Manual

Concrete Laboratory

Department of Civil Engineering

Central University of Jharkhand

CONTENTS

EXPERIMENT NO.: 01

DETERMINATION OF SPECIFIC GRAVITY OF CEMENT

AIM: To determine the specific gravity of given sample of hydraulic cement.

THEORY: Specific gravity is defined as the ratio between weight of a given volume of material and weight of an equal volume of water. To determine the specific gravity of cement, kerosene is used which does not react with cement.

APPARATUS: Physical balance, density bottle of 100ml capacity, cleans kerosene.

PROCEDURE: 1. Clean and dry the density bottle and weigh it with the stopper (W1).
2. Fill the density bottle with cement sample at least half of the bottle and weigh with stopper (W2).
3. Fill the density bottle containing the cement, with kerosene (free of water) placing the stopper and weigh it (W3).
4. While doing the above do not allow any air bubbles to remain in the specific gravity bottle.
5. After weighing the bottle, the bottle shall be cleaned and dried again.
6. Then fill it with fresh kerosene and weigh it with stopper (W4).
7. Remove the kerosene from the bottle and fill it with full of water and weigh it with stopper (W5).
8. All the above weighing should be done at the room temperature of $27°C \pm 2°C$.

OBSERVATIONS:

Description of Item		
Weight of empty density bottle	W1 g	
Weight of density bottle + Cement	W2 g	
Weight of density bottle + Cement + Kerosene	W3 g	
Weight of density bottle + Kerosene	W4 g	
Weight of density bottle + Water	W5 g	

RESULT: Average specific gravity of given sample of cement =

PRECAUTION: 1. Only kerosene which is free of water shall be used.
2. At time of weighing the temperature of the apparatus will not be allowed to exceed the specified temperature.
3. All air bubbles shall be eliminated in filling the apparatus and inserting the stopper.
4. Weighing shall be done quickly after filling the apparatus and shall be accurate to 0.1 mg.
5. Precautions shall be taken to prevent expansion and overflow of the contents resulting from the heat of the hand when wiping the surface of the apparatus.

DISCUSSIONS:

EXPERIMENT NO.: 02
DETERMINATION OF FINENESS OF CEMENT BY SIEVING

AIM: To determine the fineness of the given sample of cement by sieving.

THEORY: The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence the faster and greater the development of strength. Increase in fineness of cement is also found to increase the drying shrinkage of concrete. Fineness of cement is tested either by sieving or by determination of specific surface by air-permeability apparatus. Specific surface is the total surface area of all the particles in one gram of cement.

APPARATUS: IS-90 micron sieve conforming to IS:460-1965, standard balance, weights, brush.

PROCEDURE:
1. Weigh accurately 100 g of cement and place it on a standard 90 micron IS sieve.
2. Break down any air-set lumps in the cement sample with fingers.
3. Continuously sieve the sample giving circular and vertical motion for a period of 15 minutes.
4. Weigh the residue left on the sieve. As per IS code the percentage residue should not exceed 10%.

OBSERVATIONS:

Weight of Cement	W (gm)	100
IS Sieve size	(μ)	90
Sieving time	(minutes)	15
Weight retained on sieve	W_1 (gm)	
Percent weight retained on sieve	$\frac{W_1}{W} \times 100$	

Fineness of cement =

RESULT: Fineness of given sample of cement =

PRECAUTIONS: Air set lumps in the cement sample are to be crushed using fingers and not to be pressed with the sieve. Sieving shall be done holding the sieve in both hands and with gentle wrist motion. More or less continuous rotation of the sieve shall be carried out throughout sieving.

DISCUSSIONS:

EXPERIMENT NO.: 03

DETERMINATION OF NORMAL CONSISTENCY OF CEMENT

AIM: To determine the quantity of water required to produce a cement paste of standard consistency.

THEORY: The standard consistency of a cement paste is defined as that consistency which will permit the vicat plunger to penetrate to a point 5 to 7 mm from the bottom of the vicat mould. For finding out initial setting time, final setting time, soundness of cement and compressive strength of cement, it is necessary to fix the quantity of water to be mixed in cement in each case. This experiment is intended to find out the quantity of water to be mixed for a given cement to give a cement paste of normal consistency and can be done with the help of vicat apparatus.

APPARATUS: Vicat apparatus with plunger (10 mm in diameter) balance, weights, gauging trowel.

PROCEDURE: 1. Prepare a paste of weighed quantity of cement (300 grams) with a weighed quantity of potable or distilled water, starting with 26% water of 300g of cement.
2. Take care that the time of gauging is not less than 3 minutes, not more than 5 minutes and the gauging shall be completed before setting occurs.
3. The gauging time shall be counted from the time of adding the water to the dry cement until commencing to fill the mould.
4. Fill the vicat mould with this paste, the mould resting upon a non porous plate.
5. After completely filling the mould, trim off the surface of the paste, making it in level with the top of the mould. The mould may slightly be shaken to expel the air.
6. Place the test block with the mould, together with the non-porous resting plate, under the rod bearing the plunger (10mm diameter), lower the plunger gently to touch the surface of the test block and quickly release, allowing it to penetrate into the paste.
7. This operation shall be carried out immediately after filling the mould.
8. Prepare trial pastes with varying percentages of water and test as described above until the amount of water necessary for making the standard consistency as defined above is obtained.
9. Express the amount of water as a percentage by weight of the dry cement.

OBSERVATIONS:

Sl. No.	Weight of Cement Sample	Percentage Weight retained on sieve	Quantity Weight retained on sieve	Unpenetrated Depth in mm	Normal Consistency of Cement

RESULT: Normal consistency for the given sample of cement is =

PRECAUTIONS: Clean appliances shall be used for gauging. In filling the mould the operator hands and the blade of the gauging trowel shall alone be used. The temperature of cement, water and that of test room, at the time when the above operations are being performed, shall be $27°C \pm 2°C$. For each repetition of the experiment fresh cement is to be taken.

DISCUSSIONS:

EXPERIMENT NO.: 04
DETERMINATION OF INITIAL AND FINAL SETTING TIMES OF CEMENT

AIM: To determine the initial and final setting times for the given sample of cement.

THEORY: In actual construction dealing with cement, mortar or concrete, certain time is required for mixing, transporting and placing. During this time cement paste, mortar, or concrete should be in plastic condition. The time interval for which the cement products remain in plastic condition is known as the setting time. Initial setting time is regarded as the time elapsed between the moment that the water is added to the cement to the time that the paste starts losing its plasticity. The final setting time is the time elapsed between the moment the water is added to the cement, and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain pressure. The constituents and fineness of cement is maintained in such a way that the concrete remains in plastic condition for certain minimum time. Once the concrete is placed in the final position, compacted and finished it should lose its plasticity in the earliest possible time so that it is least vulnerable to damages from external destructive agencies. This time should not be more than 10 hours which is referred to as final setting time. Initial setting time should not be less than 30 minutes.

APPARATUS: Vicat apparatus (conforming to IS: 5513-1976) with attachments, balance, weights, gauging trowel.

PROCEDURE:

Preparation of Test Mould:

1. Prepare a neat cement paste by gauging 300 grams of cement with 0.85 times the water required to give a paste of standard consistency.
2. Potable or distilled water shall be used in preparing the paste.
3. The paste shall be gauged in the manner and under the conditions prescribed in determination of consistency of standard cement paste.
4. Start a stop-watch at the instant when water is added to the cement.
5. Fill the mould with the cement paste gauged as above the mould resting on a nonporous plate.
6. Fill the mould completely and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared in the mould is the test mould.

