



Govt. & UGC Approved

UNIVERSITY OF GLOBAL VILLAGE (UGV), BARISHAL

THE UNIVERSITY FOR HI-TECH AND HUMANITY

Engineering Materials Lab

Content of Laboratory Course

Prepared By

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University of Global Village (UGV), Barishal

Program: B.Sc. in Civil Engineering





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BASIC COURSE INFORMATION

Course Title	Engineering Materials Lab
Course Code	CE 0732-2106
Credits	01
CIE Marks	30
SEE Marks	20
Exam Hours	2 hours (Semester Final Exam)
Level	1st Semester



Engineering Materials Lab

COURSE CODE: CE 0732-2106

CREDIT: 01

CIE MARKS: 30

SEE MARKS: 20

CLO 01 **Understand** the structure and properties of different types of engineering materials.

CLO 02 **Perform** basic material testing techniques (e.g., tensile testing, hardness testing).

CLO 03 **Select** appropriate materials for specific engineering applications based on their properties and performance requirements.

CLO 04 **Apply** knowledge of material properties to solve engineering problems related to material selection, design, and failure analysis.

Sl.	Course Contents	Hours	CLOs
1	Determination of Normal Consistency of Cement with Vicat's Apparatus - the theory and practical procedure for measuring the water-cement ratio required for a standard cement paste to achieve a specific level of workability using Vicat's apparatus.	13	CLO 1, CLO 2
2	Determination of Initial Setting Time of Cement with Vicat's Apparatus - Study of the time taken by a standard cement paste to attain a specific resistance to penetration, indicating the beginning of the setting process, using Vicat's apparatus.	12	CLO2, CLO 3
3	Test for Direct Compressive Strength of Cement Mortar - Determination of the compressive strength of hardened cement mortar cubes.	12	CLO2,C LO 4
4	Sieve Analysis of Fine and Coarse Aggregate - Procedures for determining the particle size distribution of fine and coarse aggregates using standard sieves to assess their suitability for various concrete mixes.	12	CLO2,C LO 4

5	Unit Weight and Voids in Aggregate -Determining the unit weight and void content of aggregates, including bulk density, apparent specific gravity, and absorption, and their significance in concrete mix design.	12	CLO 4
6	Sampling and Testing of Brick for Efflorescence, and Absorption -Procedures for obtaining representative brick samples, conducting tests to evaluate efflorescence (salt deposits) and water absorption, and interpreting test results to assess brick quality and durability.	12	CLO3, CLO4
7	Sampling and Testing of Brick for Compression -Procedures for sampling and testing bricks to determine their compressive strength, a critical parameter for ensuring structural integrity and safe construction.	12	CLO3,CL O4

ASSESSMENT PATTERN

CIE- Continuous Internal Evaluation (30 Marks)

SEE- Semester End Examination (20 Marks)

SEE- Semester End Examination (40 Marks) (should be converted in actual marks (20))

Bloom's Category	Tests
Remember	05
Understand	07
Apply	08
Analyze	07
Evaluate	08
Create	05

CIE- Continuous Internal Evaluation (100 Marks) (should be converted in actual marks (30))

Bloom's Category Marks (out of 100)	Lab Final (30)	Lab Report (10)	Continuous lab performance (30)	Presentation & Viva (10)	External Participation in Curricular/ Final Project Exhibition (10)
Remember/ Imitation	05		05	02	Attendance 10
Understand/ manipulation	05	05	05	03	
Apply/ Precision	05		05		
Analyze/ Articulation	05		05		
Evaluate/ Naturalisation	05	05	05		
Create	05		05	05	

Week	Topic	Teaching Learning Strategy	Assessment Strategy	CLOs
1	Determination of Normal Consistency of Cement with Vicat's Apparatus	Lecture, Oral presentation	Lab Test, Quiz and Report	CLO 1, CLO 2
2	Determination of Initial Setting Time of Cement with Vicat's Apparatus	Lecture, Discussion	Lab Test, Quiz and Report	CLO2, CLO 3
3,4	Test for Direct Compressive Strength of Cement Mortar	Lecture, Discussion	Lab Test, Quiz and Report	CLO2,C LO 4
5	Sieve Analysis of Fine and Coarse Aggregate	Lecture, Discussion	Lab Test, Quiz and Report	CLO2,C LO 4
6,7	Unit Weight and Voids in Aggregate	Lecture, Discussion	Lab Test, Quiz and Report	CLO3, CLO4
8,9	Sampling and Testing of Brick for Efflorescence, and Absorption	Lecture, Discussion	Lab Test, Quiz and Report	CLO3, CLO4
10,11	Sampling and Testing of Brick for Compression	Lecture, Discussion	Lab Test, Quiz and Report	CLO3, CLO4

12,13	Practice, Review/Reserved Day	Lecture, Discussion	Lab Test, Quiz and Report	CLO 4
14,15	Lab Report Assessment, Self study	Lecture, Discussion	Lab Test, Quiz and Report	CLO 4
16-17	Lab Test, Viva, Quiz, Overall Assessment, Skill Development Test (Competency)	Lecture, Discussion	Lab Test, Quiz and Report	CLO 4

References

Engineering Materials Book by Dr. M. A. Aziz
 Engineering Material by ER R.K Rajput

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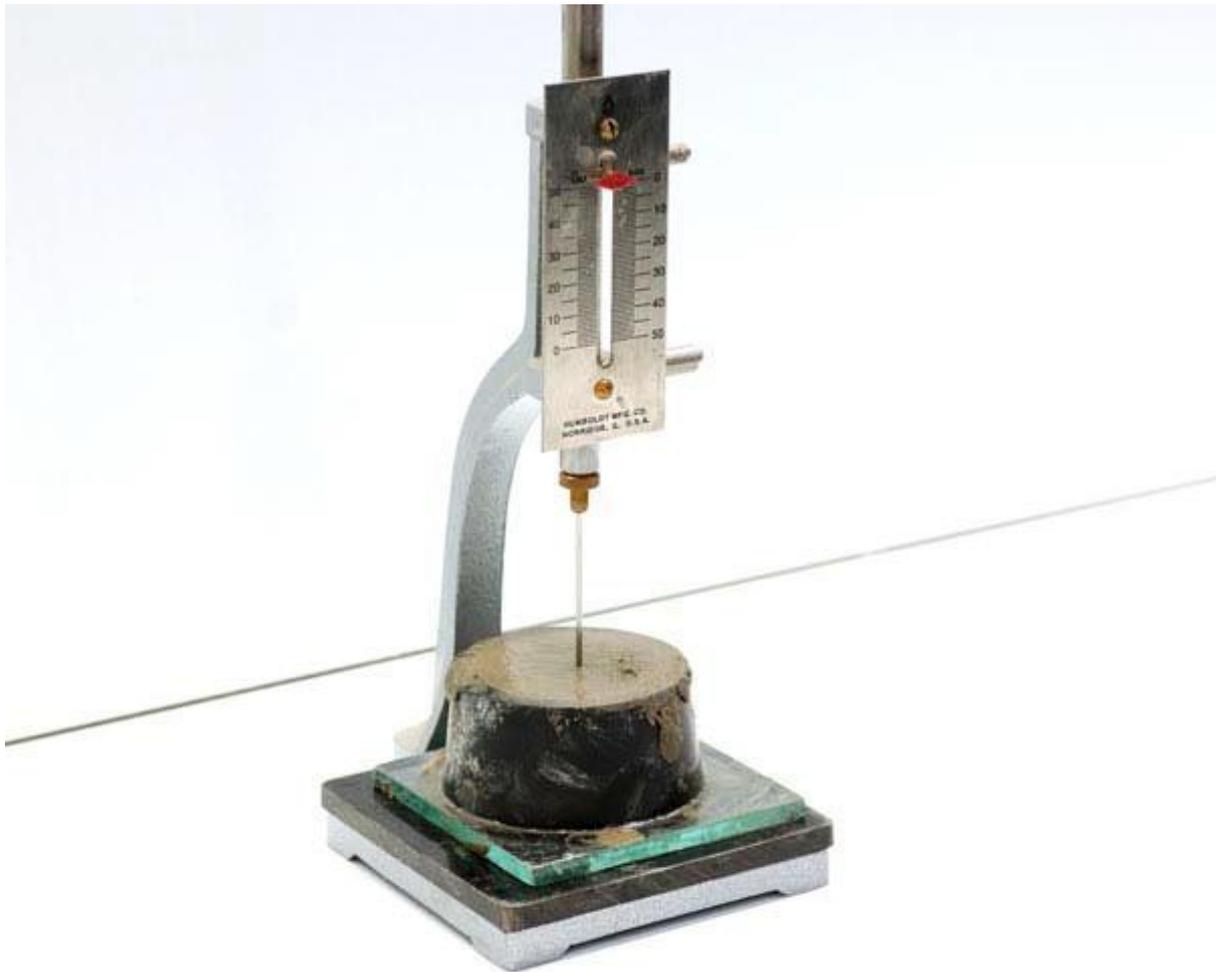
University of Global Village (UGV), Barishal

Determination of Normal Consistency of Cement with Vicat's Apparatus

Week 1

Experiment 1

Determination of Normal Consistency of Cement with Vicat's Apparatus



1.1 Objective:

This test method covers the determination of the normal consistency of hydraulic cement paste with Vicat's Apparatus.

1.2 Introduction:

Soundness of cement: Stability of the volume change in the process of setting and hardening.

The amount of water content that brings the cement paste to a standard condition of wetness is called "normal consistency". It has a marked effect upon the time of set as well as upon other properties of cement. The paste at normal consistency is fairly stiff and is used only for the determination of **time of set and soundness of cement**. It is necessary to fix the quantity of water to be mixed in cement while experimenting on it.

The normal consistency of a cement paste is defined as that consistency (% of water) which will permit the vicat plunger to penetrate to a point 10 mm from the top of the vicat mould. **The usual range of values being between 22 to 30 percent by weight of dry cement**. Normal consistency is also called **standard consistency**.

1.3 Reference Standard:

This test method conforms to the **ASTM standard requirements of specification C187**.

1.4 Scope:

This test method is intended to be used to **determine the amount of water** (by % weight of dry cement) required to prepare hydraulic cement pastes for testing.

Necessity and Use of Normal Consistency:

- a. Cement produced by different factories may not have same properties and so it is necessary to standardize the consistency using standard equipment.
- b. The knowledge of normal consistency is required while performing other important tests such as setting time, soundness etc. as these tests are performed on cement paste using a certain percentage of water required for standard consistency.

