time of the given cement sample is 55 minutes.

8. **Precautions: -**

v) After half a minute from the instant of adding water, it should be mixed thoroughly with fingers for at least one minute. A ball of this paste is prepared and then it is pressed into the test mould, mounted on the non-porous plate.

vi) The needle should be released quickly without pressure or jerk, after the rod is brought down to touch the surface of the test block.

vii) Needle should be cleaned during every repetition and make sure that it move freely and that there are no vibrations.

viii) Each repetition of the experiment is not to be done on fresh cement.

ix) The experiment should be conducted at a room temperature of 27 ± 2 ° C and at a relative humidity of 90 %.

(Ref: - IS269 – 1989 & IS: 4031 (Part 5)– 1988)

Experiment # 4 (b)

FINAL SETTING TIME OF CEMENT

1. **Aim:** - To determine the final setting time of given cement sample.

2. **Apparatus:** - Vicat's apparatus, Vicat circular needle of 5mm diameter, as shown in figure, weighing balance, weights, mould, glass plate, trowel. Vicat apparatus with vicat circular needle and vicat mould, conforming to IS: 5513 – 1976, weighing balance (accuracy 0.05 % of weight of cement), weight box, rubber gloves, water measuring jar (100 ml to 200 ml capacity), trowel, non porous glass plate, 850 micron I.S. Sieve. The vicat apparatus as shown in figure consists of a frame bearing a movable rod with a cap at one end and detachable needle or plunger at the other end. The movable rod carries an indicator, which moves over a graduated scale having graduations in mm from zero to 40 on either direction to measure the vertical movement of the plunger. The scale is attached to the frame. The movable part with all the attachments (cap, rod with needle or plunger) weighs 300 gm.

   The vicat circular needle required for determining the final setting time is of polished brass1 mm square or 1. 13 mm in diameter with the lower end flat and small projection at upper end for insertion into the movable rod. The lower end circular hollowed out portion is of 5 mm diameter so as to leave a circular cutting edge and end projection of the needle is 0. 5 mm.

   The vicat mould for cement paste consists of a split ring 80 mm in diameter and 40 mm in height and rest on a non-porous plate (glass plate). The gauging trowel weighs 210 gm.

3. **Material:** - Cement, Clean water.

4. **Theory :-** Final setting time is that interval of time, when water is added to the cement and the time at which the needle makes an impression of 0.5 mm on test mould. The concrete is said to be finally set when it has obtained sufficient strength and hardness.

5. **Procedure: -**

   i) Take about 400 gms of cement and to it add 0.85 times the normal consistency of water (0.85 p x 400 gms). Note down the time when water is added to dry cement

   ii) Mix the paste thoroughly with the trowel and then fill the vicat mould placed on non-porous glass plate with the paste, Within 3 to 5 minutes of adding water to cement.

   iii) Place the mould and glass plate underneath the rod of vicat apparatus to which the vicat circular needle C is attached. Release the needle, the center of which makes an impression on the paste in the mould. Repeat the exercise at regular intervals, till the needle make an impression and does not pierce through the paste, more than 0.5mm.

   iv) Note the time for final setting in minutes or hours.

6. **Observations: -**

S.No	Weight of cement in grams	% Of water added	Time interval	Penetration or impression
1	400	0.85 x P x 4		
2				
3				
4				
5				
6				
7				

7. **Results:** - The final setting time for given cement sample is -----------

8. **Precautions: -**

i) After half a minute from the instant of adding water, it should be mixed thoroughly with fingers for at least one minute. A ball of this paste is prepared and then it is pressed into the test mould, mounted on the non-porous plate.

ii) The needle should be released quickly without pressure or jerk, after the rod is brought down to touch the surface of the test block.

iii) The needle should be cleaned during every repetition and make sure that it moves freely and that there are no vibrations.

iv) Each repetition of the experiment is done on the cement is to be taken

v) The experiment should be conducted at a room temperature of 27 ± 2 ° C and at a relative humidity of 90 %.

(Ref: - IS269 – 1989 & IS. 4031 (Part 5)– 1988

Experiment # 5

BULKING OF SAND

1. **Objective:** - To determine the necessary adjustments for bulking of a given sand sample (fine aggregate), by Field method and by Laboratory method

2. **Apparatus:** - Cylindrical container, water measuring jar, impervious tray, weighing balance accuracy upto 0.1 gm, steel scale, 4.75 mm IS sieve etc.

3. **Material :-** Sand, distilled water etc.

4. **Theory :-** In concrete mix design the quantity of fine aggregate used in each batch should be related to the known volume of cement. The difficulty with measurement of fine aggregate by volume is the tendency of sand to vary in bulk according to moisture contents. The extent of this variation is given by this test.

   If sand is measured by volume and no allowance is made for bulking the mix will be richer than that specified, because for given mass, moist sand occupies a considerably larger volume than the same mass of dry sand as the particles are less closely packed when the sand is moist. If as is usual the sand is measured by loose volume, it is necessary in such a case to increase the measured volume of the sand, in order that the amount of sand put into the concrete may be the amount intended for the nominal mix used (based on the dry sand). It will be necessary to increase the volume of the sand by the percentage bulking. The correction can be determined and should be applied in order to keep the concrete uniform

   The volume of a given quantity of dry sand increased with increase in moisture content, due to the formation of the film of moisture around each sand particle. This phenomenon is known as Bulking of sand.

$$\% \text{ Of Bulking} = \frac{\text{Volume of Wet Sand} - \text{Volume of Dry sand}}{\text{Volume of Dry sand}} \times 100$$

5. **Procedure: -**

   a) **Laboratory Method**

   i) Weigh the empty cylindrical container. Let this weight by W1 gms.

   ii) Put sufficient quantity of oven dry sand loosely into the container until it is about two third (2/3) full. Level of the top of sand and weigh the container. Calculate the mass of the sand by deducting the mass of the container. Let this weight be W2 gms.

   iii) Push a steel rule vertically down through the sand at the middle to the bottom and measure the height of the sand. Let it be h mm.

   iv) Empty the sand out into a clean impervious metal tray without any loss.

   v) Add 2 % of water by mass of sand. Mix the sand and water thoroughly with by hand.

   vi) Put the wet sand loosely into the container without tamping it.

vii) Smooth and level the top surface of the inundated sand and measure its depth at the middle with the steel scale. Let it be h' mm.

viii) Repeat the above procedure with 4%, 6%, 8% ... of water by mass of sand (i.e., by adding 2%, 4% etc to the already existing water in the sand sample for every trial) of the sample till the bulking is maximum and starts falling down and ultimately bulking is zero. (i.e. Saturated sand occupies the same volume as dry sand).

6. **Observation and Calculations: -**

(i) Weight of dry empty container (W1) = 300 gms

(ii) Weight of container + dry sand (W2) = 2610 gms

Weight of dry sand (W) = 2310

Height of dry sand (h) = 120 mm

Bulking factor = volume of wet sand / volume of dry sand

$$\% \text{ Of Bulking} = \frac{\text{Area (Height of wet sand– height of Dry sand)}}{\text{Area X height of dry sand}} \times 100$$

$$= \frac{h' - h}{h} \times 100$$

S.No	% Of water added	Quantity of water added in ml	Height of wet sand (h') in mm	% Of bulking = $\frac{(h' - h)}{h} \times 100$
1.	2%	46	129.6	8
2.	4%	92	136.8	14
3.	6%	138	146.4	22
4.	8%	184	154.8	29
5.	10%	230	147.6	23
6.	12%	276	139.2	16
7.	14%	323	129.6	8
8.	16%	369	120	0
9.	18%			
10.	20%			

7. **Result:** - i) Max of bulking = 29 % at 8 % of moisture content.

ii) From graph: Max % of bulking is 29 % at 8 % of water content.