DETERMINATION OF INITIAL SETTING TIME:

1. Place the test mould on the non-porous plate, under the rod bearing initial setting needle, lower the needle gently in contact with the surface of the test block and quickly release, allowing it to penetrate into the test mould.
2. In the beginning, the needle will completely pierce the test mould.
3. Repeat this procedure until the needle, when brought in contact with the test mould and released as described above, fails to pierce the mould to a point 5 to 7 mm measured from the bottom of the mould shall be the initial setting time.

DETERMINATION OF FINAL SETTING TIME:

1. Replace the needle of the Vicat apparatus by the needle with an annular attachment.
2. The cement shall be considered as finally set when, upon applying the needle gently to the surface of the test mould, the needle makes an impression there on, while the attachment fails to do so.
3. The period elapsed between the time when water is added to the cement and the time at which the needle makes an impression on the surface of test mould while the attachment fails to do so shall be the final setting time.

CALCULATION:

Weight of Cement (W) gm = gm
Normal Consistency of Cement (P) = %
Weight of Water to be Added ($0.85 \times W \times P$) = gm

OBSERVATIONS:

Sl. No.	Time in minutes	Vicat Apparatus reading (Unpenetrated depth in mm)
1		
2		
3		
4		
5		

RESULT: Initial setting time for the given sample of cement =
Final setting time for the given sample of cement =

PRECAUTIONS: Clean appliances shall be used for gauging. All the apparatus shall be free from vibration during the test. The temperature of water and that of the test room, at the time of gauging shall be 27°C $\pm$ 2°C. Care shall be taken to keep the needle straight.

DISCUSSIONS:

EXPERIMENT NO.: 05

DETERMINATION OF COMPRESSIVE STRENGTH OF CEMENT

AIM: To determine the compressive strength of standard cement mortar cubes compacted by means of standard vibration machine.

THEORY: The compressive strength of cement mortars 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 average compressive strength of at least three mortar cubes (area of the face 50 cm^2) composed of one part of cement and three parts of standard stand should satisfy IS code specifications.

APPARATUS: Vibration machine and cube moulds of size 7.06 cms (Conforming to IS: 4031- 1988)

PROCEDURE:

MIX PROPORTIONS AND MIXING:

1. Clean appliances shall be used for mixing and the temperature of the water and that of the test room at the time when the above operations are being performed shall be $27°C \pm 2°C$.
2. Place in a container a mixture of cement and standard sand in the proportion of 1:3 by weight mix it dry, with a trowel for one minute and then with water until the mixture is of uniform color.
3. The quantity of water to be used shall be as specified below.
4. In any element, it should not take more than 4 minutes to obtain uniform colored mix.
5. If it exceeds 4 minutes the mixture shall be rejected and the operation repeated with a fresh quantity of cement, sand and water.
6. The material for each cube shall be mixed separately and the quantity of cement standard sand and water shall be as follows:

    Cement 200 gm
    Standard sand 600 gm
    Water (P/4 + 3) percent of combined weight of cement and sand, where p is the percentage of water required to produce a paste of standard consistency.

STANDARD SAND: The standard sand to be used in the test shall conform to IS: 650-1991 or sand passing 100 percent through 2 mm sieve and retained 100 percent on 90 micron IS sieve.

2mm to 1mm	33.33 percent
1mm to 500 microns	33.33 percent
500mm to 90 microns	33.33 percent.

MOULDING SPECIMENS:

1. In assembling the moulds ready for use, cover the joints between the halves of the mould with a thin film of petroleum jelly and apply a similar coating of petroleum jelly between the contact surfaces of the bottom of the mould and its base plate in order to ensure that no water escapes during vibration.
2. Treat the interior faces of the mould with a thin coating of mould oil.

3. Place the assembled mould on the table of the vibration machine and firmly hold it is position by means of suitable clamps.
4. Securely attach a hopper of suitable size and shape at the top of the mould to facilitate filling and this hopper shall not be removed until completion of the vibration period.
5. Immediately after mixing the mortar, place the mortar in the cube mould and rod with a rod.
6. The mortar shall be rodded 20 times in about 8 seconds to ensure elimination of entrained air and honey combing.
7. Place the remaining quantity of mortar in the hopper of the cube mould and rod again as specified for the first layer and then compact the mortar by vibrations.
8. The period of vibration shall be two minutes at the specified speed of 12,000 + 400 vibrations per minute.
9. At the end of vibration remove the mould together with the base plate from the machine and finish the top surface of the cube in the mould by smoothing surface with the blade of a trowel.

CURING SPECIMEN:

1. Keep the filled moulds at a temperature of 27°C $\pm$ 2°C in an atmosphere of at least 90 % relative humidityfor about 24 hours after completion of vibration.
2. At the end of that period remove them from the moulds.
3. Immediately submerge in clean fresh water and keep them under water until testing.
4. The water in which the cubes are submerged shall be renewed every 7 days and shall be maintained at a temperature of 27°C $\pm$ 2°C.
5. After they have been taken out and until they are tested the cubes shall not be allowed to become dry.

TESTING:

1. Test three cubes for compressive strength at the periods mentioned under the relevant specification for different hydraulic cements, the periods being reckoned from the completion of vibration.
2. The compressive strength shall be the average of the strengths of three cubes for each period of curing.
3. The cubes shall be tested on their sides without any packing between the cube and the steel plates of the testing machine.
4. One of the platens shall be carried base and shall be self adjusting and the load shall be steadily and uniformly applied starting from zero at a rate of 350 Kgs/Cm2/ min. The cubes are tested at the following periods

Ordinary portland cement 3, 7 and 28 days.
Rapid hardening portland cement 1 and 3 days.
Low heat portland cement 3 and 7 days.

OBSERVATIONS:

Sl. No.	Age of Specimen	Identification Mark	Cross Sectional Area (mm^2)	Maximum Load (N)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	3 Days					
2						
3						
4	7 Days					
5						
6						
7	28 Days					
8						
9						

CALCULATION:
Calculate the compressive strength from the crushing load and the average area over which the load is applied. Express the results in N/mm^2 to the nearest 0.05 mm^2.
Compressive strength in N/mm^2 = P/A =
Where P is the crushing load in N and A is the area in mm2 (5000 mm^2)

RESULT: The average compressive strength of the given cement
at 3 days N/mm^2
at 7 days N/mm^2
at 28 days N/mm^2

PRECAUTIONS: Inside of the cube moulds should be oiled to prevent the mortar from adhering to the sides of the mould.

DISCUSSIONS:

EXPERIMENT NO.: 06

VERIFICATION OF SOUNDNESS OF CEMENT BY AUTOCLAVE TEST METHOD

AIM: To determine the soundness of the given sample of cement by "Autoclave" Method.

THEORY: It is essential that the cement concrete shall not undergo appreciable change in volume after setting. This is ensured by limiting the quantities of free lime, magnesia and sulphates in cement which are the causes of the change in volume known as unsoundness.
Unsoundness in cement does not come to surface for a considerable period of time. This test is designed to accelerate the slaking process by the application of heat and discovering the defects in a short time. Unsoundness produces cracks, distortion and disintegration there by giving passage to water and atmospheric gases which may have injurious effects on concrete and reinforcement.
In the soundness test a specimen of hardened cement paste is boiled for a fixed time so that any tendency to expand is speeded up and can be detected. Soundness means the ability to resist volume expansion.
By Autoclave method we only find out presence of unburnt lime (CaO) and magnesia (MgO). Magnesia content allowed in cement is limited to 6%. Indian standard specification stipulates that cement having a magnesia content of more than 3%

.