1.5 Related Terms:

Consistency: A certain **minimum quantity of water** is required to be mixed with cement so as to complete **chemical reaction between water and cement**. Less water than this quantity would not complete chemical reaction thus **resulting in reduction of strength** and more water would increase **water cement ratio** and so **would reduce its strength**. Thus correct proportion of water to cement is required to be known to achieve proper strength while using cement in structure.

Gauging Time: The period observed from **the time water is added to cement for making cement paste** till commencing the filling of mould of Vicat Apparatus in this test.

1.6 Apparatus:

Balance: (sensitive to 0.1 mg) Set of metric weights. The permissible variations on weights in use in weighing the cement shall be as prescribed in Table-1. The permissible variations on new weights shall be one half of the values in Table-1.

Table 1.1: Permissible Variations on Weights

Weight, g	Permissible Variation on Weights in Use, plus or minus, g
500	0.18
300	0.15
250	0.13
200	0.10
100	0.07
50	0.04
20	0.02
10	0.02
5	0.01
2	0.01
1	0.01

Glass Graduate: Three glass graduates of 200 or 250 ml capacity.

Vicat Apparatus: The Vicat apparatus shall consist of a frame (A) bearing a movable rod (B), weighing 300 g; one end is the plunger end (C), being 10 mm in diameter for a distance of at least 50 mm, and the other end having a removable needle (D), 1mm in diameter and 50 mm in length. The rod is reversible, and can be held in any desired position by a set screw (E), and has an adjustable indicator (F) which moves over a scale (graduated in millimeter) attached to the frame. The paste is held in a rigid conical ring (G), resting on a glass plate (H) about 100 mm square. The rod shall be made of stainless steel having a hardness of not less than 35 HRC (Rockwell Hardness number), and shall be straight with the plunger end, which is perpendicular to the rod axis. The ring shall be made of a noncorroding, non-absorbent material, and shall have an inside diameter of 70 mm at the base and 60mm at the top, and a height of 40 mm. In addition to the above, the Vicat apparatus shall conform to the following requirements:

Weight of movable rod	300 ± 0.5 g (0.661 lb± 8 grains)
Diameter of plunger end of rod	10 ± 0.05 mm (0.394 ± 0.002in.)
Diameter of needle	1±0.05 mm (0.039±0.002 in)
Height of ring	40±1 mm (1.57±0.0 4in)
Inside diameter of ring at bottom	70±3 mm (2.75±0.12 in)
Inside diameter of ring at top	60±3 mm (2.36±0.12 in)
Graduated scale	The graduated scale, when compared with a standard scale accurate to within 0.1 mm at all points, shall not show a deviation at any point greater than 0.25 mm.

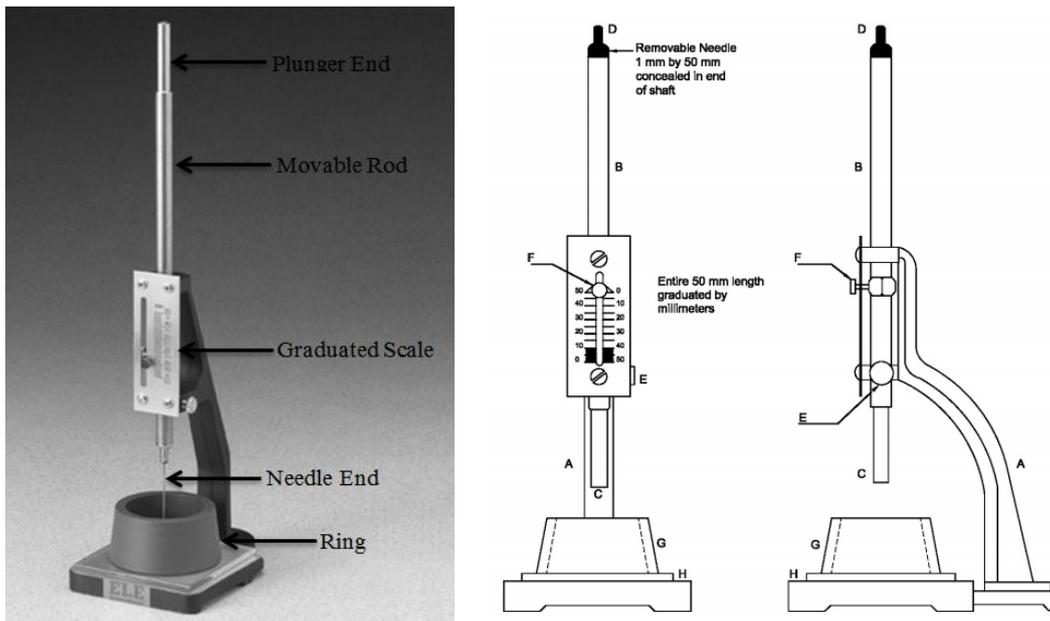


Figure 1.1: Vicat apparatus

Others: Mixing plate, small trowel, three 4-in. square glass plates.

1.7 Test Conditions:

Temperature and Humidity:

1. The temperature of the air in the vicinity of the mixing slab, the dry cement, molds, and base plates shall be maintained between 20 and 27.5°C (68 and 81.5°F).
2. The temperature of the mixing water shall not vary from 23°C (73.4°F) by more than $\pm 1.7^\circ\text{C}$ ($\pm 3^\circ\text{F}$).
3. The relative humidity of the laboratory shall be not less than 50%.

1.8 Procedure:

Preparation of Cement Paste:

Weigh out 650gm of cement and place on the mixing plate. Form crater in the center and add a measured quantity of water. (The water required for normal consistency for ordinary cement ranges from 22 to 30% by weight).

1. Turn the material at the outer edge into the crater within 30sec with a trowel.
2. After an additional interval of 30sec for the absorption of the water, complete the operation by continuous, vigorous mixing, squeezing and kneading with the hands for 1.5min.
3. If mechanical mixing machine is used, start the mixer at low speed for 30 s. Stop for (15 s) and make sure no materials have collected on the sides of the bowl. Start mixing at medium speed for (1 min).

Molding Test Specimen:

1. Quickly form the cement past into the approximate shape of a ball with gloved hands.

Then toss **six times** through a free path of about 6in. (150mm) from one hand to another so as to produce a nearly spherical mass that may be easily inserted into the Vicat ring with a minimum amount of additional manipulation.

2. Press the ball, resting in the palm of one hand, into the larger end of the conical ring, held in the other hand, completely filling the ring with paste. Remove the excess at the larger end by a single movement of the palm of the hand.
3. **Place the ring on its larger end on a plane, nonabsorptive plate,** and slice off the excess paste at the smaller end at the top of the ring by a single oblique stroke of a sharp-edged trowel held at a slight angle with the top of the ring and smooth the top, if necessary, with a few light touches of the pointed end of the trowel. **During these operations of curing and smoothing take care not to compress the paste.**

Consistency Determination:

Center the paste confined in the ring, resting on the plate, under the rod, the plunger end, of which shall be brought in contact with the surface of the paste, and tighten the set-screw. Then set the movable indicator (10 mm dia) to the upper zero mark of the scale, or take an initial reading, and release the rod immediately. This must not exceed 30 sec after completion of mixing. The apparatus shall be free of all vibrations during the test. The paste shall be of normal consistency when the rod settles to a point 10 ± 1 mm below the original surface in 30 sec after being released.

Calculation:

1. Calculate the amount of water required for normal consistency to the nearest 0.1% and report it to the nearest 0.5% of the weight of the dry cement.
2. Plot the amount of mixing water used as abscissa and observed penetration as ordinate in a plain graph paper. Then using this plot, determine the amount of water required for 10 mm penetration.

1.9 Warning:

Fresh hydraulic cementitious mixtures are caustic and may cause **chemical burns** to skin and tissue upon prolonged exposure. The use of gloves, protective clothing, and eye protection is recommended. Wash contact area with copious amounts of water after contact. Wash eyes for a minimum of 15 min. Avoid exposure of the body to clothing saturated with the liquid phase of the unhardened material. Remove contaminated clothing immediately after exposure.

DATA SHEET

Experiment Name : Determination of Normal Consistency of Cement with Vicat's Apparatus.

Experiment Date :

Student's Name :

Student's ID :

Year/ Semester :

Section/ Group :

Cement: 650 gm.

% of water	Amount of Water(ml)	Initial Reading (mm)	Final Reading (mm)	Penetration (mm)	Comments
		48.5	43.5		
27		47.5	41.5		
29		48	48		

Sample Calculation:

Result:

Percentage of water required for cement paste of Normal Consistency =

Comments:

Course Teacher :
Designation :

Signature of the Teacher

Discussion:

