Table of Contents

How to write a laboratory report?

Title –
This should indicate the nature of the test and precisely identifies the focus of the lab

Objective (Scope of the test) –
A brief statement of the purpose and significance of the test should be indicated.

Materials –
The materials used or tested should be mentioned.

Apparatus and Equipment –
Special equipment used should be briefly described.

Procedure –
Describe the precise procedure you followed when carrying out your experiment.

Data and calculations of the test –
All laboratory data shall be submitted in tabular form. Observations relating to the behavior of the materials should be included. Calculations should be properly checked. The results of the test should be summarized in tabular or graphical form.

Sample of calculations –
All equations or formulas used should be clearly indicated and applied to one of the readings.

Discussion –
There should be included a brief discussion in which attention is drawn to the silent facts shown by the tables and diagrams. The test results should be compared with the logic and standard values and conclusion should be drawn. At the last, it is necessary to mention the error sources.

Cement Testing

Experiment 1

Normal Consistency of Hydraulic Cement

1.1. Designation: ASTM C 187-86

1.2. Introduction

The Consistency of cement test is performed to determine the amount of water content that is to be added in cement to attain Standard consistency or normal consistency of cement. This water to cement ratio used to perform the cement quality tests like the setting time and soundness of cement.

Experimentally; the normal consistency is the amount of water added in cement to penetrate the Vicat rod up to a point 10 ± 1 mm below the original surface in 30sec after being released.
The Standard or Normal consistency for Ordinary Portland cement varies between 25-35%.

1.3. Scope

This test method covers the determination of the normal consistency of hydraulic cement.

1.4. Apparatus

1. Weighing device
2. Glass graduates
3. Trowel
4. Vicat Apparatus

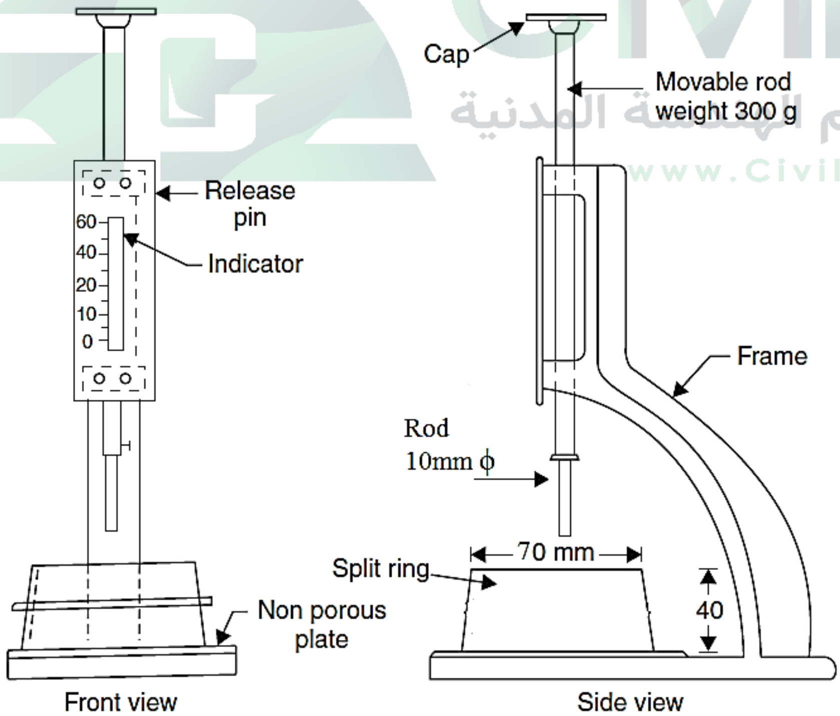


Fig 1.1: Vicat Apparatus

1.5. Materials

Cement and Distilled Water at room temperature.

1.6. Theory

The standard consistency of a cement paste is defined as the water to cement ratio which will permit a Vicat rod having 10 mm diameter and 50 mm length to settles to a point 10±1 mm below the original surface of the mould in 30 secs after being released.

1.7. Procedure

1- Place the dry paddle and the dry bowl in the mixing position in the mixer.
2- Place all the mixing water in the bowl.
3- Add the cement to the water and allow 30 s for absorption of the water.
4- Start the mixer at low speed for 30 s
5- Stop for (15 s) and make sure no materials have collected on the sides of the bowel.
6- Start mixing at medium speed for (1 min).
7- Quickly form the cement paste into the approximate shape of a ball with gloved hands
8- Putting hand at (15cm) distance, throw the cement paste ball from hand to hand six times.
9- Press the ball into the larger end of the conical ring; completely fill the ring with paste.
10- Remove the excess at the larger end by a single movement of the palm of the hand. Place the ring on its larger end on the base of the plate of Vicat apparatus.
11- Slice off the excess paste at the smaller end at the top of the ring by a single sharp- ended trowel and smooth the top. (Take care not to compress the paste).
12- Center the paste under the plunger end which shall be brought in contact with the surface of the paste, and tighten the set-screw.
13- Set the movable indicator to the upper zero mark of the scale or take an initial reading, and release the rod immediately. This must not exceed 30 seconds after completion of mixing.
14- The paste shall be of normal consistency when the rod settles to a point 10±1mm below the original surface in 30 seconds after being released.
15- Make trial paste with varying percentages of water until the normal consistency is obtained. Make each trial with fresh cement.

1.8. Report

Table 1.1: Required Data

Type of Cement	Weight of Cement (g)

Table 1.2: variation of penetration with w/c ratio

Wt. of Water (g)	W/C %	Penetration (mm)	Log (Pent.)

- Draw w/c% versus Log (penetration)

- From this curve (w/c% versus Log (pent.)), the normal consistency is…………

- Comment on the results

Experiment 2

Time of Setting of Hydraulic Cement by Vicat Needle

2.1. Designation: ASTM C 191-99

2.2. Introduction

When cement is mixed with water, it hydrates and makes cement paste. This paste can be molded into any desired shape due to its plasticity. Within this time cement continues with reacting water and slowly cement starts losing its plasticity and set harden. This complete cycle is called Setting time of cement.

Initial setting time of cement is the time to which cement can be molded in any desired shape without losing its strength. Or, the time at which cement starts hardens and completely loses its plasticity.

Final setting time of cement is the time at which cement completely loses its plasticity and became hard. Or, the time taken by cement to gain its entire strength.

2.3. Scope

This test method covers the determination of the initial and final setting times of hydraulic cement by means Vicat Needle.

2.4. Apparatus

1. Weighing device
2. Glass graduates
3. Trowel
4. Vicat Apparatus

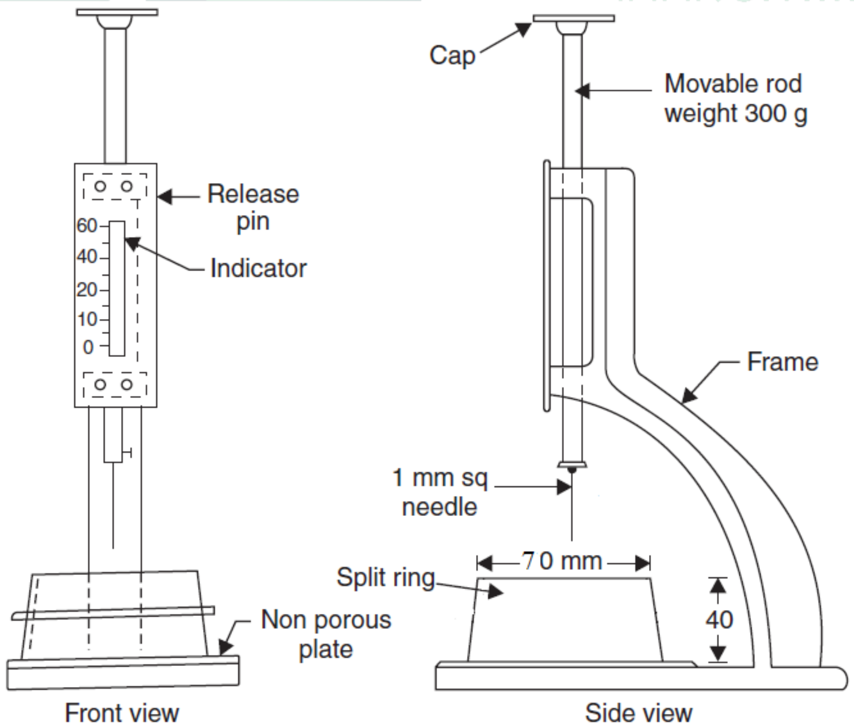


Fig 2.1: Vicat Apparatus

2.5. Materials

Cement and Distilled Water at room temperature.

2.6. Theory

Initial Setting Time (I.S.T): The period elapsing between the time when water is added to the cement and the time at which the 1 mm needle settles to a point 25 mm below the original surface of the mould.

Final Setting Time (F.S.T): The period elapsing between the time when water is added to the cement and the time at which the 1 mm needle does not sink visibly into the paste.

Approximate equations can be used to find the final setting time; as following:

F.S.T = 90 + 1.2 I.S.T …………..Eq.2.1.

OR

F.S.T= 45 + 1.5 I.S.T ……………Eq.2.2.

Where:
F.S.T: Final Setting Time (min)
I.S.T: Initial Setting Time (min)

Specifications:
Initial time of setting, not less than 45 min.
Final time of setting, not more than 375 min (6.25 hrs)

2.7. Procedure

1- Weigh (650) gm cement.
2- Prepare amount of water as to that calculated in normal consistency test.
Prepare a cement paste following same steps mentioned in the previous test (Normal consistency). Place in Vicat conical ring like the previous test. Don't forget to record the time since the cement is added to the water.
3- Allow the time of setting specimen to remain in the moist cabinet for 30 minutes after molding without being disturbed. Determine the Penetration of the 1mm needle at this time and every (15) minutes until a penetration of 25mm or more is obtained
4- To read the penetration, lower the needle of Vicat Apparatus until it touches the surface of the cement paste. Tighten the screw and take an initial reading. Release the set screw and allow the needle to settle for 30 seconds, and then take the reading to determine the penetration.
5- Note that no penetration shall be made closer than (6mm) from any previous penetration and no penetration shall be made closer than (9.5mm) from the inside of the mold. Record the results of all penetration, then by drawing a curve determine the time when a penetration of 25 mm is obtained. This is the initial setting time
6- The final setting time is when the needle does not sink visibly into the paste.

☒ Conditioning
The temperature of air in the vicinity of the mixing slab, the dry cement, mold, bowl, and base plates shall be maintained between (20 – 27.5) ^{o}C. The temperature of mixing water shall be 23±2 ^{o}C.
The relative humidity of the laboratory shall be not less than 50%.

2.8. Report

Table 2.1: Data (depending on the results of normal consistency test)

Cement Type	Weight of cement (g)	Water / cement %	Water (g)

Table 2.2: variation of penetration with time

Time (min)							
Penetration (mm)							

- Draw the penetration versus time.

- From the penetration-time curve, Initial setting time is…………

  Final setting time is…………..

- Calculate Final setting time using equation 2.1. and equation 2.2.

- Compare the results with the specifications and comment on the acceptability of using this type of cement.

Experiment 3

Time of Setting of Hydraulic Cement by Gillmore Needle

3.1. Designation: ASTM C 266 - 99

3.2. Introduction

The purpose of this test method is to establish whether a cement complies with a specification limit on Gillmore time of setting. The time of setting is affected by the percentage and temperature of the water used, the amount of kneading the paste received, and also by the temperature and humidity of the air.

Initial setting time of concrete is the time when cement paste starts hardening while final setting time is the time when cement paste has hardened sufficiently.

Theoretically, Initial setting time is the time period between addition of water to cement till the time when the test specimen can bear the initial Gillmore needle without appreciable indentation. Final setting time is that time period between the time water is added to cement and the time when the test specimen can bear the final Gillmore needle without appreciable indentation.

3.3. Scope

This test method covers the determination of the initial and final setting times of hydraulic cement by means Gillmore Needle.

3.4. Apparatus

1. Weighing device
2. Trowel
3. Glass graduates
4. Plane Non-Absorptive Plates, 102 mm ± 3 mm square
5. Gillmore Apparatus

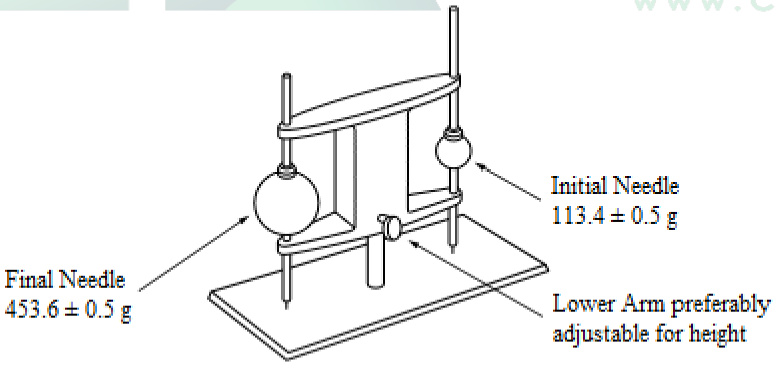


Fig 3.1: Gillmore Apparatus

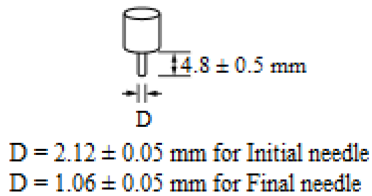


Fig 3.2.: Details of Gillmore Apparatus Needles

3.5. Materials

Cement and Distilled Water at room temperature.

3.6. Theory

<u>The initial time of setting</u> is the time required for the test specimen to bear the initial Gillmore needle without appreciable indentation, while the time required for the test specimen to bear the final Gillmore needle without appreciable indentation is <u>the final time of setting</u>.

Specifications:
Initial time of setting, not less than 60 min by Gillmore.
Final time of setting, not more than 10 hrs by Gillmore.

3.7. Procedure

1- Mix 650g of cement with the percentage of mixing water required for normal consistency (follow same steps mentioned in normal consistency test).
2- From the cement paste prepare a pat (autoclave cone) on a plane non-absorptive plate, the specified dimensions shown on figure 3.2:

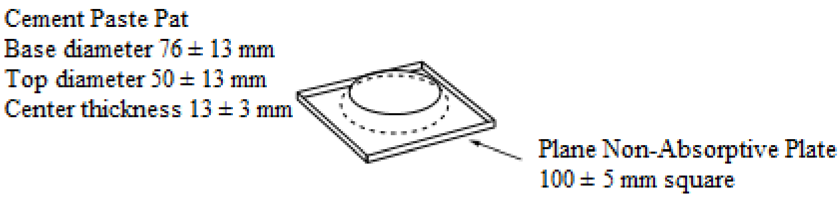


Fig 3.3: Pat with top surface flattened for determining time of setting by Gillmore method

3- Leave the sample for 30 minutes.
4- After 30 min, the sample is ready for testing.
5- The lower point of the initial needle (shown on figure 3.3) should touch the surface before releasing.

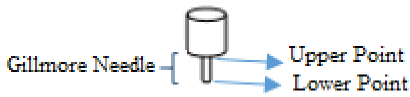


Fig 3.4: Upper and Lower Points of Gillmore Needles

6- In order to know the initial setting time, the upper point of initial needle (shown on figure 2) should not touch the sample.
7- if the upper point touched or penetrated the sample; wait for another 15 min, then test the sample again.
8- Repeat the test every 15 min until the upper point of initial needle no longer reaches the surface of the sample. Record the initial setting time at this moment.
9- Place the sample under the final needle and repeat the procedure until the upper point no longer reaches the surface of the sample. At this moment record the final setting time.

☒ <u>Conditioning</u>
The temperature of air in the vicinity of the mixing slab, the dry cement, mold, bowl, and base plates shall be maintained between (20 – 27.5)°C. The temperature of mixing water shall be 23±2 °C.
The relative humidity of the laboratory shall be not less than 50%.

3.8. Report

Table 3.1: Data (depending on the results of normal consistency test)

Cement Type	Weight of cement (g)	Water / cement %	Water (g)

Table 3.2: Results according to Gillmore Apparatus

	minutes	hours
Initial Setting Time		
Final Setting Time		

- Compare the results with the specifications and comment on the acceptability of using this type of cement.

Experiment 4

Compressive Strength of Hydraulic Cement Mortars Using 50-mm Cube Specimens

4.1. Designation: ASTM C 109/C 109M - 99

4.2. Introduction

Strength tests not made on neat cement paste because of difficulties in obtaining good specimens and the variability in test results; So, cement mortar specimens are used to determine the strength of cement. Cement mortar is an intimate mixture of cement and sand mixed with sufficient water to produce a plastic mass. The amount of water will vary according to the proportions and condition of the sand, and had best be determined independently in each case. Sand is used both for the sake of economy and to avoid the cracks due to shrinkage of cement in setting. Where great strength is required, there should be at least sufficient cement to fill the voids or air spaces in the sand, and a slight excess is preferable in order to compensate for any uneven distribution in the mixing.

There are several forms of strength tests: Direct tension, Compression, and Flexure, and these strengths can vary considerably according to the type of cement and the period of curing. In the great majority of cases cement mortar is subjected to compression, and for this reason it would be seem natural, in testing it, to determine its compressive strength. The compressive strength of cement mortar is sometimes used as a principal criterion for selecting mortar type, since the compression strength is easy to measure, and it commonly relate to other properties, such as tensile strength and absorption of the mortar. The compression strength of mortar depends largely upon the cement content and the water-cement ratio. The accepted laboratory means for measuring compression compressive strength according to ASTM C109 is to test 2in. cubes of mortar (Figure 4.1).

The proportions of materials for the compression strength test for the standard mortar (according to ASTM C109) shall be one part of cement to 2.75 parts of graded standard sand by weight. Use a water ratio of 0.485 for all Portland cements and 0.46 for all air-entraining Portland cements.

4.3. Scope

This test method covers the determination of the compressive strength of hydraulic cement mortars, using 2-in or 50-mm cube specimens.

4.4. Apparatus

1. Weighing device
2. Trowel
3. Glass graduates
4. Mixer, Bowl and Paddle
5. Specimen Molds, 2-in or 50-mm cube specimens

Fig 4.1: 2-in or 50-mm cube specimens

6. Testing Machine, Motorized or Manual Compressive Testing Machine

4.5. Materials

Cement; Graded Standard Sand; Distilled Water at room temperature.

4.6. Theory

- The compressive strength of cement mortar can be calculated as follows:

  $\sigma = \frac{P}{A}$

  Where:
  σ: compressive strength [psi or MPa]
  P: total maximum load [Ibf or N], and
  A: area of loaded surface [in^2 or mm^2];
  [2in or 50mm] Cubic specimen

  - The maximum permissible range between specimens from the same mortar batch, at the same test age is 8.7% of the average strength. [$\sigma_{range} = \sigma_{average} \pm 0.1\ \sigma_{average}$]
  - Discard the result which lies out of the range then compute the average of the remaining specimens. Make a retest of the sample if less than two specimens remain after discarding faulty specimens.

- To convert from mortar compressive strength to concrete compressive strength, use this equation; if the mortar and the concrete have same age, same w/c ratio and made from same cement type:

  $Y = 0.004\ X^2 + 1.3\ X$

  Where:
  Y: Compressive strength of concrete (MPa)
  X: Compressive strength of mortar (MPa)

  Note: this equation is applicable for ordinary Portland cement (OPC) only.

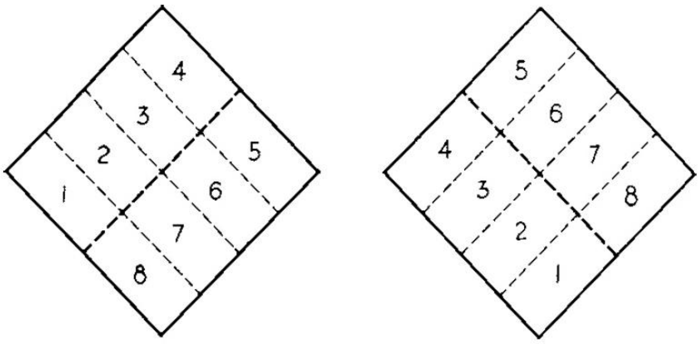
4.7. Procedure

4.7.1. Preparation of mortar

1. Prepare the quantities of standard mortar components to satisfy that C:S:W= 1:2.75:0.485, where cement= 740g, sand= 2035g, and water= 359ml for making 9 specimens
2. Place the mixing water in the bowl of the mixer, then add the cement and allow 30s for the absorption of water.
3. Start the mixer and mix at low speed (140±5rpm) for 30s
4. Add the certain quantity of sand to the cement paste gradually during the next 30s where the mixer still on slow speed.
5. Immediately, alter the mixer to medium speed (285±10rpm) for 30s.
6. Stop the mixer for 1.5min and during this time scrape down into the batch any mortar that may have collected on sides of the bowl.
7. Start the mixer at medium speed for 60s.