8. **Precautions: -**

   i) There should not be any wastage of sample during testing.

   ii) Water should be measured accurately.

   iii) Container should be clean and dry.

9. **Comments: -** It is seen that bulking increases with increase in water content upto a certain point where it is maximum then it begins to decrease until when the sand is inundated, bulking is practically nil as shown in figure. With ordinary sand the bulking varies between 15 to 30 % at about 5 to 10 % moisture content, and will result in an increase in concrete strength by as much as 13 %. The strength may vary by as much as 25 % if no allowance is made for bulking. In volume batching if no allowance is made for bulking the mix will be richer than specified, for example when the sand has bulked by 15 % the mix 1: 2: 4 by volume batching will correspond to 1:1.74:4. (i. e) 1:2/(1+15/100): 4 is 1: 1.74: 4.

b) <u>Field Method</u>

1. **Procedure: -**

   i) Fill the container to about two – third (2/3) full with given sand loosely.

   ii) Level off the top of the sand and measure the height by pushing a steel scale vertically down through the sand at the middle to the bottom. Let the height of dry sand be h mm.

   iii) Take the sand out into the clean metal tray without any loss.

   iv) Fill the container with water to half full.

   v) Pour the sand back into the container and stir it with a steel rod 6 mm in diameter, so that volume may reduce to a minimum.

   vi) Smooth and level the top surface of the inundated sand and measure its depth at the middle with a steel scale. Let the height be h' mm.

   vii) Calculate the percentage bulking of sand due to moisture.

2. **Observation and Calculations: -**

Height of dry sand = h mm =

Height of fully wet sand = h' mm =

% bulking $= \frac{(h - h')}{h} \times 100 =$

Result: - Maximum percentage of bulking is ____________

(Ref: - IS: 2386 (Part 3)– 1963)

Experiment # 6

FINENESS MODULUS OF FINE AGGREGATE

1. **Objective: -** To determine the fineness modulus of a given fine aggregate (Sand).

2. **Apparatus: -** IS sieve set of 4.75 mm, 2.36 mm, 1.18 mm, 600 microns, 300 microns, 150 microns fine mesh wire cloth and lid and receiver pan, weighing balance up to 1 gm accuracy, sieve shaker, trays, bristle brush etc.

3. **Material :-** fine aggregate (Sand).

4. **Theory :-** The Fineness Modulus is a numerical index of fineness, giving some idea of the mean size of the particles present in the entire body of the aggregate. Determination of the fineness modulus may be considered as a method of standardization of the grading of the aggregates. It is obtained by sieving a known mass of given aggregate in a set of standard sieves and by adding the percentage mass of material retained on all sieves and dividing the total percentage by 100.

   The object of finding the fineness modulus is to grade the given aggregate for the most economical mix and workability with minimum quantity of cement

$$\text{Fineness Modulus} = \frac{\text{Cumulative sum of the percentages of the aggregate retained on each sieve taken in order}}{100}$$

5. **Procedure: -**

   i) Take 1 kg of dry sand and break any clay lumps if any in a dry plate.

   ii) Arrange the sieves in order of IS sieve nos., 4.75 mm, 2.36mm, 1.18mm, 600 microns, 300 microns, 150 microns. Keep sieve number 4.75 mm at the top and 150 microns at the bottom.

   iii) Fix them in the sieve shaking machine with the pan at the bottom and lid at the top.

   iv) Keep the sand in the top sieve, carry out the sieving in the set of sieves as arranged before for not less than 10 minutes.

   v) Find the mass retained on each sieve.

   vi) A grading curve is drawn on a graph with percentage passing on Y – axis with 0 % at base point and I.S. Sieve size starting with minimum on base point and progressing to higher sieves on the X – axis.

6. **Observation and Calculations: -**

S. No	Sieve no. (size)	Weighed retained in grams	% retained	% passing	Cumulative % retained (F)
1.	4.75 mm	35	3.5	96.5	3.5
2.	2.36 mm	60	6	90.5	9.5
3.	1.18 mm	216	21.6	79.9	31.8
4.	600 micron	267	26.7	42.2	58.5
5.	300 micron	257	25.4	16.8	83.9
6.	150 micron	138	13.8	3	99.7
7.	Pan	25	2.5		$\Sigma F =$ 284.9

Fineness Modulus of fine aggregate = $\frac{\Sigma F}{100}$ = 2.849

7. **Result: -** The Fineness modulus of a given fine aggregate is = 2.849

8. **Precautions: -**

i) The sieves should be cleaned thoroughly before the experiment.

ii) Stiff worn out brushes should not be used.

iii) The sieving must be done carefully to prevent the spilling of the aggregate.

iv) Do not apply pressure to force the particles through the mesh.

(Ref: - IS: 2386 (Part 1)– 1963, I.S 460 - 1978)

Experiment # 7 (a)

SPECIFIC GRAVITY OF FINE AGGREGATE

1. **Objective:** -To determine the specific gravity of fine aggregate (sand) by using specific gravity (density) bottle

2. **Apparatus:** - Specific gravity bottle, Physical balance, 4.75 mm I.S. Sieve, weight box

3. **Material** :- Sand, clean water etc.

4. **Theory** :-

   i) **Specific Gravity:** - Specific Gravity of an aggregate is defined as the ratio of the mass of given volume of sample to the mass of equal volume of water at the same temperature. The specific gravity is generally required for calculations in concrete mix design, for determination of moisture content and for calculations of volume yield of concrete. It also gives information on qualities and properties of aggregate. Departure of specific gravity from its standard value indicates change in shape and grading. Due to voids present in aggregate there is absolute specific gravity and apparent specific gravity.

   Absolute specific gravity is defined as the ratio of mass of solid to the weight of an equal void free volume of water at stated temperature.

   Apparent specific gravity is defined as ratio of mass of aggregate dried in oven at 100 to 110 °C for 24 hours to mass of water occupying a volume equal to that of solids including voids.

5. **Procedure:** -

   i) Find the weight of the empty dry specific gravity bottle. Let the weight by W1 gms.

   ii) Fill the bottle with one third (1/3) sand and find its weight. Let this weight be W2gms.

   iii) Fill the bottle full with water containing sand. Find its weight. Let this weight be W3 gms.

   iv) Fill the bottle full with water after emptying and cleaning it from mix of fine aggregate and water, and find its weight. Let this weight be W4 gms.

   v) Repeat the above procedure for another trail by taking another sample of the fine aggregate.