APPARATUS:

NAME	CAPACITY / RANGE / SIZE	ACCURACY / LEAST COUNT
Autoclave	100^0C (min)	1^0C
Length comparator	IS:9459	0.02 mm
Mould	25 × 25 × 282 mm (IS:10086)	_
Balance	1000 g	1 g
Measuring cylinder	150 ml	1 ml

PROCEDURE:

1. Thinly cover the mould with mineral oil. Then attach the reference points so as to get an effective length of 250 mm.
2. Take 500 g of cement and mix with sufficient water to give a paste of standard consistency.
3. After mixing fill the mould in one or two layers by pressing the paste into corners by thumb. Smoothen the top layer by trowel.
4. After completion of preparation of the mould, store it in a moist room for a period of 24 hours.
5. After 24 ± ½ hrs after moulding, remove the specimen from the moist atmosphere, measure its length (L_1) and place it in the autoclave at room temperature in a rack so that the four sides of each specimen is exposed to saturated steam vapour during the entire period of test.
6. To permit air to escape from the autoclave during the early portion of the heating period left the vent

valve open until steam begins to escape.
7. Then close the vent valve and raise the temp of the autoclave at such a rate, so as to make the gauge pressure of the steam to 2.1 N/mm^2 in 1 to 1.5 hrs from the time heat turned on. This pressure is maintained for 3 hrs.
8. After 3 hrs switch off the autoclave, and let it be cooled at the rate so as to make the pressure less than 0.1 N/mm^2 in one hour and bring it to atmospheric pressure by opening vent valve.
9. Then remove the specimen from autoclave and place it in water maintained at a temp of 900C. Then cool the water to $27°C \pm 2°C$ in 15 minutes. Dry the surface of the specimen and measure its length (L_2).

OBSERVATIONS:
L_1=
L_2=
Soundness of cement = $\frac{L_2-L_1}{L_1} \times 100$
Where, L_1=Length measured after curing for a period of 24 hrs in a moist room.
L_2=Length measured after completion of autoclave test.

A contraction (negative expansion) is indicated by prefixing a (–) sign to the percentage expansion reported.

RESULT: Expansion in %

PRECAUTIONS;
1. Length L_1 and L_2 should be measured accurately.
2. The temp of autoclave should be raised and lowered gradually.

STANDARD SPECIFICATIONS:

Type/Name Of cement	Expansion ,%,(max.)
OPC	0.8
Rapid hardening	0.8
Low heat cement	0.8
Super sulphated	Not specified
Portland pozzolana	0.8
PSC	0.8
High alumina cement	Not specified
SRC	0.8
Masonry cement	1.0

DISCUSSIONS:

EXPERIMENT NO.: 07

DETERMINATION OF SPECIFIC GRAVITY OF FINE AGGREGATE

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

THEORY: Specific gravity is defined as the ratio between weight of a given volume of material and weight of an equal volume of water.

APPARATUS: Physical balances, density bottle of 100ml capacity.

PROCEDURE:

1. Clean and dry the density bottle and weigh it with the stopper (W1).
2. Fill the density bottle with fine aggregate at least half of the bottle and weigh with stopper (W2).
3. Fill the density bottle containing the fine aggregate, with water placing the stopper and weigh it (W3).
4. While doing the above do not allow any air bubbles to remain in the specific gravity bottle.
5. After weighing the bottle, the bottle shall be cleaned and dried again.
6. Then fill it with full of water and weigh it with stopper (W4).
7. All the above weighing should be done at the room temperature of $27°C \pm 2°C$.

OBSERVATIONS:

Description of Item		Trial 1	Trial 2	Trial 3
Weight of empty density bottle	W1 g			
Weight of density bottle + Fine aggregate	W2 g			
Weight of density bottle + Fine aggregate + Water	W3 g			
Weight of density bottle + Water	W4 g			
Specific gravity of Fine aggregate				

RESULT: Average specific gravity of given sample of fine aggregate =

PRECAUTION:

1. At time of weighing the temperature of the apparatus will not be allowed to exceed the specified temperature.
2. All air bubbles shall be eliminated in filling the apparatus and inserting the stopper.
3. Weighing shall be done quickly after filling the apparatus and shall be accurate to 0.1 mg.
4. Precautions shall be taken to prevent expansion and overflow of the contents resulting from the heat of the hand when wiping the surface of the apparatus.

DISCUSSIONS:

EXPERIMENT NO.:08
DETERMINATIONS OF GRADATION AND FINENESS MODULUS OF FINE AGGREGATE BY SIEVE ANALYSIS

AIM: To determine fineness modulus of fine aggregate and classifications based on IS: 383-1970

THEORY: This is the name given to the operation of dividing a sample of aggregate into various fractions each consisting of particles of the same size. The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate, which we call gradation. Many a time, fine aggregates are designated as coarse sand, medium sand and fine sand. These classifications do not give any precise meaning. What the supplier terms as fine sand may be really medium or even coarse sand. To avoid this ambiguity fineness modulus could be used as a yard stick to indicate the fineness of sand.
The following limits may be taken as guidance: Fine sand : Fineness Modulus : 2.2 - 2.6, Medium sand : F.M. : 2.6 - 2.9, Coarse sand : F.M. : 2.9 - 3.2
Sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete.

APPARATUS: Test Sieves conforming to IS : 460-1962 Specification of 4.75 mm, 2.36 mm, 1.18 mm, 600 micron, 300 micron, 150 micron, Balance, Gauging Trowel, Stop Watch, etc.

PROCEDURE:
1. The sample shall be brought to an air-dry condition before weighing and sieving. The air-dry sample shall be weighed and sieved successively on the appropriate sieves starting with the largest. Care shall be taken to ensure that the sieves are clean before use.
2. The shaking shall be done with a varied motion, backward sand forwards, left to right, circular clockwise and anti-clockwise, and with frequent jarring, so that the material is kept moving over the sieve surface in frequently changing directions.
3. Material shall not be forced through the sieve by hand pressure. Lumps of fine material, if present, may be broken by gentle pressure with fingers against the side of the sieve.
4. Light brushing with a fine camel hair brush may be used on the 150-micron and 75-micron IS Sieves to prevent aggregation of powder and blinding of apertures.
5. On completion of sieving, the material retained on each sieve, together with any material cleaned from the mesh, shall be weighed.

OBSERVATIONS:

IS Sieve Size (mm)	Weight of Empty Sieve (gm)	Weight of Sieve + Fine Aggreate (gm)	Weight Retained (gm)	Percentage Weight Retained	Cumulative Weight Retained (gm)	Cumulative Percentage Weight Retained	Percentage Finer
4.75mm							
2.36mm							
1.18mm							
600µ							
300							
150							
PAN							
Total							

CALCULATION:

Fineness Modulus = $\frac{\textbf{Total cumulative \% weight retained}}{\textbf{100}}$

Determination of Zone for Sand: Compare the result with following and decide the zone of sand

I.S. Sieve Designation	Percentage passing by weight for			
	Grading Zone - I	Grading Zone - II	Grading Zone - III	Grading Zone - IV
4.75 mm	90 - 100	90 - 100	90 - 100	95 - 100
2.36 mm	60 - 95	75 - 100	85 - 100	95 - 100
1.18 mm	30 - 70	55 - 90	75 - 100	90 - 100
600 µ	15 - 34	35 - 59	60 - 79	80 - 100
300 µ	5 - 20	8 - 30	12 - 40	15 - 50
150 µ	0 - 10	0 - 10	0 - 10	0 - 15

RESULT: The Fineness Modulus of given Fine Aggregate:

PRECAUTIONS:
1. The sample should be taken by quartering.
2. The sieving must be done carefully to prevent the spilling of aggregate.