4.7.2. Molding test specimens

1. Apply a thin coat of oil to the interior faces of the mold.
2. Immediately following completion of mixing, start molding the specimens within 2.5min.
3. Place a layer of mortar about 1in (25mm) [one half of the depth of the mold] in all of the cube compartments (in our experiment it is 9cubes).
4. For each cube compartment, tamp the first layer of mortar 32times in 10sec in 4 rounds; see figure 4.2. complete the 4 rounds in one cube before the going to the next one).



Rounds 1 and 3   Rounds 2 and 4

Fig 4.2: order of tamping in molding of test specimens

5. When the tamping procedure is finished for all cube compartments, fill the remaining depth of cubes (1in) with second layer of mortar.
6. When the filling of all cube compartments is completed, repeat the tamping procedure as in the first layer (mortar should extend slightly above the tops of the molds).
7. Bring in the mortar that has been forced out onto tops of the molds and level the mortar surface, then cut off the extra mortar above the top of mold using a trowel (straight edge).
8. Store all test specimens, immediately after molding in the moist closet or moist room from 20-27hrs.
9. Remove the specimens from the molds after 20-27hrs.
10. Immerse them in saturated lime water for curing until testing age (3, 7, and 28days).

4.7.3. <u>Determination of compressive strength</u>

1. At each testing age (3, 7, and 28days), remove the required number of specimens from water (in our experiment 3 specimens for each age).
2. Wipe each specimen to a surface dry condition and remove any loose sand grains from the faces that will be in contact with the bearing blocks of the testing machine.
3. Apply the load to the smooth faces of the first specimen at rate of 200-400lb/s (900-1800N/s) and record the max load indicating by testing machine.
4. Repeat step 5 for the remaining specimens for each age.

4.8. Report

Table 4.1: Required Data

Cement Type	Cement : Sand (ratio)	Water : Cement (ratio)	Cement (g)	Sand (g)	Water (g)

Table 4.2: Data and results sheet

Age (Day)	Compressive Force (KN)	Compressive Strength (MPa)	Average Strength (MPa)	Accepted range (MPa)	Accepted or Not	Accepted Avg. Strength (MPa)
3						
7						
28						

- Estimate the compressive strength of concrete with the same w/c ratio as the cement mortar and same cement type at 28 days

- Compare the results with the specifications (see table 4.3) and comment on the acceptability of using this type of cement.

Table 4.3: ASTM C 150-05 requirements for minimum strength of cement (MPa (Psi))

Age (Days)	ASTM C 150 – 05 (mortar cube), cement type (table 4.4)							
	I	IA	II#	IIA#	III	IIIA	IV	V
1	-	-	-	-	12.0	10.0	-	-
	-	-	-	-	(1740)	(1450)	-	-
3	12.0	10.0	10.0	8.0	24.0	19.0	-	8.0
	(1740)	(1450)	(1450)	(1160)	(3480)	(2760)	-	(1160)
7	19.0	16.0	17.0	14.0	-	-	7.0	15.0
	(2760)	(2320)	(2470)	(2030)	-	-	(1020)	(2180)
28	28.0[a]	22.0[a]	28.0[a]	22[a]	-	-	17.0	21.0
	(4060)	(3190)	(4080)	(3190)	-	-	(2470)	(3050)

[#] Strength values depend on specified heat of hydration or chemical limits of tricalcium silicate and tricalcium aluminate

[a] Optional

Table 4.4: Cement Types

Appreviation	Cement Type
I	Ordinary Portland Cement
IA	Air Entrained Type A
II	Modefied Portland Cement
IIA	Air Entrained Type II
III	Rapid Hardening Portland Cement
IIIA	Air Entrained Type III
IV	Low Heat Portland Cement
V	Sulphate Resistance Portland Cement

Experiment 5

Tensile Strength of Hydraulic Cement Mortars Using 25-mm Briquet Specimens

5.1. Designation: ASTM C 190 - 85

5.2. Introduction

In this test the tensile strength of the hardened cement will be measured. The tensile strength done on cement – sand mortar and not on the hardened cement itself, the reason of not using neat cement paste on this test is in the following points:
1. Difficulties in molding (Getting good specimens).
2. Large variability of test results.
3. Avoid the cracks due to shrinkage of cement in setting

It is important that the resultant mixture (Cement + sand +water) has the same properties as concrete. So the standard sand was chosen and the following properties were determined to it:
1. Consist of pure siliceous material.
2. The particles are nearly spherical shaped.
3. The size of its particles is smaller than 0.85mm (Pass through sieve #20) and bigger than 0.60mm (Retained on sieve #30).

The tensile strength of cement mortar, however, is usually determined and from this its resistance to compression may be assumed to be from seven to eleven times greater. The accepted laboratory means for measuring tensile strength according to ASTM C190-85 is to test a briquet of mortar with 1in. width and 1in. thickness at the waist (Figure 5.1.). The percentage of water used in the standard mortar shall depend upon the percentage of water required to produce a neat cement paste of normal consistency.

5.3. Scope

This test method covers the determination of the tensile strength of hydraulic cement mortars, using 1-in or 25-mm briquet specimens.

5.4. Apparatus

1. Weighing device
2. Trowel
3. Glass graduates
4. Mixer, Bowl and Paddle
5. Specimen Molds, 1-in or 25-mm briquet specimens

Fig 5.1: Briquet Specimen for Tensile Strength Test

6. Testing Machine, Automatic Flexural Testing Machine

5.5. Materials

Cement; Graded Standard Sand; Distilled Water at room temperature.

5.6. Theory

The tensile strength of cement mortar can be calculated as follows:

$$\sigma = \frac{P}{A}$$

Where:

σ: tensile strength [psi or MPa]

P: total maximum load [Ibf or N], and

A: area of loaded surface [in^2 or mm^2]

[1in×1in] or [25mm×25mm] Briquet specimen

- Briquets that give strengths differing by more than 15% from the average value of all test briquettes made from the same sample and tested at the same period, shall not be considered in determining the tensile strength. [$\sigma_{range} = \sigma_{average} \pm 0.15\ \sigma_{average}$]
- Discard the result which lies out of the range then compute the average of the remaining specimens. Make a retest of the sample if less than two specimens remain after discarding faulty specimens.

5.7. Procedure

5.7.1. Preparation of mortar

1. Prepare the quantities of the cement and sand such that C:S= 1:3.
2. Determine the percentage and quantity of water used in the standard cement mortar depending on the percentage of water required to produce neat cement paste of normal consistency and prepare it.
   Hint: See table 1 (Percentage of water for Standard Mortar according to ASTM C190-85)

5.7.2. Molding test specimens

1. Apply a thin film of oil (release agent) to the interior faces of the mold.
2. Immediately following completion of mixing, fill the all molds heaping full with mortar without compaction.
3. Press the mortar 12 times by thumbs to each briquette mold, try to include the entire surface.
4. Heap the mortar above the mold and smooth it off and cut off the extra mortar with trowel.
5. Store all test specimens, immediately after molding in the molds in moist closet or moist room from 20-24hrs.
6. Remove the specimens from the briquettes molds after 20-24hrs.
7. Immerse them in saturated lime water in non-corroding storage tanks until testing age (3, 7, and 28days).

5.7.3. Determination of tensile strength

1. At each testing age (3, 7, and 28days) remove the required number of specimens from water (in our experiment 3 briquettes for each age).
2. Wipe each briquette to a surface dry condition and remove any loose sand grains from the faces that will be in contact with the clips of the testing machine.
3. Carefully centre the first briquette in the clips and apply the load continuously at rate of 600±25lbf/min (2.67±0.11KN/min.
4. Repeat step 3 for the remaining briquettes for each age.

5.8. Report

Table 5.1: Required Data

Cement Type	Cement : Sand (ratio)	Water : Cement (ratio)	Cement (g)	Sand (g)	Water (g)

Table 5.2: Data and results sheet

Age (Day)	Tensile Force (KN)	Tensile Strength (MPa)	Average Strength (MPa)	Accepted range (MPa)	Accepted or Not	Accepted Avg. Strength (MPa)
3						
7						
28						

- Draw the experimental accepted average Compressive strength (use the results of experiment 4) and the experimental accepted average Tensile Strength (MPa) of Mortar versus Time (Days) on the same graph using arithmetic papers, and comment on this chart.

- Check the compressive to tensile strength ratio at 28 days.

- Compare the results with the specifications (see table 5.3) and comment on the acceptability of using this type of cement.

Table 5.3: ASTM C 190-85 requirements for minimum Tensile strength of cement [A] (Psi (KPa))

	Cement Type				
	I	II	III	IV	V
1 day in moist air, psi (KPa)	- -	- -	275 (1896)	- -	- -
1 day in moist air, 2 days in water	150 (1034)	125 (862)	375 (2586)	- -	- -
1 day in moist air, 6 days in water	275 (1896)	250 (1724)	- -	7.50 (1207)	2.50 (1724)
1 day in moist air, 27 days in water	350 (2413)	325 (2241)	- -	300 (2068)	325 (2241)

[A] taken from C 150 – 58 without change

Aggregate Testing

Experiment 6

Specific Gravity and Absorption of Coarse Aggregate

6.1. Designation: ASTM C 127 - 88

6.2. Introduction

The purpose of this test is to determine the solid volume of coarse aggregate such that the weight-volume characteristics can be determined so that the concrete design mix can be determined. The bulk specific gravity is used to determine the volume occupied by the aggregates.

The moisture conditions of aggregates in general are:
- Oven Dry
- Air Dry
- Saturated Surface Dry
- Wet

Accordingly, aggregate particles may either be absorbent or will contribute water to the mix based on its moisture conditions. In concrete mix design the saturated surface dry conditions of aggregate are normally considered, where the aggregate will neither contribute nor absorb water from the mix.

6.3. Scope

This test method covers the determination of Apparent specific gravity, Bulk specific gravity, and Absorption of Coarse Aggregate.

6.4. Apparatus

1. Balance
2. Special Balance with:
   - Wire basket of 3.35 mm (No.6) or finer mesh, with a capacity of 4 – 7 L
   - Water Tank, a water tight tank into which the wire basket with the sample may be placed while suspended below the balance to measure the sample weight in water.

Fig 6.1: Special Balance with Basket

6.5. Materials

Coarse Aggregate and water.

6.6. Theory

Apparent Specific Gravity (Gsa): The ratio of the weight in air of a unit volume of the impermeable portion of aggregate (does not include the permeable pores in aggregate) to the weight in air of an equal volume of gas-free distilled water at the stated temperature.

Gsa = A / (A - C)

Where: A = Weight of sample oven-dried in air (g)

C = Weight of sample in water (g)

Bulk SSD Specific Gravity (Gsb SSD): The ratio of the weight in air of a unit volume of aggregate, including the weight of water within the voids filled to the extent achieved by submerging in water for approximately 15 hours, to the weight in air of an equal volume of gas-free distilled water at the stated temperature.

Gsb SSD = B / (B - C)

Where: B = Weight of saturated surface in air (g)

C = Weight of sample in water (g)

Absorption: The increase in mass due to water in the pores of the material.

% Abs = [(B - A) / A] x 100

Where: A = Weight of sample oven-dried in air (g)

B = Weight of saturated surface in air (g)

Specifications:

Table 6.1: Specifications according to ASTM Standards

Aggregate Type	Specific Gravity
Heavy weight	$\geq$ 3
Normal weight	2.8 – 2.2
Light weight	$\leq$ 2
Absorption% $\leq$ 5%	

6.7. Procedure

1. Sieve the sample with 4.75mm sieves and ignore the materials passing through No.4.75 sieve.
2. Wash the sample to remove dust.
3. Put the sample in the oven at 110 ±5°C for 24hours.
4. Get the sample out of the oven, leave it to cool to a temperature that is comfortable to handle.
5. Submerge the sample in water for 24hours.
6. Remove the sample from the water and roll it in a large absorbent cloth until all visible films of water are removed. Wipe the larger particles individually. Take care to avoid evaporation of water from aggregate pores during the operation of surface- drying.
7. Take the required weight of the sample in its (S.S.D) (saturated surface dry) condition.
8. After weighing, immediately place the S.S.D sample in the sample container and determine its weight in water at 23±1°C.Take care to remove all entrapped air before weighing by shaking the container while immersed.
9. Dry the test sample to constant weight at a temperature of 110±5°C, Cool in air at room temperature 1 to 3 hours, or until the aggregate has cooled to a temperature that is comfortable to handle, and weigh.

6.8. Report

Table 6.2: Data

A: Weight of oven-dry test sample in air (g)	
B: Weight of S.S.D. sample in air (g)	
C: Weight of saturated sample in water (g)	

Table 6.3: Results

Apparent Specific Gravity (Gsa)	
Bulk Specific Gravity (Gsb SSD)	
Absorption (%)	

- Comment on the results

Experiment 7

Specific Gravity and Absorption of Fine Aggregate

7.1. Designation: ASTM C 128 - 97

7.2. Introduction

Specific Gravity is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. Water, at a temperature of 73.4°F (23°C) has a specific gravity of 1.

Bulk specific gravity is the characteristics generally used for calculation of the volume occupied by the aggregate in various mixtures containing aggregate such as Portland cement concrete.

Apparent specific gravity pertains to the relative density of the solid material making up the constituent particles not including the pore space within the particles that is accessible to water. This value is not widely used in construction aggregate technology.

Absorption values are used to calculate the change in the weight of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the absorption potential.

7.3. Scope

This test method covers the determination of Apparent specific gravity, Bulk specific gravity, and Absorption of Fine Aggregate.

7.4. Apparatus

1. Balance
2. Pycnometer
3. Mold; Metal Frustum of a Cone with dimensions as follows:
   40 mm inside diameter at the top, 90 mm inside diameter at the bottom, and 75 mm in height.
4. Metal Tamper with 25 mm in diameter

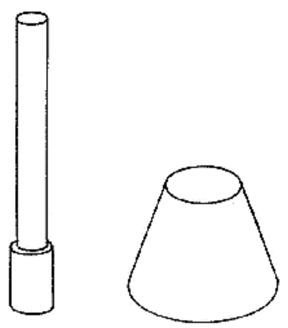


Fig 7.1: Metal Mold and Tamper

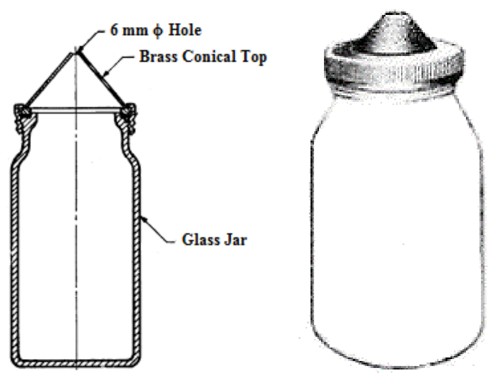


Fig 7.2: Pycnometer

7.5. Materials

Fine Aggregate and water.

7.6. Theory

Apparent Specific Gravity (Gsa): The ratio of the weight in air of a unit volume of the impermeable portion of aggregate (does not include the permeable pores in aggregate) to the weight in air of an equal volume of gas-free distilled water at the stated temperature.

$$Gsa = A / (B + A - C)$$

Where: A = Weigh of oven dry specimen in air (g)

B = Weight of Pycnometer filled with water (g)

C = Weight of Pycnometer with specimen and water to calibration mark (g)

Bulk SSD Specific Gravity (Gsb SSD): The ratio of the weight in air of a unit volume of aggregate, including the weight of water within the voids filled to the extent achieved by submerging in water for approximately 15 hours, to the weight in air of an equal volume of gas-free distilled water at the stated temperature.

$$Gsb\ SSD = S / (B + S - C)$$

Where: B = Weight of Pycnometer filled with water (g)

S = Weight of saturated surface dry specimen (g)

C = Weight of Pycnometer with specimen and water to calibration mark (g)

Absorption: The increase in mass due to water in the pores of the material.

$$\%\ Abs = [\ (S-A) / A]\ x\ 100$$

Where: A = Weigh of oven dry specimen in air (g)

S = Weight of saturated surface dry specimen (g)

Specifications:

Table 7.1: Specifications according to ASTM Standards

Aggregate Type	Specific Gravity
Heavy weight	$\geq$ 3
Normal weight	2.8 – 2.2
Light weight	$\leq$ 2
Absorption% $\leq$ 5%	

7.7. Procedure

1. Obtain approximately 1kg of the fine aggregate using sample splitter.
2. Dry it in a suitable pan or vessel to constant weight at 110°C. Allow it to cool to a comfortable handling temperature, cover with water by immersion and permit to stand for 24 hours.
3. Decant excess water with care to avoid loss of fines, spread the sample on a flat nonabsorbent surface exposed to a gently moving current of warm air.
4. Stir frequently to get homogeneous drying until achieving the saturated surface dry condition. Use cone test for surface moisture.
5. Hold the mold firmly on a smooth nonabsorbent surface with the large diameter down. Place a portion of partially dried fine aggregate loosely in the mold by filling it to over following and heaping additional materials above the top of the mold.
6. Lightly tamp the sand into the mold with 25 light drops of the tamper. Each drop should start about 5mm above the top surface of the sand. Permit the tamper to fall freely under gravitational attraction on each drop.
7. Adjust the surface, remove loose sand from the base and lift the mold vertically.
   If:
   - Surface moisture is still present the sand will retain the molded shape
   - The sand slumps slightly, it indicates that it has reached S.S.D condition.
   - The sand slumps fully, it indicates that the sand has been dried past the saturated surface dry condition. In this case, mix additional few millimeters of water with the fine aggregate and leave it in a covered container for 30 min. then resume the process of drying and cone testing until SSD condition is reached.
8. Weigh 500gm of the S.S.D sample.
9. Partially fill the pycnometer with water. Immediately put into the pycnometer 500gm saturated surface dry aggregate.
10. Then fill with additional water to approximately 90%of capacity.
11. Manually roll and invert or mechanically agitate the pycnometer to eliminate all air bubbles.
12. Bring the water level in the pycnometer to its calibrated capacity.
13. Determine the total weight of the pycnometer, specimen and water.
14. Remove the fine aggregate from the pycnometer, dry to constant weight at temp. 110±5°C, cool in air at room temperature for one hour, and weigh.
15. Determine the weight of the pycnometer filled to its capacity with water at 23±1.7°C

7.8. Report

Table 7.2: Data

A: Weight of oven-dry test sample in air (g)	
S: Weight of the saturated surface-dry specimen (g)	
B: Weight of S.S.D. sample in air (g)	
C: Weight of saturated sample in water (g)	

Table 7.3: Results

Apparent Specific Gravity (Gsa)	
Bulk Specific Gravity (Gsb SSD)	
Absorption (%)	

- Comment on the results

Experiment 8

Bulk Density (Unit Weight) and Voids in Aggregate (ASTM C 29/C 29M – 97) Angularity Number of Coarse Aggregate (IS:2386-PART 1-1963)

8.1. Designation: ASTM C 29/C 29M – 97 and IS:2386-PART 1-1963

8.2. Introduction

Bulk density of aggregate is the mass 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. A coarse aggregate with higher bulk density, then it means few of the voids can be filled by using fine aggregates and cement. Bulk density is very important to select the proportions for concrete mixtures, also for determining mass/volume relationships for conversions in purchase agreement. Bulk density may be compacted or loose; loose density is determined by the shoveling procedure, but compacted density is determined by rodding or jigging Method depending on the particle size, as following:

- Rodding procedure: for aggregate having a nominal maximum size not exceeding 37.5mm.
- Jigging procedure: for aggregate having a nominal maximum size greater than 37.5mm and less than 125mm.