6. **Observation and Calculations: -**

S.No	Observations & Calculations	Trial 1	Trial 2
1.	Weight of empty specific gravity bottle (W1 gm)	53	55
2.	Weight of empty gravity bottle + 1/3 volume fine aggregate (W2 gm)	118	121
3.	Wt. Of empty specific gravity bottle +1/3 volume of fine aggregate + water (W3 gm)	187	189
4.	Weight of empty gravity bottle + water (W4 gm)	148	151

Specific gravity of fine aggregate $= \dfrac{(W2 - W1)}{(W4 - W1) - (W3 - W2)}$

Sp. Gravity of fine aggregate for trial 1 = 2.5

Sp. Gravity of fine aggregate for trial 2 = 2.2

7. **Result: -**

i) Specific gravity of given fine aggregate = 2.35

8. **Precautions: -**

i) The air trapped in the aggregate should be brought to the surface by rolling the bottle in inclined position.

ii) Sand should not be allowed to stick to the sides of the bottle.

iii) The result of different repetitions should not differ by more than 0.02

(Ref: - IS: 2386 (Part 3)– 1963)

Experiment # 7 (b)

BULK DENSITY OF FINE AGGREGATE

1. **Objective:** - To determine the bulk density or unit weight and void ratio of fine aggregate.

2. **Apparatus:** - Weighing balance sensitive to 0.5% of the weight of the sample to be weighed, weights, cylindrical container (3, 15 or 30 liters capacity), tamping rod 60 cm long and 16 mm in diameter.

3. **Material:** - fine aggregate (sand).

4. **Theory:** - The bulk density is mass of the material in a given volume or unit weight is weight of the material per unit volume. It is measured in Kg/ litre. It is required for converting proportions by weight into proportions by volume. It is used for judging the quality by comparison with normal density for that type of aggregate. It determines the type of concrete for which it may be used. It is used in calculating the percentage of voids in the aggregate. The bulk density is affected by several factors and varies with specific gravity, shape, size and grading of the aggregate. The test should normally be carried out on dry material when determining the voids, but when bulking tests are required material with given percentage of moisture may be used.

5. **Procedure:** -

   i) Take the weight of the empty cylindrical container. Let the weight be W1 gm. Also note down the internal volume of the cylindrical container.

   ii) Fill the cylindrical container with fine aggregates in three layers, each layer being tamped with 25 strokes of the rounded end of the tamping rod distributing the strokes evenly over the surface. The container is finally filled to the surface.

   iii) Strike off the surplus aggregate using tamping rod as straight edge.

   iv) Weigh the container full of aggregate. Let it be W2 gm

   v) Calculate the net mass of the aggregate in the container and compute the unit mass of the aggregate by dividing the net mass of the aggregate in the container by volume of the container.

   vi) Pour water in the container to the surface of the cylinder so as to fill all the voids present in the aggregate. Weigh the cylinder. Let the weight be W3 gm.

   vii) Empty and clean the cylinder of the aggregate and fill it fully with water. Weigh the cylinder. Let the weight be W4 gm

   viii) Calculate the percentage void ratio by the weight of water in voids to weight of water in the cylinder.

6. **Procedure by loose mass distribution:** -

   i) Fill the cylindrical container to over flowing, the aggregate being discharged from a height not exceeding 50 mm above the top of the container.

ii) Level of the surface of the aggregate with a straight edge.

iii) Determine the net mass of the aggregate in the container.

iv) Calculate the unit mass of the aggregate by dividing the net mass of the aggregate in container by volume of the container.

v) Calculate the percentage of voids density in kg / litre $= \frac{(G_s - \Upsilon)}{G_s} \times 100$

Where G_s is specific gravity of aggregate and Υ is the bulk density in kg /litre.

7. **Observations and calculations: -**

Diameter of the cylindrical container d = 150 mm

Height of the cylindrical container h = 170 mm

Volume of the container = $\pi r^2 h$ = 3004.14 cm^3

Weight of the empty container = W1 = 3.9 kg

By compact mass method

S.No	Weight of aggregate and container (W2)	Weight of container + aggregate + water (W3)	Weight of container full of water (W4)	Weight of aggregate (W2 – W1)	Weight of water in voids (W3 – W2)
1	8.65 kg	9.75 kg	6.9 kg	4.75 kg	1.1 kg
2					

Bulk density Υ = $\frac{\text{weight of aggregate in container}}{\text{volume of container}} = \frac{(W2 - W1)}{V}$

The bulk density for trial 1 and trial 2 is = 1.58×10^{-3} kg/cm^2.

Percentage void ratio = $\frac{\text{Weight of water in voids}}{\text{Weight of water in the mould}} \times 100 = \frac{(W3 - W2)}{(W4 - W'1)} \times 100$

Void % for trial 1 and trial 2 is = 36.67 %

By loose mass method

Weight of empty container = W1 = 3.9 kg ; w_2 8.5 kg, W_3 = 9.6 kg, w_4 = 6.9 kg

Volume of container = V = 3004 cm³

Specific gravity of the aggregate = G_s = 2.9

S.No	Weight of aggregate (W2 – W1) in kg	Bulk density in kg/litre $\frac{(W2 - W1)}{V}$	% of voids $\frac{(G_s - \Upsilon)}{G_s} \times 100$
1	4.6 kg	1.53	45.5
2			

Bulk density of aggregate(Υ) = $\frac{\text{weight of aggregate in container}}{\text{volume of container}} = \frac{(W2 - W1)}{V}$

$$\% \text{ voids} = \frac{(G_s - \Upsilon)}{G_s} \times 100$$

8. **Result: -**

The bulk density of the fine aggregate is 1.53 kg/lit.

The % void ratio of fine aggregate is 45.5 %.

9. **Precautions: -**

i) The blows of the tamping rod should be evenly distributed over the surface without forcibly striking the bottom with the tamping rod

ii) In loose mass distribution care should be taken to prevent segregation of the particle sizes of which the aggregate is composed of

iii) The result with the same sample should check within 0.01 kg.

10. **Comments: -** (Ref: - IS: 2386 (Part 3)– 1963), stipulates that container should have nominal capacity of 3 litre for aggregate under 4.75 mm (inside diameter 150 mm, inside height 170 mm and thickness of metal 3.15 mm), The container should not change shape and should be protected against corrosion, otherwise variation in the resuit will be there. Based on operating conditions on the site the unit mass can be determined for any of the following four conditions. For moist unit weight the moisture content of aggregate at the time of test should be recorded.

(1) Dry loose mass. (2) Dry compacted mass. (3) Moist loose mass. (4) Moist compacted mass.

Experiment # 8

FINENESS MODULUS OF COARSE AGGREGATE

1. **Objective:** - To determine the fineness modulus of a give coarse aggregate.

2. **Apparatus:** - IS sieve set of 80 mm, 40 mm, 20 mm, 10 mm and 4.75 mm square hole, cover and pan, weighing balance up to 1 gm accuracy, trays, brush, drying oven to operate between 100 to 110°C etc.

3. **Material :-** Coarse aggregates.

4. **Theory :-** The Fineness Modulus is a numerical index of fineness, giving some idea of the mean size of the particles present in the entire body of the aggregate. Determination of the fineness modulus may be considered as a method of standardization of the grading of the aggregates. It is obtained by sieving a known mass of given aggregate in a set of standard sieves and by adding the percentage mass of material retained on all sieves and dividing the total percentage by 100.

   The object of finding the fineness modulus is to grade the given aggregate for the most economical mix and workability with minimum quantity of cement

$$\text{Fineness Modulus} = \frac{\text{Cumulative sum of the percentages of the aggregate retained on each sieve taken in order}}{100}$$

5. **Procedure: -**

   i) *Take 10 kg of Coarse aggregate of nominal size 20 mm.*

   ii) *Carry out sieving by hand. Shake each sieve in order of 80 mm, 40 mm, 20 mm, 10 mm and 4.75 mm over a clean dry tray for a period of not less than 2 minutes. The shaking is done with a varied motion backwards and forwards, left to right, circular, clockwise and anticlockwise and with frequent jarring so that the material is kept moving over the sieve surface in frequent changing direction.*

   iii) *Find the mass of aggregate retained on each sieve taken in order.*

   iv) *A grading curve is drawn on a graph with percentage passing on Y – axis with 0 % at base point and I.S. Sieve size starting with minimum on base point and progressing to higher sieves on the X – axis.*

6. **Observation and Calculations: -**

The weight of coarse aggregate taken = 10 kg.