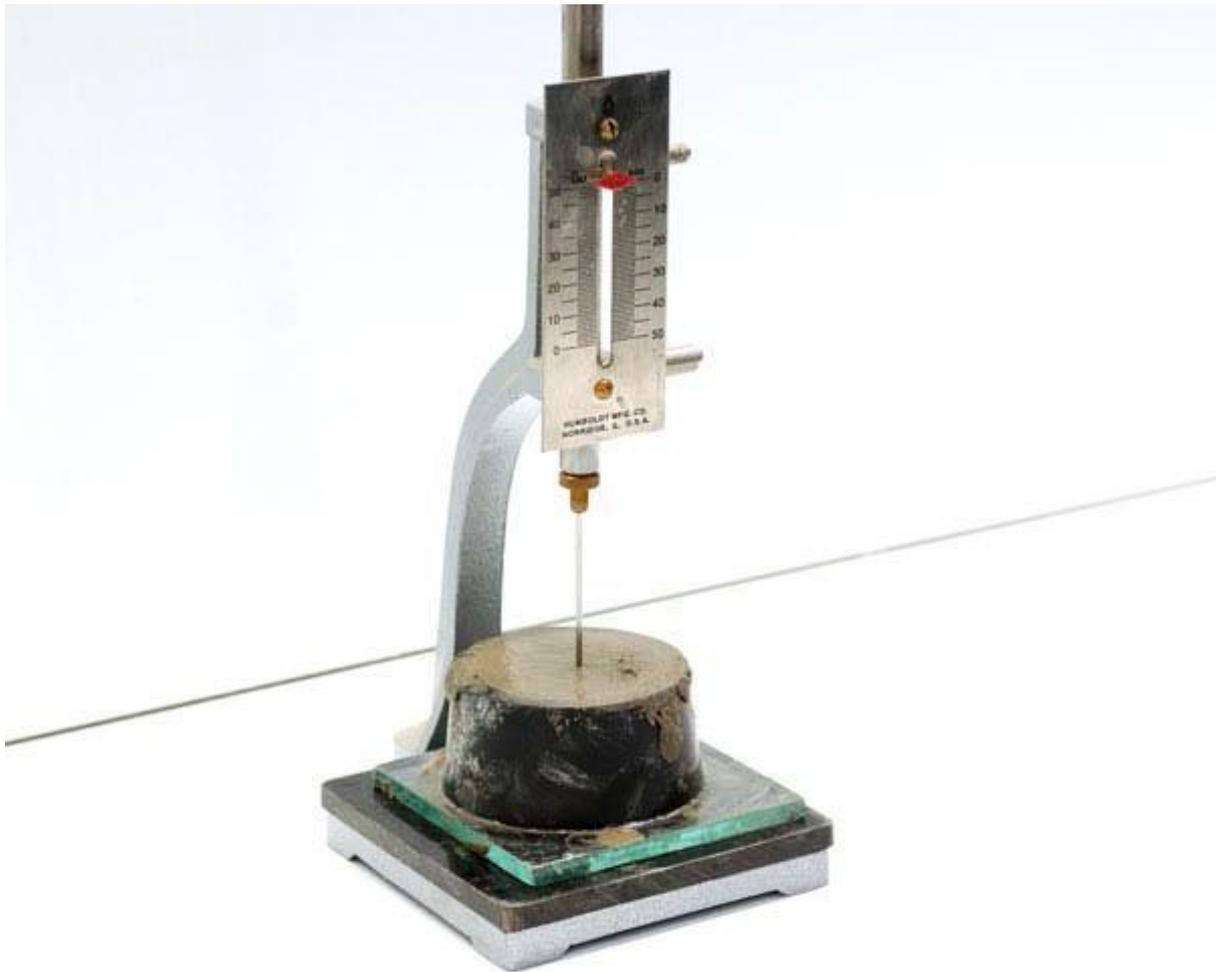
Assignment Questions:

1. Does this cement satisfy ASTM standard requirements for normal consistency?
2. Describe the factors affecting the normal consistency of cement.

Determination of Initial Setting
Time of
Cement with Vicat's Apparatus
Week 2

Experiment 2

Determination of Initial Setting Time of Cement with Vicat's Apparatus



2.1 Objective:

The objective of this experiment is to determine the initial setting time of cement.

2.2 Introduction:

Cement, when mixed with water, forms slurry, which gradually becomes less plastic with the passage of time and finally a hard mass is obtained. In this process, a stage is reached when the cement paste is sufficiently rigid to withstand a definite amount of pressure. Cement, at this stage to have set and the time required to reach this stage is termed “Setting time”.

The term “Setting” is used to describe the stiffening of the cement paste. Setting of cement refers to changes of cement paste from a semi-liquid to rigid state. Setting differs from Hardening of cement which refers to the gain of strength of a set cement paste; although during setting the cement paste acquires some strength.

2.3 Reference Standard:

This test method conforms to the ASTM standard requirements of specification C191. As per ASTM C150, Ordinary Portland Cement should have the initial setting time not less than 45 minutes & final setting time not more 375 minutes.

2.4 Scope:

The purpose of this test is to ascertain the time to be allowed to pass, between mixing of concrete and placing in position in structures. 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 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.

Cement paste setting time is affected by a number of items including: cement fineness, water-cement ratio, chemical content (especially gypsum content) and admixtures. Setting tests are used to characterize how a particular cement paste sets. For construction purposes, the initial set must not be too soon and the final set must not be too late.

2.5 Related Terms:

Initial Setting Time: The time elapsed between the moments that the water is added to the cement to the time that the paste starts losing its plasticity, stiffening to a certain degree. It marks roughly the end of the period when the wet mix can be molded into shape.

Final Setting Time: 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.

2.6 Apparatus:

Same as for the determination of normal consistency of cement (see Experiment 01).

2.7 Test Conditions:

Temperature and Humidity:

1. Maintain the temperature of the air in the vicinity of the mixing slab, the dry cement, molds, and base plates at $23.0 \pm 3.0^{\circ}\text{C}$.
2. Maintain the temperature of the mixing water at $23.0 \pm 3.0^{\circ}\text{C}$.
3. The relative humidity of the mixing room shall not be less than 50 percent.

2.8 Procedure:

Preparation of Cement Paste:

Mix 650 gm of cement with the percentage of mixing water required for normal consistency following the procedure described in Experiment 01.

Molding Test Specimen:

Same procedure as in the preceding test (Experiment 01). Immediately after molding, place the test specimen in the moist closet or moist room and allow it to remain there except when determinations of time of setting are being made.

Time of setting determination:

1. Allow the time of setting specimen to remain in the moist cabinet for 30 min after molding without being disturbed. Determine the penetration of the 1-mm needle at this time and every 15-min thereafter for Ordinary Portland Cement (Type I & every 10 min for Rapid Hardening Cement, Type III) until a penetration of 25 mm or less is obtained.
2. For the penetration test, lower the needle of the rod until it rests on the surface of the cement paste. Tighten the set screw and set the indicator at the upper end of the scale, or take an initial reading. Release the rod quickly by releasing the set screw, and allow the needle to settle for 30 sec; then take the reading to determine the penetration.
3. No penetration test shall be made closer than $1/4$ in. (6.4 mm) for any previous penetration and no penetration test shall be made closer than $3/8$ in. (9.5 mm) from the inside of the mold. Record the results of all the penetration tests and, by plotting penetration tests and, by interpolation or by plotting penetration vs. setting time curve, determine the time when a penetration of 25 mm is obtained. This is initial setting time.
4. The final setting time is when the needle does not sink visibly into the paste or the first penetration measure that does not mark the specimen surface with a complete

circular impression. Verify final set by performing two additional penetration measurements on different areas of the specimen surface. Replace the needle of the Vicat apparatus by the needle with an annular attachment. The cement shall be considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression there on, while the attachment fails to do so.

Calculation:

Calculate the time required for 25 mm penetration from a Plot of penetration (in mm) against time (in min.) in plan graph paper. This time is arbitrarily defined as the initial setting time.

2.9 Precautions:

1. All the apparatus shall be free from vibration during the penetration test.
2. Take care to keep the 1-mm needle straight, and the needle must be kept clean as the collection of cement on the sides of the needle may retard the penetration, while cement on the point (tip) may increase the penetration.
3. The time of setting is affected not only by the percentage and the temperature of the water used and the amount of kneading the paste received, but also by the temperature and humidity of the air, and its determination is therefore only approximate.

DATA SHEET

Experiment Name : Determination of Initial Setting Time of Cement with Vicat's Apparatus.

Experiment Date :

Student's Name :

Student's ID :

Year/ Semester :

Section/ Group :

Cement: _____ gm.

% of Water Added: _____ Added Water: _____ ml

Time (min)	Penetration (mm)	Comments	Time (min)	Penetration (mm)	Comments

Sample Calculation:

Result:

Initial setting time for the given sample of cement (from graph) =

Comments:

Course Teacher :
Designation :

Signature of the Teacher

Discussion:

Assignment Questions:

1. What is the significance of setting time?
2. Distinguish between “hardening” and setting.
3. Does this cement satisfy ASTM standard requirements for initial setting time?
4. What is quick setting cement?
5. How does the fineness affect the time of setting?
6. What is the function of a retarder?

Test for Direct Compressive Strength of Cement Mortar Week 3-4

Experiment 3

Test for Direct Compressive and Tensile Strength of Cement Mortar



3.1 Objective:

The objective of this experiment is to determine the compressive strength of cement mortars, using 2 in (50 mm) cube specimens and tensile strength of cured chemical-resistant materials in the form of molded briquets.

3.2 Introduction:

The mechanical strength of hardened cement is the most important property for its structural use. Test for structural strength is not made on a neat cement paste because of difficulties in molding and testing with consequent large variations in results. This test is carried out to indirectly find out the compressive strength of cement paste. As shrinkage cracks are formed in dried cement paste, test cannot be properly carried out on a block of cement paste. The test is therefore carried out on blocks of mortar made of cement, sand and water, cured for 28 days.

Several tests are performed to determine the tensile, compressive, flexural and shear strength of cement or mortar of certain portion. The tensile strength test includes materials such as mortars, brick and tile grouts, machinery grouts, and monolithic surfacings. These materials shall be based on resin, silicate, silica, or sulfur binders. Cement mortar of concrete gives a compressive strength of about ten times its tensile strength.

Concern of curing?
-Reduce the heat of hydration-keep minimum-temperature-prevent water loss

3.3 Reference Standard:

The compressive strength test method conforms to the ASTM standard requirements of specification C109. For tensile test, the test method conforms to ASTM C309. The referred documents are ASTM C 904 for terminology relating to Chemical-Resistant Nonmetallic Materials and ASTM E 4 Practices for Force Verification of Testing Machines. The tensile test method is not recommended for mortars, grouts, and monolithic surfacings containing aggregate greater than 1/4 in. The standard requirements of minimum compressive strength as per ASTM C150 for Ordinary Portland cement (type I) are as follows (Table 3.1):

Table 3.1: Probable Compressive Strength of Cement Mortar

Age (Days)	Minimum compressive Strength, psi (Mpa)
3	1800 (12.4)
7	2800 (19.3)
28	4000 (27.6)

3.4 Scope: Why longer curing period gives higher compressive strength?

This test method provides a means of determining the compressive strength of hydraulic cement and other mortars and results may be used to determine compliance with specifications and whether it will be able to develop the required compressive strength of concrete. Mortar is used extensively in building construction. It is used between bricks, stone, etc. to bond them together. Mortar is also used in plasterwork and secure ceramic tile to

floors. Moreover, mortar block is placed under reinforcement to maintain cover.

Significance of the test-

- Many other properties of cement concrete or cement mortar such as durability, porosity, shear or tensile strength is related its compressive strength.
- The compressive strength of cement from different sources may be different. Also compressive strength of different kinds of cement will be different. This test is thus indicative of quality of cement.
- It is recognized that chemical-resistant mortars, grouts, and monolithic surfacings are not usually under tension when in service; however, such data are useful for purposes of determining the rate of cure and other properties

3.5 Related Terms:

Pressure vs. Stress vs. Strength: Pressure is defined as external force per unit area applied to an object in a direction perpendicular to the surface. Stress is defined as reaction force per unit area produced by the molecules of the body to counteract the pressure. The strength of something is how much stress it can take before it fails.