DISCUSSIONS:
i) Fineness modulus of a given sample of fine aggregate is .... that indicate Coarse sand/ Medium sand/ Fine sand.
ii) The given sample of fine aggregate is belong to Grading Zones I / II / III / IV

EXPERIMENT NO.: 09

DETERMINATION OF SPECIFIC GRAVITY AND WATER ABSORPTION OF COARSE AGGREGATE

AIM: To determine specific gravity and water absorption of a given sample of coarse aggregate.

THEORY: Specific gravity is defined as the ratio between weight of a given volume of material and weight of an equal volume of water. The apparent specific gravity is then the ratio of the mass of the aggregate dried in an oven at 100ºC to 110ºC for 24 hours to the mass of water occupying a volume equal to that of the solid including the impermeable pores. The specific gravity most frequently required and easily determined, known as 'gross apparent specific gravity', is based on the saturated and surface-dry condition of the aggregate.

APPARATUS: Pycnometer, physical balances, well-ventilated oven, etc.

PROCEDURE:
1. A sample of about 350 g shall be placed in the tray and covered with distilled water at a temperature of 22 to 32°C. Soon after immersion, air entrapped in or bubbles on the surface of the aggregate shall be removed by gentle agitation with a rod. The sample shall remain immersed for 24 ± l/2 hours.
2. The water shall then be carefully drained from the sample. The coarse aggregate shall be exposed to a gentle current of warm air to evaporate surface moisture and the material just attains a 'free-running' condition. The saturated and surface-dry sample shall be weighed (weight A).
3. The aggregate shall then be placed in the pycnometer which shall be filled with distilled water. Any trapped air shall be eliminated by rotating the pycnometer on its side, the hole in the apex of the cone being covered with a finger. The pycnometer shall be dried on the outside and weighed (weight B).
4. The contents of the pycnometer shall be emptied into the tray, care being taken to ensure that all the aggregate is transferred. The pycnometer shall be refilled with distilled water to the same level as before, dried on the outside and weighed (weight C).
5. The water shall then be carefully drained from the sample and any material retained returned to the sample. The sample shall be placed in the oven in the tray at a temperature of 100 to 110°C for 24 hours, during which period it shall be stirred occasionally to facilitate drying. It shall be cooled in the air-tight container and weighed (weight D).

OBSERVATIONS:

Weight of pycnometer + Sample + Water (A) gm.	
Weight of pycnometer + Water (B) gm.	
Weight of saturated & surface dry sample (C) gm.	
Weight of oven dry sample (D) gm.	
Apparent specific gravity = $\frac{D}{B-(A-D)}$	
Gross apparent specific gravity = $\frac{C}{B-(A-C)}$	
Water absorption = (C-D) X $\frac{100}{D}$	

RESULT: Apparent specific gravity =
Gross apparent specific gravity =
Water absorption =

PRECAUTIONS:
1. At time of weighing the temperature of the apparatus will not be allowed to exceed the specified temperature.
2. All air bubbles shall be eliminated in filling the apparatus.
3. Weighing shall be done quickly after filling the apparatus and shall be accurate to 0.01g.
4. Precautions shall be taken to prevent expansion and overflow of the contents resulting from the heat of the hand when wiping the surface of the apparatus.

DISCUSSIONS:

EXPERIMENT NO.: 10

DETERMINATION OF GRADATION AND FINENESS MODULUS OF COARSE AGGREGATE BY SIEVE ANALYSIS

AIM: To determination of particle size distribution of coarse aggregates by sieving

THEORY: Grading refers to the determination of the particle-size distribution for aggregate. Grading limits and maximum aggregate size are specified because grading and size affect the amount of aggregate used as well as cement and water requirements, workability, and durability of concrete. In general, if the water-cement ratio is chosen correctly, a wide range in grading can be used without a major effect on strength. When gap-graded aggregate are specified, certain particle sizes of aggregate are omitted from the size continuum. Gap-graded aggregate are used to obtain uniform textures in exposed aggregate concrete. Close control of mix proportions is necessary to avoid segregation.

APPARATUS: Test Sieves conforming to IS : 460-1962 Specification of 80 mm, 40 mm, 20 mm, 10 mm, 4.75 mm, Balance, Gauging Trowel, Stop Watch, etc.

PROCEDURE:

1. The sample shall be brought to an air-dry condition before weighing and sieving. This may be achieved either by drying at room temperature or by heating at a temperature of 100|| to 110°C. The air-dry sample shall be weighed and sieved successively on the appropriate sieves starting with the largest. Care shall be taken to ensure that the sieves are clean before use.
2. Each sieve shall be shaken separately over a clean tray until not more than a trace passes, but in any case for a period of not less than two minutes. The shaking shall be done with a varied motion, backward sand forwards, left to right, circular clockwise and anti-clockwise, and with frequent jarring, so that the material is kept moving over the sieve surface in frequently changing directions.
3. Material shall not be forced through the sieve by hand pressure. Lumps of fine material, if present, may be broken by gentle pressure with fingers against the side of the sieve.
4. On completion of sieving, the material retained on each sieve, together with any material cleaned from the mesh, shall be weighed.

OBSERVATIONS:

IS Sieve Size (mm)	Weight of Empty Sieve (kg)	Weight of Sieve + Coarse Aggreate (kg)	Weight Retained (kg)	Percentage Weight Retained	Cumulative Weight Retained (kg)	Cumulative Percentage Weight Retained	Percentage Finer
80mm							
40mm							
20mm							
10mm							
4.75mm							
2.36mm							
1.18mm							
600µ							
300							
150							
PAN							
Total							

CALCULATION:

$$\textbf{Fineness Modulus} = \frac{\textbf{Total cumulative \% weight retained}}{\textbf{100}}$$

RESULT: The Fineness Modulus of given Coarse Aggregate:

PRECAUTIONS:
1. The sample should be taken by quartering.
2. The sieving must be done carefully to prevent the spilling of aggregate.

DISCUSSIONS:

EXPERIMENT NO.: 11

DETERMINATION OF BULKING AND BULKING FACTOR OF FINE AGGREGATE

AIM: To ascertain the bulking phenomena of given sample of sand.

THEORY: Increase in volume of sand due to presence of moisture is known as bulking of sand. Bulking is due to the formation of thin film of water around the sand grains and the interlocking of air in between the sand grains and the film of water. When more water is added sand particles get submerged and volume again becomes equal to dry volume of sand. To compensate the bulking effect extra sand is added in the concrete so that the ratio of coarse to fine aggregate will not change from the specified value. Maximum increase in volume may be 20 % to 40 % when moisture content is 5 % to 10 % by weight. Fine sands show greater percentage of bulking than coarse sands with equal percentage of moisture.

APPARATUS: 1000ml measuring jar, brush.

PROCEDURE: 1) Take 1000ml measuring jar.
2) Fill it with loose dry sand upto 500ml without tamping at any stage of filling.
3) Then pour that sand on a pan and mix it thoroughly with water whose volume is equal to 2% of that of dry loose sand.
4) Fill the wet loose sand in the container and find the volume of the sand which is in excess of the dry volume of the sand.
5) Repeat the procedure for moisture content of 4%, 6%, 8%, etc. and note down the readings.
6) Continue the procedure till the sand gets completely saturated i.e till it reaches the original volume of 500ml.