S.No	Sieve No. (Size)	Weight retained	% retained	% passing	Cumulative % retained (F)
1.	80 mm	0	0	100	0
2.	40 mm	0	0	100	0
3.	20 mm	38.55	38.55	61.45	38.55
4.	10 mm 10 mm	29.30 26.70	29.30 26.70	70.7	67.8 94.55
5.	4.75 mm	500	5	73.3 96	99.55
6.	Pan	45	0.45	$\Sigma F =$	300.4

Fineness modulus of coarse aggregate = $\frac{\Sigma F}{100}$

7. **Result: - The** Fineness modulus of given Coarse aggregate is = ~~8%~~

8. **Precautions: -**
   - i) The sieves must be cleaned thoroughly before the experiment.
   - ii) Stiff worn out brushes should not be used
   - iii) The sieving must be done carefully to prevent the spilling of the aggregate.
   - iv) Do not apply pressure to force the particles through the mesh.

(Ref: - IS: 2386 – 1963, I.S 460 - 1978)

Experiment # 9 (a)

SPECIFIC GRAVITY OF COARSE AGGREGATE

1. **Objective:** - To determine the specific gravity and bulk density of a given coarse aggregate.

2. **Apparatus:** - Cylindrical container about 15 litres capacity, Weighing balance with weights, water measuring jar etc.

3. **Material :-** Coarse aggregate, water etc

4. **Theory :-**

Specific Gravity: - Specific Gravity of an aggregate is defined as the ratio of the mass of given volume of sample in air to the mass of equal volume of water at the same temperature. The specific gravity is generally required for calculations in concrete mix design, for determination of moisture content and for calculations of volume yield of concrete. It also gives information on qualities and properties of aggregate. Departure of specific gravity from its standard value indicates change in shape and grading. Higher the specific gravity of aggregate, harder and stronger the aggregate will be. Due to voids present in aggregate there is absolute specific gravity and apparent specific gravity.

Absolute specific gravity is defined as the ratio of mass of solids to the weight of an equal void free volume of water at stated temperature.

Apparent specific gravity is defined as the ratio of mass of aggregate dried in oven at 100 to 110 °C for 24 hours to mass of water occupying a volume equal to that of solids including voids.

Bulk Density: - The bulk density of an aggregate is defined as the mass of the material in a given volume and is expressed in kilograms/litre

(or) unit weight is the weight of material per unit volume.

5. **Procedure: -**

i) Find the weight of the empty container. Let the weight be W1 gms.

ii) Fill the container (fully) with coarse aggregate and find its weight. Let this weight be W2 gms.

iii) Fill the container with water up to the level of the coarse aggregate so that all the voids inside the aggregate are filled with water. Find its weight. Let this weight be W3 gms.

iv) Fill the container fully with water after emptying and cleaning it from mix of coarse aggregate and water. Water level should be up to which coarse aggregate is filled and weigh it. Let this weight be W4 gms.

v) Repeat the above procedure for another trail by taking the coarse aggregate.

6. **Observation and Calculations: -**

S.No	Observations & Calculations		Trial 1	Trial 2
1.	Weight of empty container	W1 gm	9500	93500
2.	Weight of container + material	W2 gm	32800	35550
3.	Wt. Of container + material + water	W3 gm	34700	41350
4.	Weight of container + water	W4 gm	24700	25000
5.	Sp. Gr. = $\frac{(W2-W1)}{(W4-W1)(W3-W2)}$		2.8	2.7
6.	Unit weight = $\frac{\text{Wt. Of solids}}{\text{Total volume}}$ = $\frac{(W2-W1)}{(W4-W1)}$		1.53	1.67

7. **Result: -**

i) Specific gravity of given coarse aggregate for trial 1 and trial 2 is 2.8 and ____________

ii) Unit weight of given coarse aggregate = 1.6

8. **Precautions: -**

i) The sample should be free from foreign matters that are not related to the aggregate.

ii) Duplicate determination should be checked within 0.02

(Ref: - IS: 2386 (Part 3)– 1963)

Experiment # 9 (b)

BULK DENSITY OF COARSE AGGREGATE

1. **Aim:** - To determine the bulk density or unit weight and void ratio of coarse aggregate.

2. **Apparatus:** - Weighing balance sensitive to 0.5% of the weight of the sample to be weighed, weights, cylindrical container (15 or 30 litres capacity), tamping rod 60 cm long and 16 mm in diameter.

3. **Material:** - coarse aggregate.

4. **Theory:** - The bulk density is mass of the material in a given volume or unit weight is weight of the material per unit volume. It is measured in Kg/ litre. It is required for converting proportions by weight into proportions by volume. It is used for judging the quality by comparison with normal density for that type of aggregate. It determines the type of concrete for which it may be used. It is used in calculating the percentage of voids in the aggregate. The bulk density is affected by several factors and varies with specific gravity, shape, size and grading of the aggregate. The test should normally be carried out on dry material when determining the voids, but when bulking tests are required material with given percentage of moisture may be used.

5. **Procedure: - By compact mass method.**

ix) Take the weight of the empty cylindrical container. Let the weight be W1 gm. Also note down the internal volume of the cylindrical container.

x) Fill the cylindrical container with coarse aggregates in three layers, each layer being tamped with 25 strokes of the rounded end of the tamping rod distributing the strokes evenly over the surface. The container is finally filled to the surface.

xi) Strike off the surplus aggregate using tamping rod as straight edge.

xii) Weigh the container full of aggregate. Let it be W2 gm

xiii) Calculate the net mass of the aggregate in the container and compute the unit mass of the aggregate by dividing the net mass of the aggregate in the container by volume of the container.

xiv) Pour water in the container to the surface of the cylinder so as to fill all the voids present in the aggregate. Weigh the cylinder. Let the weight be W3 gm.

xv) Empty and clean the cylinder of the aggregate and fill it fully with water. Weigh the cylinder. Let the weight be W4 gm

xvi) Calculate the percentage void ratio by the weight of water in voids to weight of water in the cylinder.

6. **Procedure by loose mass distribution: -**

i) Fill the cylindrical container to over flowing, the aggregate being discharged from a height not exceeding 50 mm above the top of the container.

ii) Level of the surface of the aggregate with a straight edge.

iii) Determine the net mass of the aggregate in the container.

iv) Calculate the unit mass of the aggregate by dividing the net mass of the aggregate in container by volume of the container.

v) Calculate the percentage of voids density in kg / litre = $\frac{(G_s - \Upsilon) \times 100}{G_s}$

Where G_s is specific gravity of aggregate and ϒ is the bulk density in kg / litre.