Compressive Strength: Maximum stress a material can sustain under crush loading. Compressive strength is calculated by dividing the maximum load by the original cross-sectional area of a specimen.

Tensile strength:

Chemical resistant Mortar: Chemical resistant mortars have better physical properties and resist a wider variety of chemicals than inorganic mortars. The liquid resin may be phenolic, furan epoxy, polyester, vinyl ester, or some other resinous material capable of forming a chemical-resistant mortar when mixed with a suitable setting agent and filler. The fillers may be silica, carbon, or some other chemical-resistant material.

Air-entraining Mortar: Intentional creation of tiny air bubbles in mortar. The bubbles are introduced into the mortar by the addition to the mix of an air entraining agent. The primary purpose of air entrainment is to increase the durability of the hardened concrete, especially in climates subject to freeze-thaw; the secondary purpose is to increase workability of the concrete while in a plastic state.

3.6 Apparatus:

Balance: (sensitive to 0.1 gm) Set of metric weights.

Graduated measuring jar: 250-ml capacity.

Cube molds for compressive strength: 2 or 3 sets of 2-in with base plates. The molds shall have not more than three cube compartments and shall be separable into not more than two parts. The parts of the molds when assembled shall be positively held together. The molds shall be made of hard metal not attacked by the cement mortar. For new molds

the Rockwell hardness number of the metal shall be not less than 55 HRB.

Mold for tension test :The molds for making briquet test specimens shall be sufficiently rigid to prevent deformation during molding and shall be made of corrosion-resistant material. Gang molds, when used, shall be of the type shown in Fig. 1. The dimensions of the briquet molds shall be the width of the mold, between inside faces, at waist line of briquet, 1 in. The width and the depth of the briquet mold at the waist line shall be 1 in. 6 ± 0.02 in. (25mm 6 ± 0.5 mm). The molds shall conform to the dimensional requirements shown in Fig. 2.



Figure 3.1: Briquet Gang Mold

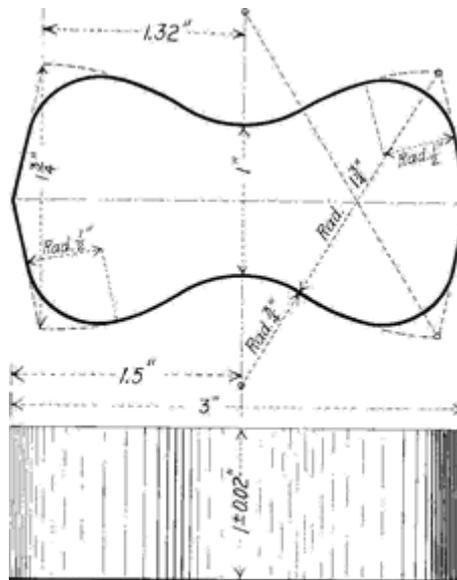


Figure 3.2: Briquet Specimens for Tensile Strength Test

Mixer: Consist from stainless steel bowl with a capacity of about 5 l and stainless blade. Bowl has to be provided with means by which it can be fixed securely to the mixer frame during mixing and by which the height of the bowl in relation to the blade and the gap between blade and bowl can be finely adjusted and fixed. The blade is revolving about its own axis as it is driven in planetary movement around the axis of the bowl by an electric motor (Figure 3.1). The two directions of rotation shall be opposite and the ratio between two speeds shall not be a whole number. The mixer shall operate at the speeds given in Table 3.2.

Table 3.2: Rotation of Mixing Blade

	Rotation (min^{-1})	Planetary movement (min^{-1})
Low speed	140 ± 5	62 ± 5
High Speed	285 ± 5	125 ± 5

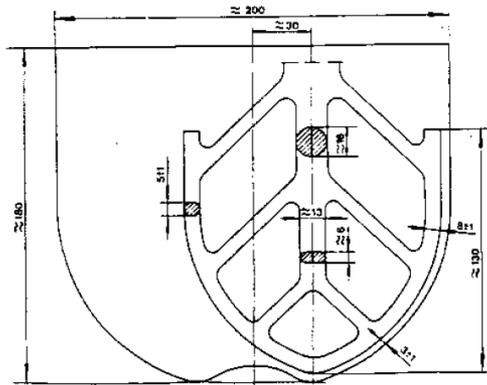


Figure 3.3: Mixing Bowl and Blade

Tamper: A nonabsorptive, nonabrasive, nonbrittle material. Have a cross section of about ½ by 1 in. (13 by 25 mm) and a convenient length of about 5 to 6 in (120 to 150 mm). The tamping face shall be flat and at right angles to the length of the tamper.

Trowels: Having a steel blade 4 to 6 in. (100 to 150 mm) in length, with straight edges.

Testing machine: Either the hydraulic or the screw type.

Moist Cabinet or Room.

3.7 Procedure for Compressive strength test:

Composition of mortars:

The proportion of materials for the slandered mortars shall be 1 part of cement to 2.75 parts of graded standard sand by weight (Table 3.4). Use a water-cement ratio of 0.485 for all Portland cement. The quantities of materials should be mixed at one time in the batch of mortar for making six and nine specimens.

Table 3.4: Composition of Mortar

		Number of specimens	
		6	9
Cement (gm)		500	740
Sand (gm)		1375	2035
Water (ml)	Portland (0.485)	242	359
	Air-entraining (0.46)	230	340

Note: For other than Portland and air- entraining Portland cements, do flow table test to determine the amount of mixing water.

Temperature and Humidity:

1. The temperature of the air in the vicinity of the mixing slab, the dry materials, molds, base plates, and mixing bowl, shall be maintained between 73.5 ± 5.5 °F (23.0 ± 3.0 °C).
2. The temperature of the mixing water, moist closet or moist room, and water in the storage tank shall be set at 73.5 ± 3.5 °F (23 ± 2 °C).
3. The relative humidity of the laboratory shall be not less than 50 %. The moist closet or moist room shall be so constructed as to provide storage facilities for test specimens at a relative humidity of not less than 95%.

Materials:

The sand use for making test specimens of compressive strength test shall be **natural silica sand** conforming to the requirements for graded standard sand (natural silica sand conforming C 778) in the following specifications (Table 3.3).

Table 3.3: Specification for Sand

Sieve	Accumulative % Retained
No. 16	None
No. 30	2 ± 2
No. 40	30 ± 5
No. 50	75 ± 5
No. 100	98 ± 2

Preparation of mortar:

1. Place required amount of water in dry mixing bowl and add the cement.
2. Start the mixer immediately at low speed and, after 30 s add the sand steadily during the next 30 s.
3. Switch the mixer to the higher speed and continue for an additional 30 s.
4. Stop the mixer for 1 min 30 s. During the first 15 s remove by means of a rubber scraper all the mortar adhering the wall and bottom part of the bowl and place in the middle of the bowl.
5. Continue the mixing at the high speed for 60 s.

Molding Test Specimens:

1. Apply a thin coating of release agent to the interior faces of the mold and non-absorptive base plates.
2. Place a layer of mortar about 1 in. (25mm) (approximately one half of the depth of the mold) in all of the cube compartments. Tamp the mortar in each cube compartment 32 times in about 10 sec in 4 rounds, each round to be at right angles to the other and consisting of eight adjoining strokes over the surface of the specimens as illustrated in figure 3.2. The tamping pressure shall be just sufficient to ensure uniform filling of the molds. The 4 rounds of tamping (32 strokes) of the mortar shall be completed in one cube before going to the next.

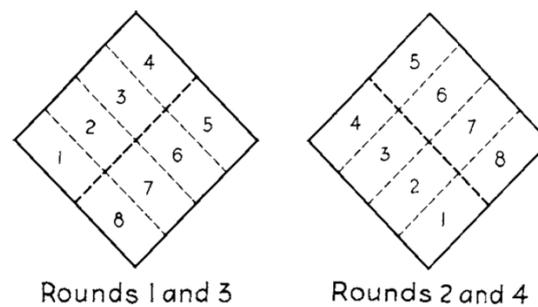


Figure 3.2: Order of Tempering in molding of Test Specimens

3. When the tamping of the first layer in all of the cube compartments is completed, fill the compartments with remaining mortar and then tamp as specified for the first layer. During tamping of the second layer bring in the mortar forced out onto the tops of the molds after each round of tamping by means of the gloves figures and the temper upon completion of each round and before starting the next round of tamping.
4. On completion of tamping, the tops of all cubes should extend slightly above the tops of the molds. Bring in the mortar that has been forced out on to the topes of the molds with a trowel and smooth off the cubes by drawing the flat side of the trowel (with the leading edge slightly raised) one across the top of the each cube at right angles to the length of the mold. Then for the purpose of leveling the mortar that protrudes above top of the molds of more uniform thickness, draw the fiat side of the trowel (with leading edge slightly raised) lightly once along the length of the mold. Cut off the mortar to plane surface flush with the top of the mold by drawing the straight edge of the trowel (held nearly perpendicular to the mold) with sawing motion over the length of the mold.
5. Label or mark the moulds to identify the specimens.

Storage of Test Specimens:

Immediately upon completion of molding, place the test specimens in the moist closet or **moist room**. Keep all the specimens, immediately after molding, in the mold on the base places in the moist closet or moist room from **20 to 24 h** with their upper surfaces exposed to

the moist air but protected from dripping water. If the specimens are removed from the mold before 24 h old, and then immerse the specimens, except those for the 24-h test, in **saturated limewater in storage tanks constructed of no corroding materials**. Keep the storage water clean by changing as required.

Determining of compressive strength:

1. Test the specimens immediately after their removal from the moist closet in the case of 24-hspecimen, and from storage water in the case of all other specimens. All the test specimens for a given test age should be broken under compressive force within the permissible time tolerance prescribed as follows:

Table 3.5: Permissible Time Tolerance

Test Age	Permissible Tolerance
24 h	±½ h
3 days	±1 h
7 days	±3 h
28 days	±12 h

If more than one specimen at a time is removed from the moist closet for the 24-h tests, keep the specimens covered with a damp cloth until the time of testing. If more than one specimen at a time is removed from the storage water of testing, keep these specimens in water at a temperature of 73.4 ± 3°F (23 ± 1.7°C) and have sufficient depth to completely immerse each specimen until the time of testing.