OBSERVATIONS:

Sl. No.	Volume of dry loose sand (V_1)	% moisture content added	Volume of wet loose sand (V_2)	% Bulking $(\frac{V_2 - V_1}{V_1} \times 100)$
1	500 ml	2%		
2	500 ml	4%		
3	500 ml	6%		

GRAPH: Draw a graph between percentage moisture content on X-axis and percentage bulking on Y-axis. The points on the graph should be added as a smooth curve. Then from the graph, determine maximum percentage of bulking and the corresponding moisture content.

RESULT: The maximum bulking of the given sand is -----------at -----------% of moisture content.

PRECAUTIONS:

1) While mixing water with sand grains, mixing should be thorough and uniform.
2) The sample should not be compressed while being filled in jar.
3) The sample must be slowly and gradually poured into measuring jar from its top.
4) Increase in volume of sand due to bulking should be measured accurately.

DISCUSSIONS:

EXPERIMENT NO.:12

DETERMINATION OF BULK DENSITY AND VOIDS IN COARSE AGGREGATE

AIM: Determination of bulk density & voids in coarse aggregate

THEORY: The bulk density of an aggregate is defined as the mass of the material in a given total bulk volume of aggregate and is expressed in kg/l. The total volume of sample consists of the volume of solid material, and the volume of voids. The bulk density of aggregate is affected by the factors such as, amount of moisture present, amount of effort used to fill the container as densely as possible, particle size distribution, shape of the particle and specific gravity. For the same type of aggregate materials, the bulk density is greater for well-graded aggregate.

$$\text{Bulk Density } (\gamma) = \frac{\text{Weight of the materials (kg)}}{\text{Volume of the container occupied by materials (litre)}}$$

$$\text{Percentage of voids} = \frac{(G_S - \gamma)}{G_S} \times 100$$

Where G_S = Apparent Specific Gravity of the saturated surface-dry aggregate
γ = Bulk Density (kg/litre)

APPARATUS:

1. Cylindrical Metal Measure:

Size of largest particles (mm)	Normal capacity (l)	Inside diameter (mm)	Inside height (mm)	Minimum thickness of metal (mm)
4.75 mm and less than 4.75 mm	3	150	170	3.15
4.75 mm to 40 mm	15	250	300	4.00
Over 40 mm	35	350	310	5.00

2. Balance: Sensitive up to 0.5% of the weight of the sample to be weighed
3. Tamping rod: A straight metal tamping rod of cylindrical cross-section 16 mm in diameter and 60 mm long, rounded at one end.

PROCEDURE:

A) Using Compacted Weight:

1. Fill the measure selected accordingly to the size of the aggregate, up to one-third full with thoroughly mixed aggregate.
2. Tamp with 25 strokes by using the rounded end of the tamping rod.
3. Add a similar quantity to the measure and tamp with 25 strokes.
4. Fill the measure to overflowing and tamp with another 25 strokes.

5. Remove the surplus aggregate by using tamping rod as a straight edge.
6. Determine the net weight of the aggregate in the measure.
7. Calculate the volume occupied by the aggregate in the measure.

B) Using Uncompacted Weight:

1. Fill the measure to overflowing by means of a shovel or scoop, the aggregate being discharged from a height not exceeding 50 mm above top of the measure.
2. Level the surface of aggregate with a straight edge of tamping rod.
3. Find the net weight of the aggregate and use the same volume of the measure for determination of bulk density in kilogram per litre.

OBSERVATIONS:

Condition of Aggregate (Air Dry / Surface Dry / Moist)		**Sample**
Capacity of measure (V)	**litre**	
Weight of measure (W_1)	**kg**	
Weight of measure + compacted aggregate (W_2)	**kg**	
Weight of measure + loose aggregate (W_3)	**kg**	
Compacted bulk density $(\gamma_c) = \left(\frac{W_2 - W_1}{V}\right)$	**kg/lit.**	
Loose bulk density $(\gamma_l) = \left(\frac{W_3 - W_1}{V}\right)$	**kg/lit.**	
Apparent specific gravity (G_s) (done earlier)		
Voids for compacted aggregate $\left(\frac{G_s - \gamma_c}{G_s} \times 100\right)\%$		
Voids for loose aggregate $\left(\frac{G_s - \gamma_l}{G_s} \times 100\right)\%$		

RESULT: Compacted bulk density=
Loose bulk density=
Voids for compacted aggregate=
Voids for loose aggregate=

PRECAUTIONS:

1. Care should be taken to calibrate the measure as accurately as possible.
2. Oven dried material shall be used for the determination of percentage void in the materials.

DISCUSSIONS:

EXPERIMENT NO.: 13
WORKABILITY OF CONCRETE – SLUMP TEST

AIM: To determine the workability or consistency of concrete mix of given proportion by slump test.

THEORY: Unsupported concrete, when it is fresh, will flow to the sides and a sinking in height will take place. This vertical settlement is called slump. Slump is a measu6, 0.7 and 0.8. For each mix take 10 Kg. C.A., 5 Kg., FA and 2.5 Kg. Cement.

APPARATUS: Iron pan to mix concrete, weighing machine, trowel slump, cone, scale and tamping rod. The slump cone is a hollow frustum made of thin steel sheet with internal dimensions, as the top diameter 10 cms. The bottom diameter 20 cms, and height 30cms. It stands on a plane nonporous surface. To facilitate vertical lifting from moulded concrete it is provided with a suitable guide attachment and suitable foot pieces and handles. The tamping rod is 16mm. dia. 60 cm. long and is bullet pointed at the lower end.

PROCEDURE: 1) Mix the dry constituents thoroughly to get a uniform colour and then add water.
2) The internal surface of the mould is to be thoroughly cleaned and placed on a smooth, horizontal, rigid and non absorbent surface.
3) Place the mixed concrete in the cleaned slump cone in 4 layers each approximately 1/4 in height of the mould. Tamp each layer 25 times with tamping rod.
4) Remove the cone immediately, rising it slowly and carefully in the vertical direction.
5) As soon as the concrete settlement comes to a stop, measure the subsistence of the concrete in cm, which gives the slump.
Note: Slump test is adopted in the Laboratory or during the progress of the work in the field for determining consistency of concrete where nominal max., size of aggregates does not exceed 40 mm. Any slump specimen which collapses or shears off laterally gives incorrect results and at this juncture the test is repeated only true slump should be measured.

OBSERVATIONS:

Sl. No.	w/c ratio	Slump in mm
1	0.5	
2	0.6	
3	0.7	

RESULT: Slump for given proportions of concrete = (w/c ratio =)

PRECAUTIONS:
1) The strokes are to be uniformly applied through the entire area of the concrete section.
2) The cone should be removed very slowly by lifting it upwards without disturbing the concrete.
3) During filling the mould must be firmly pressed against the base.
4) Vibrations from nearly machinery might also increase subsidence; hence test should be made beyond the range of ground vibrations

DISCUSSIONS:

EXPERIMENT NO.: 14
WORKABILITY OF CONCRETE – COMPACTING FACTOR TEST

AIM: To determine the workability of concrete mix of given proportion by compaction factor test.

THEORY: This test is adopted to determine workability of concrete where nominal size of aggregate does not exceed 40 mm. It is based on the definition, that workability is that property of concrete, which determines the amount of work required to produce full compaction.
The test consists essentially of applying a standard amount of work to standard quantity of concrete and measuring the resulting compaction. The compaction factor is defined as the ratio of the weight of partially compacted concrete to the weight of fully compacted concrete. It shall be stated to the nearest second decimal place.