7. **Observations and calculations: -**

Diameter of the cylindrical container d = 25 Cm

Height of the cylindrical container h = 30 cm

Volume of the container = $\pi r^2 h$ = 14726 cm³

Weight of the empty container = W1 = 9.5 kg

By compact mass method

S.No	Weight of aggregate and container (W2)	Weight of container + aggregate + water (W3)	Weight of container full of water (W4)	Weight of aggregate (W2 – W1)	Weight of water in voids (W3 – W2)
1	28.8 kg	39.7 kg	24.7 kg	23.3 kg	6.9 kg
2					

Bulk density ϒ = $\frac{\text{weight of aggregate in container}}{\text{volume of container}} = \frac{(W2 - W1)}{V}$

The bulk density for trial 1 and trial 2 is = 1.49 gm / cm³

Percentage void ratio = $\frac{\text{Weight of water in voids}}{\text{Weight of water in the mould}} \times 100 = \frac{(W3 - W2)}{(W4 - W1)} \times 100$

Void % for trial 1 and trial 2 is = 45.39 %

By loose mass method (un compacted)

Weight of empty container = W1 = 9.5 kg

Volume of container = V = 15576.15 cm^3

Specific gravity of the aggregate = G_s = 2.8

S.No	Weight of aggregate (W2 – W1) in kg	Bulk density in kg/litre $\frac{(W2 - W1)}{V}$	% of voids $\frac{(G_s - \Upsilon)}{G_s} \times 100$
1	23.3	14.9	46.78
2			

Bulk density of aggregate(Υ) = $\frac{\text{weight of aggregate in container}}{\text{volume of container}} = \frac{(W2 - W1)}{V}$

$$\% \text{ voids} = \frac{(G_s - \Upsilon)}{G_s} \times 100$$

8. **Result: -**

The bulk density of the coarse aggregate is = 14.9 kg/lit

The % void ratio of coarse aggregate is = 46.78%

9. **Precautions: -**

iv) The blows of the tamping rod should be evenly distributed over the surface without forcibly striking the bottom with the tamping rod

v) In loose mass distribution care should be taken to prevent segregation of the particle sizes of which the aggregate is composed of

vi) The result with the same sample should check within 0.01 kg.

i) **Comments: -** (Ref: - IS: 2386 (Part 3)– 1963), stipulates that container should have nominal capacity of 15 litres for aggregate of size from 4.75 mm to 40 mm (inside diameter 250 mm, inside height 300 mm and minimum thickness of metal 4 mm), and 30 litres for aggregate over 40 mm (inside diameter350 mm, inside height 310 mm and minimum thickness of metal 5 mm). The container should not change shape and should be protected against corrosion, otherwise variation in the result will be there. Based on operating conditions on the site the unit mass can be determined for any of the following four conditions. For moist unit weight the moisture content of aggregate at the time of test should be recorded. (1) Dry loose mass. (2) Dry compacted mass. (3) Moist loose mass. (4) Moist compacted mass

Experiment # 10

WORKABILITY OF CEMENT MORTAR (using Flow Table)

1. **Objective:** - To determine the workability of cement mortar.

2. **Apparatus:** - The apparatus shall consist of a standard flow table and truncated conical mould, tray, trowels, physical balance, vernier calipers, scale, tamping rod 16 mm diameter and 40 mm long with flat end etc.

3. **Material :-** Cement, Fine aggregate (sand), water etc.

4. **Theory :-** The flow of mortar is the percentage increase in the average diameter of the spread mortar over the base diameter of the mould. This method specifies the procedure of the use of the flow table to determine the fluidity of mortar. It also gives an indication of consistency of the mortar and its tendency of segregation by measuring the spread of the pile of the mortar subjected to jolting, however it should be noted the flow test does not measure workability as mortars having the same flow may differ in other tests in their workabilities. It is regard to stability and mobility aspect of workability that the flow test is of greatest value. It gives good assessment of consistencies of stiff and rich cohesive mixes. The disadvantage of the flow test lies in the fact that the flow is uncontrolled and some of the aggregates ride along only partly embedded in the mortar and that at the end of the test the mass is scattered instead of being homogeneous.

$$\% \text{ of flow} = \frac{\text{Spread diameter } (d') - \text{Base diameter of the mould } (d)}{\text{Base diameter of the mould } (d)} \times 100$$

$$\% \text{ of flow} = \frac{\text{Increase in perimeter} \times 100}{\text{Initial perimeter}} = \frac{\text{Final perimeter} - \text{Initial perimeter} \times 100}{\text{Initial perimeter}}$$

5. **Procedure:** -

   i) Wipe the top of the flow table clean and dry.

   ii) Place the mould at the centre of the flow tabletop and hold it firmly in place.

   iii) Take cement mortar constituents of 100 gms of cement without any lumps and 300 gms of sand passing through IS 4.75 sieve for mixing (i.e.1: 3 ratio). Total quantity being 200 gms and 600 gms. Mix the dry constituents thoroughly in a tray until to get a uniform colour.

   iv) Add water to this mix with water – cement ratio of 0.40. Mix the mortar thoroughly and fill the mould with this cement mortar in 2 layers by tamping each layer 25 times with a tamping rod. Level the surface with trowel.

   v) Lift and remove the mould vertically away from the table without disturbing the sample.

   vi) Turn the handle 15 times at the rate of One revolution per second such that the mortar is given a jolt by raising and then dropping by 12.5 mm (15 jolts in 15 seconds).

vii) The diameter of the spread mortar is measured in all directions and average diameter of the results is taken. Express the flow value as percentage of the initial diameter of the base. Measure the perimeter of the spread mortar

viii) Repeat the above procedure for different water-cement ratios say by 0.45, 0.50. 0.60.

6. **Observation and Calculations: -**

S.No	W/c Ratio	Initial diameter or initial perimeter (l) in (mm)	Final (avg.) diameter or final perimeter (L) in mm	% flow = (D - d) x 100 / d or $\frac{(L - l) \times 100}{l}$
1.	0.40	100 mm	10.55	55%
2.	0.45	100 mm	11.73	17.3%
3.	0.50	100 mm	12.63	26.3%
4.	0.60	100 mm	17.45	74.5%
5.	0.70	100 mm	21.9	119%

7. **Result: - The** flow of cement mortar is 78.52 %

8. **Precautions: -**

i) The top of the flow table should be wiped clean with water after each use.

ii) The mould should be kept clean and dry.

iii) The vertical shaft should be lubricated with light oil.

iv) The strokes of tamping rod should be distributed uniformly over the cross section of the mould.

v) The mould should be removed very slowly by lifting it upwards so that the mortar with in the mould does not get disturbed.

(Ref: - IS: 269-1976 & IS 4031 – 1968)

Experiment # 11

DETERMINATION OF COMPRESSIVE STRENGTH OF CEMENT MORTAR

1. **Objective:** - To determine the compressive strength of 1: 3 cement – sand mortar cubes after 3 days and 7 days curing compacted by means of a standard vibration machine.

2. **Apparatus:** - Vibration machine, cube moulds of size of 70.5 mm, trowels, tray, crucible for mixing cement and sand, measuring cylindrical jar, Compression testing machine or universal testing machine, I.S. Sieve 850 micron and 600 micron, non porous plate, physical balance with weights, etc.

   Vibrating machine (12000 ± 400 revolutions per minute i.e. rpm, is running speed of mortar amplitude of vibration 0.055 mm, 3 phase mortar with automatic cut off). It consists of a heavy frame, on one side of which is fixed an electric mortar and on the other side there is a set of four springs. Above this spring is fixed a mould on another frame and this mould is removable. With the frame carrying mould, a pulley is attached and the belt runs on the pulley and the mortar. The mould is fitted with a detachable hopper at the top. Through the hopper mortar is put in the mould without any loss of sample. A weight is attached to the frame to keep the mould in balance. When mortar is started, the belt moves the pulley and gives vibrations to the mould at the rate of 12000 ± 400 cycles per minute. Due to load attached to the frame, the c.g of the machine falls near the weight.