2. Wipe each specimen to a surface-dry condition, and remove any loose sand grains or incrustations from the face that will be contact with the bearing blocks of the testing machine. Check these faces by applying a straightedge. If there is applicable curvature, grind the face or faces or discard the specimen. A periodic check of the cross-sectional area of the specimens should be made. Remove the specimens from the water not more than 15 min before the test is carried out. Cover the specimens with a damp cloth until tested.
3. Apply the load to specimen faces that were in contact with the true plane surface of the mold. Carefully place the specimen in the testing machine bellow the center of the upper bearing block. Prior to the testing of each cube, it shall be ascertained that the spherically seated block is free to tilt. Use no cushioning or bedding materials. Apply the load rate at a relative rate of movement between the upper and lower platens corresponding to a loading on the specimen with the range of 200 to 400 lbs/s (900 to 1800 N/s). Load is applied without interruption, to failure such a rate that the maximum load will be reached in neither in 20 sec nor in more than 80 sec from the start of loading. Make no adjustment in the controls of the testing machine while a specimen is yielding prior to failure.

Calculation:

Record the total maximum loads indicated by the testing machine, and calculate the compressive strength in pounds per square inch (or in N/mm² (MPa)). The compressive strength shall be the average of the strengths of two or three cubes for each period of curing. If the cross sectional area of a specimen varies more than 1.5 % from the normal, Use the actual area for the calculation of the compressive strength. The maximum permissible range between specimens from the same mortar batch, at the same test age is 8.7 % of the average when three cubes represent a test age and 7.6 % when two cubes represent a test age.

Draw the compressive strength vs. age curve on a plain graph paper. Report the result to the nearest 10 psi (0.1 MPa).

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.

3.8 Procedure for Tensile strength test :

Test Specimens

All specimens for a single determination shall be made from a single mix containing sufficient amounts of the components in the proportions and in the manner specified by the manufacturer of the materials. If the proportions so specified are by volume, the constituents shall be weighed and the corresponding proportions by weight shall be reported.

Number of Specimens:

Prepare a minimum of six briquet specimens for each material tested.

Temperature:

Resin, Silicate, and Silica Materials—The standard temperature of the materials, molds apparatus, and the ambient temperature of the mixing area shall be 73 ± 4°F (23 ± 2°C). Record the actual temperature.

Sulfur Mortars—The material shall be maintained at 275 ± 15°F (135 ± 8°C). The temperature of the molds and the ambient temperature of the mixing area shall be 73 ± 4°F (23 ± 2°C). Record the actual temperature.

Molding Test Specimens:

Assemble and lubricate the mold by applying a thin film of an appropriate mold release or lubricant like silicone stop-cock grease or petroleum jelly.

Resin, Silicate, and Silica Materials—Mix a sufficient amount of the components in the proportions and in the manner specified by the manufacturer of the materials. Fill the molds one-half full. Remove any entrapped air by using a cutting and stabbing motion with a spatula

or rounded-end rod. Fill the remainder of the mold, working down into the previously placed portion. Upon completion of the filling operations, the tops of the specimens should extend slightly above the tops of the molds. When the molds have been filled, strike off the excess material so that it is even with the top of the mold. Permit the material to remain in the mold until it has set sufficiently to allow removal without danger of deformation or breakage.

Silicate Materials—Some silicates may require covering during the curing period. After removal from the molds, acid-treat the specimens, if required, in accordance with the recommendations given by the manufacturer. No other treatment shall be permitted. Record the method of treatment in the report section under Conditioning Procedure.

Sulfur Mortars—Assemble the mold in 6.3.1. However, cover the waist of the mold with a small lubricated plate. Melt at least 2.2 lb (1.0 kg) of sulfur mortar in the melt chamber in not more than 1 h. Hold the temperature of the melt at $275 \pm 15^\circ\text{F}$ for at least 15 min while stirring gently with the laboratory mixer. (The mixer speed should be controlled so that it is sufficient to lift the aggregate without beating air into the melt.) Using the ladle, pour the molten sulfur mortar into both sides of the mold and puddle it to completely fill the space under the plate. Allow the plate, placed across the center of the mold, to remain in place for at least 15 min after the briquet has been poured.

Conditioning

Resin, Silicate, and Silica Materials—Age the test specimens for a period of seven days, including the cure period in the mold, at $73 \pm 4^\circ\text{F}$ ($23 \pm 2^\circ\text{C}$). If a longer or shorter conditioning period is used, the time shall be reported.

Sulfur Materials—Before testing, condition the specimens at $73 \pm 4^\circ\text{F}$. The time between casting the specimen and testing the specimen shall be at least 24 h.

Measurement of Specimens:

Measure the depth and the width at the waist of each test specimen to the nearest ± 0.02 in. (0.5 mm). Test the specimens on the seventh day after preparation. If desired, the conditioning time may be lengthened or short-end to establish the age-strength relationship. Report the age of the specimens. Sulfur materials may be tested 24 h after preparation. Center the specimens carefully in the clips of the testing machine. Pull the specimens at a speed of 0.20 to 0.25 in./min (5 to 6.4 mm/min) of crosshead movement (speed of movement when the machine is running without a load).

Calculation:

Tensile Strength :The tensile strength is equal to the stress calculated at maximum load. It is calculated as follows

$$S = P/bd(1)$$

S = stress in the specimen at the waist, psi (MPa),

P = load at the moment of crack or break, lbf (N),

b = width at the waist of the briquet tested, in. (mm), and

d = depth of briquet tested, in. (mm).

3.9 Precautions:

The graded standard sand should be handled in such a manner as to prevent segregation, since variations in the grading of the sand cause variations in the consistency of the mortar.

Results much lower than the true strength will be obtained by loading faces of the cube specimen that are not truly plane surfaces. Therefore, it is essential that specimen molds be kept scrupulously clean, as otherwise, large irregularities in the surfaces will occur.

If any tensile strength value differs from the mean by more than 15 %, the farthest value from the mean shall be rejected and the mean recalculated. Repeat the process until all the tested values are within 15 % of the mean. If less than two-thirds of the values remain, the test shall be rerun.

In determining the compressive strength, do not consider specimens that are manifestly faulty.

DATA SHEET

Experiment Name : Test for Direct Compressive and Tensile Strength of cement mortar.

Experiment Date :

Student's Name :

Student's ID :

Year/ Semester :

Section/ Group :

Compressive Strength Test

Specimen: 2" cube.

No. of Specimens: 03

Cement: 750 gm.

Sand: 2062.5 gm.

Water-cement ratio: 0.48

Age (days)	Specimen No.	Crushing Load (lb)	Specimen Area (in ²)	Compressive strength (psi)	Average compressive strength
0					
3	G1	15559.4			
	G2	14590.12			
	G3	10598.99			
7	G1	12569.35			
	G2	14780.42			
	G3	11387.13			
28	G1	25145.44			
	G2	29409.83			
	G3	22763.22			

Sample Calculation:

Result:

Compressive strength of cement mortar =

Comments:

Tensile Strength Test

Specimen:

Width at the waist of the briquet tested, $b =$ in.

Depth of briquet tested $d =$ in. .

No. of Specimens:

Cement: gm.

Sand: gm.

Water-cement ratio:

Age (days)	Specimen No.	Crushing Load (lb)	Specimen Area (in ²)	Tensile strength (psi)	Average Tensile strength

Sample Calculation:

Result:

Tensile strength of cement mortar =

Comments:

Course Teacher :
Designation :

Signature of the teacher

Discussion:

Assignment Questions:

1. Compare your result with standard strength requirement of ordinary Portland cement as specified by the ASTM. Discuss on the factors responsible if you observe any deviation from the standard requirement.
2. Explain curing method you adopted in your test. Explain the importance of curing in strength development. Explain the variation of strength of time.
3. Why mortar sample should be cured in saturated lime water?

Sieve Analysis of Fine and Coarse Aggregate Week 5

Experiment 4

Sieve Analysis of Fine and Coarse Aggregate



4.1 Objective:

The objective of this experiment is to determine the particle size distribution of fine and coarse aggregate by sieving.

4.2 Introduction:

The term sieve analysis is given to the sample operation of dividing a sample of aggregates in to fraction each consisting of particles between specific limits. The analysis is conducted to determine the grading of material proposed for use as aggregates. Gradation is determined by passing the material through a series of sieves stacked with progressively smaller openings from top to bottom and weighing the material retained on each sieve.

The term fineness modulus (F.M) is a ready index of coarseness or fineness of material. It is an empirical factor obtained by adding the cumulative percentages of aggregates retained on each of the standard sieves and dividing this sum arbitrarily by 100. No.100, No.50, No.30, No.16, No.8, No.4, 3/8 in., 3/4 in., 1.5 in., 3 in. and 6 in. are the ASTM standards sieves.

4.3 Reference Standard:

This test method conforms to the ASTM standard requirements of specification C136.

4.4 Scope:

This method is used primarily to determine the grading of materials proposed for use as aggregates or being used as aggregates. Aggregates having a smooth grading curve and neither a deficiency nor excess of any one particle size generally produce mixtures with fewer voids between particles. Because cement costs more than aggregate and the cement paste requirement for concrete increases with increasing void content of the combined aggregates, it is desirable to keep the void content as low as possible. If there is not enough fine aggregate to fill the voids between coarse aggregate particles, the space must be filled with cement paste. Such under-sanded mixtures also tend to be harsh and difficult to finish. On the other hand, aggregate combinations with excessive amounts of fine aggregate or excessively fine sands may produce uneconomical concretes because of the larger surface area of finer particles, which requires additional cement.

Fineness Modulus (FM) is used in determining the degree of uniformity of the aggregate gradation. It is an empirical number relating to the fineness of the aggregate. The higher the FM is, the coarser the aggregate is. Determination of fineness modulus is considered as a method of standardization of grading of aggregates i.e. the main object of finding fineness modulus is to grade the given aggregate for the most economical mix and workability with minimum quantity of cement.

4.5 Related Terms:

Aggregate: Granular material, such as sand, gravel, crushed stone, or iron blast-furnace slag, used with a cementing medium to form hydraulic-cement concrete or mortar. Aggregate predominantly retained on the 4.75-mm (No. 4) sieve or that portion of an aggregate retained

on the 4.75-mm (No. 4) sieve is termed as coarse aggregate. The portion passes through the 4.75-mm (No. 4) sieve is called fine aggregate.

Maximum size and nominal maximum size: In specifications for aggregates, the smallest sieve opening through which the entire amount of aggregate is required to pass is called the maximum size. The smallest sieve opening through which the entire amount of aggregate is permitted to pass is called the nominal maximum size.