APPARATUS: Compaction factor apparatus, trowel weighing machine conical hoppers mounted vertically above the cylindrical mould. The upper mould has internal dimensions as top dia 25 cm bottom dia 12.5 cm and height 22.5 cm. The lower hopper has internal dimensions, top 22.5cm bottom dia 12.5cm and height 22.5cm. The cylinder has internal dimensions as 15 cm dia and 30cm height. The dimensions between bottom of the upper hopper and top of the lower hopper, bottom of the lower hopper and top of cylinder are 20 cm, each case. The lower ends of the hoppers are filled with quick release trap doors.

PROCEDURE: Conduct test for W/c ratio 0.5, 0.6, 0.7, and 0.8, for each mix take 10 kg of coarse aggregate 5kg of fine aggregate and 2.5 Kg of cement.
1. Grease the inner surface of the hoppers and the cylinder.
2. Fasten the hopper doors.
3. Weigh the empty cylinder accurately (Wt. Kgs).
4. Fix the cylinder on the base with fly nuts and bolts
5. Mix coarse and fine aggregates and cement dry until the mixture is uniform in colour and then with water until concrete appears to be homogeneous.
6. Fill the freshly mixed concrete in upper hopper gently with trowel without compacting.
7. Release the trap door of the upper hopper and allow the concrete of fall into the lower hopper bringing the concrete into standard compaction.
8. Immediately after the concrete comes to rest, open the trap door of the lower hopper and allow the concrete to fall into the cylinder, bringing the concrete into standard compaction.
9. Remove the excess concrete above the top of the cylinder by a trowel.
10. Find the weight of cylinder i.e cylinder filled with partially compacted concrete (W2 kgs)
11. Refill the cylinder with same sample of concrete in approx. 4 layers, tamping each layer with tamping for 25 times in order to obtain full compaction of concrete.
12. Level the mix and weigh the cylinder filled with fully compacted concrete (W3 Kg)
13. Repeat the procedure for different for different a trowel.

OBSERVATIONS AND CALCULATIONS:

Sl. No.	w/c ratio	Wt. of cylinder (W_1 kg)	Wt. of cylinder + concrete falling a standard height (W_2 kg)	Wt. of cylinder + fully compacted concrete (W_3 kg)	Wt of partially compacted concrete ($W_2 - W_1$)	Wt of fully compacted concrete ($W_3 - W_1$)	Compacting factor $\frac{(W_2-W_1)}{(W_3-W_1)}$
1	0.5						
2	0.6						
3	0.7						

Suggested ranges of workability of concrete for different conditions of placing as per IS: 456 (Part III) – 1978 and IS: 1199 – 1959

Sl. No.	Placing Condition	Degree of Workability	Compacting Factor
1	Concreting of small sections with vibrations	Very low (stiff)	0.75 – 0.80
2	Concreting of lightly reinforced sections with vibrations	Low (stiff plastic)	0.80 – 0.85
3	Concreting of lightly reinforced sections without vibrations or heavily reinforced sections with vibrations	Medium (plastic)	0.85 – 0.92
4	Concreting of heavily reinforced sections without vibrations	High (flowing)	More than 0.92

RESULT: The compacting factor or degree of compaction of the concrete = (w/c ratio =)

PRECAUTIONS:
1. The top hopper must be filled gently.
2. The mix should not be pressed or compacted in the hopper.
3. If the concrete in the hopper does not fall through when the trap door is released, it should be freed by passing a metal rod. A single steady penetration will usually affect release.

DISCUSSIONS:

EXPERIMENT NO.: 15

DETERMINATION OF CUBE, CYLINDER COMPRESSIVE STRENGTH OF CONCRETE

AIM: The test method covers determination of compressive strength of concrete specimens (cube/cylinder). It consists of applying a compressive axial load to molded cubes/cylinder at a rate which is within a prescribed range until failure occurs.

THEORY:

Age at Test - Tests shall be made at recognized ages of the test specimens, the most usual being 7 and 28 days. Where it may be necessary to obtain the early strengths, tests may be made at the ages of 24 hours ± ½ hour and 72 hours ± 2 hours. The ages shall be calculated from the time of the addition of water to the dry ingredients. For a given set of materials and proportion, the compressive strength of concrete depends on the w/c ratio mostly. With increase in compressive strength, its durability and bond strength also improves. Cylinder strength is approximately equal to 0.8 times the cube strength for 150 mm sizes.

Number of Specimens - At least three specimens, preferably from different batches, shall be made for testing at each selected age.

APPARATUS:

Testing Machine - The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load at the rate specified in 5.5. The permissible error shall be not greater than ± 2 percent of the maximum load.

Cube Moulds - The mould shall be of 150 mm size conforming to IS: 10086-1982.

Cylinders -The cylindrical mould shall be of 150 mm diameter and 300 mm height conforming to IS: 10086-1982.

Weights and weighing device, Tools and containers for mixing, Tamper (square in cross section) etc.

PROCEDURE:

1. **Sampling of Materials** - Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material.
2. **Proportioning** - The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work.
3. **Weighing** - The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 0.1 percent of the total weight of the batch.
4. **Mixing Concrete** - The concrete shall be mixed by hand, or preferably, in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials. Each batch of concrete shall be of such a size as to leave about 10 percent excess after moulding the desired number of test specimens.
5. **Mould** - Test specimens cubical in shape shall be 15 × 15 × 15 cm. If the largest nominal size of the aggregate does not exceed 2 cm, 10 cm cubes may be used as an alternative. Cylindrical test specimens shall have a length equal to twice the diameter.
6. **Compacting** - The test specimens shall be made as soon as practicable after mixing, and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance.
7. **Curing** - The test specimens shall be stored in a place, free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of $27°C \pm 2°C$ for 24 hours ± ½ hour from the time of additionof water to the dry ingredients.
8. **Placing the Specimen in the Testing Machine** - The bearing surfaces of the testing machine shall be

wiped clean and any loose sand or other material removed from the surfaces of the specimen which are to be in contact with the compression platens.

9. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom.
10. The axis of the specimen shall be carefully aligned with the centre of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine.
11. The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained.
12. The maximum load applied to the specimen shall then be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.

OBSERVATIONS:

Calculations of Mix Proportion

Mix Proportion of Concrete	For one cubic meter of Concrete	For one batch of Mixing
Coarse Aggregate (kg)		
Fine Aggregate (kg)		
Cement (kg)		
Water (kg)		
w/c		
Admixture		

Sl. No.	Age of Specimen (Cube/Cylinder)	Identification Mark	Cross Sectional Area (mm^2)	Maximum Load (N)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	7 Days					
2						
3						
4	28 Days					
5						
6						

RESULT: 1. Compressive Strength of Cube=
2. Compressive Strength of Cylinder=

PRECAUTIONS: 1. Verify the dimensions of all cubes and cylinders properly.
2. Apply load without shock, increasing continuously.

DISCUSSIONS:

EXPERIMENT NO.: 16
DETERMINATION OF FLEXURAL TENSILE STRENGTH OF CONCRETE

AIM: This clause deals with the procedure for determining the flexural strength of moulded concrete flexure test specimens

THEORY:
Age at Test - Tests shall be made at recognized ages of the test specimens, the most usual being 7 and 28 days. Where it may be necessary to obtain the early strengths, tests may be made at the ages of 24 hours ± ½ hour and 72 hours ± 2 hours. The ages shall be calculated from the time of the addition of water to the dry ingredients.
Number of Specimens - At least three specimens, preferably from different batches, shall be made for testing at each selected age.