   The moulds are of special shape and dimensions having 70.5 mm side (50000 mm^2 face). It is constructed in such a way that it can be split in parts in order to take out the cube without any damage. The base plate is non porous and of such a size that there should be no leakage of water from bottom.

3. **Material :-** Cement, standard sand, clean water etc.

   Standard Sand: The standard sand to be used in the test shall conform to IS: 650-1991 or sand passing 100 percent through 850 micron I.S. Sieve and retained at least by 90 % on 600 micron IS sieve).

4. **Theory :-** The compressive strength of cement mortar is determined in order to verify whether the cement conforms to IS specifications and whether it will be able to develop the required compressive strength of concrete. The strength of hardened cement is the property of the material. Strength tests are not conducted on pure cement paste, because of difficulty of moulding.

$$\text{Compressive strength} = \frac{\text{Crushing load (P) in Newtons}}{\text{Area (A) of the mould}}$$

5. **Procedure: -**

   (a) For preparing mortar cubes for compressive strength.

   i) Calculate the material required. The material for each cube shall be mixed separately (1: 3). The quantity of cement and standard sand is 200 gm and 600 gm.

ii) Water required = $\frac{P}{4} + 3.5$ % of combined weight of cement and mortar.

Where P is the percentage of water for standard consistency. That is say P is 30 % then water required is [(30/4) + 3.5] x 100 x 8.

iii) Take the calculated mixture of cement and standard sand in the proportion 1: 3 by mass on a non porous tray or plate and mix it dry with a trowel for one minute and then add the calculated quantity of water and mix the mixture for another 2 minutes, the mixing time should not be in any case less than 3 minutes and if the time taken to obtain a uniform colour exceeds 4 minutes, the mixture should be rejected and the experiment is repeated with fresh quantity of cement, standard sand and water.

iv) Place the assembled mould on the table of the vibrating machine and firmly hold it in position by means of suitable clamps. Securely attach the hopper at the top of the mould to facilitate filling and this hopper shall not be removed until the completion of the vibration period.

v) Immediately after mixing the mortar as explained above fill the entire quantity of mortar in the hopper of the cube mould and compact by vibration. The period of vibration shall be 2 minutes at the specified of 12000 ± 400 cycles per minute.

vi) Remove the mould from the machine and keep it at a temperature of 27 ± 2 °C in an atmosphere of at least 90 % relative humidity for 24 hours after completion of vibration.

vii) At the end of this period, remove the cube from the moulds and immediately submerged in clean and fresh water, and keep there until taken out just prior to testing. The water in which the cubes are submerged shall be renewed after every 7 days and be maintained at a temperature of 27 ± 2 °C. Keep the cubes wet till they are placed in machine for testing.

(b) For testing mortar cubes for compressive strength.

i) The specimens should be tested for required periods, say for a period of 3 days and 7 days.

ii) The cubes should be tested on their sides on the U.T.M / C.T.M, the loading being applied at the rate of 35 N/mm^2/minute.

6. **Observation and Calculations: -**

S.No	3 – day strength		7 – day strength	
	Load in N	Strength in N / mm²	Load in N	Strength in N / mm²
1.				
2.				
3.				
Average Strength =			Average Strength =	

7. **Result: - Compressive** strength of cement mortar

i) After 3 days = ____________ N/sq mm

ii) After 7 days = ____________ N/sq mm

8. **Precautions: -**

i) The mortar shall not be compressed into the moulds with hand.

ii) The cubes should be tested on their sides and not on their faces.

iii) The inside of the cube mould should be oiled to prevent the mortar from adhering to the sides of the mould.

iv) The time of wet mixing shall not be less than 3 minutes. If the time of mixing exceeds 4 minutes to bring a uniform colour, the mixture shall be rejected and fresh mortar should be prepared.

v) The cubes shall not be allowed to dry until they are broken.

(Ref: - IS: 269-1989 & IS 4031 – 1968, I.S 650 1966)

Experiment # 12 (a)

TEST ON STUDY OF WORKABILITY
SLUMP TEST

1. **Objective:** - To determine the consistency of Concrete mix by slump test.

2. **Apparatus:** - Slump test apparatus with 300 mm scale, iron pan to mix concrete, weighing platform machine or weighing balance sensitive to 10 gm, water measuring jar, trowels, tamping rod 16 mm in diameter and 600 mm long and is bullet pointed at the lower end, etc.

   Slump cone test apparatus is shown in figure. It is a hollow frustrum made of thin steel sheet with internal dimension as, top diameter 100 mm, bottom diameter 200 mm and the height 300 mm. It stands on a plane non-porous surface. To facilitate vertical lifting from moulded concrete it is provided with a suitable guide attachment and suitable foot pieces and handle.

3. **Material :-** Cement, sand, coarse aggregate, water.

4. **Theory :-**

   Slump: Slump is defined as the vertical distance through which the top of the unsupported moulded mass of freshly mixed concrete sinks on removal of the mould, under specified conditions of the test (i.e) fresh concrete flows to the sides and sinking in height will take place.

   Slump is a measure of indicating the consistency or workability of cement concrete. It gives an idea of water-cement needed for concrete to be used for different works.

   Workability: - Workability is defined as that property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, compacted and finished. A workable concrete should not show any segregation or bleeding.

   (The optimum workability of fresh concrete varies from situation to situation, e.g., the concrete which can be termed as workable for pouring into large sections with minimum reinforcement may not be equally workable when pouring into heavily reinforced thin sections.)

5. **Procedure:** -

   i) Take a mix ratio of nominal mix concrete 1: 2: 4. The calculated quantity of concrete constituents being 2.5 kg of cement, 5 kg of sand and 10 kg of coarse aggregate for mixing.

   ii) Mix the dry constituents thoroughly to a uniform colour and then add assumed percentage of water, say 50 % by weight of cement (w/c = 0.50).

   iii) Place the mixed concrete in the cleaned slump cone mould in 4 layers, each approximately ¼ of the height of the mould. Tamp each layer 25 times with tamping rod distributing the strokes in a uniform manner over the cross-section of the mould.

For the second and subsequent layers the tamping rod should penetrate in to the underlying layer.

iv) Strike off the top with a trowel or tamping rod so that the mould is exactly filled.

v) Remove the cone immediately, raising it slowly and carefully n the vertical direction.

vi) As soon as the concrete settlement comes to a stop, measure the subsidence of concrete in mm, which will give the slump.

vii) Repeat the experiment three more times by taking fresh material for each trial test and increasing the water content by 60 %, 70 %, 80 %.

6. **Observation and Calculations: -**

S.No	Water – cement Ratio	Slump (mm)	Type of Slump, True / Shear / Collapse
1.	0.5	7mm	True
2.	0.6	110 mm	Shear
3.	0.7	—	Collapse
4.	0.8		

7. **Result: -** ~~The~~ water-cement ratio for consistency or workability of cement concrete is ____________

8. **Precautions: -**

i) The strokes are to be applied uniformly throughout the entire area of the concrete section.

ii) The cone should be removed very slowly by lifting it upwards with out disturbing the concrete. The unsupported concrete should be allowed to spread and settle, and after settlement the height should be measured.

iii) The experiment should be completed within 3 minutes. During filling, the mould must be firmly pressed against its base.

iv) It should be ensured that the interior of the mould is clean and damp but not wet.

v) The base-plate should be smooth and clean so that the contact is made with bottom of the mould around its whole circumference.

vi) On completion of tamping, any surplus concrete is carefully removed with a trowel so that the mould is exactly filled. The surplus should not be forced into the mould.

vii) Care should be taken not to cause subsidence by jarring the base.

viii) Vibration from nearby machinery might also increase subsidence, hence test should be made beyond the range of ground vibrations.