Sieve Number: A number used to designate the size of a sieve, usually the approximate number of openings per inch. The number is applied to sieves with openings smaller than 1/4" (6.3mm). But the actual opening size is hard to estimate since the thickness of the wire varies (finer screens are made from finer wire). Modern practice is to refer to the screen by the size of the opening in microns or in millimeters.

Gradation curve or Grading charts: Used to show the results of a sieve analysis graphically. The percent passing is usually plotted on the vertical axis, while the sieve sizes are plotted on the horizontal axis.

Fineness Modulus: Using the sieve analysis results, a numerical index called the fineness modulus (FM) is often computed. The FM is the sum of the total percentages coarser than each of a specified series of sieves, divided by 100. The specified sieves are the standard sieves. The coarser the aggregate, the higher the FM. For fine aggregate used in concrete, the FM generally ranges from 2.3 to 3.1. But in some cases, fine sands are used with an FM less than 2.0 and in other cases, a coarser fine aggregate with an FM higher than 3.1.

$$FM = \frac{\sum (\text{Cumulative \% Retained on Standard Sieves of } 150\mu\text{m or above})}{100}$$

4.6 Apparatus:

Balance (sensitive to within 0.1% of the weight of the sample), Sieves (conform to ASTM E11), Mechanical sieve shaker, Oven (capable of maintaining a uniform temperature of 110 ± 5 °C (230 ± 9 °F)).

4.7 Materials:

Sampling:

Thoroughly mix the sample and reduce it to an amount, so that the sample for test shall be approximately of the weight desired when dry.

Fine Aggregate –

The test sample of the aggregate (F.M) shall weight, after drying, approximately the following requirement:

Aggregate with at least 85 % passing a No. 4 sieve and more than 5% retained on a No .8 sieve. 500 gm

Aggregates unites at least 95% passing No. 8 sieve. 100 gm

Coarse aggregate-

The weight of the test sample of coarse aggregate (C.A) shall conform to the following requirements:

Aggregate with nominal maximum size of ¾ in. 10 lbs

Coarse and Fine Aggregate mixtures-

The weight of the test sample of CA and FA mixtures shall conform to the following:

Table 4.1: Weight of the test sample of CA and FA mixtures

Nominal Maximum Size, Square Opening, mm (in)	Minimum Weight of Test Sample, kg (lb)
9.5 (3/8)	1 (2)
12.5 (1/2)	2 (4)
19.0 (3/4)	5 (11)
25.0 (1)	10 (22)
37.5(1.5)	15 (33)
50(2)	20 (44)
63 (2.5)	35 (77)
75(3)	60 (130)
90 (3.5)	100 (220)
100 (4)	150 (330)
112 (4.5)	200 (440)
125 (5)	300 (660)
150 (6)	500 (1100)

4.8 Procedure:

Procedure for FA and CA:

1. Dry the sample to constant weight at a temperature of $110 \pm 50^{\circ}$ C.
2. Nest the sieve in order of decreasing size of opening from top to bottom and place the sample on the top sieve.
3. Agitate the sieves by hand or by mechanical apparatus for a sufficient period, say 15

Unit Weight and Voids in Aggregate

Week 6-7

Experiment 5

Unit Weight and Voids in Aggregate



7.1 Objective:

The objective of this experiment is to determine the unit weights of and voids in a sample of coarse, fine or mixed aggregate.

7.2 Introduction:

This test method covers the determination of unit weight a compacted or loose condition of fine and coarse aggregates. The procedure yields values based on aggregates in a dry condition. Unit weight values of aggregates are necessary for use for many methods of selecting proportions for concrete mixtures. They may also be used for determining mass/volume relationships for conversions and calculating the percentages of voids in aggregates. Voids with him particles, either permeable or impermeable, are not included in voids as determined by this test method.

7.3 Reference Standard:

This test method conforms to the ASTM standard requirements of specification C29.

7.4 Scope:

The results of this test are frequently used when materials are proportioned on a volume basis or where a minimum density is specified by the governing agency. The test is also useful in determining mass/volume relationships for purchase agreements.

If we know the bulk density of aggregate material than we can easily calculate the mass required to fill a unit volume container. Bulk Density also indicates the %age of voids present in the aggregate material. This %age of voids effects the grading of the aggregate which is important in higher strength concrete. When measured on any aggregate of a known grading, uncompacted void content provides an indication of the aggregate's angularity, spherical shape, and surface texture.

Bulk Density depends upon how densely the aggregate is packed. It also depends upon the size, distribution and shape of the particles. If particles are of the same size then it can be packed to a limited extent but when the smaller particles are added, the voids get filled with them and thus the bulk density increases. For a coarse aggregate a higher bulk density means that there are few voids which are to be filled by the fine aggregate and cement.

7.5 Related Terms:

Air void: is a space filled with air. The void contents ranges from about 35 to 40 % for coarse aggregates. The void contents ranges from about 40 to 50 % for fine aggregates.

Unit weight or bulk density: the mass/weight of a unit volume of bulk aggregate material, in which the volume includes the volume of the individual particles and the volume of the voids between the particles. The unit weights of both fine and coarse normal-weight aggregates falling within the ASTM grading limits are generally in the range 1450 to 1750 kg/m³ (90 to 110 lb/ft³). The unit weight of the mixture of FA and CA is maximum when the fine aggregate content is 35 to 40 % of the weight of total aggregate.

Light weight aggregate: The unit weight of aggregate is less than 1120 kg/m³. The corresponding concrete has a bulk density less than 1800 kg/m³. (cinder, blast furnace slag, volcanic pumice).

Normal weight aggregate: The aggregate has unit weight of 1520-1680 kg/m³. The concrete made with this type of aggregate has a bulk density of 2300-2400 kg/m³.

Heavy weight aggregate: The unit weight is greater than 2100 kg/m³. The bulk density of the corresponding concrete is greater than 3200 kg/m³. A typical example is magnesite limonite, a heavy iron ore. Heavy weight concrete is used in special structures such as radiation shields.

Absolute Density: It is the mass per unit volume of individual particles only.

7.6 Apparatus:

Tamping rod- A round, straight steel rod, 5/8 in (16mm) in diameter and approximately 24in (600) in length, having one end rounded to a hemispherical tip of the same diameter as the rod.

Balance- Accurate within 0.1% of the test load and graduated at least 0.1 lb (0.05 kg).

*Shovel or Scoop-*A shovel or scoop of convenient size for filling the measure with aggregate.

Table 7.1: Capacity of Measures

Nominal Maximum size of Aggregate		Capacity of Measure	
inch	mm	ft ³	litre(m ³)
0.5	12.5	1/10	2.8(0.0028)
1	25.0	1/3	9.3(0.0093)
1.5	37.5	1/2	14(0.014)
3	75	1	28.(0.028)
4.5	112	2.5	70(0.070)
6	150	3.5	100(0.100)

Table 7.2: Requirements for Measures

Capacity of Measure	Thickness of Metal(minimum)		
	Bottom	Upper 1.5 in or 38mm of wall	Remainder of wall
Less than 0.4 ft ³	0.20 in	0.10 in.	0.10 in.
0.4ft ³ to 1.5 ft ³ ,incl.	0.20 in	0.20 in	0.10 in
Over 1.5 to 2.8 ft ³ ,incl.	0.20 in	0.25 in.	0.15 in.
Over 2.8 to 4.0 ft ³ ,incl.	0.40 in	0.30 in.	0.20 in.
Less than 11 litre	0.50 in	2.5 mm.	2.5 mm.
11 to 42 litre,incl.	5.0 mm	5.0 mm.	3.0 mm.
Over 42 to 80 litre,incl.	10.0 m	6.4 mm.	3.8 mm.
Over 80 to 133 litre,incl.	13.0 mm	7.6 mm.	5.0 mm.

Note- The indicated size of measure shall be used to test aggregates of a nominal maximum size equal to or smaller than that listed. The actual volume of the measure shall be at least 95% of the normal volume listed.

Note- The added thickness in the upper portion of the wall may be obtained by placing a reinforcing band around the top of the measure.

Measure- A cylindrical metal measures preferably provided with handles. It shall be watertight, with the top and bottom true and even, and sufficiently rigid to retain its form under rough usage. The measure shall have a height approximately equal to the diameter; but in no case shall the height be less than 80% nor more than 150% of the diameter. The capacity of the measure shell conforms to the limits in Table-7.1 for the aggregate size to be tested. The thickness of metal in the measure shall conform to the limits in as described in Table-7.2. The interior wall of the measure shall be smooth and continuous surface.

*Calibration Equipment-*A piece of plate glass ,preferably at least ¼ in. (6mm)thick and at least 1in(25mm)larger than the diameter of the measure to be calibrated.A supply of water pump or chassis grease that can be placed on the rim of the container to prevent leakage.

7.7 Test Conditions:

Temperature:

Drying temperature of the sample of aggregate to essentially constant mass in an oven is preferably be $230 \pm 9^{\circ}\text{F}$ ($110 \pm 5^{\circ}\text{C}$).

The measure should be calibrated with water at room temperature.

7.8 Procedure:

Sampling

The size of the sample shall be approximately 125 to 200% of the quantity required to fill the measure, and shall be handled in a manner to avoid segregation. Dry the aggregate sample to essentially constant mass in an oven at $230 \pm 9^{\circ}\text{F}$ ($110 \pm 5^{\circ}\text{C}$).

Calibration of Measure

1. Fill the measure with water at room temperature and cover with a piece of plate glass in such a way as to eliminate bubbles and excess water.
2. Determine the mass of the water in the measure using the balance.
3. Measure the temperature of the water and determine its density from Table-7.3, interpolating if necessary.
4. Calculate the volume, V , of the measure by the dividing the mass of the water required to fill the measure by its density. Alternatively, calculate the factor for the measure $F(=1/V)$ by dividing the density of the water by the mass required to fill the measure.
5. Measures shall be recalibrated at least once a year or whenever there is reason to question the accuracy of the calibration.

Table 7.3: Density of Water

Temperature		Density	
⁰ F	⁰ C	lb/ft ³	kg/m ³
60	15.6	62.366	999.01
65	18.3	62.366	998.54
70	21.1	62.301	997.97
(73.4)	(23.0)	(62.274)	(997.54)
75	23.9	62.261	997.32
80	26.7	62.216	996.59
85	29.4	62.166	995.85

Selection of Procedure

Their different procedure is generally followed for the determination of unit weight. They are a) Shoveling procedure, b) Rodding procedure and c) Jigging procedure.