Voids is the space between particles in an aggregate mass not occupied by solid mineral matter. Voids within particles, either permeable or impermeable, are not included in voids.

Angularity is the absence of roundness. An aggregate particle, which is more rounded, is less angular and vice versa.
Angularity number of an aggregate is the amount (to the higher whole number) by which the percentage of voids in it after compacting in a prescribed manner exceeds 33. Where, “33” is the percentage of volume of voids, in a perfectly rounded aggregate. “67” is the percentage of volume of solids in a perfectly rounded aggregate. The value of angularity number generally lies between 0 & 11. The rounded aggregate has Angularity Number zero.

8.3. Scope

This test method covers the determination of bulk density (unit weight) of aggregate in compacted or loose condition, and calculated voids between particles. Also, covers the determination of angularity number of coarse aggregates.

8.4. Apparatus

1. Balance
2. Measure: cylindrical metal measure
   - It shall have a height approximately equal to the diameter
   - The capacity of the measure shall confirm to the limits in table 8.1.
3. Tamping rod: a round steel rod (16 mm in diameter and 600 mm in length)
4. Glass plate: larger in diameter than the measure itself

Table 8.1: Capacity of measures according to ASTM C 29/C 29M

Nominal maximum size of aggregate (mm)	Capacity of measure (Lt)
12.5	2.8
25.0	9.3
37.5	14.0
75.0	28.0

8.5. Materials

Aggregate and water.

8.6. Theory

Bulk Density: The mass of unit volume of bulk aggregate material, in which the volume of the individual particles and the volume of the voids between the particles is included in the total volume. The bulk density value gives an indication to classify the aggregate as heavy, normal or light weight; as indicated in table 8.2.

M = (G – T)/V

Where: M = Bulk density of aggregate, kg/m^3 (lb/ft3)

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

T = Mass of the measure, kg (lb/f)

V = volume of the measure, m^3 (ft^3)

Table 8.2: Aggregate classification according to the bulk density result

Aggregate Type	Bulk Density (Kg/m^3)
Heavy weight	> 2080
Normal weight	1520 - 1680
Light weight	< 1120

void ratio: The space between the aggregate particles that is not occupied by solid mineral matter. That is, voids within particles, whether permeable (open) or impermeable (closed), are not included. It is not less than 33%.

% voids = [1 – M/(S*W)] *100

Where: M = Bulk density of aggregate, kg/m^3 (lb/ft3)

S = Specific gravity

W = Density of water, kg/m^3 (lb/ft3)

Angularity number: The amount by which the percentage of voids in it after compacting in a prescribed manner exceeds 33. Where, “33” is the percentage of volume of voids, in a perfectly rounded aggregate. “67” is the percentage of volume of solids in a perfectly rounded aggregate. The normal aggregate suitable for making concrete have angularity number lying between 0 and 10. The rounded aggregate has Angularity Number zero.

Angularity Number = 67- Solid% = 67 – [100M/(S*W)]

Where: M = Bulk density of aggregate, kg/m^3 (lb/ft3)

S = Specific gravity

W = Density of water, kg/m^3 (lb/ft3)

8.7. Procedure

8.7.1. Calibration of the measure:

1. Weigh the empty measure is weighted.
2. 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.
3. Determine the weight of the measure full with water, then calculate the weight of water.
4. Calculate the volume, V of the measure by dividing the weight of water required to fill the measure by its density.

8.7.2. Bulk Density (Unit Weight) and Voids in Aggregate:

In all fallowing cases initially get the weight of the empty measure.

8.7.2.1. Compacted by Rodding Method:

1. Fill the cylinder to one third of its height and rod the layer of aggregate with (25) strokes of the tamping rod evenly distributed over the surface. Fill the cylinder two-thirds full and again level and rod as previous. Finally, fill the cylinder to overflowing and rod again in the manner previously mentioned. In rodding the first layer, don't allow the rod to reach the bottom of the measure. In rodding the second and third layers, use strong effort, but not more force than to cause the tamping rod to penetrate the previous layer.
2. Level the surface of the aggregate with the fingers or a straight edge in such 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 cylinder
3. Determine the weight of the measure plus its contents and calculate the wt. of aggregate by subtracting the empty weight of the cylinder.

8.7.2.2. Compacted by Jigging Method:

1. Fill the measure in three equal layers.
2. For each layer left the opposite sides of the measure's base about 5 cm relative to the other, and allow it to fall to the floor 50 times (25 times on each side).
3. Level the surface with fingers or straight edge.
4. Get the weight of the full measure.

8.7.2.3. Loose by Shoveling Method:

1. Fill the measure to overflowing by means of a scoop, discharging the aggregate from a height not exceeding (50mm) above the top of the measure.
2. Level the top as described above.
3. Get the weight of the full measure.

8.7.3. Angularity Number of Coarse Aggregate:

1. Calibrate the measure using water (see part 8.7.1.).
2. Compact the aggregate in three layers, each layer being given 100 blows using the standard tamping rod at a rate of 2 blows/second by lifting the rod 5 cm above the surface of the aggregate and then allowing it to fall freely. The blows are uniformly distributed over the surface of the aggregate.
3. After compacting the third layer, fill the cylinder to overflowing and excess material is removed off with tamping rod as a straight edge.
4. Weigh the aggregate with cylinder. Three separate determinations are made and mean weight of the aggregate in the cylinder is calculated.

8.8. Report

8.8.1. Compacted and Loose Bulk Density

Table 8.3: Data of compacted and loose aggregate

Weight of measure plus compacted aggregate (kg)	
Weight of measure plus loose aggregate (kg)	
Weight of measure filled with water (kg)	
Weight of empty measure (kg)	
Density of water (kg/m^3**)**	
Specific gravity of aggregate (from experiment 6)	

Table 8.4: Results of compacted and loose aggregate

Volume of measure (m^3)	
Compacted Bulk Density (Kg/m^3)	
Loose Bulk Density (Kg/m^3)	
Compacted Voids Ratio (%)	
Loose Voids Ratio (%)	

- Comment on the results and compare the compacted with loose results

8.8.2. Angularity Number of Coarse Aggregate

Table 8.5: Required data to determine the angularity number

Weight of measure plus Rodded aggregate (kg)	
Weight of measure filled with water (kg)	
Weight of empty measure (kg)	
Density of water (kg/m^3**)**	
Specific gravity of aggregate (from experiment 6)	

Table 8.6: Angularity Number Results

Volume of measure (m^3)	
Bulk Density (Kg/m^3)	
Angularity Number	

- Comment on the results

Experiment 9

Sieve Analysis of Fine and Coarse Aggregates

9.1. Designation: ASTM C 136 – 96a

9.2. Introduction

A sieve analysis (or gradation test) is a practice or procedure used to assess the particle size distribution (also called gradation) of a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass. It is evident that all the materials below a certain sieve in a sieve stack is finer than the materials on the sieve, or any sieve in the stack above it.

Aggregate are broadly divided into fine and coarse aggregates. Those passing #4 (4.75 mm) sieve and retained on #200 (0.075 mm) are called fine aggregates. However, the fraction of aggregates retained on #4 sieve are called coarse aggregates.

The gradation of aggregates has a great influence on concrete. Very coarse aggregates or very fine aggregates were found unsatisfactory for making concrete, both economically and from workability point of view. When well graded aggregate consisting of particles of different sizes are used, the voids are minimized, the fresh concrete is more workable, stronger, and economical.

The particle size analysis is presented on semi-log plot of percent finer versus particle size. This makes it easy to compare several aggregate groups. The graph further allows one to estimate the percentage of particle sizes that are finer than selected diameters which may not have been used in the sieve stack.

9.3. Scope

This test method covers the determination of the particle size distribution (gradation) of fine and coarse aggregates by sieving.

9.4. Apparatus

1. Balance
2. Sieves for fine and coarse aggregates
3. Mechanical Sieve Shaker
4. Brush

9.5. Materials

Fine and Coarse Aggregates

9.6. Theory

1. % Loss is accepted if it is ≤ 0.3%

$$\% \text{ Loss} = \frac{sample\ weight - total\ weight\ retained}{sample\ weight} * 100\%$$

2. Percent of aggregate retained on nth sieve:

$$\text{Rn} = \frac{weight\ retained}{total\ weight\ retained} * 100\%$$

3. Cumulative percent of aggregate retained on nth sieve = $\sum_{i=0}^{n}$ Rn

4. Cumulative percent of aggregate passing through the nth sieve (%Finer):

%Finer = 100 - $\sum_{i=0}^{n}$ Rn

5. Fineness modulus = $\frac{\sum cumulative\ retained\ on\ the\ standard\ sieves}{100}$

6. Maximum Size of Aggregate – the smallest sieve opening through which the entire amount of aggregate is required to pass.

7. Nominal Maximum Aggregate Size – one size larger than the first sieve that retains more than 15% aggregate.

8. Depending on the fineness modulus result, the aggregate (According to ASTM Standards) can be classified as Coarse or Fine, see table 8.1.

Table 9.1: Aggregate Classification according to ASTM

<table>
<tr><th colspan="4">Fineness Modulus</th></tr>
<tr><td rowspan="4">Coarse Aggregate

> 5</td><td colspan="3">Fine Aggregate (Sand)</td></tr>
<tr><td colspan="3">< 5</td></tr>
<tr><td>Coarse Sand</td><td>Medium Sand</td><td>Fine Sand</td></tr>
<tr><td>≥ 3</td><td>2.8 – 2.2</td><td>≤ 2</td></tr>
</table>

9.7. Procedure

1. Dry the sample to constant mass at a temperature of 110±5°C.
2. Select sieves with suitable openings depending on the material to be tested.
3. Determine the empty weight of each sieve and record.
4. Nest the sieves in order of decreasing size of opening from top to bottom and place the sample on the top sieve.
5. Agitate the sieves by placing the set on mechanical shaker for a sufficient period (10min).
6. Weigh each sieve with the residue; be careful not to lose any particle of the sample.
7. Make sure that the summation of the residue weights equals to the original sample weight with a difference not more than 0.3% of the original weight.

9.8. Report

<u>Sieve analysis of coarse aggregates</u>

Sample weight = -----------

Table 9.2: Sieve analysis of coarse aggregates

sieve size (mm)	sieve No.	sieve wt. (g)	Sieve + ret. (g)	Ret. Wt. (g)	Retained (%)	Cum. Ret. (%)	Cum. Pass (%)
37.5	1 1/2"						
25	1"						
19	3/4"						
12.5	1/2"						
9.5	3/8"						
4.75	4						
2.36	8						
1.18	16						
0.075	200						
pan	-----						
		Total weight retained =					

- Calculate the Fineness Modulus (F.M.)
- Determine the Maximum Size (M.S.)
- Determine the Nominal Maximum Size (N.M.S.)
- Plot the [cumulative passing (%)] versus [sieve size (mm)]; ((Excluding sieve #200))

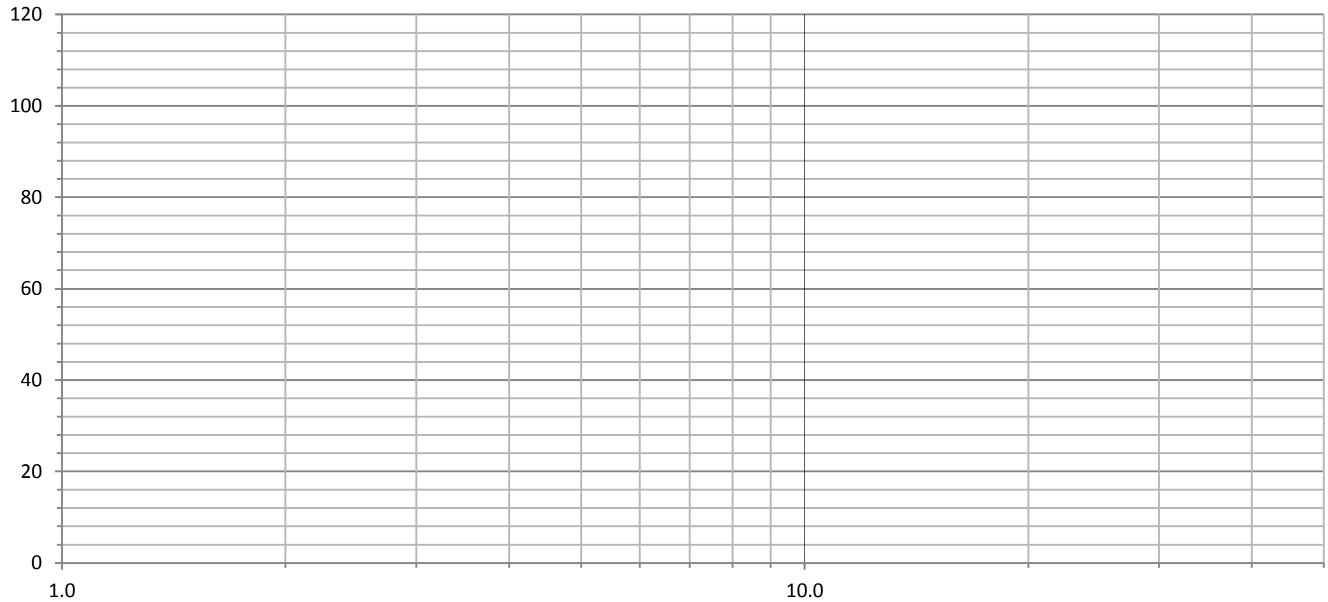


Fig 9.1: Grading Curve for Coarse Aggregate

Sieve analysis of fine aggregates

Sample weight= -------------

Table 9.3: Sieve analysis of fine aggregates

sieve size (mm)	sieve No.	sieve wt. (g)	Sieve + ret. (g)	Ret. Wt. (g)	Retained (%)	Cum. Ret. (%)	Cum. Pass (%)
9.5	3/8"						
4.75	4						
2.36	8						
1.18	16						
0.6	30						
0.3	50						
0.15	100						
0.075	200						
pan	------						
		Total weight retained =					

- Calculate the Fineness Modulus (F.M.)
- Determine the Maximum Size (M.S.)
- Determine the Nominal Maximum Size (N.M.S.)
- Plot the [cumulative passing (%)] versus [sieve size (mm)]

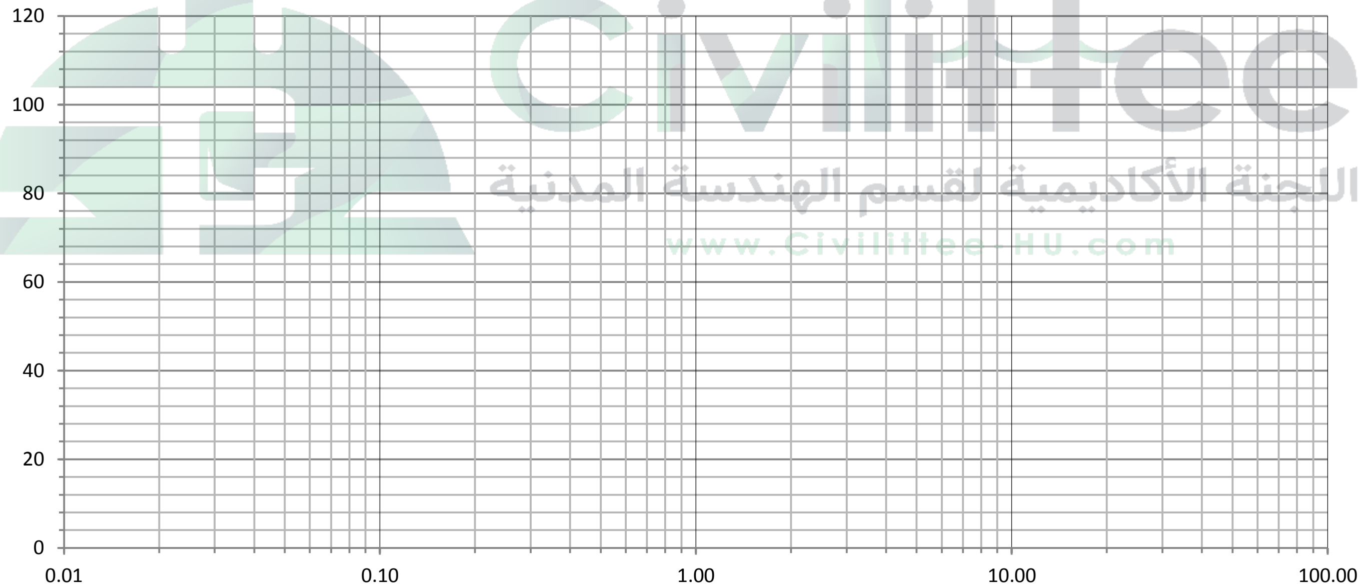


Fig 9.2: Grading Curve for Fine Aggregate

For both Fine and Coarse Aggregate:

- The aggregate is well graded, gap graded or single sized
- Classify the aggregate type according to ASTM Standards
- The aggregate is accepted or not according to ASTM, BS, and Jordanian Specifications
- If the Fine Aggregate is accepted, classify it according to BS Standards

9.9. Specifications

Table 9.4: BS and ASTM grading requirements for fine aggregate

Sieve size		Percentage by mass passing sieve				
		BS 882: 1992				ASTM C 33-92a
BS	ASTM No.	Overall limits	Additional limits*			
			C	M	F	
10 mm	$\frac{3}{8}$ in.	100	-	-	-	100
5 mm	$\frac{3}{16}$ in.	89 – 100	-	-	-	95 – 100
2.36 mm	8	60 – 100	60 – 100	65 – 100	80 – 100	80 – 100
1.18 mm	16	30 – 100	30 – 90	45 – 100	70 – 100	50 – 85
600 μm	30	15 – 100	15 – 54	25 – 80	55 – 100	25 – 60
300 μm	50	5 – 70	5 – 40	5 – 48	5 – 70	10 – 30
150 μm	100	0 – 15 ‡	-	-	-	2 – 10

* C = coarse; M = medium; F = fine.
‡ For crushed rock sands the permissible limit is increased to 20 percent, except when used for heavy duty floors.

Table 9.5: Some of the grading requirements for coarse aggregate according to ASTM C 33-92a

Sieve size		Percentage by mass passing sieve				
		Nominal size of graded aggregate			Nominal size of single-sized aggregate	
mm	in.	37.5-4.75mm ($1\frac{1}{2}$ to $\frac{3}{16}$ in.)	19 – 4.75mm ($\frac{3}{4}$ to $\frac{3}{16}$ in.)	12.5-4.75mm ($\frac{1}{2}$ to $\frac{3}{16}$ in.)	63 mm ($2\frac{1}{2}$ in.)	37.5 mm ($1\frac{1}{2}$ in.)
75.0	3	-	-	-	100	-
63.0	$2\frac{1}{2}$	-	-	-	90 – 100	-
50.0	2	100	-	-	35 – 70	100
38.1	$1\frac{1}{2}$	95 – 100	-	-	0 – 15	90 – 100
25.0	1	-	100	-	-	20 – 55
19.0	$\frac{3}{4}$	35 – 70	90 – 100	100	0 – 5	0 – 15
12.5	$\frac{1}{2}$	-	-	90 – 100	-	-
9.5	$\frac{3}{8}$	10 – 30	20 – 55	40 – 70	-	0 – 5
4.75	$\frac{3}{16}$	0 – 5	0 – 10	0 – 15	-	-
2.36	No. 8	-	0 – 5	0 – 5	-	-

Table 9.6: Grading requirements for coarse aggregate according to BS 882: 1992

Sieve size		Percentage by mass passing BS sieve							
		Nominal size of graded aggregate			Nominal size of single-sized aggregate				
mm	in.	40–5mm ($1\frac{1}{2}$ - $\frac{3}{16}$ in)	20–5mm ($\frac{3}{4}$ - $\frac{3}{16}$ in)	14–5mm ($\frac{1}{2}$ - $\frac{3}{16}$ in)	40 mm ($1\frac{1}{2}$ in.)	20 mm ($\frac{3}{4}$ in.)	14 mm ($\frac{1}{2}$ in.)	10 mm ($\frac{3}{8}$ in)	5 mm ($\frac{3}{16}$ in)
50	2	100	-	-	35 – 70	100	-	-	-
37.5	$1\frac{1}{2}$	95 - 100	-	-	0 – 15	90 – 100	-	-	-
20	$\frac{3}{4}$	35 – 70	90 – 100	100	0 – 5	0 – 15	100	-	-
14	$\frac{1}{2}$	-	-	90 – 100	-	-	85 – 100	100	-
10	$\frac{3}{8}$	10 – 30	20 – 55	40 – 70	-	0 – 5	0 – 50	85 - 100	100
5	$\frac{3}{16}$	0 – 5	0 – 10	0 – 15	-	-	0 – 10	0 – 25	50–100
2.36	#7	-	0 – 5	0 – 5	-	-	-	0 – 5	0 – 30

Table 9.7: Grading requirements for coarse aggregate according to J.S. (Jordanian Standards)

Sieve size		Percentage by mass passing sieve			
		Nominal size of graded aggregate			
mm	in.	40 mm ($1\frac{1}{2}$ in.)	25 mm (1 in.)	20 mm ($\frac{3}{4}$ in.)	12 mm ($\frac{1}{2}$ in.)
51	2	100	-	-	-
38	$1\frac{1}{2}$	80 – 100	100	-	-
25.4	1	20 – 50	95 – 100	100	-
19	$\frac{3}{4}$	10 – 30	40 – 80	95 – 100	100
12.7	$\frac{1}{2}$	-	5 – 50	50 – 80	90 – 100
9.5	$\frac{3}{8}$	0 – 10	0 – 15	25 – 60	80 – 100
4.75	$\frac{3}{16}$	0 – 5	0 – 5	0 – 10	5 – 50
2.36	#8	0 – 2	0 – 5	0 – 10	0 – 25
0.075	#200	0 – 2	0 – 2	0 – 2	0 – 2

Table 9.8: Grading requirements for fine aggregate according to J.S. (Jordanian Standards)

Sieve size		Percentage by mass passing sieve		
		Nominal size of graded aggregate		
mm	No.	9.5 mm ($\frac{3}{8}$ in.)	4.75 mm (No. 4)	1.18 mm (No. 8)
9.5mm	$\frac{3}{8}$ in.	95 – 100	100	-
4.75 mm	4	80 – 100	90 – 100	-
2.36 mm	8	50 – 80	75 – 100	100
1.18 mm	16	20 – 70	55 – 90	90 – 100
600 µm	30	10 – 35	35 – 59	60 – 90
300 µm	50	5 – 15	8 – 30	20 – 60
150 µm	100	0 – 5	0 – 10	0 – 20
75 µm	200	0 – 5	0 – 5	0 – 10

Experiment 10

Resistance to degradation of small-size coarse aggregate by abrasion and impact in the Los Angeles machine

10.1. Designation: ASTM C 131 - 96

10.2. Introduction

This test has been widely used as an indicator of the relative quality or competence of various sources of aggregate having similar mineral compositions. The results do not automatically permit valid comparisons to be made between sources distinctly different in origin, composition, or structure.

Aggregates undergo substantial wear and tear throughout their life. In general, they should be hard and tough enough to resist crushing, degradation and disintegration from any associated activities including manufacturing, stockpiling, production, placing and compaction. Aggregates not adequately resistant to abrasion and polishing may cause premature structural failure. Furthermore, poor resistance to abrasion can produce excessive dust during concrete production resulting in possible environmental problems as well as mixture control problems.

The Los Angeles (L.A.) abrasion test is a common test method used to indicate aggregate quality, toughness and abrasion characteristics. Aggregate abrasion characteristics are important because the constituent aggregate in concrete must resist crushing, degradation and disintegration in order to produce a high quality concrete.

The standard L.A. abrasion test subjects a coarse aggregate sample to abrasion, impact, and grinding in a rotating steel drum containing a specified number of steel spheres. As the drum rotates, a shelf inside the drum picks up the aggregate and steel spheres. The shelf carries them around until they drop on the opposite side of the drum, subjecting the aggregate to impact and crushing. Then, the aggregate is subjected to abrasion and grinding as the drum continues to rotate until the shelf picks up the contents, and the process is repeated, see fig 10.1.

Fig. 10.1: Impact-Crushing Affect by the Shelf Plate

The drum is rotated for a specified number of revolutions. Afterward, the aggregate is removed from the drum and sieved on a No. 12 (1.70 mm) sieve. The aggregate retained on the sieve is weighed and the difference between this weight and the original weight is expressed as a percentage and reported as the L.A. abrasion loss value. Therefore, an L.A. abrasion loss value of 30 indicates that 30% of the original sample passed through the No. 12 (1.70 mm) sieve.

10.3. Scope

This test method covers a procedure for testing of coarse aggregates with a maximum size smaller than 37.5 mm ([11/2 in.] for resistance to degradation and wearing (abrasion) using the Los Angeles testing machine. Also used to check the quality and hardness of aggregate and it gives an indirect indication about the strength of aggregate.

10.4. Apparatus

1. Los Angeles machine:
   Details are on Fig 10.2.

2. Set of Standard sieves:
   - Set of sieves used before testing in L.A. machine: the selection of testing sieves depends on the specifications of the required grading; as shown in table 10.1.
   - Sieve No.12 (1.7 mm) used after testing in L.A. machine.

3. Charge:
   Consist of steel balls averaging approximately 47mm in diameter and each having a mass of between 390 and 445.
   The number of charges depends on the required grading as shown in table 10.2.

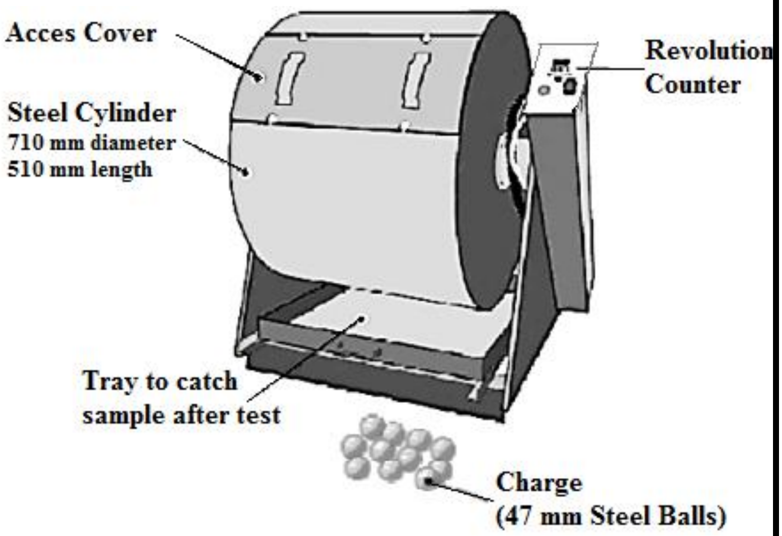


Fig 10.2: Los Angeles Machine

Table 10.1: Gradation and separation of test samples

Sieve Size (mm)		Weight of Test Sample for Grade (g)			
		Grading			
Passing	Retained on	A	B	C	D
37.5	25	1250±25	-	-	-
25	19	1250±25	-	-	-
19	12.5	1250±10	2500±10	-	-
12.5	9.5	1250±10	2500±10	-	-
9.5	6.3	-	-	2500±10	-
6.3	4.75	-	-	2500±10	-
4.75	2.36	-	-	-	5000±10
Total	5000±10	5000±10	5000±10	5000±10	5000±10

Table 10.2: Specified abrasive charge based on 5000 g specimen weight

Grading (Table 10.1)	Number of spheres	Number of balls (Large / Small)
A	12	6 / 6
B	11	5 / 6
C	8	4 /4
D	6	3 / 3

10.5. Materials

The test sample consist of clean aggregate which has been dried in an oven at 105°C to 110°C and it should conform to one of the grading shown in table 10.1.

10.6. Theory

The abrasion % of tested aggregate gives an indication about its quality; the details shown in table 10.3, and it is calculated using the flowing equation:

$$\text{Abrasion\%} = \frac{\text{Weight of passing sieve No.12}}{\text{Weight of original sample}} * 100\%$$

<u>OR:</u>

$$\text{Abrasion\%} = \frac{\text{Weight og original sample - Weight of retained on sieve No.12}}{\text{Weight of original sample}} * 100\%$$

Table 10.3: Quality of tested aggregate depending on the abrasion % result

Abrasion %	Quality of Aggregate
< 15	Ultra-High Quality
15 – 25	High Quality
25 – 35	Medium Quality
35 – 45	Low Quality
> 45	Can't be used

10.7. Procedure

1. The test sample shall consist of clean aggregate which has been dried in an oven at 105 to 110°C to substantially constant weight and shall conform to one of the grading (A to D). The grading used shall be the most nearly representing the aggregate furnished for the work.

2. The test sample and the abrasive charge (according to table 10.2) shall be placed in the Los Angeles abrasion testing machine and the machine rotated at a speed of 30 to 33 rev/min. For grading A, B, C and D, the machine shall be rotated for 500 revolutions.

4. At the completion of the test, the material shall be discharged from the machine and sieved on sieve No.12 (1.7 mm).

5. The material retained on 1.70 mm IS Sieve (No.12) shall be washed and dried in an oven at 105 to 110°C to a substantially constant weight, and accurately weighed to the nearest gram.

10.8. Report

Table 10.4: Required Data and Results

Weight of aggregate before testing (g)	Weight of aggregate retained on sieve #12 after testing (g)	Abrasion %

- Comment on the results

Steel Testing

Experiment 11

Tensile Strength of Steel

11.1. Designation: A615/A615M − 15a´1

11.2. Introduction

The term tensile strength refers to the amount of tensile (stretching) stress a material can withstand before breaking or failing. The ultimate tensile strength of a material is calculated by dividing the area of the material tested (the cross section) by the stress placed on the material.
The tensile strength is most commonly measured by placing a test piece in the jaws of a tensile machine. The tensile machine applies stretching stress by gradually separating the jaws. The amount of stretching needed to break the test piece is then measured and recorded. The yield strength of metals may also be measured. Yield strength refers to the amount of stress a material can withstand without permanent deformation.

Concrete is damn good in compression while steel is great in tension. Steel is also good in compression but because it has very high strength, the cross section generally becomes small and the smaller the cross section the more are the chances of buckling, while concrete on the other hand has low strength so we require larger cross sections and in doing so we overcome the buckling effects. Steel is the only metal used in construction with concrete because when both the materials are heated they possess a similar coefficient of thermal expansion; concrete has of the order of 14 x 10^-6 while steel has 12.6 x 10^-6. So when it gets hot, both the material experience almost similar strains and there is no internal stress formation. Now one more question comes to mind is, what would happen even if internal stresses are formed? Well, those small strains can create tensile stresses in concrete, once these stresses are induced then concrete cracks and once the concrete cracks the bond strength between steel and concrete is reduced and once it is lost then the material is as good as an independent one. So this gives a great advantage of using steel rather than anything else in concrete.

11.3. Scope

This experiment covers the determination of carbon steel bars properties for concrete reinforcement; such as its behavior under load, the strength, elastic and plastic properties. And finally to judge the suitability of bars for use in structures.

11.4 Apparatus

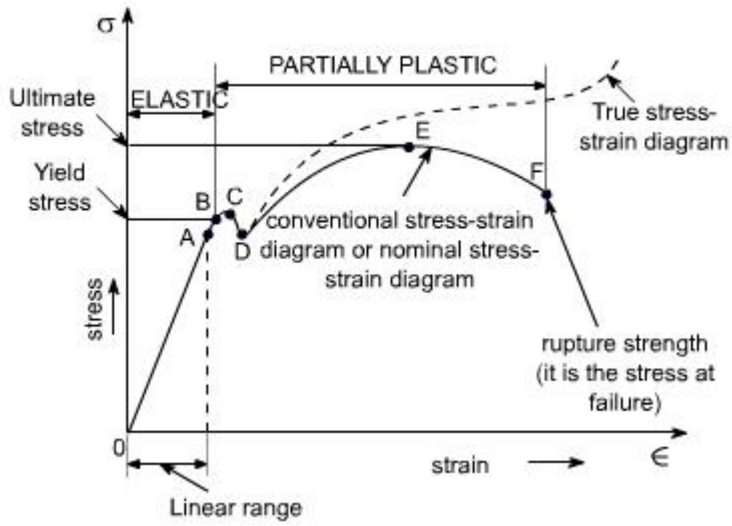
1. Balance
2. Full Computerized Universal Testing Machine (UTM)

11.5. Materials

Carbon Steel Bars; grade 40 and 60.

11.6. Theory

Typical tensile test curve for the mild steel has been shown below



A: Proportional Limit

B: Elastic Limit

C: Upper yield point

D: lower yield point

E: Ultimate stress

F: Rupture point

<u>Nominal stress – Strain OR Engineering Stress – Strain diagrams</u>:

Stresses are usually computed on the basis of the original area of the specimen; such stresses are often referred to as Engineering or nominal stresses.

<u>True stress – Strain Diagram</u>:

Since when a material is subjected to a uniaxial load, some contraction or expansion always takes place. Thus, dividing the applied force by the corresponding actual area of the specimen at the same instant gives the actual stresses so called true stress.

<u>POINTS OF THE GRAPH</u>:

(A) So it is evident form the graph that the strain is proportional to strain or elongation is proportional to the load giving a straight-line relationship. This law of proportionality is valid up to a point A. or we can say that point A is some ultimate point when the linear nature of the graph ceases or there is a deviation from the linear nature. This point is known as *the limit of proportionality or the proportionality limit*.

(B) For a short period beyond the point A, the material may still be elastic in the sense that the deformations are completely recovered when the load is removed. The limiting point B is termed as *Elastic Limit*.

(C) and (D) - Beyond the elastic limit plastic deformation occurs and strains are not totally recoverable. There will be thus permanent deformation or permanent set when load is removed. These two points are termed as *upper and lower yield points* respectively. The stress at the yield point is called the yield strength. For grade 40 the yield stress is 275MPa (40ksi) at least and for grade 60 is 415MPa (60ksi) at least.

(E) A further increase in the load will cause marked deformation in the whole volume of the metal. The maximum load which the specimen can with stand without failure is called the load at the ultimate strength. The highest point 'E' of the diagram corresponds to *the ultimate strength of a material*. For grade 40 the ultimate stress is 380MPa (55ksi) at least and for grade 60 is 520MPa (75ksi) at least.

(F) Beyond point E, the bar begins to forms neck. The load falling from the maximum until fracture occurs at F. Beyond point E, the cross-sectional area of the specimen begins to reduce rapidly over a relatively small length of bar and the bar is said to form a neck. This necking takes place whilst the load reduces, and fracture of the bar finally occurs at point F.

Engineering (normal) stress (σ), and engineering strain (ε):

These are quantities based on the original dimensions of the specimens and defined as:

$$\sigma = \frac{\text{Load at the required time}}{\text{Original Area}} = \frac{P_i}{A_\circ}$$

$$\varepsilon = \frac{\text{Length at the required time} - \mathit{Original\ Length}}{\text{Original Length}} = \frac{L_i - L_\circ}{L_\circ}$$

True (actual) stress (σ), and engineering strain (ε):

These are quantities based on the dimensions of the specimens at any time t during testing and defined as:

$$\sigma = \frac{\text{Load at the required time}}{\text{Area at the required time}} = \frac{P_i}{A_i}$$

$$\varepsilon = \frac{\text{Length at the required time} - \mathit{Original\ Length}}{\text{Length at the required time}} = \frac{L_i - L_\circ}{L_i}$$

The Modulus of elasticity (E):

Modulus of elasticity (Young's modulus) is the ratio of stress to strain in elastic range of deformation. For steel, modulus of elasticity is in the range between 190GPa to 210GPa. Modulus of elasticity is the slope of the stress-strain curve in the range of linear proportionality of stress to strain, and it is computed as follows:

$$\sigma = \frac{\Delta\sigma}{\Delta\varepsilon}$$

Poisson's ratio:

It is the ratio of the relative contraction strain (transverse, lateral or radial strain) normal to the applied load - to the relative extension strain (or axial strain) in the direction of the applied load.

$$\mu = \frac{-\varepsilon_t}{\varepsilon_l}$$

Where:

μ = Poisson's ratio

ε_t = lateral or radial strain (m/m, ft/ft); $[\Delta D/Di]$

ε_l = longitudinal or axial strain (m/m, ft/ft); $[\Delta L/Li]$

The ductility of material:

Is ability of material to deform under load, ductility is indicated by the tensile property of percentage of elongation and Percentage of reduction in cross-sectional area of a specimen.

- The percentage of elongation must be equal or greater than 16% and it is given by:

$$Ductility\% = \frac{\text{Final Length} - Original\ Length}{\text{Original Length}} * 100\%$$

$$Ductility\% = \frac{L_f - L_\circ}{L_\circ} * 100\%$$

- The Percentage of reduction in cross-sectional area is given by:

$$Ductility = \frac{\text{Cross sectional area at fracture} - Original\ cross\ sectional\ area}{\text{Original cross sectional area}} * 100\%$$

$$Ductility = \frac{A_f - A_\circ}{A_\circ} * 100\%$$

The Modulus of Resilience (UR):

It is the amount of energy stored in stressing the material to the elastic limit as given by the area under the elastic portion of σ - ε curve. This quantity is important in selecting materials for energy storage such as springs; the Modulus of Resilience is given by:

$$\text{UR} = \frac{\text{Area in } (\text{P} - \Delta)\ curve\ in\ elastic\ region}{\text{Original Volume of the specimen}} = Area\ in\ (\sigma\ -\ \varepsilon) curve\ in\ elastic\ region$$

The modulus of Toughness (UT):

It is the total energy absorption capabilities of the materials to failure and it is given by:

$$\text{UT} = \frac{\text{Total area in } (\text{P} - \Delta)\ curve}{\text{Original Volume of the specimen}} = Total\ area\ in\ (\sigma\ -\ \varepsilon) curve$$

11.7. Procedure

1. Check the specimen dimensions, measure the diameter or width, thickness of the specimen and compute the cross-sectional area and measure the gauge length.
2. Tight the specimen at the grippes located at the machine.
3. Calibrate the machine in such a manner that the extension and load are set to zero.
4. Choose a suitable loading rate.
5. Apply the tension load on the specimen until failure.
6. Obtain the load-deformation curve from the machine.

11.8. Report

Table 11.1: Required Data and Results

	L_i (mm) =		L_F (mm) =	
	D_i (mm) =		A_i (mm^2) =	
	D_F (mm) =		A_F (mm^2) =	
	Load (KN)	Elongation (mm)	Eng. Stress (MPa)	Eng. Strain
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
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23				
24				
25				
26				
27				
28				
29				
30				

1. Draw the stress strain Diagram and show Elastic, Plastic, Yield, Hardening, and Necking regions.

2. Determine the following properties:
   a) Proportional Limit
   b) Yield Point
   c) Hardening Point
   d) Ultimate Strength
   e) Fracture Point

3. Calculate the following properties:
   a) Modulus of Elasticity
   b) Ductility (Elongation)
   c) Ductility (Reduction in area)
   d) True Stress at fracture Point
   e) True Strain at Fracture Point
   f) Modulus of Resilience
   g) Modulus of Toughness

4. Compare your values of modulus of elasticity, yield stress, ultimate stress, with the typical values for tested specimens.

5. Draw the shape of failure. What is called?

6. What is the type (grade) of steel? Why?

7. Comment on the suitability of the material for use in concrete buildings.

Concrete Testing

Experiment 12

Concrete Mix Design (ACI Method)

12.1. Designation: ACI 211.1-91

12.2. Introduction

The concrete mix design is a process of selecting suitable ingredients for concrete and determining their proportions which would produce, as economically as possible, a concrete that satisfies the job requirements, i.e. concrete having a certain minimum compressive strength, workability and durability. The proportioning of concrete mixes is accomplished by the use of certain relations which afford a reasonably accurate guide to select the best combination of the ingredients so as to achieve the desired properties. The common method of expressing the proportions of the materials in a concrete mix is in the form of parts, 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 concrete mix design proportions are either by volume or by mass. The water-cement ratio is usually expressed in mass.

The design of concrete of medium strength can be based on the following assumptions:

- The compressive strength of concrete is governed by its water-cement ratio.
- The workability of concrete is governed by its water content.

Moreover, there are various factors which affect the properties of concrete, e.g. the quality and quantity of cement, water and aggregates; techniques used for batching, mixing, placing, compaction and curing, etc. therefore, the specific relationships used in the proportioning of a concrete mix should be considered only as a basis for making an initial guess at the optimum combination of the ingredients and the final mix proportion is obtained only on the basis of further trial mixes.

12.3 Scope

This part describes method for selecting proportions for hydraulic cement concrete.

12.4. Apparatus

1. Mixer, tilting drum type of a capacity 10% to 50% greater than the maximum batch of concrete.

2. Scoop, or similar sampling device, made from non-absorbent material not readily attacked by cement paste, suitable for taking increments of concrete.

3. Slump cone with tamping rod

12.5. Materials

Cement, Coarse Aggregate, Fine Aggregate and Mixing Water.

12.6. Procedure and Theory

1. The following data should be collected before starting the mix design of concrete:
   - The required compressive strength of concrete cylinder.
   - The Slump of concrete.
   - The Nominal maximum size of the coarse aggregate.
   - The Fineness modulus of the fine aggregate.
   - The bulk specific gravities of fine and coarse aggregates.
   - The dry-rodded unit weight of the coarse aggregate.
   - The absorption and moisture of fine and coarse aggregate.

2. Determine the mean target strength F_{MD} from the specified characteristic compressive strength at 28-day F_{STRUC} and the level of quality control.

   F_{MD} (MPa) = F_{STRUC} + 1.34 S --------OR-------- F_{MD} (MPa) = F_{STRUC} + 2.33 S – 3.5
   Calculate F_{MD} using the both equations and take the larger one.

   where S is the standard deviation obtained from the table of approximate contents given after the design mix.

   In the absence of such data (S), approximate required increase in strength (safety factor) for the specified strength can be taken from Table 12.1. Then F_{MD} will be calculated as following:
   F_{MD} = F_{STRUC} + safety factor

Table 12.1: Required increase in strength for specified compressive strength when no tests records are available, according to ACI 318-05

Specified compressive strength		Required increase in strength	
MPa	Psi	MPa	Psi
Less than 21	Less than 3000	7	1000
21 to 35	3000 to 5000	8.5	1200
35 or more	5000 or more	10	1400

3. Obtain the water cement ratio for the desired strength using Table 12.2.

Table 12.2: Relationships between water-cement ratio and compressive strength of concrete

Compressive strength at 28 days, MPa	Water-cement ratio, by mass	
	Non-air-entrained concrete	Air-entrained concrete
40	0.42	—
35	0.47	0.39
30	0.54	0.45
25	0.61	0.52
20	0.69	0.60
15	0.79	0.70

4. Select the water content, for the required workability and maximum size of aggregates (for aggregates in saturated surface dry condition) from table 12.3.

5. Estimate the amount of entrapped air for maximum nominal size of the aggregate from the table 12.3.

Table 12.3: Approximate mixing water and air content requirements for different slumps and nominal maximum sizes of aggregates

	Water, kg/m^3 of concrete for indicated nominal maximum sizes of aggregate							
Slump, mm	10	12	20	25	40	50	75	150
	Non-air-entrained concrete							
25 to 50	207	199	190	179	166	154	130	113
75 to 100	228	216	205	193	181	169	145	124
150 to 175	243	228	216	202	190	178	160	—
Approximate amount of entrapped air in non-air-entrained concrete, %	3.0	2.5	2.0	1.5	1.0	0.5	0.3	0.2
	Air-entrained concrete							
25 to 50	181	175	168	160	150	142	122	107
75 to 100	202	193	184	175	165	157	133	119
150 to 175	216	205	197	184	174	166	154	—
Recommended average total air content, percent for level of exposure:								
Mild exposure	4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0
Moderate exposure	6.0	5.5	5.0	4.5	4.5	4.0	3.5	3.0
Extreme exposure	7.5	7.0	6.0	6.0	5.5	5.0	4.5	4.0

6. Calculate the cement content per unit volume of concrete from the water-cement ratio and the water content, where:
Cement = water / (w/c)

7. Obtain the volume of the coarse aggregate per unit volume of concrete using table 12.4. This volume is converted to dry weight of coarse aggregate required in a m^3 of concrete by multiplying it by the oven-dry-rodded weight per m^3 of the coarse aggregate.

Table 12.4: Volume of coarse aggregate per unit of volume of concrete

Nominal maximum size of aggregate, mm	Volume of dry-rodded coarse aggregate per unit volume of concrete for different fineness modulus of fine aggregate			
	2.40	2.60	2.80	3.00
10.0	0.50	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
20.0	0.66	0.64	0.62	0.60
25.0	0.71	0.69	0.67	0.65
40.0	0.75	0.73	0.71	0.69
50.0	0.78	0.76	0.74	0.72
75.0	0.82	0.80	0.78	0.76
150	0.87	0.85	0.83	0.81

8. Use the absolute volume method to estimate the quantity of fine aggregate. In this case, the total volume displaced by the known ingredients--water, air, cementitious materials, and coarse aggregate--is subtracted from the unit volume of concrete to obtain the required volume of fine aggregate. The volume occupied in concrete by any ingredient is equal to its weight divided by the density of that material (the latter being the product of the unit weight of water and the specific gravity of the material).

9. The mixing water added to the batch must be adjusted by reducing an amount equal to the free moisture content and by increasing an amount equal to the absorption of the used aggregates.

   Water to be added = free water + (absorbed water – moisture content) $_{C.A.}$
   + (absorbed water – moisture content) $_{F.A.}$

10. Determine the concrete mix proportions for the first trial mix.

11. Prepare the concrete using the calculated proportions. the concrete should be checked for slump and for air content. It should also be carefully observed for freedom from segregation, and finishing properties. Appropriate adjustments should be made in the proportions for subsequent batches in accordance with the following procedure.
    - If the slump of the trial batch was not correct, increase or decrease the re-estimated amount of water by 2 kg for each 1 cm required increase or decrease in slump.
    - If the desired air content was not achieved, reduce the mixing-water content by 3 kg to increase the air content 1 percent or increase the mixing water by 3 kg to decrease the air 1 percent.

12. Calculate new batch weights starting with Step 5. The coarse aggregate will be the same since it depends on the finesses modulus of fine aggregate and on the size of aggregate.

12.7. Sample Computations

<u>EXAMPLE</u>

PART 1:

Design a concrete that is required for a portion of a structure that will be below ground level in a location where it will not be exposed to severe weathering or sulfate attack. Structural considerations require it to have an average 28-day compressive strength of 20 MPa. On the basis of previous experience, it is determined that under the conditions of placement to be employed, a slump of 90 mm should be used and that the available 40 mm nominal size coarse aggregate will be suitable. The dry-rodded weight of coarse aggregate is found to be 1550 Kg/m^3.
Type I non-air-entraining cement will be used and its specific gravity is assumed to be 3.15.
The coarse aggregate has a bulk specific gravity of 2.68, an absorption of 0.5 percent and total moisture content of 2%.
The fine aggregate has a bulk specific gravity of 2.64, an absorption of 0.7 percent, total moisture of 6%, and a fineness modulus of 2.8.

PART 2:

A trial mix done using the results of part 1 and the results as the following:
Slump = 40 mm
Entrapped air = 4%
Adjust your mix design (in part A) to achieve the required slump and entrapped air content.

MIX DESIGN

PART 1:

Step 1: From table 12.1, the approximate required increase in strength (safety factor) = 7 MPa, then:

$F_{MD} = F_{STRUC}$ + safety factor

$F_{MD} = 20 + 7$

$F_{MD} = 27$ MPa

Step 2: From table 12.2,

Compressive strength at 28 days, MPa	W/C (Non-air-entrained concrete)
30	0.54
27	x
25	0.61

By interpolation:
w/c (related to 27 MPa) = 0.58

Step 3: For slump of 90 mm and maximum nominal size of aggregate of 40 mm, using table 12.3:

The water content = 181 Kg/m^3

The entrapped air = 1%

Step 4: From the information derived in Steps 2 and 3, the required cement content is found to be $\frac{181}{0.58}$ = 312 Kg/m^3

Step 5: The quantity of coarse aggregate is estimated from Table 12.4. For a fine aggregate having a fineness modulus of 2.8 and a 40mm nominal maximum size of coarse aggregate, the table indicates that 0.71 m^3 of coarse aggregate, on a dry-rodded basis, may be used in each m^3 of concrete. Since the dry-rodded weight of coarse aggregate is found to be 1550 Kg/m^3, the dry weight of coarse aggregate is: 1550*0.71= 1101 Kg/m^3

Step 6: With the quantities of water, cement, and coarse aggregate established, the remaining material comprising the m^3 of concrete must consist of fine aggregate and whatever air will be entrapped. The required fine aggregate will be determined on the basis of absolute volume, as following.

Volume of water = $\frac{181}{1000}$ = 0.181 m^3

Solid volume of cement = $\frac{312}{3.15*1000}$ = 0.099 m^3

Solid volume of coarse aggregate = $\frac{1101}{2.68*1000}$ = 0.41 m^3

Volume of entrapped air = 0.01 m^3

Total solid volume of ingredients except fine aggregate = 0.181 + 0.099 + 0.41 + 0.01 = 0.7 m^3

Solid volume of fine aggregate required = 1 – 0.7 = 0.3 m^3

Required weight of dry fine aggregate = 0.3 x 2.64 x 1000 = 792 Kg/m^3

Step 7: Batch weights (Kg) per m^3 of concrete calculated as follows:

Water, net mixing	181
Cement	312
Coarse aggregate, dry	1101
Fine aggregate, dry	792

Step 8: Tests indicate total moisture of 2 percent in the coarse aggregate and 6 percent in the fine aggregate, then the adjusted aggregate weights (as it is in the laboratory environment) become:

Coarse aggregate, wet = wt. of aggregate, dry + wt. of water content

= 1101 + 1101 x 2/100 = 1101 (1.02)

= 1123 Kg

Fine aggregate, wet = 792 + 792 x 6/100 = 792 (1.06)

= 840 Kg

Step 9: The requirement of added water should be adjusted for both moisture and absorption as following:

Water to be added = net mixing water (free water) + (absorbed water – moisture content) $_{C.A.}$

+ (absorbed water – moisture content) $_{F.A.}$

Water to be added = 181 + 1123 (0.005 – 0.02) + 840 (0.007 – 0.06) = 120 Kg

Step 10: The estimated batch weights for a m^3 of concrete are:

Water, to be added	120
Cement	312
Coarse aggregate, wet	1123
Fine aggregate, wet	840
Total weight	2395

PART 2:

Step 1: Add 2 kg to the free water to increase the slump 1 cm and add 3 kg to reduce the air 1%, then take the larger weight of water; as following:

For slump adjustment: new water =181 + 2 x (9 – 4) = 191 Kg

For air adjustment: new water =181 + 3 x (4 – 1) = 190 Kg

The new added water equals the larger value = 191 Kg

Step 2: From part 1, Step 2, w/c = 0.58

Cement = $\frac{191}{0.58}$ = 329 Kg/m^3

Step 3: From part 1, Step 5; C.A. = 1101 Kg/m^3

Step 4: With the quantities of water, cement, and coarse aggregate established, the remaining material comprising the m^3 of concrete must consist of fine aggregate and whatever air will be entrapped. The required fine aggregate will be determined on the basis of absolute volume, as following.

Volume of water = $\frac{191}{1000}$ = 0.191 m^3

Solid volume of cement = $\frac{329}{3.15*1000}$ = 0.104 m^3

Solid volume of coarse aggregate = $\frac{1101}{2.68*1000}$ = 0.41 m^3

Volume of entrapped air = 0.01 m^3

Total solid volume of ingredients except fine aggregate = 0.191 + 0.104 + 0.41 + 0.01 = 0.715 m^3

Solid volume of fine aggregate required = 1 – 0.715 = 0.285 m^3

Required weight of dry fine aggregate = 0.285 x 2.64 x 1000 = 752 Kg/m^3

Step 5: Batch weights (Kg) per m^3 of concrete calculated as follows:

Water, net mixing	191
Cement	329
Coarse aggregate, dry	1101
Fine aggregate, dry	752

Step 8: Tests indicate total moisture of 2 percent in the coarse aggregate and 6 percent in the fine aggregate, then the adjusted aggregate weights (as it is in the laboratory environment) become:

Coarse aggregate, wet = wt. of aggregate, dry + wt. of water content
= 1101 + 1101 x 2/100 = 1101 (1.02)
= 1123 Kg

Fine aggregate, wet = 752 + 752 x 6/100 = 752 (1.06)
= 797 Kg

Step 9: The requirement of added water should be adjusted for both moisture and absorption as following:

Water to be added = net mixing water (free water) + (absorbed water – moisture content) $_{C.A.}$
+ (absorbed water – moisture content) $_{F.A.}$

Water to be added = 191 + 1123 (0.005 – 0.02) + 797 (0.007 – 0.06) = 132 Kg

Step 10: The estimated batch weights for a m^3 of concrete are:

Water, to be added	132
Cement	329
Coarse aggregate, wet	1123
Fine aggregate, wet	797
Total weight	2381

Experiment 13

Making and Curing Concrete Test Specimens in the Laboratory

13.1. Designation: C 192/C 192M – 06, C 31/C 31M – 03a, BS 1881-108:1983, BS 1881-109:1983

13.2. Introduction

This experiment provides the standard methods for making and curing concrete specimens (cubes, cylinders, and beams) in the laboratory under accurate control of materials and test conditions using concrete that can be consolidated by rodding or vibration.

If the specimens are made and standard cured, the resulting strength test data are able to be used for:

- checking whether the prepared concrete is suitable to use in structure or not.
- Evaluation of different mixtures and materials.

13.3 Scope

This practice covers procedures for making and curing test specimens of concrete in the laboratory under accurate control of materials and test conditions using concrete that can be consolidated by rodding or vibration.

13.4. Apparatus

4. Mixer, tilting drum type of a capacity 10% to 50% greater than the maximum batch of concrete.

5. Scoop, or similar sampling device, made from non-absorbent material not readily attacked by cement paste, suitable for taking increments of concrete.

6. Cubic molds, 100mm or 150mm

7. Cylindrical molds, 150 mm× 300 mm or 100 mm× 200 mm

8. Beams, 150 mm× 150 mm× 750 mm or 100 mm× 100 mm× 500 mm

9. Compacting bar or vibrator

13.5. Materials

Cement, Coarse Aggregate, Fine Aggregate and Mixing Water.

13.6. Procedure

13.6.1. Machine Mixing

1. Put the coarse aggregate in the mixer, add some of the mixing water. If admixture is used, add the admixture to water and mix thoroughly.
2. Start the mixer, then add the fine aggregate, cement and water with the mixer running. If it is impractical to add the fine aggregate, cement and water with the mixer is running, these components may be added to the stopped mixer after permitting it to turn a few revolutions following charging with coarse aggregate and some of the water.
3. Mix the concrete, after all integrates are in the mixer, for 3 minutes followed by 3 minutes' rest, following by 2-minutes final mixing.

13.6.2. Molding Specimens

13.6.2.1. Casting Cylinders

1. Place the cylinder molds on a level surface free of vibration.
2. Determine the method of consolidation:
   - For concrete with slump less than 25mm, concrete should be consolidated by vibration, have a look at part 13.7.3.2.
   - For concrete with slump 25mm or higher, either rodding or vibration is permitted.
3. Determine the number of layers of concrete to be placed in the mold from table 13.1.

Table 13.1: Number of layers to prepare cylindrical specimen of concrete

Method of consolidation	Rodding		Vibration	
Cylinder Size (mm)	150×300	100×200	150×300	100×200
No. of layers	3	2	2	2

4. Place the concrete in the mold using the scoop.
5. If the method of consolidation is rodding (have a look at part 13.7.3.1), consolidate each layer by rodding 25times. When using the vibration method, insert it long enough so the surface is smooth and large air pockets stops to break through the top. 2 insertions of vibrator are required for a 150×300mm and one insertion for a 100×200mm cylinder.
6. Level the surface and cover with a plastic bag or lid.

13.7.2.2. Casting Beams

1. Place the beam molds on a level surface free of vibration.
2. Determine the method of consolidation:
   - For concrete with slump less than 25mm, concrete should be consolidated by vibration.
   - For concrete with slump 25mm or higher, either rodding or vibration is permitted.
3. Determine the number of layers of concrete to be placed in the mold from table 13.2.

Table 13.2: Number of layers to prepare beams of concrete

Method of consolidation	Rodding		Vibration	
Beam Width (mm)	100 - 200	>200	100 - 200	>200
No. of layers	2	3 or more	1	2 or more

4. Place the concrete in the mold using the scoop.

5. If the method of consolidation is rodding, determine the number of rodding per layer, one for each $2in^2$ [$14cm^2$] of top surface area of the beam. When using the vibration method, insert it long enough so the surface is smooth and large air pockets stops to break through the top.
6. Level the surface and cover with a plastic bag or lid.

13.6.2.3. Casting cubes

1. Place the cubic molds on a level surface free of vibration.
2. Place the mold the concrete in the mold in layers approximately 50mm deep and compact each layer by using either the compacting bar or the vibrator.
3. If the method of consolidation is rodding, the number of strokes per layer required to produce full compaction will depend upon the workability of concrete but in no case shall the concrete be subjected to less than 35 strokes per layer for 150mm cubes or 25 strokes per layer for 150mm cubes. When compacting each layer by means of the vibrating table use minimum duration necessary to achieve full compaction, and vibration shall cease as soon as the surface of concrete becomes smooth and has a glozed appearance.
4. Level the surface and cover with a plastic bag or lid.

13.6.3. Methods of Consolidation

13.7.3.1 Rodding

1. Place the concrete in the mold, in the required number of layers of approximately equal volume.
2. Rod each layer with the tamping rod using the required number of strokes. Rod the bottom layer throughout its depth. Distribute the roddings uniformly over the cross section of the mold. For each upper layer, allow the rod to penetrate through the layer being rodded and into the layer below approximately 1 in. [25 mm].
3. After each layer is rodded, tap the outsides of the mold lightly 10 to 15 times with the mallet, to close any holes left by rodding and to release any large air bubbles that may have been trapped.
4. Level the surface and cover with a plastic bag or lid.

13.6.3.2 Vibration

1. Fill the molds and vibrate in the required number of approximately equal layers. Place all the concrete for each layer in the mold before starting vibration of that layer.
2. Add the final layer, avoid overfilling by more than 1⁄4 in. [6 mm].

Note: The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Usually sufficient vibration has been applied as soon as the surface of the concrete has become relatively smooth and large air bubbles cease to break through the top surface. Over-vibration may cause excessive segregation and bleeding or loss of entrained air.

13.6.4. Curing

1. 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° ± 2°C for 24 hours ± ½ hour from the time of addition of water to the dry ingredients.
2. After this period, the specimens shall be marked and removed from the moulds and, unless required for test within 24 hours, immediately submerged in clean, fresh water or saturated lime solution and kept there until taken out just prior to test.
3. The water or solution in which the specimens are submerged shall be renewed every seven days and shall be maintained at a temperature of 27° ± 2°C. The specimens shall not be allowed to become dry at any time until they have been tested.

13.7. Report

- What is dimensions of the used molds in our experiment (cylinders, cubes and beams)?

- What is the consolidation method that used to consolidate our concrete?

- What is the number of layers for each mold type (beams, cylindrical and cubic molds)?

- If the vibration method had been used, what is the vibration duration per layer?

- If the rodding method had been used, what is the number of strokes per layer for each mold type?

- Why do we make these specimens?

Experiment 14

Slump of Hydraulic-Cement Concrete

14.1. Designation: ASTM C 143/C 143M - 98

14.2. Introduction

The concrete slump test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows The test is popular due to the simplicity of apparatus used and simple procedure. Slump test is useful for concrete of low to high workability but not useful for concrete of very low and very high workability.

The test is carried out using a metal mould in the shape of a conical frustum known as a slump cone, that is open at both ends and has attached handles. This cone is filled with fresh concrete in a standard manner. Then the mould is carefully lifted vertically upwards, so as not to disturb the concrete cone. The concrete then slumps. The slump of the concrete is measured by measuring the distance from the top of the slumped concrete to the level of the top of the slump cone.