(Ref: - IS: 1199 –1959)

Experiment # 12 (b)

TEST ON STUDY OF WORKABILITY
COMPACTION FACTOR TEST

1. **Objective:** - To determine the workability of concrete mix of given proportions by the compaction factor test.

2. **Apparatus:** - Compaction factor apparatus, trowels, hand scoop, platform balance, weighing balance, tamping rod, water measuring jar, etc.

   The compaction test apparatus consists of two conical hoppers A and B mounted vertically above a cylindrical mould C. The upper hopper has A has internal dimension as top diameter250 mm, bottom diameter 125 mm and height 225 mm. The lower hopper B has internal dimensions as top diameter 225 mm, bottom diameter 125 mm and height 225 mm. The cylinder has internal dimension as 150 mm diameter and 300 mm height. The distance between the bottom of upper hopper and top of lower hopper is 200 mm and between bottom of lower hopper and top cylinder is 200 mm. The lower ends of the hopper are fitted with quick release flap doors. The hoppers and cylinders are rigid in construction and rigidly mounted on a frame. These hoppers and cylinder are easily detachable from the frame.

3. **Material :-** Cement, sand, coarse aggregate, clean water, etc.

4. **Theory :-** Compaction factor test is adopted to determine the workability of concrete, where nominal size of aggregate does not exceed 40 mm. It gives an idea to control the quantity of water in cement concrete mix to get uniform strength.

   Compaction factor is defined as the ratio of the weight of partially compacted concrete to the weight of the fully compacted concrete.

5. **Procedure: -**

   i) Keep the compaction factor apparatus on a level ground and apply grease on the inner surface of the hoppers and cylinder.

   ii) Fasten the flap doors.

   iii) Weigh the empty cylinder accurately and note down the weight as W1 kg.

   iv) Fix the cylinder on the base with fly nuts and bolts in such a way that the central points of hoppers and cylinder lie on one vertical line. Cover the cylinder with a plate.

   v) Four mixes are to be prepared with water-cement ratio by weight 0.5, 0.6, 0.7, and 0.8 respectively. For each mix take 2.25 kg of cement, 4.5 kg of sand and 9.0 kg of coarse aggregate (i.e., in 1:2:4 ratio).

   Mix dry sand and cement, until a mixture of uniform color is obtained. Now mix the coarse aggregate and cement-sand mixture until coarse aggregate is uniformly distributed through out the batch. Add the required amount of water to the above mixture based on assumed percentage of water by weight of cement. Mix the mix thoroughly until concrete appears to be homogeneous.

vi) Fill the freshly mixed concrete in upper hopper gently and carefully with hand scoop without compacting.

vii) After two minutes, release the trap door so that the concrete may fall into the lower hopper bringing the concrete into standard compaction.

viii) Immediately after the concrete has come to rest, open the trap door of lower hopper bringing the concrete to fall into the cylinder bringing the concrete into standard compaction.

ix) Remove the excess concrete above the top of the cylinder by a pair of trowels, one in each hand with trowel blades horizontally slide them from the opposite edges of the mould inward to the center with a sawing motion.

x) Clean the cylinder from all sides properly. Find the mass of the partially compacted concrete thus filled in the cylinder. Let it be W2 kg.

xi) Refill the cylinder with the same sample of concrete in approximately 50 mm layers, vibrating each layer heavily so as to expel all the air and to obtain full compaction of concrete.

xii) Struck off the top level of the concrete and weigh the cylinder filled with fully compacted concrete. Let the weight be W3 kg.

xiii) Repeat the above procedure for different water-cement ratios with fresh material.

xiv) Plot a curve between water cement ratio on X axis and compaction factor on Y-axis.

6. **Observation and Calculations: -**

S. Nc	W/c ratio	Wt. With partially compaction W2 kgs.	Wt. With fully compaction W3 kgs.	Wt. Of partially compacted concrete (W2 – W1) kgs.	Wt. Of partially compacted concrete (W3 – W1) kgs.	Compaction factor $\frac{(W2 - W1)}{(W3 - W1)}$
1.	0.5	21.7	23.4			
2.	0.6	21.9	23.			
3.	0.7	22	23.2			
4.	0.8					

7. **Result: -**

i) Compaction factor for water-cement ratio of 0.5 = ______________

ii) Compaction factor for water-cement ratio of 0.6 = ______________

iii) Compaction factor for water-cement ratio of 0.7 = ______________

iv) Compaction factor for water-cement ratio of 0.8 = ______________

8. **Precautions: -**

i) The top hopper must be filled gently and to the same extent on each occasion and thee time between the end of mixing and release of concrete from top hopper must be constant, say for 2 minutes.

ii) The mix should not be pressed or compacted in the hopper.

iii) The outside of the mould must be wiped clean before weighing and mass should be recorded to the nearest 10-gram.

iv) If the concrete in the hopper does not fall through when the trapdoor is released, it should be freed by passing a metal rod. A single steady penetration will usually affect the release.

(Ref: - I.S: 1199 – 1959)

Experiment # 13 (a)

TEST ON HARDENED CONCRETE
COMPRESSIVE STRENGTH OF CEMENT CONCRETE

1. **Objective:** - To determine the compressive strength of concrete cubes and cylinders.

2. **Apparatus:** - Cube moulds 150 mm in size, cylinder moulds 150 mm in diameter and 300 mm in height, tamping rod 16 mm in diameter and 600 mm long bullet pointed at the end, mixer, weighing machine, platform balance with weights, compression testing machine of at least 200 tonnes or universal testing machine, tray, buckets.

   The moulds and cylinders are of cast iron or steel. A base plate large enough to prevent leakage of water and cement during filling of the mould is provided. Clips and screws are provided to assist in holding the mould on the base plate.

3. **Material :-** Cement, fine aggregate(sand), coarse aggregate(gravel) and water

4. **Theory :-** The compressive strength of concrete is one of the most important and useful properties and one of the most easily determined in most structural applications. Concrete is employed primarily to resist compressive stresses because of its strength in compression. The strength has a definite relationship with other properties of concrete, in those cases where strength in tension or in shear is of primary importance; the compressive strength is frequently used as measure of these properties (i.e) these properties are improved with the improvement in compressive strength and properties relating to deformations or durability. The height of the test piece in relation to its lateral dimensions greatly influences the result. The more slender the test piece lower will be the crushing strength. The ratio of minimum dimension of the specimen to maximum size of the aggregate should be at least 4:1.

5. **Procedure: -**

   i) Weigh 3 kg of cement, 6 kg of fine aggregate and 12 kg of coarse aggregate (1:2:4) and 1.8 litre of water (water being taken as 60 % by weight of cement). Mix them thoroughly in the mechanical mixer until uniform colour concrete is obtained. This material will be sufficient for casting 1 cube, 1 cylinder of size 150 mm x 150 mm x 150 mm and 150 mm x 300 mm respectively.

   The concrete may also be mixed by hand in such manner as to avoid loss of water. In mixing by hand the cement and fine aggregate shall be mixed dry first to uniform color and then the coarse aggregate is added and mixed thoroughly. Then the water is added and the ingredients of concrete are mixed until the resulting concrete mix is uniform in color (Mix at least for 2 minutes).

   ii) Pour the concrete so prepared in the moulds, which are oiled with medium viscosity oil. Fill the concrete in cube moulds in two layers and cylinder moulds in four layers each of approximately 75mm and ramming layer as follows: -

   a. 150 mm cube: - Each layer to be rammed more than 35 times, distributing the blows evenly over the surface of the layer.

b. 150 x 300 mm: - Each layer to be rammed more than 35 times over the surface. The blows shall be uniformly distributed to the layer.

c. In place of hand ramming suitable vibrators may be used.

d. Trowel off surplus concrete from the top of moulds.

e. Cover the moulds with wet mats and mark them after 2 to 3 hours for identification.

iii) Curing of Specimens: - Specimens are removed from the moulds after 24 hours and cured in water for 3 days, 7 days and 28 days.

iv) Testing of specimens: - Compression test of cube and cylindrical specimens are made as soon as practicable after removing from curing tank. Test specimens during the period of their removal from the curing pit and testing are kept moist by a wet mat covering and tested in moist condition. The size of the specimen is determined to the nearest 0.2 mm by averaging the perpendicular dimensions, at least at two places. The weight of each specimen is also recorded.

Place the specimen centrally in the compression-testing machine and load is applied continuously, uniformly and without shock. The rate of loading should be 14 N/mm^2 (140 Kg/Cm^2) / minute or 300 KN / Minute for cube and 250 KN / Minute for cylinder. The load is increased until the specimen fails. Record the maximum load taken by each specimen during test. Also note the type of failure and appearance of crack.

6. Observations and Calculations: - The following information is normally included in the report of each compression test.

Table No. 1

i) Identification mark ____________________
ii) Date of casting ____________________
iii) Date of testing ____________________
iv) Age of specimen ____________________
v) Curing condition ____________________
vi) Dimensions of specimen ____________________
vii) Weight of specimen ____________________
viii) Cross sectional area ____________________
ix) Maximum load ____________________
x) Compressive strength ____________________
xi) Appearance of fractured faces of concrete and type of fracture ____________________

Table No. 2

Specimen No.	1	2	3	Average
Load in Newton on cube				
Load in Newton on cylinder				

7. **Result: -**

i) Cube strength = $\frac{\text{Average Load}}{\text{Area of c/s of cube specimen}}$

ii) Cube strength = $\frac{\text{Average Load}}{\text{Area of c/s of cylinder specimen}}$

8. **Precautions: -**

i) Both the base plate and the mould should be lightly oiled before use to prevent the concrete from sticking to the mould.

ii) Excess compaction should be avoided when using vibration with more workable mixes, as this is likely to produce segregation and loss of water from the spaces between moulds and their base plates.

iii) The blows should be evenly distributed over the surface of each layer. The moulds should be slightly overfilled and the surplus be struck off flush with trowel.

iv) On no account should the specimen be allowed to dry and they must be tested in moist conditions.

v) The material used for mixes should be dried and brought to room temperature before use

vi) At least three specimens should be used for each test and mean crushing strength of concrete should be taken. While calculating the average load, if any individual variation from the average is more than 15 % the tests results are rejected and tests are repeated.

(Ref: - I.S: 516 – 1959)

Experiment # 13 (b)

TEST ON HARDENED CONCRETE
FLEXURAL STRENGTH OF CEMENT CONCRETE

1. **Objective: -** To determine the flexural strength of cement concrete beams with two point loads at 1/3rd span.

2. **Apparatus: -** Flexure testing machine, beam moulds 100mm x 100mm x 500mm, spade, trowel, cement, sand, gravel and water.

3. **Material required:** - Cement, fine aggregate (sand), coarse aggregate (gravel).

4. **Theory: -** Flexural strength is expressed in terms of modulus of rupture (N/mm^2) and is defined as the maximum tensile stress in concrete at rupture. The symmetric loads (P) at 1/3rd point's produces pure bending zone with constant bending moment and zero shear at middle third of span. The modulus of rupture is useful in design criteria for concrete pavement designs.

5. **Procedure.**

(a) Preparation of specimens.

i) Take about 1.9 kg of cement, 3.8 kg of sand and 7.6 kg of aggregate. The size of the aggregate must not be more than 38 mm. Take water cement ratio as 0.60 or the quantity of water as 0.60 x 1.9 = 1.14 liter. Mix them thoroughly in the mechanical mixer until uniform color concrete is obtained. This material will be sufficient for casting 1 beam.

ii) The concrete may also be mixed by hand in such manner as to avoid loss of water. In mixing by hand the cement and fine aggregate shall be mixed dry first to uniform color and then the coarse aggregate is added and mixed thoroughly. Then the water is added and the ingredients of concrete are mixed until the resulting concrete mix is uniform in color (Mix at least for 2 minutes).

iii) Pour the concrete so prepared in the moulds, which are oiled with medium viscosity oil. Fill the concrete in beam in two layers and of approximately 50mm and ramming each layer 35 times with the tamping rod, distributing the blows evenly over the surface of the layer. Trowel off concrete flush with the top of the moulds.

iv) Curing of Specimens: - Specimens are removed from the moulds after 24 hours and cured in water for 3 days, 7 days and 28 days.

(b) Testing of specimen: -

The specimen must be tested immediately after taking out from water. The specimen is turned on its side with respect to its position as moulded and centered on bearing rollers, spaced 400mm apart for a 500mm span beam c/c. The load-applying block shall be brought in contact with the upper surface of specimen at 1/3rd point between supports. Load is applied at the rate of 0.7 N/mm^2/minute, till the specimen fractures. The load is noted. Also note down first crack at how much load is occurring.

Flexural strength = PL/bd^2 N/mm^2 =

Where P = Load =

b = width of specimen in mm =

d = depth of specimen in mm =

If fracture occurs outside middle third span, but within 5% of span length, then

Flexural strength = $3Pa/bd^2$ N/mm^2, where P = load

and 'a' = distance between section of fracture and nearest support

If failure point falls outside middle third span by more than 5%, results shall be discarded.

6. Observation: -

i) Date of casting

ii) Date of testing

iii) Age of specimen

iv) Size of specimen

v) Weight of specimen

Table 1

Specimen No	1	2	3	Average
Load in New ton				
Flexural strength in N/ mm^2				

7. **Result:** - The average flexural strength of concrete =

9. **Precautions: -**

i) Both the base plate and the mould should be lightly oiled before use to prevent the concrete from sticking to the mould.

ii) Excess compaction should be avoided when using vibration with more workable mixes, as this is likely to produce segregation and loss of water from the spaces between moulds and their base plates.

iii) The blows should be evenly distributed over the surface of each layer. The moulds should be slightly overfilled and the surplus be struck off flush with trowel.

iv) On no account should the specimen be allowed to dry and they must be tested in moist conditions.

v) The material used for mixes should be dried and brought to room temperature before use

vi) At least three specimens should be used for each test and mean crushing strength of concrete should be taken. While calculating the average load, if any individual variation from the average is more than 15 % the tests results are rejected and tests are repeated.

(Ref: - I.S: 516 – 1959)