The shoveling procedure for loose unit weight shall be used only when specifically stipulated. Otherwise, the compact unit weight shall be determined by the rodding procedure for aggregates having a nominal maximum size of 1.5 in. (37.5mm) or less, or by the jigging procedure for aggregates having a nominal maximum size greater than 1.5in. (37.5mm) and not exceeding 6 in. (150mm).

A. Shoveling procedure:

Fill the measure to overflowing by means of a shovel or scoop, discharging the aggregate from a height not exceeding 2 in. (50mm) above the top of the measure. Exercise care to prevent, so far as possible, segregation of the particle sizes of which the sample is composed. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

Determine the mass of the measure plus its contents, and the mass of the measure alone, and record the values to the nearest 0.1 lb. (0.05kg).

B. Rodding procedure:

Fill the measure one-third full and level the surface with the fingers. Rod the layer of aggregate with 25 strokes of the tamping rod evenly distributed over the surface. Fill the measure two-thirds full and again level and rod as above. Finally, fill the measure to overflowing and rod again in the manner previously mentioned. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

In rodding the first layer, do not allow the rod to strike the bottom of the measure forcibly. In rodding the second and the third layers, use vigorous effort, but do not apply such a force as to cause the tamping rod to penetrate to the previous layer of aggregate.

Determine the mass of the measure plus its contents, and the mass of the measure alone, and record the values to the nearest 0.1 lb. (0.05kg).

C. Jigging procedure:

Fill the measure in three approximately equal layers as described previously, compacting each layer by placing the measure on a firm base such as a cement-concrete floor, raising the opposite sides alternately about 2 in. (50mm), and allowing the measure to drop in such a manner as to hit with a sharp, slapping blow. The aggregate particles, by this procedure, will arrange themselves in a densely compacted condition. Compact each layer by dropping the by measure 50 times in the manner described, 25 times on each side. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

Determine the mass of the measure plus its contents, and the mass of the measure alone, and record the values to the nearest 0.1 lb. (0.05kg).

Calculation

Unit weight: Calculate the unit weight for the rodding procedure as follows-

$$M = \frac{G-T}{V} \quad \text{or,} \quad M = (G-T) \times F$$

Where,

M= Unit weight of the aggregate, lb/ft³ (kg/m³),

G=Mass of the aggregate plus the measure,lb. (kg),

T= Mass of the measure, lb. (kg),

V=Volume of the measure,ft³(m³) and

F=Factor for measure,ft⁻³(m⁻³).

The unit weight determined by this test method is for aggregate in an oven-dry condition. If the unit weight in terms of saturated-surface (S.S.D) condition is desired, use the exact procedure in this test method, and then calculate the SSD unit weight using the following formula

$$M_{SSD} = M \left[1 + \frac{A}{100} \right]$$

Where

M_{SSD}=Unit weight in SSD condition, lb/ft³(kg/m³) and

A=% absorption, determined in accordance with test Method C127 or Test Method C128 (see

Expt.no-5 or 6).

Void content: Calculate the void content in the aggregate using the unit weight determined by rodding procedure as follows-

$$\% \text{ Voids} = 100 \frac{(S \times W) - M}{(S \times W)}$$

Where

M= Unit weight of the aggregate, lb/ft³(kg/m³),

S= Bulk specific gravity (dry basic) as determined in accordance with Test Method C 127 or Test Method C 128 (see Expt. no.-5 or 6) and

W= Density of water, 62.4 lb/ft³(998 kg/m³).

Report

Report the results for unit weight to the nearest lb/ft³(10kg/m³) as follows-

- a) unit weight by rodding
- b) loose unit weight.

Report the results for the void content to the nearest 1% as follows-

- a) voids in aggregate compacted by rodding, %
- b) voids in loose aggregate, %

7.9 Instructions:

The method is applicable to aggregates not exceeding 5 in. [125 mm] in nominal maximum size.

If the measure may also be used for testing for unit weight of concrete, the measure should be made of steel or other suitable metal not readily subject to attack by cement paste.

DATA SHEET

Experiment Name : Unit Weight and Voids in Aggregate.

Experiment Date :

Student's Name :

Student's ID :

Year/ Semester :

Section/ Group :

Bulk specific gravity (OD basis), (choose A and S from your previous experiments)

$S_{FA} =$ _____ $S_{CA} =$ _____

Absorption capacity (%),

$A_{FA} =$ _____ $A_{CA} =$ _____

Density of water, $W =$

Type of aggregate	Test Method	Wt. of Bucket, T (kg)	Wt. of Bucket+ Material, G (kg)	Volume of Bucket, V (m ³)	Unit wt., M (kg/m ³)	Avg. Unit wt., M (kg/m ³)	SSD Unit wt., M_{SSD} (kg/m ³)	% Void

Sample Calculation:

Results:

Comments:

Course Teacher :
Designation :

Signature of the Teacher

Discussion:

Assignment Questions:

1. What would be the effect upon the unit weight if the fine and coarse aggregates be combined?
2. What would be the effect upon the unit weight if the aggregate be placed in the cylinder without rodding?
3. What would be the effect upon the unit weight if damp fine aggregate be used?

**Sampling and Testing of Brick
for Efflorescence,
Compressive Strength and
Absorption
Week 8-11**

Experiment 6-7
Sampling and Testing of Brick for Efflorescence,
Compressive Strength and Absorption



A Efflorescence test for bricks

A.11.1 Objective:

The objective of this test is to determine the efflorescence of bricks.

A.11.2 Introduction:

The deposition of salts on the surface of clay or ceramic materials is called efflorescence. It is resulted from the migration and evaporation of aqueous saline solutions. The efflorescence is basically an aesthetic problem, but due to be a complex phenomenon with economic consequences it worries manufactures and building constructors. Raw materials, building materials, subsoil water, can be the source of soluble salts, which generate the efflorescence.

A.11.3 Reference Standard:

This test method conforms to the BDS standard requirements of specification 208:2002.

A.11.4 Test Method:

Efflorescence test is done as following:

Number of Specimens: Test specimens shall consist of 5 whole dry bricks which shall be tested for efflorescence as laid down in the following:

Procedure: Each bricks shall be placed on end in a shallow flat bottom non-absorbent dish keeping minimum clearance of 5 cm (2 inches) between two consecutive bricks. Distilled water shall then be poured to depth of 2.54 cm (1 inch) so that it surrounds each bricks by one inch only. The whole arrangement shall be allowed to stand in a well-ventilated room at about 15 degree C to 20 degree C. After a few days when the water has been absorbed and the bricks appear to be dry, as similar quantity of water shall again be poured in the dish and further drying period allowed. The bricks shall then be examined for efflorescence.

A.11.5 Result:

The tendency to efflorescence shall be reported as “Nil”, “Slight”, “Moderate”, “Heavy”, or “Serious” in accordance with the following definitions.

Nil: No perceptible deposit of salt.

Slight: Not more than 10 percent of the area of the bricks covered with a thin deposit of salt.

Moderated: A heavier deposit than under “Slight” and covering up to 50 percent of the area of the bricks surface but unaccompanied by powdering or flaking of the surface.

Heavy: A heavy deposit of salt covering 50 percent or more of the bricks surface but unaccompanied by powdering or flaking of the surface.

Serious: A heavy deposit of salt accompanied by powdering and/or flaking of the surfaces

B.11.1 Objective:

Sampling and testing of brick for compressive strength and absorption.

B.11.2 Introduction:

According to the characteristics of good brick, they should be uniform in colour, size and shape and also should be sound, compact and free from crack or other flaws such as air bubbles, stone nodules, etc. The minimum compressive strength of 1st class bricks should not be less than 2500 psi they should not absorb more than 1/6th of their own weight of water when immersed in water for 24 hours (15 to 20% dry wt.). The strength of a brick decreases by about 25% when soaked in water. The wt. of each brick should be in the range of 6 to 7 lbs. Some other important tests of brick includes Modulus of Rupture, Freezing and Thawing, Initial Rate of Absorption (Suction), Efflorescence, Measurement of Size, Measurement of Warpage, Measurement of Length Change, Measurement of Void Area, Measurement of Out of Square, Measurement of Shell and Web Thickness, Breaking Load.

B.11.3 Reference Standard:

This test method conforms to the ASTM standard requirements of specification C 67.

B.11.4 Scope:

Brick made from clay and shale, some of the most abundant, natural materials on earth, and then fired through a kiln at up to 2000 degrees. The use of brick also has a multitude of benefits, for example,

- Clay Brick an Environmentally Sustainable Product
- Long Life and Value Retention
- Fire Protection
- Comfort

Some advantages of bricks:

- A pure, natural product
- Strong and durable
- Low maintenance
- Thermal performance
- Acoustic performance
- Fire resistance
- Easily recyclable
- Minimal waste

- Design flexibility

Grades classify brick according to their resistance to damage by freezing when wet. Three grades are covered and the grade requirements are shown in Table 10.1.

Grade SW (Severe Weathering)-Brick intended for use where high and uniform resistance to damage caused by cyclic freezing is desired and where the brick may be frozen when saturated with water.

Grade MW (Moderate Weathering)-Brick intended for use where moderate resistance to cyclic freezing damage is permissible or where the brick may be damp but not saturated with water when freezing occurs.

Grade NW (Negligible Weathering)-Brick with little resistance to cyclic freezing damage but which are acceptable for applications protected from water absorption and freezing.

Table 11.1: Physical requirements

Designation	Minimum Compressive Strength gross area, psi (MPa)		Maximum Water Absorption by 5-h Boiling, %		Maximum Saturation Coefficient*	
	Average of 5 Brick	Individual	Average of 5 Brick	Individual	Average of 5 Brick	Individual
Grade SW	3000 (20.7)	2500 (17.2)	17	20	0.78	0.80
Grade MW	2500 (17.2)	2200 (15.2)	22	25	0.88	0.90
Grade NW	1500 (10.3)	1250 (8.6)	no limit	no limit	no limit	no limit

*Note: The saturation coefficient is the ratio of absorption by 24-h submersion in cold water to that after 5-h submersion in boiling water.

B.11.5 Related Terms:

Bed surface: the bed surface of the brick is the in situ non-vertical surface intended to be joined by mortar.

Brick face: the face of brick is any surface intended for use to form the exposed surface of the masonry structure.

Frog: an indentation in one bed surface of a brick manufactured by molding or pressing. The indentation may be shallow (not exceeding 3/8 in. (9.5 mm)) and is termed a panel. A deeper indentation is called a deep frog.