APPARATUS:
Testing Machine - The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load at the rate specified in 5.5. The permissible error shall be not greater than ± 2 percent of the maximum load.
Beam Moulds - The beam moulds shall conform to IS: 10086-1982. The standard size shall be 15 × 15 × 70 cm. Alternatively, if the largest nominal size of the aggregate does not exceed 19 mm, specimens 10 × 10 × 50 cm may be used.
Weights and weighing device, Tools and containers for mixing, Tamper (square in cross section) etc.

PROCEDURE:
1. **Sampling of Materials** - Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material.
2. **Proportioning** - The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work.
3. **Weighing** - The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 0.1 percent of the total weight of the batch.
4. **Mixing Concrete** - The concrete shall be mixed by hand, or preferably, in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials. Each batch of concrete shall be of such a size as to leave about 10 percent excess after moulding the desired number of test specimens.
5. **Mould** - The standard size shall be 15 × 15 × 70 cm. Alternatively, if the largest nominal size of the aggregate does not exceed 19 mm, specimens 10 × 10 × 50 cm may be used.
6. **Compacting** - The test specimens shall be made as soon as practicable after mixing, and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance.
7. **Curing** - The test specimens shall be stored in a place, free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of 27°C ± 2°C for 24 hours ± ½ hour from the time of additionof water to the dry ingredients.

8. **Placing the Specimen in the Testing Machine** - The bearing surfaces of the supporting and loading rollers shall be wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers.
9. The specimen shall then be placed in the machine in such a manner that the load shall be applied to the uppermost surface as cast in the mould, along two lines spaced 20.0 or 13.3 cm apart.
10. The axis of the specimen shall be carefully aligned with the axis of the loading device. No packing shall be used between the bearing surfaces of the specimen and the rollers.
11. The load shall be applied without shock and increasing continuously at a rate such that the extreme fibre stress increases at approximately 7 kg/sq cm/min, that is, at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens.
12. The load shall be increased until the specimen fails, and the maximum load applied to the specimen during the test shall be recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure shall be noted.

OBSERVATIONS:

Calculations of Mix Proportion

Mix Proportion of Concrete	For one cubic meter of Concrete	For one batch of Mixing
Coarse Aggregate (kg)		
Fine Aggregate (kg)		
Cement (kg)		
Water (kg)		
w/c		
Admixture		

Sl. No.	Age of Specimen	Identification Mark	Size of Specimen (mm)	Span Length (mm)	Maximum Load (N)	Position of Fracture 'a' (mm)	Modulus of Rupture (MPa)
1	7 Days						
2							
3							
4	28 Days						
5							
6							

CALCULATION:

The flexural strength of the specimen shall be expressed as the modulus of rupture fb, which, if ‘a’ equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in cm, shall be calculated to the nearest 0.5 kg/sq cm as follows:

$f_b = \frac{Pl}{bd^2}$

when ‘a’ is greater than 20.0 cm for 15.0 cm specimen, or greater than 13.3 cm for a 10.0 cm specimen, or

$f_b = \frac{3Pa}{bd^2}$

when ‘a’ is less than 20.0 cm but greater than 17.0 cm for 15.0 cm specimen, or less than 13.3 cm but greater than 11.0 cm for a 10.0 cm specimen

where

b = measured width in cm of the specimen
d = measured depth in cm of the specimen at the point of failure
l = length in cm of the span on which the specimen was supported
P = maximum load in kg applied to the specimen

RESULT:

i) The average 7 Days Modulus of Rupture of concrete sample is found to be ……….
ii) The average 28 Days Modulus of Rupture of concrete sample is found to be ……….

PRECAUTIONS:

1. Fix the span of beam carefully.
2. Place the specimen such that the axis of specimen and axis of loading device should be in one alignment.
3. Apply load without shock, increasing continuously.

DISCUSSIONS:

EXPERIMENT NO.: 17

MIX DESIGN OF CONCRETE

INTRODUCTION:

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in 2 states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.

The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labour. The variations in the cost of materials arise from the fact that the cement is several times costly than the aggregate, thus the aim is to produce as lean a mix as possible. From technical point of view the rich mixes may lead to high shrinkage and cracking in the structural concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking.

The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The extent of quality control is often an economic compromise, and depends on the size and type of job. The cost of labour depends on the workability of mix, e.g., a concrete mix of inadequate workability may result in a high cost of labour to obtain a degree of compaction with available equipment.

REQUIREMENTS OF CONCRETE MIX DESIGN:

The requirements which form the basis of selection and proportioning of mix ingredients are:

a) The minimum compressive strength required from structural consideration

b) The adequate workability necessary for full compaction with the compacting equipment available.

c) Maximum water-cement ratio and/or maximum cement content to give adequate durability for the particular site conditions

d) Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete.

TYPES OF MIXES:

i) Nominal Mixes: In the past the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed nominal mixes. These offer simplicity and under normal circumstances, have a margin of strength above that specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

ii) Standard mixes: The nominal mixes of fixed cement-aggregate ratio (by volume) vary widely in strength and may result in under- or over-rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed standard mixes. IS 456-2000 has designated the concrete mixes into a number of grades as M10, M15, M20, M25, M30, M35 and M40. In this designation the letter M refers to the mix and the number to the specified 28 day cube strength of mix in N/mm2. The mixes of grades M10, M15, M20 and M25 correspond approximately to the mix proportions (1:3:6), (1:2:4), (1:1.5:3) and (1:1:2) respectively.

iii) Designed Mixes: In these mixes the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics. The approach results in the production of concrete with the appropriate properties most economically. However, the designed mix does not serve as a guide since this does not guarantee the correct mix proportions for the prescribed performance.
For the concrete with undemanding performance nominal or standard mixes (prescribed in the codes by quantities of dry ingredients per cubic meter and by slump) may be used only for very small jobs, when the 28-day strength of concrete does not exceed 30 N/mm2. No control testing is necessary reliance being placed on the masses of the ingredients.

FACTORS AFFECTING THE CHOICE OF MIX PROPORTIONS:
The various factors affecting the mix design are:
i) Compressive strength: It is one of the most important properties of concrete and influences many other describable properties of the hardened concrete. The mean compressive strength required at a specific age, usually 28 days, determines the nominal water-cement ratio of the mix. The other factor affecting the strength of concrete at a given age and cured at a prescribed temperature is the degree of compaction. According to Abraham's law the strength of fully compacted concrete is inversely proportional to the water-cement ratio.
ii) Workability: The degree of workability required depends on three factors. These are the size of the section to be concreted, the amount of reinforcement, and the method of compaction to be used. For the narrow and complicated section with numerous corners or inaccessible parts, the concrete must have a high workability so that full compaction can be achieved with a reasonable amount of effort. This also applies to the embedded steel sections. The desired workability depends on the compacting equipment available at the site.
iii) Durability: The durability of concrete is its resistance to the aggressive environmental conditions. High strength concrete is generally more durable than low strength concrete. In the situations when the high strength is not necessary but the conditions of exposure are such that high durability is vital, the durability requirement will determine the water-cement ratio to be used.
iv) Maximum nominal size of aggregate: In general, larger the maximum size of aggregate, smaller is the cement requirement for a particular water-cement ratio, because the workability of concrete increases with increase in maximum size of the aggregate. However, the compressive strength tends to increase with the decrease in size of aggregate. IS 456:2000 and IS 1343:1980 recommend that the nominal size of the aggregate should be as large as possible.
v) Grading and type of aggregate: The grading of aggregate influences the mix proportions for a specified workability and water cement ratio. Coarser the grading leaner will be mix which can be used. Very lean mix is not desirable since it does not contain enough finer material to make the concrete cohesive. The type of aggregate influences strongly the aggregate-cement ratio for the desired workability and stipulated water cement ratio. An important feature of a satisfactory aggregate is the uniformity of the grading which can be achieved by mixing different size fractions.
vi) Quality Control: The degree of control can be estimated statistically by the variations in test results. The variation in strength results from the variations in the properties of the mix ingredients and lack of control of accuracy in batching, mixing, placing, curing and testing. The lower the difference between the mean and minimum strengths of the mix lower will be the cement-content required. The factor controlling this difference is termed as quality control.