The slumped concrete takes various shapes and according to the profile of slumped concrete, the slump is termed as true slump, shear slump or collapse slump (see figure 13.1). True slump is the accepted shape of most concrete mixes. If a shear slump is achieved, a fresh sample should be taken and the test repeated, if the shear slump is still observed then the mix should be rejected since it is an indication of segregation. Collapse slump occurs in concrete of very high workability or when incorrect high water amounts added to the concrete mix.

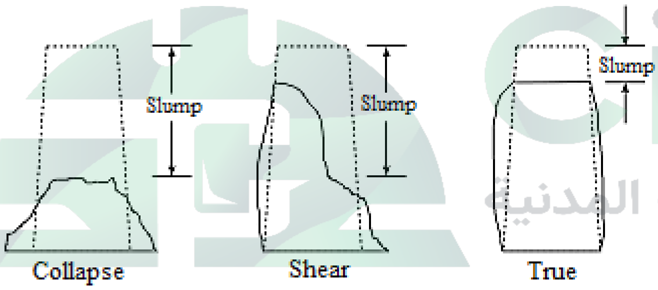


Fig. 14.1: Types of Slump

Only a true slump is of any use in the test. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which the slump test is not appropriate. Very dry mixes having slump 0 – 25 mm are typically used in road making, low workability mixes having slump 10 – 40 mm are typically used for foundations with light reinforcement, medium workability mixes with slump 50 – 90 mm, are typically used for normal reinforced concrete placed with vibration, high workability concrete with slump > 100 mm is typically used where reinforcing has tight spacing, and/or the concrete has to flow a great distance.

14.3 Scope

This test method covers determination of slump of fresh hydraulic-cement concrete which used as an estimation for the workability.

14.4. Apparatus

1. Concrete Mixer

2. Standard Slump Mold; Fig.13.2
   - A steel frustum of a cone
   - The base is about 200mm ϕ
   - The top is about 100 mm ϕ
   - The height is 300 mm

3. Tamping Rod
   - 16 mm in diameter
   - About 600 mm length

4. Balance

5. Scale of 5mm accuracy

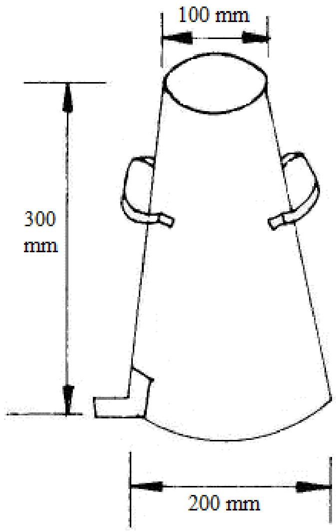


Fig. 14.2: Standard Slump Mold

14.5. Materials

Cement, Coarse Aggregate, Fine Aggregate and Mixing Water.

14.6. Theory

Slump: difference between height of the concrete before removing slump cone (mold) and height of the concrete after removing of slump cone; see fig. 13.3.

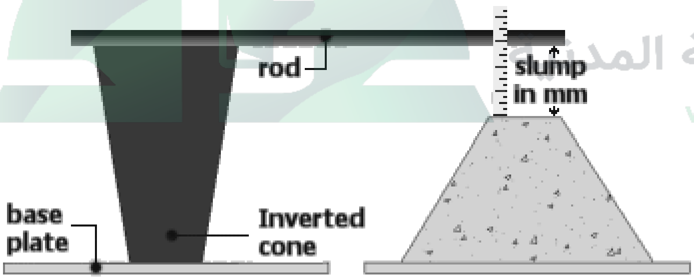


Fig 14.3: Brief Description of Slump Test

The table below gives a description of the workability and the magnitude of slump:

Table 14.1: Degree of concrete workability according to the slump value

Degree of Workability	Slump (mm)
very low	0 – 25
Low	25 – 50
Medium	50 – 100
High	100 - 175
Very High	> 175

14.7. Procedure

Machine Mixing

1. Put the coarse aggregate in the mixer, add some of the mixing water. If admixture is used, add the admixture to water and mix thoroughly.
2. Start the mixer, then add the fine aggregate, cement and water with the mixer running. If it is impractical to add the fine aggregate, cement and water with the mixer is running, these components may be added to the stopped mixer after permitting it to turn a few revolutions following charging with coarse aggregate and some of the water.
3. Mix the concrete, after all integrates are in the mixer, for 3 minutes followed by 3 minutes' rest, following by 2-minutes final mixing.

Slump Test

1. Dampen the mold and place it on a flat, moist, nonabsorbent (rigid) surface. It shall be held firmly in place during filling by the operator standing on the two foot pieces. Immediately fill the mold in three layers, each approximately one third the volume of the mold.
2. Rod each layer with 25 strokes of the tamping rod. Uniformly distribute the strokes over the cross section of each layer.
3. In filling and rodding the top layer, heap the concrete above the mold before rodding start. If the rodding operation results in subsidence of the concrete below the top edge of the mold, add additional concrete to keep an excess of concrete above the top of the mold at all time.
4. After the top layer has been rodded, strike off the surface of the concrete by means of screeding and rolling motion of the tamping rod.
5. Remove the mold immediately from the concrete by raising it carefully in the vertical direction. Raise the mold a distance of 300 mm in 5 ± 2 sec by a steady upward lift with no lateral or torsional motion.
6. Immediately measure the slump by determining the vertical difference between top of the mold and then displaces original center of the top surface of the specimen. Complete the entire test from the start of the filling through removal of the mold without interruption and complete it within 2½ min.
7. If a decided falling away or shearing off of concrete from one side or portion of the mass occurs, disregard the test and make a new test on another portion of the sample. If two consecutive tests on a sample of concrete show a falling away or shearing off of a portion of concrete from the mass of specimen, the concrete lacks necessary plasticity and cohesiveness for the slump test to be applicable.

14.8. Report

- What is the slump value?

- What is the workability degree of the tested concrete? Why?

- What is the slump shape of the tested mix? Draw it.

- Depending on the slump shape, is the tested concrete mix is accepted or not?

Experiment 15

Compacting Factor Test of Hydraulic-Cement Concrete

15.1. Designation: BS 1881: Part 103: 1993

15.2. Introduction

Compacting factor test is a workability test for concrete conducted in laboratory, it gives the behavior of fresh concrete under the action of external forces. The compacting factor is the ratio of density of partially compacted to fully compacted concrete.

The compacting factor test has been held to be more accurate than slump test, especially for concrete mixes of medium and low workabilities, i.e. compacting factor of 0.9 to 0.8, because the test is more sensitive and gives more consistent results. For concrete of very low workabilities of the order of 0.7 or below, the test is not suitable, because this concrete cannot be fully compacted for comparison in the manner described in the test.

15.3. Scope

This test method covers determination of compactability of fresh hydraulic-cement concrete which used as an estimation for the workability.

15.4. Apparatus

1. Concrete Mixer
2. Standard compacting factor apparatus; consisting of two conical hoppers mounted above a cylinder; Fig.14.1
3. Balance capable of weighing up to 25 kg
4. Tamping rod (iron or steel,16 mm in diameter and 600 mm length)
5. Compacting bar or vibrator;
   Compacting bar made from iron or steel, at least 380 mm long and having a ramming face 25 mm square

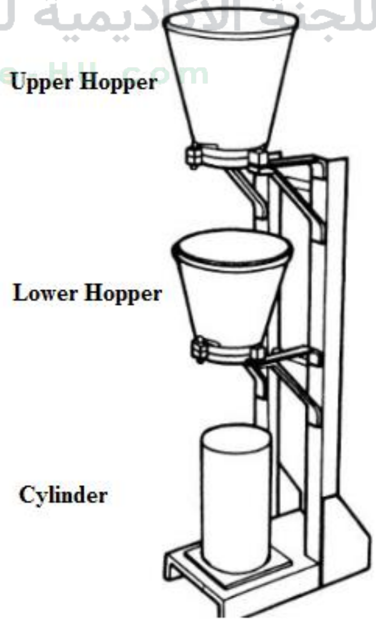


Fig. 15.1: Compacting Factor Apparatus

15.5. Materials

Cement, Coarse Aggregate, Fine Aggregate and Mixing Water.

15.6. Theory

Compacting factor: the ratio of the density of partially compacted concrete to the density of the concrete when fully compacted, so it must be less than 1.

Compacting factor = Density of partially compacted concrete / Density of compacted concrete

If same mould (same volume), then:
Compacting factor = weight of partially compacted concrete / weight of compacted concrete

The table below gives a description of the workability depending on the value of the compacting factor:

Table 15.1: Degree of concrete workability according to the compacting factor value

Degree of Workability	Compacting Factor
very low	0.78
Low	0.85
Medium	0.92
High	0.95
Very High	-

15.7. Procedure

1. Prepare a concrete mix as in slump test.

2. The internal surface of the hoppers and cylinder shall be thoroughly clean and free from superfluous moisture and any set of concrete commencing the test.

3. The sample of concrete to be tested shall be placed gently in the upper hopper using the scoop. The trap door shall be opened immediately after filling or approximately 6 min after water is added so that the concrete fails into the lower hopper. During this process the cylinder shall be covered.

4. Immediately after the concrete has come to the rest the cylinder shall be uncovered, the trap door of the lower hopper opened and the concrete allowed falling to into the cylinder.

5. For some mixes have a tendency to stick in one or both of the hoppers. If this occurs the concrete shall be helped through by pushing the tamping rod gently into the concrete from the top.

6. The excess of concrete remaining above the level of the top of the cylinder shall then be cut off by holding a trowel in each hand, with the plane of the blades horizontal, and moving them simultaneously one from each side across the top of the cylinder, at the same time keeping them pressed on the top edge of the cylinder. The outside of the cylinder shall then be wiped clean. This entire process shall be carried out at a place free from vibration or shock.

7. Determine the weight of concrete to the nearest 10 g. This is known as "weight of partially compacted concrete".

8. Refill the cylinder with concrete from the same sample in layers approximately 50 mm depth. The layers being heavily rammed with the compacting rod or vibrated to obtain full compaction. The top surface of the fully compacted concrete shall be carefully struck off and finished level with the top of the cylinder. Clean up the outside of the cylinder.

9. Determine the weight of concrete to the nearest 10 g. This is known as "weight of fully compacted concrete".

15.8. Report

Table 15.2: Data and Results

Wt. of Partially compacted concrete (kg)	Wt. of Fully compacted concrete (kg)	Compacting Factor

- What is the workability degree of the tested concrete? Why?

- Is the compacting factor test accurate to measure the workability of the tested concrete? Why?

- What is the expected slump value for the tested concrete?

Experiment 16

Vebe Test of Hydraulic-Cement Concrete

16.1. Designation: BS 1881: Part 104: 1983

16.2. Introduction

Vebe test is a workability test for concrete conducted in laboratory, it is suitable for stiff concrete mixes having low and very low workability. Compared to the slump test and compacting factor test, the vebe test has an advantage that the concrete in the test receives a similar treatment as it would in actual practice.

Vebe test is useful for knowing concrete workability by measuring the time that need to change mix concrete shape from conical to cylinder, so it is done by vibration the mix. The more the vebe time needed the less workability the mix is.

16.3. Scope

This test covers the determination of workability of concrete using a Vebe Consistometer, which determines the time required for transforming, by vibration, a concrete specimen in the shape of a conical frustum into a cylinder.

16.4. Apparatus

1. Concrete Mixer
2. Vebe Consistometer; consisting of cylindrical container, slump cone, transparent disk and vibrating table.; Fig.15.1
3. Stop watch, accurate to 0.5 sec
4. Tamping rod (iron or steel,16 mm in diameter and 600 mm length)

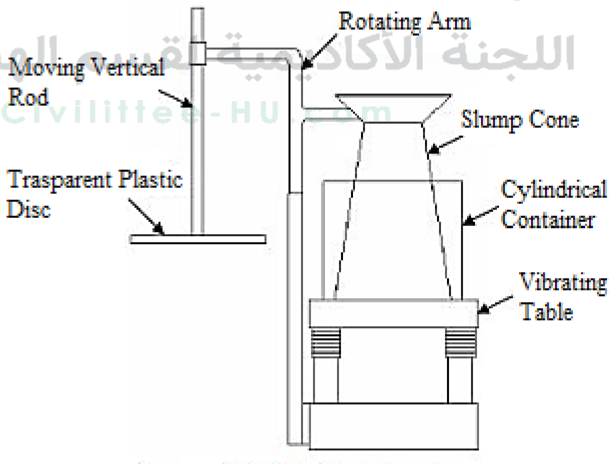


Fig. 16.1: Vebe Consistometer

16.5. Materials

Cement, Coarse Aggregate, Fine Aggregate and Mixing Water.

16.6. Theory

This test is based on measuring the time (Called VEBE time) needed to transfer the shape of a concrete mix from a frustum cone to a cylinder (these shapes are standardized by the apparatus of this test), by vibrating and compacting the mix.

The table below gives a description of the workability depending on the vebe time:

Table 16.1: Degree of concrete workability according to the vebe time

Degree of Workability	Compacting Factor
very low	20 - 40
Low	10 - 20
Medium	7 - 10
High	3 - 7
Very High	1 - 3

16.7. Procedure

1. Prepare a concrete mix as in slump test.
2. Slump test as described earlier is performed, placing the slump cone inside the sheet metal cylindrical pot of the Consistometer.
3. The glass disc attached to the swivel arm is turned and placed on the top of the concrete in the pot. The electrical vibrator is then switched on and simultaneously a stop watch started.
4. The vibration is continued till such a time as the conical shape of the concrete disappears and the concrete assumes a cylindrical shape. This can be judged by observing the glass disc from the top for disappearance of transparency.
5. Immediately when the concrete fully assumes a cylindrical shape, the stop watch is switched off. The time required for the shape of concrete to change from slump cone shape to cylindrical shape in seconds is known as VeBe Degree.
6. This method is very suitable for very dry concrete whose slump value cannot be measured by Slump Test, but the vibration is too vigorous for concrete with a slump greater than about 50 mm.

16.8. Report

- The vebe time of the tested concrete is --------------sec
- What is the workability degree of the tested concrete? Why?
- Is the Vebe test accurate to measure the workability of the tested concrete? Why?
- What is the expected slump and compacting factor values for the tested concrete?

Experiment 17

Flow Table Test of Hydraulic-Cement Concrete

17.1. Designation: BS1881: Part 105:1984

17.2. Introduction

Flow table test is a workability test for concrete conducted in laboratory by examining the flowing property of concrete, it is suitable for liquid concrete mixes having high and very high workability.

The 700 mm square flow table is hinged to a rigid base, proved with a stop that allows the far end to be raised by 40 mm. A cone, similar to that used for slump testing but truncated, is filled with concrete in two layers. Each layer is tamped 15 times with a special wooden bar and the concrete of the upper layer finished off level with the top of the cone. Any excess is cleaned off the outside of the cone. The cone is then raised allowing the concrete to flow out and spread out a little on the flow table. The table top is then raised until it meets the stop and allowed to drop freely 15 times. This causes the concrete to spread further, in a roughly circular shape. The flow diameter is the average of the maximum diameter of the pool of concrete and the diameter at right angles.

The flow test gives an indication of the cohesion. A mix that is prone to segregation will produce a non-circular pool of concrete. Cement paste may be seen separating from the aggregate. If the mix is prone to bleeding, a ring of clear water may form after a few minutes.

17.3. Scope

This test covers the determination of workability of concrete using a flow table, which determines the flow of concrete of high to very high workability.

17.4. Apparatus

1. Concrete Mixer
2. Flow Table; Fig.17.1

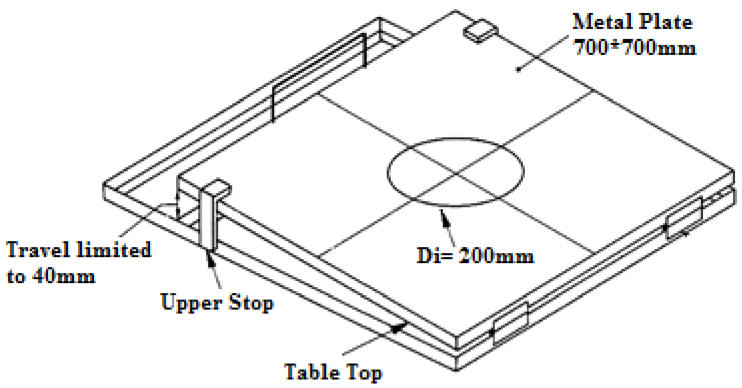


Fig. 17.1: Flow Table Apparatus

3. Mold made of metal; fig.17.2

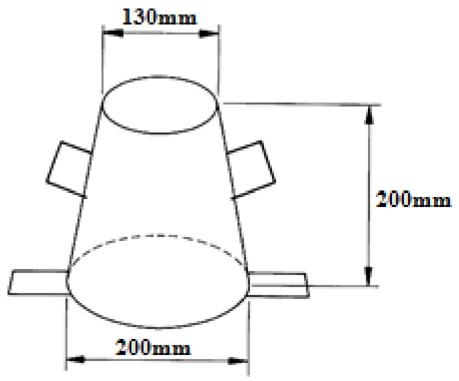


Fig. 17.2: Metal Mold

4. Tamping bar; made of hardwood; fig.17.3

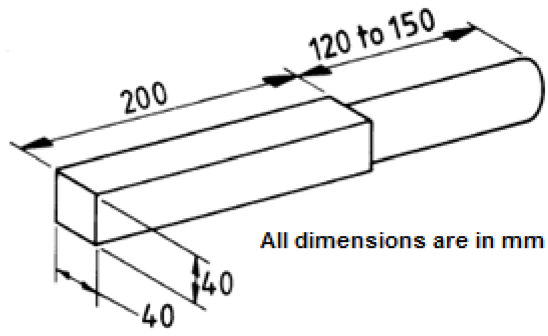


Fig. 17.3: Hardwood Tamping Bar

17.5. Materials

Cement, Coarse Aggregate, Fine Aggregate and Mixing Water.

17.6. Theory

The flow table test or flow test is a method to determine consistency of fresh concrete using table (700*700mm) and frustum cone (100*200*300mm). After testing, the concrete mix spreads approximately as a circle, and the maximum spread parallel to the two edges of the table is measured. The average of these two values, given to the nearest mm, represents the flow. A value of 400 mm indicates a medium workability, and 500 mm a high workability. See fig 16.4 and the related equation below:

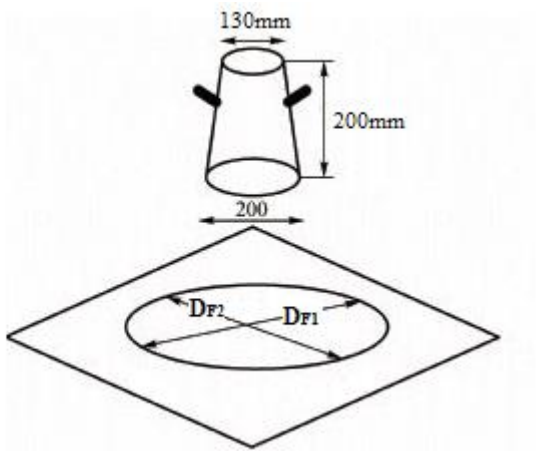


Fig 17.4: The flow diameters of the tested concrete

$$D_{Favg} = \frac{D_{F1} + D_{F2}}{2}$$

$$\text{Flow Factor} = \frac{D_{avg} - 20}{20} * 100\%$$

17.7. Procedure

1. Prepare a concrete mix as in slump test.
2. Moist the table top and the frustum of the cone.
3. Try lifting and dropping the table then, keep the table horizontal.
4. Hold the mold firmly in place and fill in two layers, each approximately one half the volume of the mold. Rod each layer with 10 strokes with the wooden tamper.
5. Before lifting the mould, excess concrete is removed, the surrounding table top is cleaned.
6. After an interval of 30 seconds, the mould is vertically, slowly removed within 3-6seconds.
7. The table top is lifted slowly and allowed to drop, avoiding a significant force against the stop, 15 times, each cycle taking not less than 3.5 and not more than 5 sec.
8. In consequence, the concrete spreads and the maximum spread parallel to the two edges of the table is measured.

17.8. Report

Table 17.1: Data and Results

Dimensions (cm)	Readings (mm)	Diameters (mm)		$D_{F\text{-}avg}$ (mm)	Flow Factor (%)
Table 70 x 70		D_{F1}			
D_i 20		D_{F2}			

- What is the workability degree of the tested concrete? Why?
- Is the Flow table test accurate to measure the workability of the tested concrete? Why?
- Depending on the cohesion, is the tested concrete mix is accepted or not?

Experiment 18

High Range Water Reducer Admixtures (Superplasticizers)

18.1. Designation: ASTM C 494/C 494M – 04

18.2. Introduction

Admixtures are the chemical compounds in concrete other than the hydraulic cement (OPC), water, aggregate, plus the mineral additives that are added to the concrete mix immediately before or during mixing to modify one or more of the specific properties of concrete in the fresh hardened state. The use of admixture should offer an improvement not economically attainable by adjusting the proportions of water, cement and aggregates, and should not adversely affect the performance of the concrete.

Superplasticizers are more recent and more effective type of water-reducing admixtures. These admixtures are principally surface reactive agent. They confer negative charge on individual cement particles such that they are kept in a dispersed or suspended state due to inter-particle repulsion; thus they confer high mobility to the particles. The result mix has a high workability; so flow table test used to do a check and values between 500 and 600mm are the typical ones without any segregation or bleeding.

Superplasticizers used to:

- Produce flowing concrete in situation where placing inaccessible without causing segregation or bleeding:
  superplasticizer raising the slump from 75mm to 200mm without using an excess of water.

- Production of very high strength concrete by reducing water to cement ratio while maintaining the workability at the desired level:
  the use of superplasticizer can result in a water reduction of 25 – 35%

- Produce concrete mix with reduced cement content:
  Superplasticizer can be used to produce concrete with reduced cement content while maintaining the water-cement ratio and workability at the required levels.

18.3. Scope

This test is concerned with studying the effect of addition of superplasticizer on the workability of concrete while maintaining the water-cement ratio at the required levels (without using any excessive water).

18.4. Apparatus

1. Concrete Mixer
2. Slump Apparatus
3. Flow Table Apparatus
4. Cubic Molds

18.5. Materials

Cement, Coarse Aggregate, Fine Aggregate, Mixing Water and Superplasticizer.

18.6. Theory

A super plasticizer is a material other than water, aggregates and cement used as an ingredient of concrete as well as added to the batch immediately before or during the mixing. In this experiment superplasticizer will be used to increase the workability of concrete without any effect on the strength; i.e. the water-cement ratio must be preserved with no change. Before mixing, a volume of water, which equals to the volume of superplasticizer that will be added to the mix, should be taken apart to insure that the water-cement ratio and then the strength of concrete are the same for both of concrete with and without admixture.

Slump test will be done to check the workability increasing, collapse slump is accepted in case of superplasticizer without segregation or bleeding. Flow table also must be done to check about segregation and bleeding, finally cubic specimens should be prepared to compare the strength with and without admixture which must be the same for both of them.

Super Plasticizers (IS 9103 – 1999) are used where a high degree of workability and its retention are required, where a delay in transportation or placing is required, or when high ambient temperatures cause rapid slump loss. The super plasticizers enable quicker placing and compaction of concrete. They also minimize the risk of segregation and bleeding; thus aids pumping of concrete.

18.7. Procedure

1. Prepare a concrete mix as in slump test without addition of superplasticizer, and then measure the slump value.

2. Prepare cubic molds from this batch to check about the strength of concrete. Have a look at the experiment No. 13.

3. Prepare a new mix to add the superplasticizer; add it before or during the mixing in the manner recommended by the manufacturer and in the amount necessary to comply with the applicable requirements of the specifications for water reduction.

   Note: make sure that the added volume of superplasticizer must be taken from the volume of water itself.

4. Measure the slump of this concrete mixture.

5. Make the flow table test to check about segregation and bleeding.

6. Prepare cubic molds from this batch to check about the strength of concrete with superplasticizer.

18.8. Report

- Compare the slump value for both mixtures with and without superplasticizer, which one is the greater and why?

- What is the slump type for both mixtures with and without superplasticizer? Are they accepted or not?

- Flow table test must be done in case of superplasticizer. Why?

- What is the result of flow table test? Is it accepted or not?

- The superplasticizer volume, that will be added to the mix, must be subtracted from the volume of mixing water. Why?

Experiment 19

Rebound Number of Hardened Concrete

19.1. Designation: ASTM C 805 – 02, BS 1881-202:1986

19.2. Introduction

This test is also known as the Schmidt hammer or impact hammer, and is a nondestructive method of testing concrete. The test is based on the principle that the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges. The main reason behind its popularity is its simplicity, rabidity, easiness, low cost and convenience of use for field applications.

The device consists of a plunger rod and an internal spring loaded steel hammer and a latching mechanism, have a look at fig 19.1. When the extended plunger rod is pushed against a hard surface, the spring connecting the hammer is stretched and when pushed to an internal limit, the latch is released causing the energy stored in the stretched spring to propel the hammer against the plunger tip. The hammer strikes the shoulder of the plunger rod and rebounds a certain distance. There is a slide indicator on the outside of the unit that records the distance traveled during the rebound. This indication is known as the rebound number. By pressing the button on the side of the unit, the plunger is then locked in the retracted position and the rebound number (R-number) can be read from the graduated scale. A higher R-number indicates a greater hardness of the concrete surface.

The tests can be performed in horizontal, vertically upward, vertically downward or any intermediate angled positions in relation to the surface. The devices are furnished with correlation curves by the manufacturer. ASTM C805 now states that these references to the relationship between the rebound number and compressive strength provided by the manufacturer "*shall be used only to provide indications of relative concrete strength at different locations in a structure*."

ASTM C805 states that this method is applicable for the following uses:
- To assess the in-place uniformity of concrete
- To delineate regions in a structure of poor quality or deteriorated concrete
- To estimate in-place strength if a correlation is developed

Factors affect the test results:
- Surface Smoothness – The surface texture significantly affects the R-number obtained. Tests performed on a rough-textured finish will typically result in crushing of the surface paste, resulting in a lower number. Alternately, tests performed on the same concrete that has a hard, smooth texture will typically result in a higher R-number.
- Age of Concrete – Concrete continues to develop strength with age due to cement hydration.
- Moisture Content – Dry concrete surfaces result in higher rebound numbers than wet surfaces.
- Surface Carbonation – With greater amounts of surface carbonation, higher rebound numbers will be obtained.
- Aggregate, air voids, and steel reinforcement – If the test is performed over a hard aggregate particle or a section of steel reinforcement, the result may be an unusually high rebound number. Otherwise, if it is performed over air voids, the result will be low number.
- Temperature – Tests should not be performed on frozen concrete surfaces. Wet concrete at temperatures of 0ºC or less may result in higher rebound numbers.

19.3. Scope

This test method covers the determination of a rebound number of hardened concrete using a spring-driven steel, to make an estimation for the strength using correlation curves provided by the manufacturer.

19.4. Apparatus

1. Rebound Hammer, see fig. 19.1

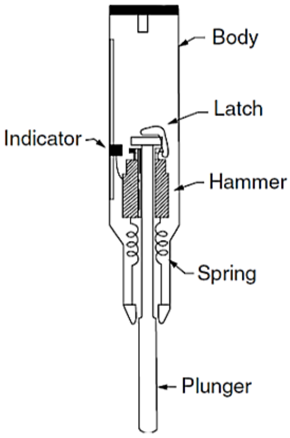


Fig 19.1: Rebound Hammer Apparatus

2. Abrasive Stone, consisting of medium-grain texture silicon carbide or equivalent material.

19.5. Materials

Hardened concrete with least 100 mm thick and 150mm in diameter, and fixed within a structure. Smaller specimens must be rigidly supported. Areas exhibiting honeycombing, scaling, rough texture, or high porosity should be avoided.
In our experiment, cubic specimens of hardened concrete will be used.

19.6. Theory

Take ten readings and discard readings differing from the average of 10 readings by more than 6 units and determine the average of the remaining readings. If more than 2 readings differ from the average by 6 units, discard the entire set of readings. Use the final average to convert from rebound number to compressive strength using correlation curves provided by the manufacturer.

19.7. Procedure

1. Use the abrasive stone to ground heavily textured, soft, or surfaces with loose mortar.
2. Firmly hold the instrument in a position that allows the plunger to strike perpendicularly to the surface tested. Gradually increase the pressure on the plunger until the hammer impacts.
3. After impact, record the rebound number.
4. Take ten readings from each test area. No two impact tests shall be closer together than 25 mm.

19.8. Report

Table 19.1: Readings of rebound number

Reading #	1	2	3	4	5	6	7	8	9	10
Re #										

- Describe the tested sample (shape, dimensions, and whether the surfaces require smoothing or not).
- Find the final modified average of the rebound number.
- Find the related approximate strength using correlation curves provided by the manufacturer.

Experiment 20

Velocity of Ultrasonic Pulses in Concrete

20.1. Designation: ASTM C597 - 09, BS 1881: Part 203:1986

20.2. Introduction

An ultrasonic pulse velocity (UPV) test is a nondestructive test to check the quality of concrete. In this test, the strength and quality of concrete is assessed by measuring the velocity of an ultrasonic pulse passing through a concrete structure.

This test is conducted by passing a pulse of ultrasonic through concrete to be tested and measuring the time taken by pulse to get through the structure. Higher velocities indicate good quality and continuity of the material, while slower velocities may indicate concrete with many cracks or voids.

Ultrasonic testing equipment includes a pulse generation circuit, consisting of electronic circuit for generating pulses and a transducer for transforming electronic pulse into mechanical pulse, and a pulse reception circuit that receives the signal, have a look at fig 20.1. After calibration to a standard sample of material with known properties (calibration base), the transmitting and receiving transducers are placed on opposite sides of the material, the transit time T is measured electronically. The pulse velocity V is calculated by dividing L by T.

Ultrasonic Pulse Velocity can be used to:

- Evaluate the quality and homogeneity of concrete materials
- Predict the strength of concrete
- Estimate the depth of cracks in concrete.
- Detect internal flaws, cracks, honeycombing, and poor patches.

20.3. Scope

This test method covers the determination of the propagation velocity of longitudinal stress wave pulses through concrete.

20.4. Apparatus

1. Pulse Velocity Apparatus, shown schematically in Fig. 20.1, consists of a pulse generator, a pair of transducers (transmitter and receiver), an amplifier, a time measuring circuit, a time display unit, and connecting cables.

2. Reference bar for checking zero (Calibration base).

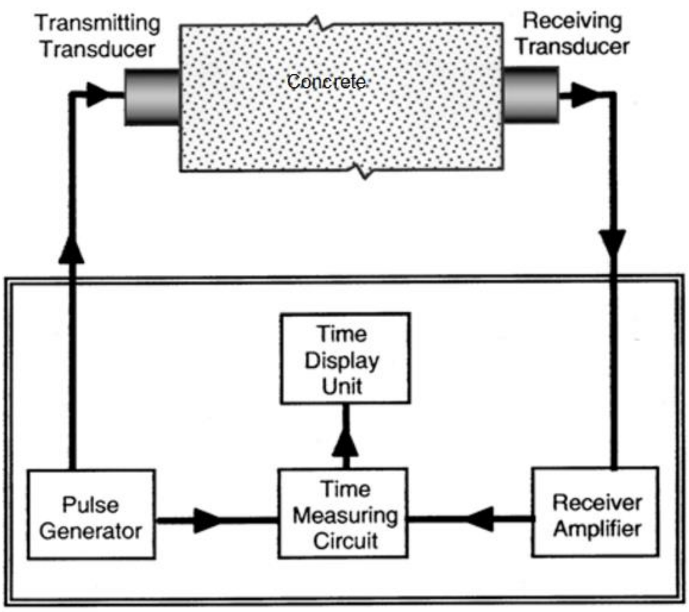


Fig 20.1: Schematic of Pulse Velocity Apparatus

20.5. Materials

Hardened concrete; In our experiment, cubic specimens of hardened concrete will be used.

20.6. Theory

Take 8 readings (the time the waves need to pass from the transmitter to the receiver through the concrete), then calculate the average time (μsec).

Calculate the pulse velocity as follows:

$$\text{Pulse velocity } \left[\frac{\text{m}}{\text{sec}}\right] = \frac{\text{width of structure (distance between transducers)[m]}}{\text{average of time taken by pulse to go through [sec]}}$$

20.7. Procedure

1. Connect the cables of the transmitting and receiving transducers to the UPV apparatus and turn it on.
2. Check the accuracy of measurement using the reference bar, by applying coupling agent (petroleum jelly, grease, soft soap or kaolin/glycerol paste) to the ends of the reference bar, and press the transducers firmly against the ends of the bar until a stable transit time is displayed. Adjust the zero reference until the displayed transit time agrees with the value marked on the bar.
3. Grease the surfaces of the transducers with a thin layer of the coupling agent.
4. Press the transducers firmly against the surfaces of the structure (cube); locate the transducers directly opposite each other. Continue pressing until the time indicator gives a constant reading.
5. Record the reading in microseconds, t.
6. Measure the direct distance between the centers of the transducers locations.

20.8. Report

Table 20.1: Readings of ultrasonic pulse time

Reading #	1	2	3	4	5	6	7	8
T (μsec)								

- Calculate the average time

- Calculate the pulse velocity

- Do you think there are any cracks or internal flaws through the tested structure (cube)? Why?

Experiment 21

The Compressive Strength of Cubic Concrete Specimens

21.1. Designation: BS 1881-116: 1983

21.2. Introduction

Of the various strengths of concrete, the determination of compressive strength has received a large amount of attention because the concrete is primarily meant to withstand compressive stresses. The compressive strength consists of applying a compressive axial load to molded cubes at a rate which is within a prescribed range until failure occurs. The compressive strength is calculated by dividing the maximum load attained during the test by the cross sectional area of the specimen. The used cubes are usually of 100mm or 150mm side. The specimens are cast, cured and tested by standards prescribed for such tests.

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

The strength of concreted affected by:

- Quality of raw materials
- Mix design: water to cement ratio, coarse to fine aggregate ratio and cement to aggregate ratio
- Compaction of concrete
- Age of concrete
- Rate of loading
- Moisture condition
- Specimen size
- Curing condition

21.3. Scope

This test method describes the method for determining the compressive strength of concrete cubes.

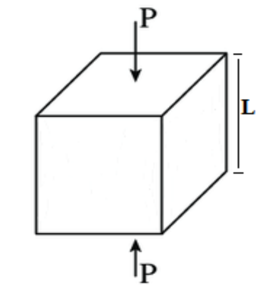
21.4. Apparatus

Testing Machine has a rate within the range of (0.2 $N/mm^2.s$ to 0.4 $N/mm^2.s$)

21.5. Materials

Cubic specimens of hardened concrete; 150 mm size or 100mm.

21.6. Theory



$$\sigma = \frac{P}{A}$$

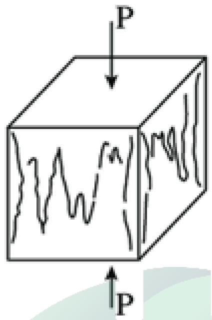
$$\sigma = \frac{P}{L^2}$$

Where:
σ: compressive strength, MPa
P: maximum applied load indicating by testing machine, N
L: dimension of cube, mm

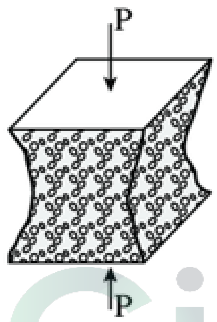
Type of failure
Refer to table 21.1 for examples of satisfactory and un-satisfactory failures.

Table 21.1: Satisfactory failure and some of un-satisfactory failures

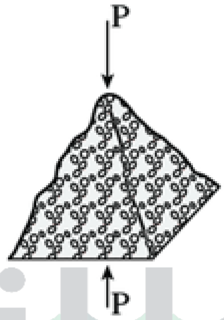
Satisfactory Failure



Non-Explosive

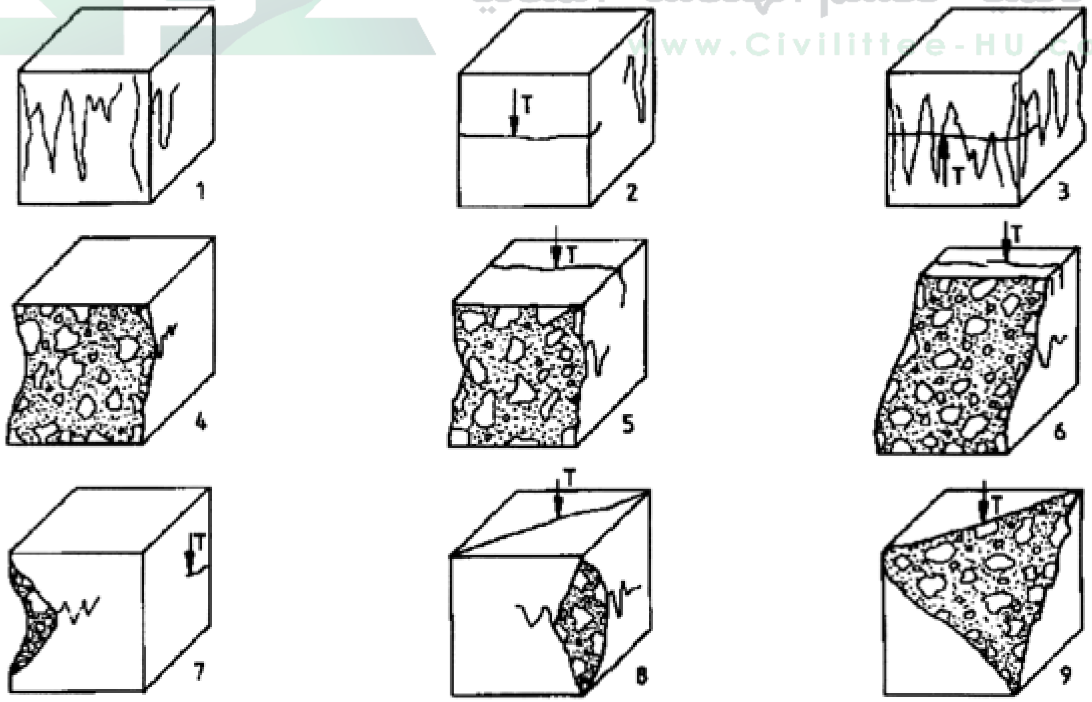


Non-Explosive



Explosive

Un-Satisfactory Failure



NOTE Unsatisfactory failures are usually caused by insufficient attention to the detail of the various procedures that have to be followed to make and test the specimens. For example, unsatisfactory failure may be due to the cubes being badly made, the use of molds that do not comply with the specification, or mis-placement of the cubes in the testing machine. It is also possible for a machine fault to be the cause of unsatisfactory failure.

21.7. Procedure

1. Take cubes from water bath and dry them to SSD.
   Note: When the cubes are surface dry, or have not been cured in water, immerse them in water, for a minimum of 5 minutes, before testing. They must be tested while they are still wet.
2. Ensure that all testing machine bearing surfaces are wiped clean.
3. Carefully center the cube on the lower platen and ensure that the load will be applied to two opposite cast faces of the cube.
4. Without shock, apply and increase the load continuously at a nominal rate within the range of (0.2 $N/mm^2.s$ to 0.4 $N/mm^2.s$) until no greater load can be sustained. On manually controlled machines, as failure is approached, the loading rate will decrease, at this stage operate the controls to maintain, as far as possible, the specified loading rate. Record the maximum load applied to each cube.
5. Observe the shape of failure.

21.8. Report

- Calculate the cross-sectional area of the cube face from the checked nominal dimensions.
- Calculate the compressive strength for each cube by dividing the maximum load by the cross-sectional area.
- Calculate the average for the three cubes.
- What is the type of failure? Record any unusual feature in the type of failure. Refer to table 21.1.

Experiment 22

The Compressive Strength of Cylindrical Concrete Specimens

22.1. Designation: ASTM C39/C39M-18

22.2. Introduction

The compressive strength of the concrete cylinder is one of the most common performance measures performed by the engineers in the structural design. Here, the compressive strength of concrete cylinders is determined by applying continuous load over the cylinder until failure occurs. The test is conducted on a compression-testing machine. The used cylinders are usually of 150mm diameter by 300mm height. When cylinders are used, they have to be suitably capped before the test, an operation not required when other types of specimens are tested. For this test method, the test age shall start at the beginning of casting specimens.

The compressive strengths given by different specimens for the same concrete mix are different. The cylinders of a ratio of height to diameter of 2 may give a strength of about 75 to 85% of the cube strength.

22.3. Scope

This test method covers determination of compressive strength of cylindrical concrete specimens.

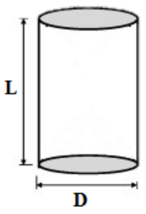
22.4. Apparatus

Testing Machine — with a constant rate of 0.25 MPa/sec [35 Psi/s].

22.5. Materials

Cylindrical specimens of hardened concrete; 150 mm× 300 mm or 100 mm× 200 mm

22.6. Theory



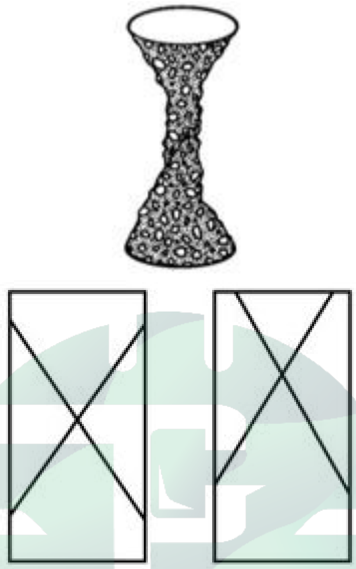
$$\sigma = \frac{P}{A}$$

$$\sigma = \frac{P}{\pi r^2}$$

Where:
σ: compressive strength, MPa
P: maximum applied load indicating by testing machine, N
D: diameter of cylinder, mm
r: radius of cylinder, mm
L/D should be ≥ 2

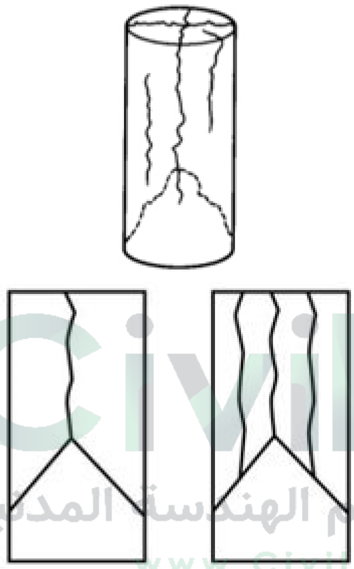
Types of failure

Refer to fig. 22.1 for the typical types of failure.



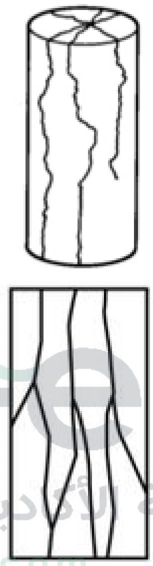
Type 1: Shear

Reasonably well-formed cones on both ends, less than 1in. [25mm] of cracking through caps



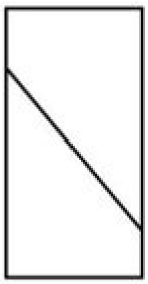
Type 2: Shear and Split

Well-formed cone on one end, vertical cracks running through caps, no well-defined cone on other end

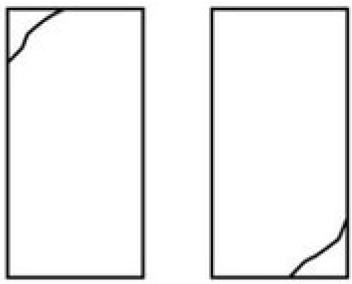


Type 3: Splitting

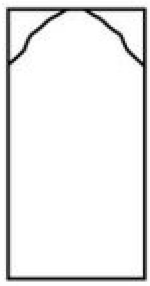
Columnar vertical cracking through both ends, no well-formed cones



Type 4
Diagonal fracture with no cracking through ends; tap with hammer to distinguish from type 1



Type 5
Side fractures at top or bottom (occur commonly with un-bonded caps)



Type 6
Similar to type 5 but end of cylinder is pointed

Fig. 22.1: Schematic of typical fracture patterns

22.7. Procedure

1. Remove the cylindrical samples from the curing tank and wipe out the excess water from the surface of the specimen using an absorbent cloth. Ensure that the cylinder is saturated surface dry; the specimens shall be tested in the moist condition.

2. Prepare the top unsmooth surface of the cylinder, and place it vertically in the machine.
   Note: Uniform load application and distribution is facilitated by having pad caps at the ends of the cylinders.

3. Before starting to apply the load, make it sure that the loading platforms touch the top of the cylinder.

4. Load the specimen gradually and continuously at a constant rate of 0.25 MPa/sec [35 Psi/s].

5. Continue loading until specimen breaks. Record the load at failure, P.

6. Observe the shape of failure. Discard cylinders that show incorrect failure patterns.

22.8. Report

- Calculate the cross-sectional area of the cylinder face from the checked dimensions.

- Calculate the compressive strength for each cylinder by dividing the maximum load by the cross-sectional area.

- Calculate the average for the three cylinders.

- What is the failure pattern? Record any incorrect feature in the type of failure. Refer to fig 22.1.

Experiment 23

Splitting Tensile Strength of Cylindrical Concrete Specimens

23.1. Designation: ASTM C 496/C 496M – 04

23.2. Introduction

The tensile strength of concrete is one of the basic and important properties which greatly affect the extent and size of cracking in structures. Direct and indirect methods are used to determine it. The direct methods suffer from a number of difficulties related to:

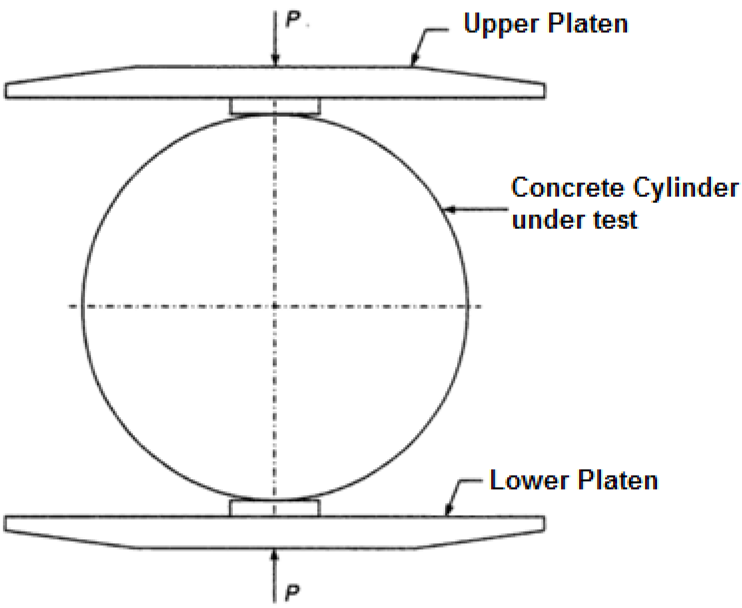
- Holding the specimen properly in the testing machine: due to grips there is a tendency for specimen to break at its ends.
- The application of true uniaxial tensile load; there will be always some eccentricity present.

Because of these difficulties, a number of indirect methods have been developed to determine the tensile strength. The splitting test is one of these tests that are used for determining indirectly the tensile strength by applying a compressive force to a concrete specimen in such a way that the specimen fails due to tensile stresses induced in the specimen; as shown in fig.23. B.

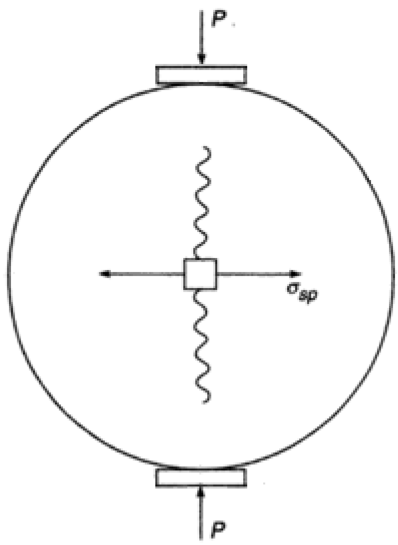
This test method consists of applying a compressive force along the length of a concrete cylinder placed with its axis horizontal between the platens of the compression testing machine, as shown in fig.23.1. A. This loading induces tensile stresses on the plane containing the applied load and relatively high compressive stresses in the area immediately around the applied load. Tensile failure occurs rather than compressive failure because the areas of load application are in a state of triaxial compression, thereby allowing them to withstand much higher compressive stresses than would be indicated by a uniaxial compressive strength test result. At least three specimens, preferably from different batches, shall be made for testing at each selected age.

This test is becoming very popular because of the following advantages:

- The test is simple to perform and gives more uniform results than that given by other tests.
- The strength determined is closer to the actual tensile strength of concrete than the modulus of rupture value (modulus of rupture will be discussed in the next experiment; experiment 24).
- The same molds and testing machine can be used for compression and tension tests.



(A)



(B)

Fig.23.1: Loading arrangement for split strength determination

23.3. Scope

This test method covers the determination of the splitting tensile strength of cylindrical concrete specimens.

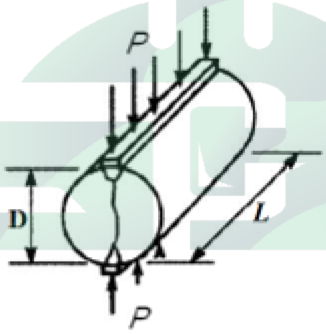
23.4. Apparatus

1. Compression Testing Machine — with a constant rate within the range 100 to 200 psi/min [0.7 to 1.4 MPa/min] splitting tensile stress.
2. Supplementary Bearing Bar or Plate — If the diameter or the largest dimension of the upper bearing face or the lower bearing block is less than the length of the cylinder to be tested, a supplementary bearing bar or plate of machined steel shall be used.

23.5. Materials

Cylindrical specimens of hardened concrete; 150 mm× 300 mm or 100 mm× 200 mm

23.6. Theory



$$\sigma sp = \frac{2P}{\pi DL}$$

Where:

σ_{sp}: splitting tensile strength, MPa

P: maximum applied load indicating by testing machine, N

D: diameter of cylinder, mm

L: length of cylinder, mm

Failure Type

2 Splits with the direction of the compression load plane, as shown in fig 23.2.

Fig.23.2: Typical splitting fracture pattern

23.7. Procedure

3. Remove the cylindrical samples from the curing tank and wipe out the excess water from the surface of the specimen using an absorbent cloth. Ensure that the cylinder is saturated surface dry; the specimens shall be tested in the moist condition.

4. Draw diametrical lines on two ends of the specimen so that they are in the same axial plane.

5. Determine the length of the cylinder by taking at least two measurements. Record the average as the length of the sample. Also determine the diameter of specimen by averaging the diameters of the specimen lying in the plane of premarked lines.

6. Place the specimen in the testing machine or between the supplementary Bearing Plates. The assembly is positioned to ensure that lines marked on the end of specimen are vertical and the projection of the plane passing through these two lines interest the center of the platen.

5. Load the specimen gradually and continuously at a constant rate of 100 to 200 psi/min [0.7 to 1.4 MPa/min] splitting tensile stress.

6. Continue loading until specimen breaks. Record the maximum load applied to specimen, P.

7. Observe the shape of failure and any unusual feature in the type of failure.

23.8. Report

- Determine the average length and average diameter of the specimens.
- Calculate the splitting tensile strength for each cylinder.
- Calculate the average strength for the three cylinders.
- What is the failure pattern? Record any incorrect feature in the type of failure. Refer to fig 23.2.

Experiment 24

The Flexural strength of Hardened Concrete Specimens

24.1. Designation: ASTM C 78 – 02, ASTM C 293 – 02

24.2. Introduction

Flexural test evaluates the tensile strength of concrete indirectly, since it is difficult to determine the tensile strength of concrete by conducting a direct tension test. The results of flexural test on concrete expressed as a modulus of rupture which denotes as (R) in MPa or psi. At least three specimens, preferably from different batches, shall be made for testing at each selected age.

This test is important to estimate the load at which the concrete members may crack using either third point loading test or central point loading test, the configuration of each test is shown in figure 24.1 and figure 24.2 respectively.

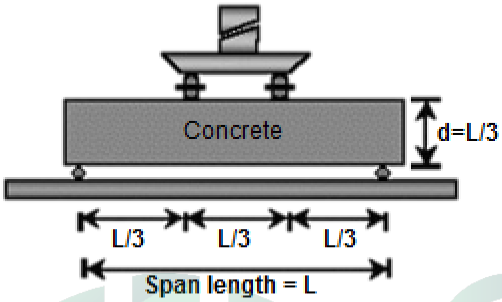


Fig.24.1: Third Point Loading Test

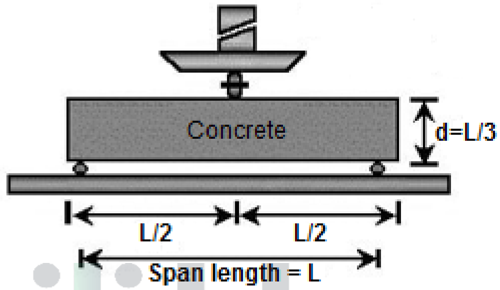
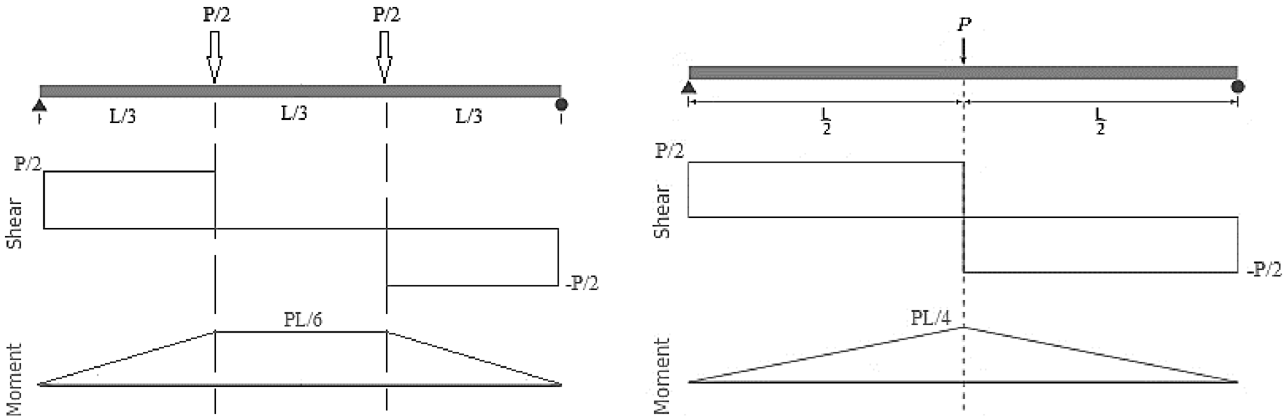


Fig.24.2: Central Point Loading Test

The center-point flexural test results are somewhat higher than the third-point test results, due to the following reasons: (referring to figure 24.3)

- It can be observed that in three-point loading case the middle (L/3) part of beam is subjected to maximum bending moment while in center point loading case only mid-point is subjected to maximum bending moment, and this point may or may not be the weakest point in the beam. Now, the possibility of weaker concrete in flexure in a span of L/3 is, of course, much higher than just at a point.
- The entire middle one-third of the beam is exposed to pure moment where shear is zero, but in central method the mid-point exposed to moment with shear which increases its strength value.



(A) **(B)**

Fig.24.3: Shear and Moment diagram for both Third Point Loading Test (A) and Central Point Loading Test (B)

24.3. Scope

This test method covers the determination of the flexural strength of hardened concrete specimens.

24.4. Apparatus

Testing Machine capable of applying loads at a uniform rate without interruption of shocks — the required rate is (3870 – 5445 MN/min) for 150mm specimen and (1720 – 2420 MN/min) for 100mm specimens.

In our experiment the testing machine is: Computerized Universal Testing Machine (UTM)

24.5. Materials

Beams or prisms of hardened concrete; 150 mm× 150 mm× 750 mm or 100 mm× 100 mm× 500 mm.

NOTE The preferred size of test specimen is 150 mm× 150 mm× 750 mm long.

24.6. Theory

24.6.1. Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

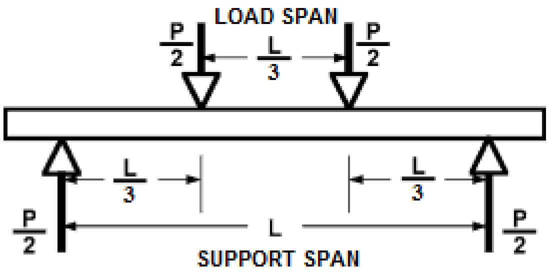


Fig 24.4: Third-Point Loading Diagram

24.6.1.1. If the fracture initiates in the tension surface within the middle third of the span length, calculate the modulus of rupture as follows:

$R = PL/bd^2$

where:

R = modulus of rupture, psi, or MPa,

P = maximum applied load indicated by the testing machine, lbf, or N,

L = span length, in., or mm, b = average width of specimen, in., or mm, at the fracture, and

d = average depth of specimen, in., or mm, at the fracture.

24.6.1.2. If the fracture occurs in the tension surface outside of the middle third of the span length by not more than 5 % of the span length, calculate the modulus of rupture as follows:

$R = 3Pa/bd^2$

where:

a = average distance between line of fracture and the nearest support measured on the tension surface of the beam, in., (or mm).

24.6.1.3. If the fracture occurs in the tension surface outside of the middle third of the span length by more than 5 % of the span length, discard the results of the test.

24.6.2. Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading)

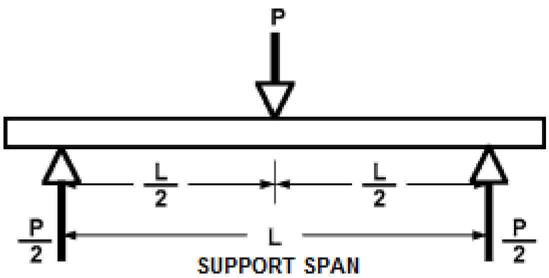


Fig 24.5: Center-Point Loading Diagram

Calculate the modulus of rupture as follows:

$R = 3\ PL/2bd^2$

where:

R = modulus of rupture, psi, or MPa,

P = maximum applied load indicated by the testing machine, lbf, or N,

L = span length, in., or mm, b = average width of specimen, at the fracture, in., or mm, and

d = average depth of specimen, at the fracture, in., or mm.

Failure Type:
2 parts with the direction of the applied load

Fig.24.6: Typical flexural fracture pattern

24.7. Procedure

1. 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.

   Note Flexural tests of moist-cured specimens shall be made directly after removal from moist storage. Surface drying of the specimen results in a reduction in the measured flexural strength.

2. Center the specimen on the support blocks in such a manner that the load shall be applied to the uppermost surface as cast in the mould. No packing shall be used between the bearing surfaces of the specimen and the rollers.

3. Bring the load-applying blocks in contact with the surface of the specimen and apply the load continuously without shock, the load shall be applied at a constant rate of loading of (3870 – 5445 MN/min) for 150mm specimen and (1720 – 2420 MN/min) for 100mm specimens until rupture occurs.

4. Record the maximum load applied to the specimen during the test.

5. Note the appearance of the fractured faces of concrete and any unusual features in the type of failure.

24.8. Report

24.8.1. Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

- Calculate the modulus of rupture for each beam.

- Calculate the average modulus of rupture for the three beams.

- What is the failure pattern and the position of the fracture? Record any incorrect feature in the type of failure. Refer to fig 24.3.

24.8.2. Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading)

- Calculate the modulus of rupture for each beam.

- Calculate the average modulus of rupture for the three beams.

- What is the failure pattern? Record any incorrect feature in the type of failure. Refer to fig 24.6.

- Compare the result of the center point-method with the result of the third-point method.

- Which one is more accurate, center-point method or third-point method? Why?

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