Absorption: weight of water picked up by a clay masonry unit during immersion at prescribed conditions expressed in relation to the dry weight of the unit. Two conditions of immersion are designated in standards relating to brick: 24 h in room temperature (60-86°F (15.5-30°C)) water or 5 h in boiling water. The resulting absorptions are termed cold absorption and boiling absorption

Initial rate of absorption: a distinct property that offers different information from absorption. It is a measure of the suction of water upward into a dry brick from a bed face

during one minute of exposure. It is expressed as grams of water picked up in one minute by a net area of 30 in²(194 cm²). Initial rate of absorption is one factor influencing the quality of bond between brick and mortar.

B.11.6 Apparatus:

- Balance
- Measurement Devices
- Compression Testing Machine
- Capping Equipment

B.11.7 Test Conditions:

Temperature:

Drying temperature of the test specimen in an oven is preferably be 230 ± 239°F (110 to 115°C). Room temperature of 75° ± 15°F (24° ± 8°C) with a relative humidity between 30 and 70% is preferable.

B.11.8 Procedure:

Sampling of Brick:

Selection of test specimen- For the purpose of these tests, full-size bricks shall be selected which are representative of the whole lot of units from which they are selected and shall include specimens representative of the complete range of colours, textures and sizes in the shipment and shall be free of dirt, mud, mortar, or other foreign materials unassociated with the manufacturing process.

Number of specimens- For the compressive strength and absorption determinations, at least ten bricks shall be selected from each lot of 1000,000 bricks or fraction thereof. For larger lots, five individual bricks shall be selected from each 500,000 bricks of fraction thereof contained in the lot. In no case shall less than ten bricks be taken. Additional specimens may be taken at the discretion of the purchaser.

Identification- Each specimen shall be marked so that it may be identified at any time. Markings shall cover not more than 5% of the superficial area of the specimen.

Weight determination-

- Drying- Dry the test specimens in a ventilated oven at 230 to 239°F (110 to 115°C) for not less than 24 h and until two successive weighings at intervals of 2 h show an increment of loss not greater than 0.2% of the last previously determined weight of the specimen.
- Cooling- After drying, cool the specimens in a drying room maintained at a temperature of 75° ± 15°F (24° ± 8°C) with a relative humidity between 30 and 70%.

Store the units free from drafts, unstacked, with separate placement, for a period of at least 4 h and until the surface temperature is within 5°F (2.8°C) of the drying room temperature. Do not use specimens noticeably warm to the touch for any test requiring dry units.

- Weigh dry full size specimens. Calculate the weight per unit area of a specimen by dividing the total weight in pounds by the average area in square feet of the two faces of the unit as normally laid in a wall.
- Report results separately for each unit with the average for five units or more to the nearest 1 g.

Compressive Strength Determination:

Test specimens-The test specimens shall consist of dry half brick (as described above), the full height and width of the unit, with a length equal to one half of the full length of the unit ± 1 in. (25.4 mm). Test specimens shall be obtained by any method that will produce without shattering or cracking a specimen with approximately plane and parallel ends. Five specimens shall be tested.

Capping- All specimens shall be dry and cool (as described above during weight determination) before any portion of the capping procedure is carried out. If the surface which will become bearing surfaces during the compression test are recessed or paneled, fill the depressions with a mortar composed of 1 part by weight of quick hardening cement and 2 parts by weight of sand. Age the specimens at least 48 h before capping them. Where the recess exceeds $\frac{1}{2}$ in. (12.7 mm), use a brick or tile slab section or metal plate as a core fill. Cap the test specimens using one of the two procedures described below.

- *Gypsum Capping*- Coat the two opposite bearing surfaces of each specimen with shellac and allow to dry thoroughly. Bed one of the dry shellacked surfaces of the specimen in a thin coat of neat paste of calcined gypsum (plaster of paris) that has been spread on an oiled nonabsorbent plate, such as glass or machined metal. The casting surface plate shall be plane within 0.003 in. (0.0076 mm) in 16 in. (406.4 mm) and sufficiently rigid; and so supported that it will not be measurably deflected during the capping operation. Lightly coat in with oil or other suitable material. Repeat this procedure with the other shellacked surface. Take care that the opposite bearing surfaces so formed will be approximately parallel and perpendicular to the vertical axis of the specimen and the thickness of the gaps will be approximately the same and not exceeding $\frac{1}{8}$ in. (3.18 mm). Age the caps at 24 h before testing the specimens.
- *Sulfur-Filler Capping*- Use a mixture containing 40 to 60 weight % sulfur the remainder being ground fire clay or other suitable inert materials passing a No. 100 (150 μm) sieve with or without plasticizer. The casting surface flat requirements shall be as described above. Place four 1 in. (25.4 mm) square steel bars on the surface plate to form a rectangular mold approximately $\frac{1}{2}$ in. (12.7 mm) greater in either inside dimension than the specimen. Heat the sulfur mixture in a thermostatically controlled heating pot to a temperature sufficient to maintain fluidity for a reasonable period of time after contact with the surface being capped. Take care to prevent

overheating, and stir liquid in the pot just before used. Fill the mold to a depth of ¼ in. (6.35 mm) with molten sulfur material. Place the surface of the unit to be capped quickly in the liquid and hold the specimen so that its vertical axis is at right angles to the capping surface. The thickness of the caps shall be approximately the same. Allow the unit to remain undisturbed until solidification is complete. Allow the caps to cool for a minimum of 2 h before testing the specimens.

Procedure-

- Test brick specimens flatwise (that is the load shall be applied in the direction of the depth of the brick). Center the specimens under the spherical upper bearing within 1/16 in. (1.59 mm).
- The upper bearing shall be a spherically seated hardened metal block firmly attached at the center of the machine. The center of the sphere shall lie at the center of the surface of the block in contact with the specimen. The block shall be closely held in its spherical seat, but shall be free to turn in any direction, and its perimeter shall have at least ¼ in. (6.35 mm) clearance from the head to allow for specimens whose bearing surfaces are not exactly parallel. The diameter of the bearing surface shall be at least 5 in. (127 mm). Use a hardened metal bearing block surface intended for contact with the specimen, having hardness not less than HRC 60 (HB 620). These surfaces shall not depart from plane surfaces by more than 0.001 in. (0.03 mm). When the bearing area plate with surfaces machined to true planes within ± 0.001 in. (0.03 mm) and with a thickness equal to at least one third of the distance from the edge of the spherical bearing to the most distant corner between the spherical bearing block and the capped specimen.
- Apply the load up to one half of the expected maximum load, at any convenient rate, after which adjust the controls of the machine so that the remaining load is applied at a uniform rate in not less than 1 nor more than 2 min.

- Calculation and Report-

Calculation the compressive strength of each specimen as follows:

Compressive strength, $C = W/A$

Where,

C = compressive strength of the specimen. $1b/in^2$ (or kg/cm^2) (or Pa. 10^4)

W = maximum load, 1bf. (orkgf) (or N), indicate by the testing machine and

A = average of the gross areas of the upper and lower bearing surfaces of the specimen in^2 (or cm^2).

Report the result to the nearest 10 psi.

Absorption:

The scale or balance used shall have a capacity of not less than 2000 gm and shall be sensitive to 0.5 gm.

Test specimens- The test specimens shall consist of half brick conforming to the requirements same as for compressive strength. Five specimens shall be tested.

Procedure-

- Dry and cool the test specimens in accordance with weight determination in sampling and weigh each one.
- Saturation- Submerge the dry, cooled specimen, without preliminary partial immersion, in clean water (soft, distilled or rain water at 60 to 86°F (15.5 to 30°C)) for the specified timer. Remove the specimen, wipe off the surface water with a damp cloth and weigh the specimen. Complete weighing of each specimen within 5 min after removing the specimen from the bath.
- *Calculations and Report-* Calculate the absorption of each specimen as follows:

$$\text{Absorption, \%} = \frac{W_s - W_d}{W_d} \times 100\%$$

Where,

W_d = dry weight of the specimen, and

W_s = saturated weight of the specimen after submersion in cold water.

Report the absorption of all the specimens tested as the absorption of the lot to the nearest 0.1 %.

DATA SHEET

Experiment Name : Sampling and Testing of Bricks- Field Tests, Compressive Strength and Absorption Capacity.

Experiment Date :

Student's Name :

Student's ID :

Year/ Semester :

Section/ Group :

Table: Field Tests

Description	Sample 1	Sample 2	Sample 3
Color			
Shape			
Size			
Weight			
Soundness			
Fractured Surface			
Efflorescence			
T-test			
Surface Hardness			

Table: Compressive Strength of Bricks

Sample No.	Length (in.)	Width (in.)	Area (in ²)	Compressive Strength, psi (MPa)	Avg. Compressive Strength, psi (MPa)

Table: Absorption Capacity

Sample No.	SSD Weight (gm)	OD Weight (gm)	Absorption Capacity (%)	Avg. Absorption Capacity (%)

Sample Calculation:

Result:

Comments:

Course Teacher :
Designation :

Signature of the Teacher

Discussion:

Assignment Questions:

1. How do you measure the absorption capacity of a brick? What will happen if a brick absorb more water

Reference Standard

ASTM C29	Standard Test Method for Bulk Density (“Unit Weight”) and Voids in Aggregate
ASTM C39	Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C67	Standard Test Method for Testing and Sampling Brick and Structural Clay
ASTM C109	Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (using 50 mm [2 in.] Cube ASTM Specimens)
ASTM C127	Standard Test Method for Density, Relative Density (Specific Gravity) and Absorption of Coarse Aggregate
ASTM C128	Standard Test Method for Density, Relative Density (Specific Gravity) and Absorption of Fine Aggregate
ASTM C131	Standard Test Method for Resistance to Degradation of Small Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C136	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C138	Standard Test Method for Density (Unit Weight), Yield and Air Content (Gravimetric) of Concrete
ASTM C150	Standard Specification for Portland Cement
ASTM C173	Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
ASTM C187	Standard Test Method for Normal Consistency of Hydraulic Cement
ASTM C191	Standard Test Method for Time of Setting of Hydraulic Cement by Vicat Needle
ASTM C192	Standard Practice for Making and Curing Concrete Test Specimens
ASTM C231	Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
BDS 208:002	Standard for Efflorescence Test

**Practice, Review/Reserved
Day
Week 12-13**

**Lab Report Assessment, Self
study
Week 14-15**

Lab Test, Viva, Quiz, Overall
Assessment, Skill
Development Test
(Competency)
Week 16-17