MIX PROPORTION DESIGNATIONS:

The common method of expressing the proportions of ingredients of a concrete mix is in the terms of parts or ratios of cement, fine and coarse aggregates. For e.g., a concrete mix of proportions 1:2:4 means that cement, fine and coarse aggregate are in the ratio 1:2:4 or the mix contains one part of cement, two parts of fine aggregate and four parts of coarse aggregate. The proportions are either by volume or by mass. The water-cement ratio is usually expressed in mass.

FACTORS TO BE CONSIDERED FOR MIX DESIGN:

i) The grade designation giving the characteristic strength requirement of concrete.
ii) The type of cement influences the rate of development of compressive strength of concrete.
iii) Maximum nominal size of aggregates to be used in concrete may be as large as possible within the limits prescribed by IS 456:2000.
iv) The cement content is to be limited from shrinkage, cracking and creep.
v) The workability of concrete for satisfactory placing and compaction is related to the size and shape of section, quantity and spacing of reinforcement and technique used for transportation, placing and compaction.

EXAMPLES OF CONCRETE MIX PROPORTIONING:

Design of M30 concrete mix as per IS: 10262-2009, Concrete mix proportioning-guidelines (First revision)

DESIGN STIPULATIONS FOR PROPORTIONING:

i) Grade designation	: M30
ii) Type of cement	: OPC 43 grade confirming to IS 8112
iii) Maximum nominal size of aggregates	: 20 mm
iv) Minimum cement content	: 350 kg/m3
v) Maximum water cement ratio	: 0.50
vi) Workability	: 25 - 50 mm (slump)
vii) Exposure condition	: Moderate
viii) Degree of supervision	: Good
ix) Type of aggregate	: Crushed angular aggregate
x) Maximum cement content	: 450 kg/m3
xi) Chemical admixture	: Not recommended

TEST DATA FOR MATERIALS:

i) Cement used	: OPC 43 grade confirming to IS 8112
ii) Specific gravity of cement	: 3.15
iii) Specific gravity of coarse aggregate	: 2.68
iv) Specific gravity of fine aggregate	: 2.65
v) Water absorption of coarse aggregate	: 0.6 percent
vi) Water absorption of fine aggregate	: 1.0 percent
vii) Free (surface) moisture of coarse aggregate	: Nil (absorbed moisture full)
viii) Free (surface) moisture of fine aggregate	: Nil
ix) Sieve analysis of coarse aggregate	: Conforming to Table 2 of IS: 383
x) Sieve analysis of fine aggregate	: Conforming to Zone I of IS: 383

TARGET STRENGTH FOR MIX PROPORTIONING:

$f_t = f_{ck} + 1.65\ s$

Where, f'_t = Target average compressive strength at 28 days,
f_{ck} = Characteristic compressive strength at 28 days,
s= Standard deviation

From Table 1 standard deviation, s = 5 N/mm^2

Therefore target strength = 30 + 1.65 x 5 = 38.25 N/mm^2

SELECTION OF WATER CEMENT RATIO:

From Table 5 of IS: 456-2000, maximum water cement ratio = 0.50 (Moderate exposure)

Based on experience adopt water cement ratio as 0.45 as the cement is 53 grade 0.45 < or =0.5, hence ok

SELECTION OF WATER CONTENT:

From Table-2, maximum water content = 186 liters (for 25mm – 50mm slump range and for 20 mm aggregates)

Estimated water content for 25-50 mm slump = 186 liters

CALCULATION OF CEMENT CONTENT:

Water cement ratio = 0.45

Cement content = 186/0.45 = 413 kg/m3 >350 kg/m3(given)

From Table 5 of IS: 456, minimum cement content for moderate exposure condition = 300 kg/m3, Hence OK.

PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT:

From Table 3, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone I) for water-cement ratio of 0.50 =0.60. Modify this as w/c is 0.45. The new value is 0.61. Volume of fine aggregate is 0.39.

MIX CALCULATIONS:

The mix calculations per unit volume of concrete shall be as follows

a) Volume of concrete = 1 m^3

b) Volume of cement = $\frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000}$

= [413/3.15] × [1/1000] = 0.131 m^3

c) Volume of water = [186/1] × [1/1000] = 0.186 m^3

d) Volume of all in aggregates (e) = a – (b + c)

= 1 – (0.131 + 0.186) = 0.683 m^3

e) Volume of coarse aggregates = e x Volume of CA x specific gravity of CA

= 0.683 × 0.61 × 2.68 × 1000 = 1117 kg

f) Volume of fine aggregates = e x Volume of FA × specific gravity of FA

= 0.683 × 0.39 × 2.65 × 1000 = 706 kg

MIX PROPORTIONS FOR TRIAL NUMBER 1

Cement = 413 kg/m^3
Water = 186 kg/m^3
Fine aggregate = 706 kg/m^3
Coarse aggregates = 1117 kg/m^3
Water cement ratio = 0.45
Yield =2422 kg

APPARATUS:

Testing Machine - The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load at the rate specified in 5.5. The permissible error shall be not greater than ± 2 percent of the maximum load.
Cube Moulds - The mould shall be of 150 mm size conforming to IS: 10086-1982.

PROCEDURE:

1. **Sampling of Materials** - Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material.
3. **Weighing** - The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 0.1 percent of the total weight of the batch.
4. **Mixing Concrete** - The concrete shall be mixed by hand, or preferably, in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials. Each batch of concrete shall be of such a size as to leave about 10 percent excess after moulding the desired number of test specimens.
5. **Mould** - Test specimens cubical in shape shall be 15 × 15 × 15 cm.
6. **Compacting** - The test specimens shall be made as soon as practicable after mixing, and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance.
7. **Curing** - The test specimens shall be stored in a place, free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of 27°C $\pm$ 2°C for 24 hours ± ½ hour from the time of additionof water to the dry ingredients.
8. **Placing the Specimen in the Testing Machine** - The bearing surfaces of the testing machine shall be wiped clean and any loose sand or other material removed from the surfaces of the specimen which are to be in contact with the compression platens.
9. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom.
10. The axis of the specimen shall be carefully aligned with the centre of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine.
11. The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained.
12. The maximum load applied to the specimen shall then be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.

OBSERVATIONS:

Sl. No.	Age of Specimen (Cube/Cylinder)	Identification Mark	Cross Sectional Area (mm^2)	Maximum Load (N)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	28 Days					
2						
3						

RESULT: 1. Compressive Strength of Cube=

PRECAUTIONS: 1. Verify the dimensions of all cubes and cylinders properly.
2. Apply load without shock, increasing continuously.

DISCUSSIONS: