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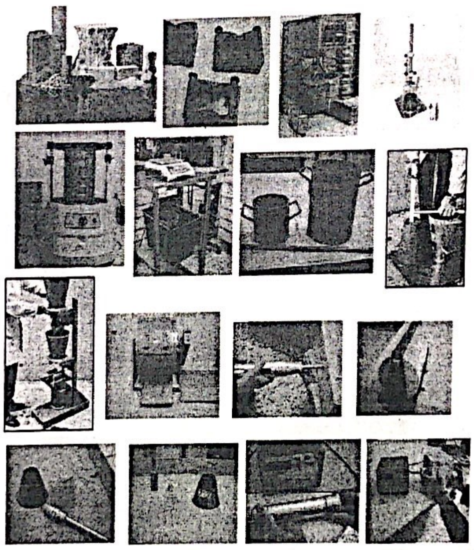


Building Materials Laboratory Manual

هذا التلخيص لا يغني عن شرح المختبر والتقارير

Experiment # 1: DETERMINATION OF CONSISTENCY OF CEMENT PASTE

American Association State Highway and Transportation Officials Standard AASHTO No.: T 129Designation: C 187 – 98

Standard consistency of a cement paste is defined as that consistency which will permit a vicat plunger having 10 mm dia and 50 mm length to penetrate to a depth of 10±1 mm from top of the mould in 30 second.

Cement paste of standard consistency is to be used for the determination of cement initial and final setting times; soundness; and tensile and compressive tests. This experiment can be performed according to MS 522.1977, BS 4550: Part 3 and EN 1063:1987. The following experiment will be performed according to MS 522.1977.

The objective of this experiment is to determine the required amount of water to be added to acertain amount of cement to achieve a cement paste of normal or standard consistency.

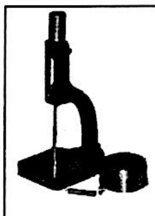
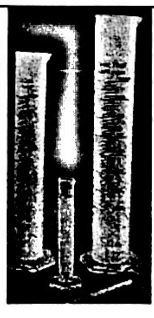
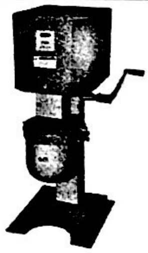
The temperature of the air in the vicinity of the mixing slab, the dry cement, molds, and base plates shall be maintained between 20 and 27.5°C.

The temperature of the mixing water shall not vary from 23.0°C (23 ± 2 °C).

The relative humidity of the laboratory shall be not less than 50 %.

Apparatus and Equipments

- VICAT Apparatus with Plunger of 10mm diameter and 50mm length.
- Conical mold
- Base plate
- scale
- Glass graduates
- Mixer
- Stop watch

						
VICAT Apparatus with Plunger of 10mm diameter	Conical mold	Glass plate	Scale	Glass graduated	mixer	Towel

Materials

- Cement (650 g)
- Water

To calculate the amount of water make try and error to reach water cement ratio (w/c %) penetrate the sample 10 mm and water cement ratio between 26-33 %.

Assume w/c =	Cement (g)	Water (ml)	Penetration (mm)
26 %	650	**169**	3
28 %	650	**182**	4
30 %	650	**195**	14

w/c % = 26 %

w/650 =26/100 → w= 169 ml

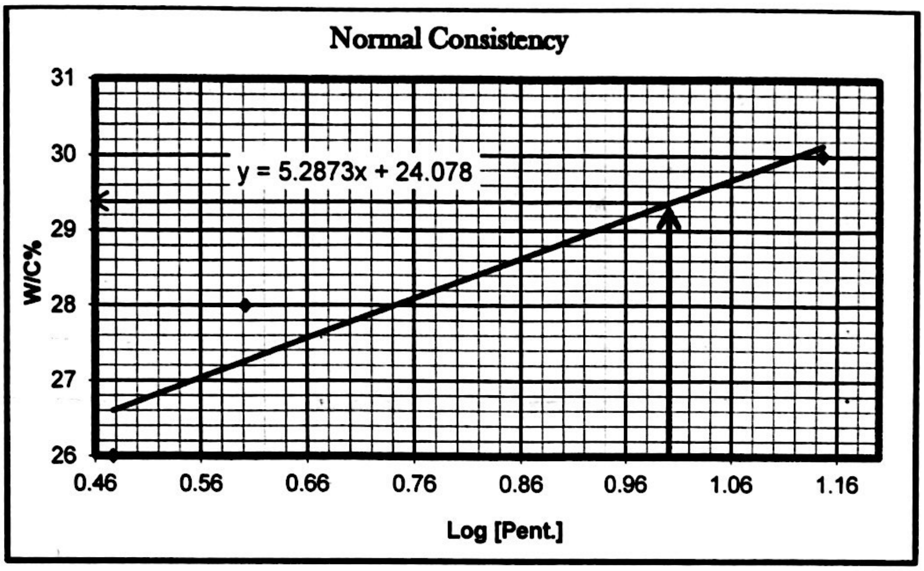
@ w/c % equal 26% the penetration is 3 mm, you should rise the w/c % to obtained penetration equal 10mm therefore try w/c % equal 28%.

Also @ w/c % equal 28% ,the penetration is 4 which is less than 10 mm therefore we will choose higher percentage ,for example 30% .

At w/c%= 30% the penetration is 14 mm which larger than 10 that is ok.

Example:

Wt. of Water (g)	W/C %	Penetration (mm)	Log (Pent.)
169.0	26.0	3	0.48
182.0	28.0	4	0.60
195.0	30.0	14	1.15



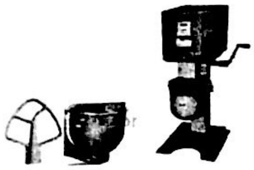
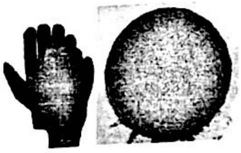
N.C.	W/C%	29.4	%
	Water	190.9	g

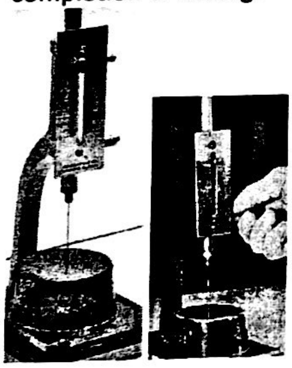
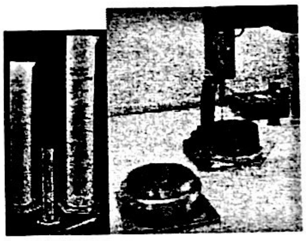
At penetration 10 mm (1 on the log scale) the water cement ratio is 29.4 that's mean the water quantity is 190.9 ml that use in *setting time experiment*.

Setting time of cement:

When cement is mixed with water, it hydrates and makes cement paste. This paste can be moulded 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.

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 a 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. 	10- 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. 

Experiment # 2: Setting time of hydraulic cement

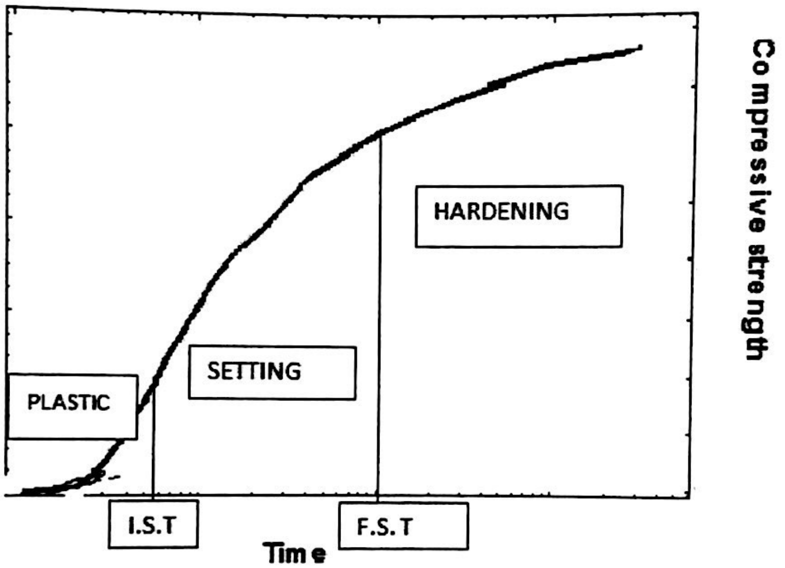
American Association State Highway and Transportation Officials Standard AASHTO No.: T131

ASTM C 266: Time of Setting of Hydraulic-Cement Paste by Gillmore Needles

Setting time of cement: When cement is mixed with water, it hydrates and makes cement paste. This paste can be moulded 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.

Standard Test Methods

- AASHTO T 131 and ASTM C 191: Time of Setting of Hydraulic Cement by Vicat Needle
- ASTM C 266: Time of Setting of Hydraulic-Cement Paste by Gillmore Needles



Initial Setting time of Cement:-

The time to which cement can be moulded in any desired shape without losing it strength is called Initial setting time of cement

Or

The time at which cement starts hardens and completely loses its plasticity is called Initial setting time of cement.

Or

The time available for mixing the cement and placing it in position is an Initial setting time of cement. If delayed further, cement loses its strength.

Final setting time of Cement:-
The time at which cement completely loses its plasticity and became hard is a final setting time of cement.
Or
The time taken by cement to gain its entire strength is a Final setting time of cement.

Temperature & Humidity: The temperature of the air in the vicinity should be between 20-27.5 °C. The temperature of the mixing water should be 23±2 °C. The relative humidity of the laboratory should not be less than 50%.

Factors that affect initial and final setting time of cement:-
The type of cement , water type, water cement ratio, standard procedure & atmospheric conditions. For example, cement requires a temperature of 27°c to complete Hydration, during winters the climate is low which stops the hydration and takes a longer time to set harden.

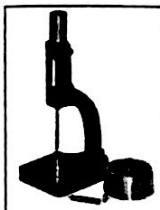
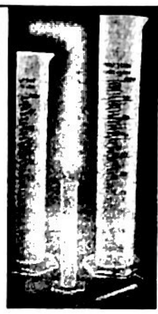
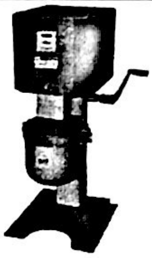
The Vicat initial time of setting is calculated as the time elapsed between the initial contact of cement and water and the time when the penetration is at 25 mm.

The Vicat final time of setting is calculated as the time elapsed between initial contact of cement and water and the time when the needle does not sink visibly into the paste. (F.S.T=90+1.2(I.S.T)).

Test Method	Set Type	Time Specification
Vicat	Initial	≥ 45 minutes
	Final	≤ 375 minutes
Gillmore	Initial	≥ 60 minutes
	Final	≤ 600 minutes

Apparatus and Equipments

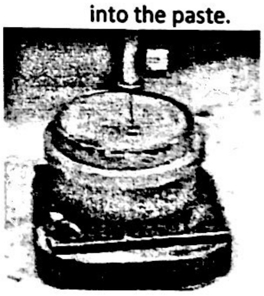
- VICAT Apparatus with needle of 1mm diameter and 50mm length.
- Conical mold
- Base plate
- scale
- Glass graduates
- Mixer
- Stop watch
- Trowel

						
VICAT Apparatus with Plunger of 10mm diameter	Conical mold	Glass plate	Scale	Glass graduated	mixer	Trowel

Materials

- **Cement (650 g)**
- **Water (** The amount of water that achieves the ratio of water to cement) – amount of water that calculated in normal consistency test .

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. 

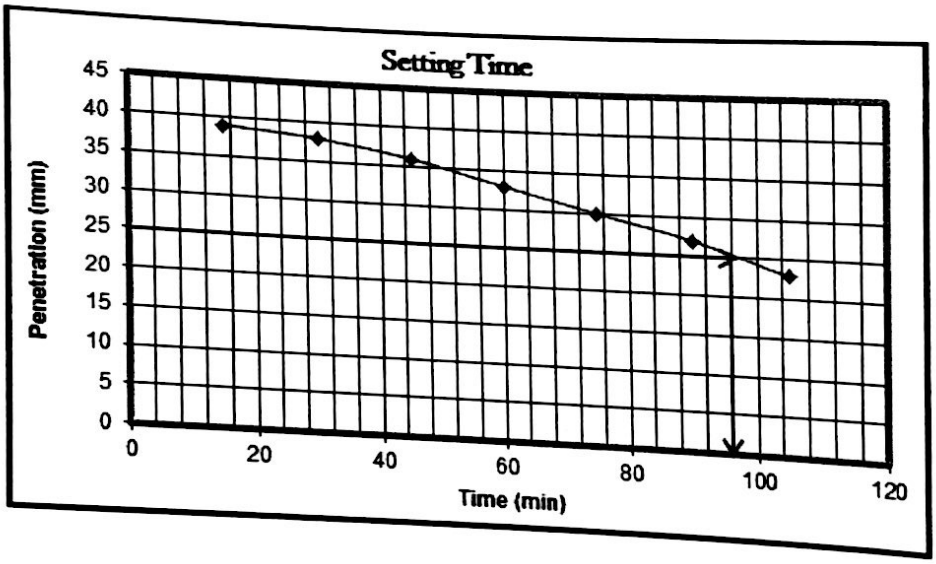
Example:

Initial and Final Setting Time

Wt. of Cement = 650 W/C% = 29.4 Water =190.9

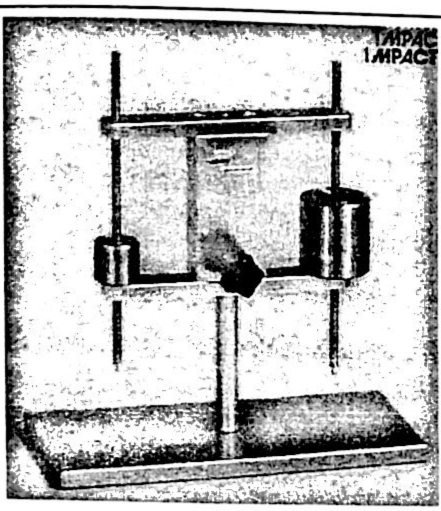
Table :variation of penetration with time

Time (min)	Penetration (mm)
15	39
30	38
45	36
60	33
75	30
90	27
105	23



I.S.T= 96

F.S.T= 90+1.2(96)=205.2



The Gillmore Apparatus is used to determine the setting time of cement.

The vertical support shaft has a device to maintain the horizontal arms in alignment. The support assembly is adjustable. The two steel needle weights are calibrated to meet specifications. The needle points are manufactured from stainless steel. The initial setting needle is 2.12 mm in diameter and weighs 115 g. The final setting needle is 1.06mm in diameter and weighs 450g.

Experiment #3: Compressive and Tensile Strength of Cement Mortar

Compressive strength or compression strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate. In other words, compressive strength resists compression (being pushed together), whereas tensile strength resists tension (being pulled apart). In the study of strength of materials, tensile strength, compressive strength, and shear strength can be analyzed independently.

I- Compressive Strength of Hydraulic Cement Mortars

Hydraulic Cement Mortars are typically formed by a combination of cement, sand, and water, but may include a variety of other materials in the mix. The strength of the final mortar is strongly dependent on the type of materials and the ratio of the components, and testing is required to determine the correct proportions for each application.

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

Apparatus and Equipments

- Balance
- Glass Graduate .
- Specimens molds: three cubes of (50mm) side.
- Mixer with paddle and mixing bowl
- Testing machine.
- Tamper and trowel & brush for oiling

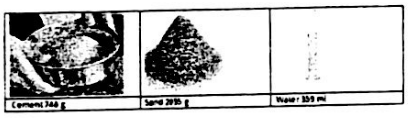
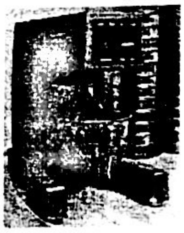
							
Balance	Glass Graduate	Specimens molds: three cubes of (50mm) side.	Mixer with paddle and mixing bowl	Testing machine.	Tamper	trowel	brush

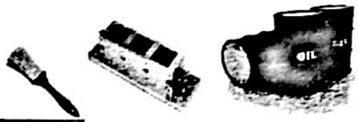
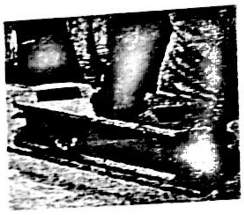
Materials

The percentage is (cement: sand: water = 1 : 2.75 : 0.485)

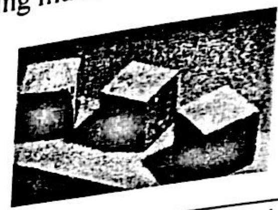
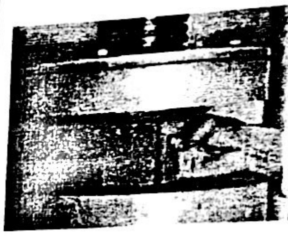
- Cement (740 g)
- Water (2035 g)
- Sand (359 ml)
- Oil for Lubricating molds

Procedure

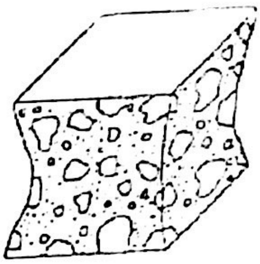
Preparation of mortar		
1. Prepare the quantities of standard mortar components to satisfy thatC:S:W=1:2.75:0.485, where cement= 740g, sand= 2035g, and water= 359ml for making 9 specimens 	2. Place the mixing water in the bowl of the mixer, then add the cement and allow 30s for the absorption of water. 	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. 		

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 (complete the 4 rounds in one cube before the going to the next one). 
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). 

Determination of compressive strength	
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 3 for the remaining specimens for each age.  

The shape of compression fracture sample is on angle 45



Example:

Compressive Strength

Ratios:

Cement: Sand = 1:2.75

Water: Cement = 0.485

Weights: Cement = 740g

Sand = 2035g

Water = 359g

Age (Day)	Compressive Force (KN)	Compressive Strength (MPa)	Average Strength (Mpa)	Lower Limit	Upper Limit	Accepted or Not	Accepted Avg. Strength	Strength Of Concrete
3	6.8	2.72	2.97	2.673	3.267	Yes	2.76	3.62
	7	2.8				yes		
	8.5	3.4				No		
7	15.9	6.36	6.77	6.093	7.447	Yes	6.77	8.98
	18.5	7.4				Yes		
	16.4	6.56				Yes		
28	57	22.8	23.07	20.763	25.377	Yes	23.07	32.12
	60	24				Yes		
	56	22.4				Yes		

To calculate the compressive Strength :

Strength = load / area

AREA= 50*50 = 2500 mm^2

At age 3 days and compressive force 6.8 KN→ The compressive strength = ($6.8*10^3$ N) /(2500 mm^2)= 2.72 MPa

And so on

The average of Compressive strength = (2.72+2.8+3.4)/3= 2.97

The accepted Compressive strength is ***(average strength ± 0.1 average strength)***, that's mean the accepted rang is 2.97± 0.1*2.97 = 2.673 -3.267

Check the all sample if it's within the rang

2.72 ∊ (2.673,3.267) → ok

2.8 ∊ (2.673,3.267) → ok

3.4 Not ∊ (2.673, 3.267) → not ok

The new average = (2.72+2.8)/2 = 2.76

And so on

To estimate the compressive strength of concrete with the same w/c ratio as the cement mortar and same cement type at 3 days

Compressive strength of concrete= 0.004(mortar Compressive strength)^2+1.3* mortar Compressive strength

Compressive strength of concrete= 0.004(2.76)^2+1.3* 2.76 = 3.62

And so on

The sample is within the specification if we have all samples accepted according to the table below

Specifications

Table 2.6: **BS EN 197–1: 2000 and ASTM C 150–05 requirements for minimum strength of cement (MPa (psi))**

Age (days)	BS EN 197–1: 2000 (mortar prism), strength class					
	32.5 N	32.5 R	42.5 N	42.5 R	52.5 N	62.5 R
2	–	10 (1450)	10 (1450)	20 (2900)	20 (2900)	20 (2900)
7	16 (2300)	–	–	–	–	–
28	32.5* (4700)	32.5* (4700)	42.5 (6200)	42.5** (6200)	52.5 (7600)	62.5 (9100)

Age (days)	ASTM C 150–05 (mortar cube), cement type (Table 2.7)							
	I	IA	II^a	IIA^a	III	IIIA	IV	V
1	–	–	–	–	12.0 (1740)	10.0 (1450)	–	–
3	12.0 (1740)	10.0 (1450)	10.0 (450)	8.0 (1160)	24.0 (3480)	19.0 (2760)	–	8.0 (1160)
7	19.0 (2760)	16.0 (2320)	17.0 (2470)	14.0 (2030)	–	–	7.0 (1020)	15.0 (2180)
28	28.0^b (4060)	22.0^b (3190)	28.0^b (4080)	22.0^b (3190)	–	–	17.0 (2470)	21.0 (3050)

* and not more than 52.5 (7600); ** and not more than 62.5 (9100)
^a Strength values depend on specified heat of hydration or chemical limits of tricalcium silicate and tricalcium aluminate
^b Optional

Assume we use the type IV cement (ASTM)

AGE (DAYS)	ASTM (IV) CEMENT MIN. STRENGTH (MPa)	Avg. Strength	Accepted or not
3	-	2.76	YES
7	7	6.77	NO
28	17	23.07	YES

The sample is <u>rejected</u> in compression therefore it's rejected in tension also.

In last of the exp. Data and result .Draw the experimental accepted average Compressive and Tensile Strength (MPa) of Mortar versus Time (Days) on the same graph .

II- Tensile Strength of Cement Mortar

[redacted]

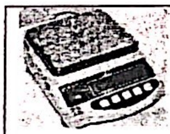
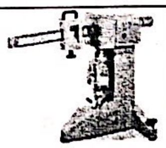
This test method covers the determination of the tensile strength of hydraulic cement mortar employing the briquet specimen. It is primarily for use by those interested in research on methods for determining tensile strength of hydraulic cement.

The temperature of the air in the vicinity of the mixing slab, the dry materials . molds , and base plates shall be maintained between (20 and 27.5 °C). The temperature of the mixing water, moist closet or moist room, and water in the briquet storage tank shall not vary from (23 °C) by more than ± (1.7 °C).

The relative humidity of the laboratory shall not be less than 50 %. The moist closet or moist room shall be so constructed as to provide storage facilities for test specimens at a relative humidity of not less than 95 %.

Apparatus and Equipments

- Balance
- Glass Graduate
- Briquet molds.
- Mixer with paddle and mixing bowl
- Testing machine.
- trowel & brush for oiling

						
Balance	Glass Graduat e	Specimens molds	Mixer with paddle and mixing bowl	Testing machine	trowel	brush

Materials

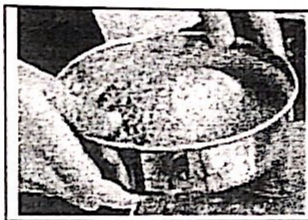
The percentage is (cement: sand: water = 1 : 3 : 0.46)

- Cement (400 g)
- Water (1200 g)
- Sand (184 ml)
- Oil for Lubricating molds

Procedure

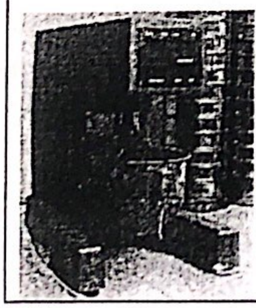
Preparation of mortar

1. Prepare the quantities of the cement and sand and water such that C:S:W= 1 :3: 0.46

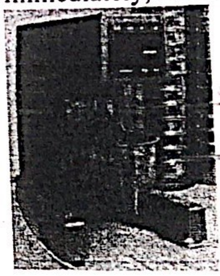
		
Cement 400 g	Sand 1200g	Water 184 ml

2. Place the mixing water in the bowl of the mixer, then add the cement and allow <u>30s</u> for the absorption of water.

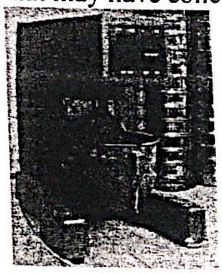
3. Start the mixer and mix at low speed (140±5rpm) for 30s, Add the certain quantity of sand to the cement paste gradually during the next 30s where the mixer still on slow speed.



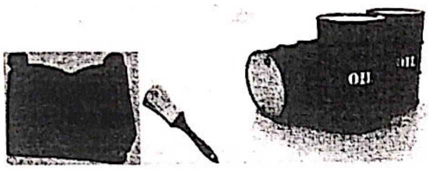
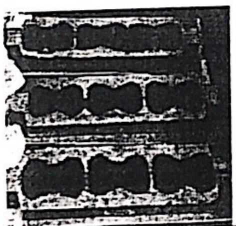
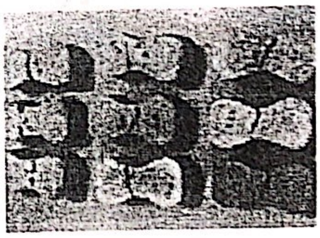
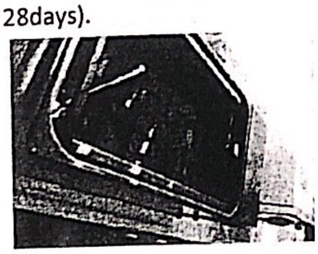
4. Immediately, alter the mixer to medium speed (285±10rpm) for 30s



5. 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.

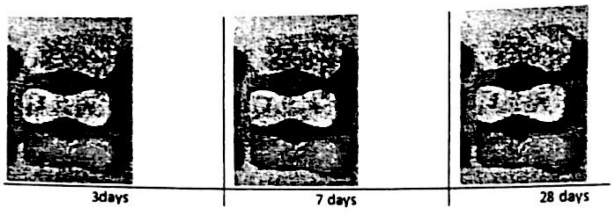


6. Start the mixer at medium speed for 60s.

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 noncorroding storage tanks until testing age (3, 7, and 28days). 	

Determination of tensile strength

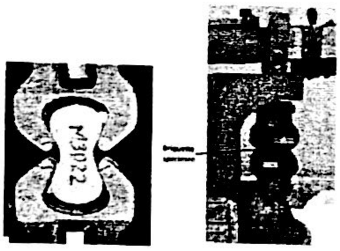
1.At each testing age (3, 7, and 28days) remove the required number of specimens from water (in our experiment 3 briquettes for each age).



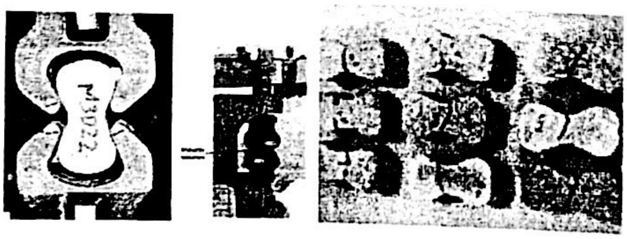
3days | 7 days | 28 days

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.

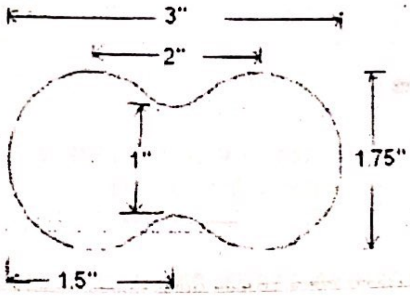
3.Carefully centre the first briquette in the clips and apply the load continuously at rate of 600±25lbf/min (2.67±0.11KN/min.



4.Repeat step 3 for the remaining briquettes for each age.



The shape of tension fracture sample is on angle 90



STANDARD BRIQUETTE

Example:

Tensile Strength

Ratios:

Cement: Sand = 1:3

Water: Cement = 0.46

Weights: Cement =400 g

Sand = 1200 g

Water = 184 g

Age (Day)	Tensile Force (N)	Tensile Strength (MPa)	Average Strength (Mpa)	Lower Limit	Upper Limit	Accepted or Not	Accepted Avg. Strength
3	578	0.92	0.86	0.73	0.99	Yes	0.95
	423	0.68				No	
	611	0.98				Yes	
7	1140	1.82	1.74	1.48	2.00	Yes	1.74
	1070	1.71				Yes	
	1050	1.68				Yes	
28	1200	1.92	1.95	1.66	2.25	Yes	1.95
	1240	1.98				Yes	
	1222	1.96				Yes	

To calculate the tensile Strength:

Strength = load / area

AREA=25*25 = 625 mm^2

At age 3 days and tensile force 578 N→ The tensile strength = (578 N) /(625mm^2)= 0.92 MPa

And so on

The average of tensile strength = (0.92+0.68+0.98)/3= 0.86

The accepted tensile strength is ***(average strength ± 0.15 average strength)***, that's mean the accepted rāng is 0.86 ± 0.15*0.86 = 0.73 -0.99

Check the all sample if it's within the rang

0.92 ϵ (0.73,0.99) → ok

0.68 not ϵ (0.73,0.99)) → not ok

0.98 ϵ (0.73,0.99) → ok

The new average = (0.92+0.98)/2 = 0.95

And so on.

The sample is within the specification if we have all samples accepted according to the table below

Specifications

CRD-C 260-01

Table 2 Tensile Strength[A]

	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, psi (kPa)	150 (1034)	125 (862)	375 (2586)	. . .	. . .
1 day in moist air, 6 days in water, psi (kPa)	275 (1896)	250 (1724)	. . .	75 (1207)	250 (1724)
1 day in moist air, 27 days in water, psi (kPa)	350 (2413)	325 (2241)	. . .	300 (2068)	325 (2241)

[A] Taken from Specification C 150 - 58 without change.

Assume we use the type IV cement (ASTM)

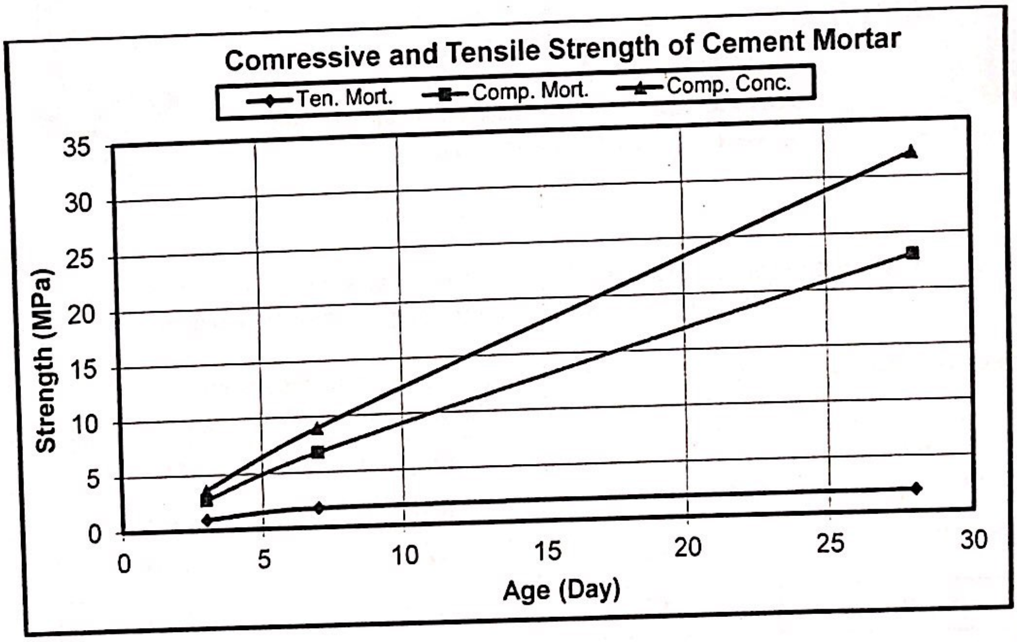
AGE (DAYS)	ASTM (IV) CEMENT MIN. STRENGTH (MPa)	Avg. Strength	Accepted or not
3	-	0.95	YES
7	1.207	1.74	YES
28	2.068	1.95	NO

The sample is <u>rejected</u> in tension therefore it's rejected in compression also.

<u>The sample is rejected .</u>

The experimental accepted average Compressive and Tensile Strength (MPa) of Mortar versus Time (Days) on the same graph .and compressive Strength (MPa) of concrete versus Time (Days)

Age (days)	Accepted Avg. Strength **Comp.**	Accepted Avg. Strength **Tension**	Accepted Avg. Strength **Comp. Concrete**
3	2.76	0.95	3.62
7	6.77	1.74	8.98
28	23.07	1.95	32.12



<u>Comp. strength = ~ (7-11) Ten. strength</u>

<u>Comp. strength = ~ 10Ten. Strength</u>

Exp# 10: Tensile Strength of Steel ASTM E8

The most common material in construction besides concrete is steel. Concrete, though it has a high compressive strength, its tensile strength is usually much lower and mounts up to 8 – 12 % of its compressive strength. Steel, therefore, is used in concrete structural elements to bare tensile loads and bending moments.

The major components of steel are Iron and carbon which ranges between 0.01 and 1 percent. Sulfur, phosphorus, manganese, silicon and as much as 20 other alloys are present in steel and are added in various quantities to steel during its manufacturing process depending on the desired hardness, toughness and tensile strength of steel.

Reinforcing steel bars are usually manufactured in 3 different forms:
- Plain bars
- Deformed bars
- Plain & deformed wires

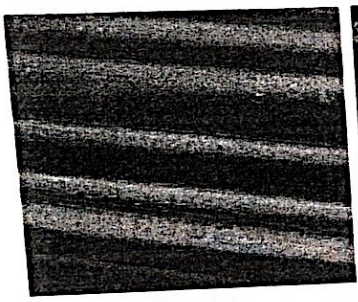


Figure 1: Plain Bars

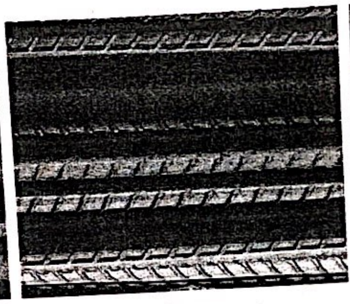


Figure 2: Deformed Bars

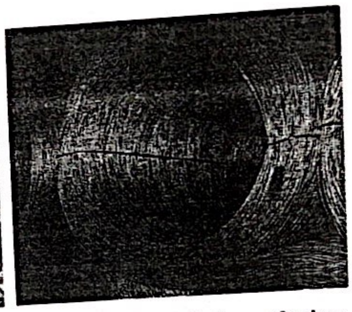


Figure 3:Plain & Deformed wires

The deformation in deformed steel bars is intended to increase the bonding between steel and concrete and to prevent slippage of the steel reinforcement bars.

Steel reinforcement bars are produced mainly with four different yield strengths, shown in the table below. The grade of steel indicates its yield strength in Ksi.

Type	σ_{yield} (psi)	σ_{yield} (MPa)	Grade
Type1	40,000	300	40
Type 2	50,000	350	50
Type 3	60,000	400	60
Type 4	75,000	500	75

Table 1: Reinforcement Steel Strength

Definitions:

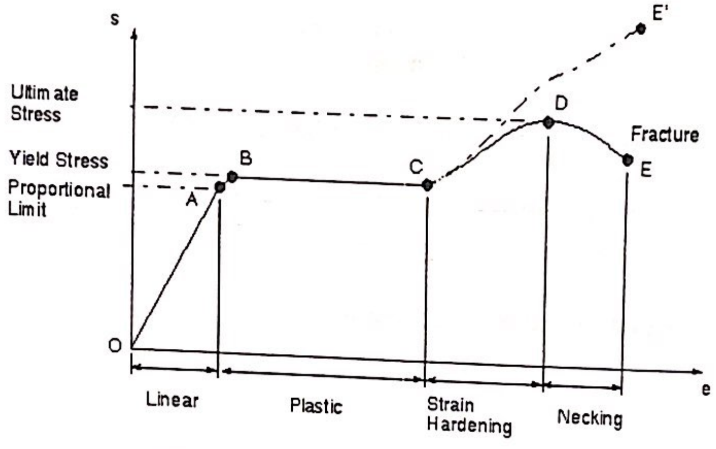
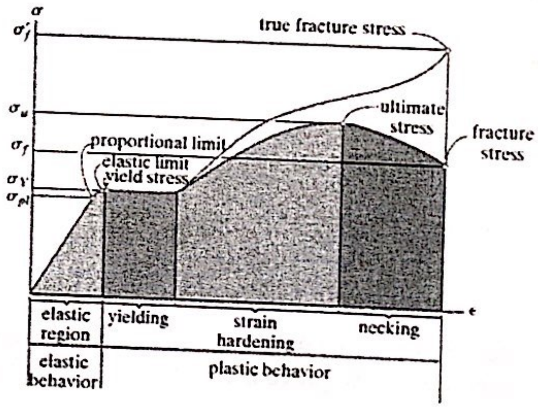


Figure 2. Stress-strain diagram for structural steel.



Modulus of Elasticity of Steel: is a measure of the stiffness of a solid material. It is a mechanical property of linear elastic solid materials. It defines the relationship between stress (force per unit area) and strain (proportional deformation) in a material.

Elastic limit (linear|) -it can be defined as the point in the graph up to which material comes back to original shape when loads are removed.

Proportional limit - Limit till which stress is Proportional to strain. Linear relationship. Slope of graph in this region is a constant and is the young's modulus. Hookes law is obeyed here.

Proportionality limit-it is the point in the stress strain graph up to which stress is directly proportional to strain

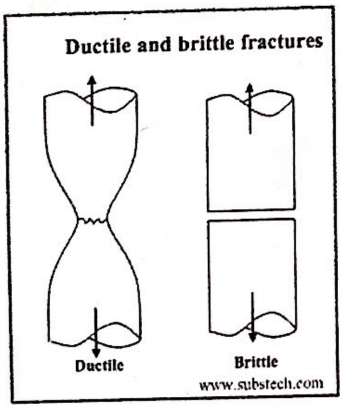
Yield Point: The Point at which an increase in strain occurs without an increase in
the stress is defined as the yield point. Stress at this point is defined as the steel yield stress.

Yield point-when the specimen is loaded beyond elastic limit a short den elongation of bar takes place without appreciable increase in stress this point is known as yeild point.

Ultimate tensile strength : is the capacity of a material to withstand loads tending to elongate, as opposed to compressive strength, which withstands loads tending to reduce size.

Fracture point-the point at which material or specimen fails ie. Fractures called fracture point.

Ductility is defined as the ability of a material to deform plastically before fracturing. Two measures of ductility are elongation and reduction of area.



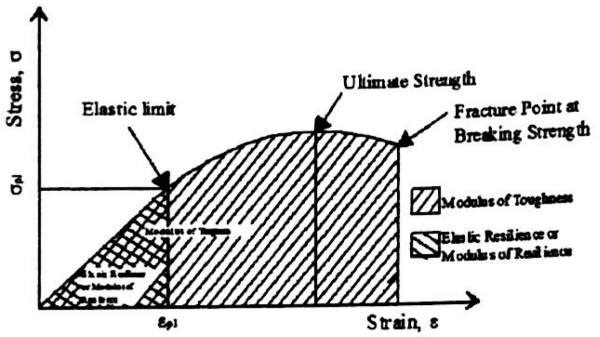
Ductility (Elongation) =(Lf-Li)/ Li *100%

Ductility (Reduction in area) =(Ai-Af) /Ai *100

Proof resilience - Maximum energy that can be absorbed during the elastic limit , that is till the Proportional limit.

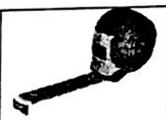
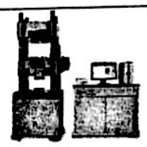
Resilience - Area under the stress strain curve within the proportionality limit (energy absorbed during the linear limit).

toughness is the ability of a material to absorb energy and plastically deform without fracturing. One definition of material toughness is the amount of energy per unit volume that **a material** can absorb before rupturing. It is also defined as a material's resistance to fracture when stressed.



Apparatus and Equipment

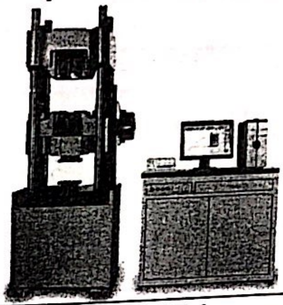
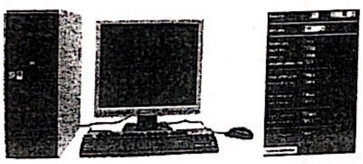
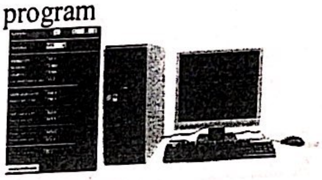
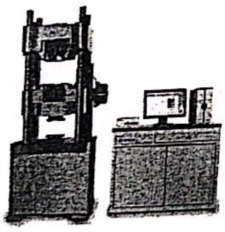
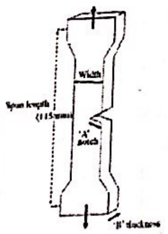
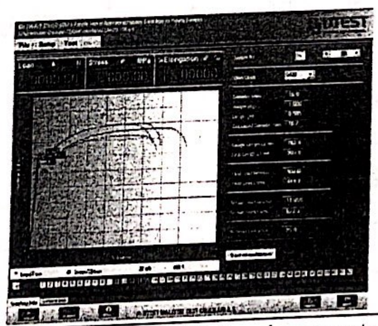
- Balance
- Meter
- caliber measurement
- universal testing machine (UTM) with computer

			
Balance	Meter	caliber measurement	universal testing machine with computer

Materials

Steel bars

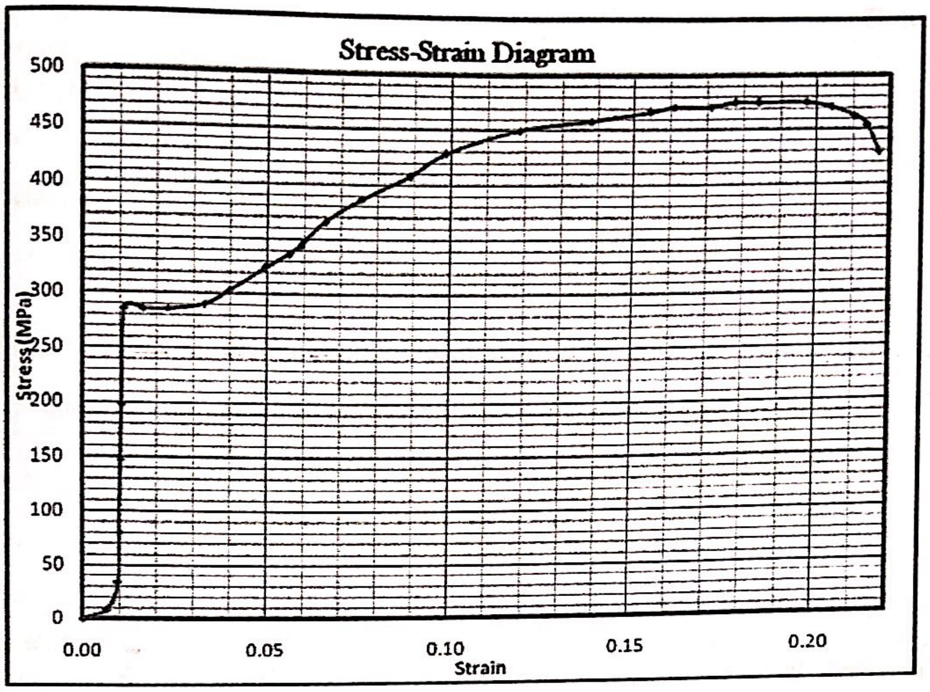
Procedure

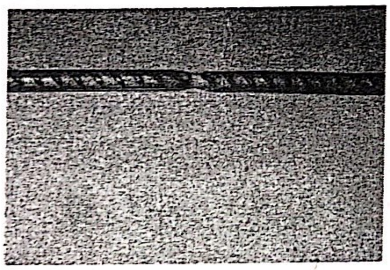
1. Measure the weight & the length of the sample 	2. Open the UTM machine (on) 
3. . Open the computer & open UTM program & enter **the weight & length** 	4. operate the UTM pump using the same program 
5. . Load a Steel bar into the machine, with length of steel between the testing machine clamps. and measure L_0 and enter it on computer .  	6.. operate the program (press zero icon then press  Then show the graph when its gradually drawn . 
7.. take the data	8. turn off the UTM and computer

Example:

L_i mm=	304	L_f=Li+ΔL =370	mm
D_i mm^2 =	17.4	A_i mm^2 =	237.8
D_F mm^2=	14.1	A_F mm^2 =	156.1

	Load(P) (KN)	Elongation(ΔL) (mm)	Eng. Stress (MPa)=P/Ai	Eng. Strain =ΔL/ li
1	0	0	0.00	0.0000
2	2	2	8.41	0.0066
3	8	2.9	33.64	0.0095
4	19	3	79.90	0.0099
5	35	3.1	147.19	0.0102
6	47	3.2	197.66	0.0105
7	68	3.4	285.97	0.0112
8	68	5	285.97	0.0164
9	68	7	285.97	0.0230
10	69	10	290.17	0.0329
11	72	12	302.79	0.0395
12	77	15	323.82	0.049342
13	80	17	336.43	0.055921
14	82	18	344.85	0.059211
15	87	20	365.87	0.065789
16	92	23	386.90	0.075658
17	97	27	407.93	0.088816
18	102	30	428.95	0.098684
19	107	36	449.98	0.118421
20	109	42	458.39	0.138158
21	111	47	466.80	0.154605
22	112	49	471.01	0.161184
23	112	52	471.01	0.171053
24	113	54	475.21	0.177632
25	113	56	475.21	0.184211
26	113	60	475.21	0.197368
27	112	62	471.01	0.203947
28	110	64	462.60	0.210526
29	108	65	454.19	0.213816
30	102	66	428.95	0.2171





Necking of the rebar before fracture

The shape of broken
is cup and cone (45 °)

Experiment #3 :

I-Specific Gravity and Absorption of Coarse Aggregate (ASTM C 127 – 88)

II- Specific Gravity and Absorption of fine Aggregate (ASTM C 127 – 88)

III-Unit Weight and Voids in Aggregate in its compacted or loose condition (ASTM C 29 – 89)

Specific gravity (S.G): is the ratio of the density of a substance to the density of a reference substance; equivalently, it is the ratio of the mass of a substance to the mass of a reference substance for the same given volume at a stated temperature.

S.G = $\frac{\text{density of a substance}}{\text{density of a reference substance}} = \frac{\text{mass of a substance}}{\text{mass of a reference substance}}$; for the same given volume where the density = mass / volume

The reference substance is nearly always water at its densest (4°C) for liquids.

Mass water =water density * volume of water

That's mean,

S.G = $\frac{\text{mass of a substance}}{\text{mass of a reference substance (WATER)}} = \frac{\text{mass of a substance}}{Water\ density \bullet volume\ of\ water}$

Density of water = 1 g/cm^3

S.G = $\frac{\text{mass of a substance}}{volume\ of\ water} = \frac{\text{mass of a substance}}{volume\ of\ \text{substance}}$, where the volume of water = the volume of substance .

The specific gravity may be expressed as bulk specific gravity, or apparent specific gravity.

1.Apparent Specific Gravity, G_{as}.

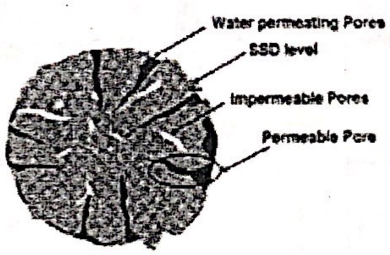
The volume measurement only includes the volume of the aggregate particle; it does not include the volume of any water permeable voids.

Apparent Specific Gravity = solid mass / solid volume

2.Bulk Saturated Surface Dry (SSD) Specific Gravity.

Volume measurement includes the overall volume of the aggregate particle as well as the volume of the water permeable voids.

Bulk Specific Gravity = (solid & water) mass / (solid volume + pores volume)



I-Specific Gravity and Absorption of Coarse Aggregate (ASTM C 127 – 88)

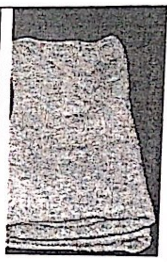
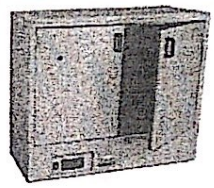
This test method covers the determination of Specific Gravity and Absorption of coarse aggregate. The specific gravity may be expressed as bulk specific gravity SSD or apparent specific gravity. The bulk specific gravity and absorption are based on aggregate after 24 hour soaking in water.

Coarse Aggregate (gravel): Coarse aggregate includes the particles that retain on 4.75 mm sieve (ASTM)
Coarse Aggregate (gravel): Coarse aggregate includes the particles that retain on # 4 sieve (BS)

Absorption is the increase in weight of aggregate due to water in the pores, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry weight.

Apparatus and Equipment

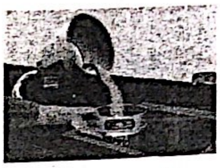
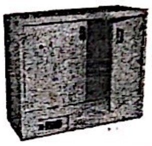
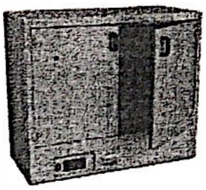
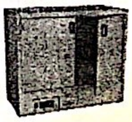
- A weighing balance sensitive
- The balance with sample container in water (A wire basket) and with Water tank
- Sieves; 4.75mm (No.4)
- Towel
- Oven

				
Weighing balance sensitive	The balance with sample container in water (A wire basket) and with Water tank	Sieves; 4.75mm (No.4)	Towel	Oven

Materials

Coarse Aggregate, water in balance

Procedure

Specific gravity and absorption of coarse aggregates		
1. Sieve the sample with 4.75mm sieves and ignore the materials passing through No.4.75 sieve. #4 Sieve with Gravel 	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.  ***Weight of S.S.D. sample in air (B)***	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  ***Weight of saturated sample in water(C)***	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.   ***Weight of oven-dry test sample in air (A)***

Example: Specific gravity and absorption of coarse aggregates

A: Weight of oven-dry test sample in air = 1350 g

B: Weight of S.S.D. sample in air = 1355 g

C: Weight of saturated sample in water = 850 g

Calculations:

1. Apparent Specific Gravity = $\frac{A}{A-C} = \frac{1350}{1350-850}$ = 2.7
2. Bulk Specific Gravity (SSD) = $\frac{B}{B-C} = \frac{1355}{1355-850}$ = 2.68
3. Absorption (%) = = $\frac{B-A}{A} * 100\ \% = \frac{1355-1350}{1350}$ = 0.37 %

Apparent specific gravity is larger than the bulk specific gravity where apparent specific depend on volume of particle only without external pores while the bulk specific gravity depends on volume of particle with external pores

Apparent Specific Gravity = solid mass / solid volume

Bulk Specific Gravity = (solid & water) mass / (solid volume + pores volume)

Denominator (المقام) in bulk s.g is larger therefore its smaller than gsa

Classification of Aggregates According to Unit Weight

1. Heavy weight agg.: Hematite, Magnetite Specific Gravity, $G_s \geq 3$
2. Normal weight agg.:Gravel, sand, crushed stone $2.8 \leq G_s \leq 2.2$
3. Light weight agg.:Expanded perlite, burned clay $G_s < 2$

Apparent specific gravity = 2.7 → Normal weight agg

Typically, aggregate have an absorption between just above zero and 5 percent

0.37 % < 5% ok

If the aggregate is not oven-dried before soaking, specific gravity values may be significantly higher. This is because in the normal procedure the water may not be able to penetrate the pores to the center of the aggregate particle during the soaking time. If the aggregate is not oven-dry to start, the existing water in the aggregate pore structrure may be able to penetrate further into the pores (AASHTO, 2000c[1]).

Not oven- dried before soaking→ water penetrate the internal pores→ mass(agg.+water in internal pores + water in external pores)→ S.G=mass / volume → (mass increase → S.G increase) .

Not oven- dried before soaking→ water penetrate the internal pores→ ABSORPION ↑

Certainly, the accuracy of all measurements is important. However, of specific concern is the mass of the SSD sample. The determination of SSD conditions can be difficult. If the sample is actually still wet on the surface then the mass of the SSD sample will be higher than it ought to be, which will cause a lower calculated bulk specific gravity. Conversely, if the sample is beyond SSD and some of the pore water has evaporated (which is more likely), the mass of the SSD sample will be lower than it ought to be, which will cause a higher calculated bulk specific gravity. Either type of error will have a cascading effect on volumetric parameters in other tests that require specific gravity as an input and Superpave mix design.

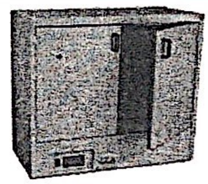
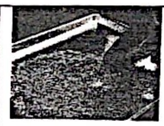
II-Specific Gravity and Absorption of Fine Aggregate (ASTM C 127 – 88)

This test method covers the determination of Bulk and Apparent Specific Gravity and Absorption of fine aggregate.

Fine Aggregate (sand): Fine aggregate includes the particles that all passes through 4.75 mm sieve and retain on 0.075 mm sieve.

Apparatus and Equipment

- balance
- Pycnometer.
- Mold: a metal mold in the form of a frustum of a cone with dimensions as follows: 37mm inside diameter at the top, 90mm inside diameter at the bottom and 75mm in height.
- Tamper
- Oven.
- Tray (container suitable to submerge the sample with water)

					
balance	Pycnometer	Mold	Tamper	Oven	Tray

Materials

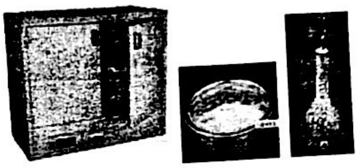
Fine Aggregate(1 kg sand) , water inpycnometer

Procedure

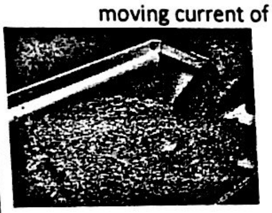
Specific gravity and absorption of fine aggregates

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.

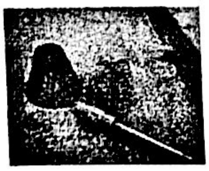


4. Stir frequently to get homogeneous drying until achieving the saturated surface dry condition. Use cone test for surface moisture.

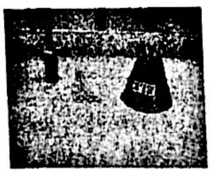
5. Hold the mold firmly on a smooth nonabsorbent surface with the large diameter down. Place a portion of partially dried fine aggregate loosely in the mold by filling it to over following and heaping additional materials above the top of the mold.

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.



The fine aggregate is still damp.



The fine aggregate is in SSD condition.

8. Weigh 500gm of the S.S.D sample.

Weight of the saturated surface-dry specimen(S)

9. Partially fill the pycnometer with water. Immediately put into the pycnometer 500gm saturated surface dry aggregate.

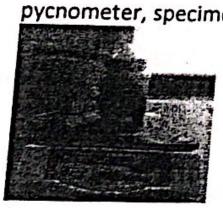
 

10. Then fill with additional water to approximately 90%of capacity.

11. Manually roll and invert or mechanically agitate the pycnometer to eliminate all air bubbles.

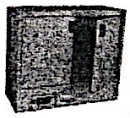
12. Bring the water level in the pycnometer to its calibrated capacity

13. Determine the total weight of the pycnometer, specimen and water.



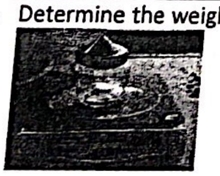
Weight of pycnometer with specimen and water(C)

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.

Weight of oven —dry specimen in air(A)

15. Determine the weight of the pycnometer filled to its capacity with water at 23±1.7°C



Weight of pycnometer filled with water(B)

Example: Specific gravity and absorption of fine aggregate

A: Weight of oven —dry specimen in air = 490 g

B: Weight of pycnometer filled with water = 1605 g

S: Weight of the saturated surface-dry specimen =500 g

C: Weight of pycnometer with specimen and water =1888 g

Calculations:

1. Apparent Specific Gravity = $\frac{A}{(B+A)-C} = \frac{490}{(1605+490)-1888}$ = 2.37

2. Bulk Specific Gravity (SSD) = $\frac{S}{(B+S)-C} = \frac{500}{(1605+500)-1888}$ = 2.304

3. Absorption (%) = $\frac{S-A}{A} * 100\% = \frac{500-490}{490} * 100\%$= 2.041%

Classification of Aggregates According to Unit Weight

- Heavy weight agg.: Hematite, Magnetite Specific Gravity, $G_s \geq 3$
- Normal weight agg.:Gravel, sand, crushed stone $2.8 \leq G_s \leq 2.2$
- Light weight agg.:Expanded perlite, burned clay $G_s < 2$

Apparent specific gravity = 2.37 → Normal weight agg

Typically, aggregate have an absorption between just above zero and 5 percent

2.041 % < 5% ok

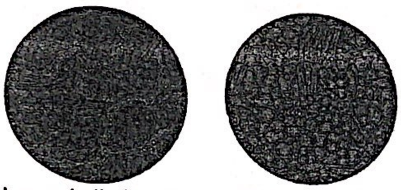
The air bubbles must be eliminated from pycnometer ; if there is a bubbles in sample that's mean the mass decrease then the density decrease also the specific gravity will decrease

High absorption of an aggregate means more pores then means weak aggregate therefor its effect on concrete mix if it's used.

III-Unit Weight and Voids in Aggregate in its compacted or loose condition (ASTM C 29 – 89)

Bulk density of aggregates is the mass of aggregates required to fill the container of a unit volume after aggregates are batched based on volume.

It depends on the packing of aggregate i.e. Either **loosely packed aggregates** or **well dense compacted aggregates**. In case, if the **specific gravity** of material is known, then it depends on the **shape and size of particles**. It is because, if all the particles are of **same size** than packing can be done up to a very limited extent. If the addition of smaller particles is possible within the voids of larger particles than these smaller particles enhance the bulk density of the **packed material**. Shape of the particles also influence very widely, because closeness particles depends on the **shape of aggregates**.



Lower bulk density
Lower weight
More pore space

Higher bulk density
Higher weight
Less pore space

5377117

If a statement is like: A coarse aggregates with higher bulk density, then it means few of the voids can be filled by using fine aggregates and cement. For testing, British Standard (BS 812) has specified the degree of compaction. These are;

1. Loose (Un-compacted)
2. Compacted

The test will be carried out by using metal cylinder having prescribed depth and diameter and the bulk density is to be determined depending on the **maximum size of aggregates** and the **degree of compaction.**

LOOSE BULK DENSITY

Loose bulk density can be determined by **filling the container with dried aggregates until it overflows from the container.** Now level the top surface of container by rolling a rod on it. After that, weight the aggregate mass that is inside the container and divide it by the volume of container. This will give you the bulk density of the loose aggregates.

COMPACTED BULK DENSITY

Compacted bulk density can be determined by filling the container in three layers and tamped each layer with a 16mm diameter rounded nosed rod. After filling in three layers, now **leveled the top surface** and evaluate compacted bulk density by using the **same expression** as for loose bulk density.

Apparatus and Equipment

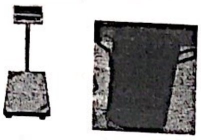
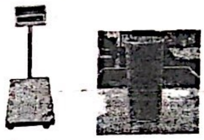
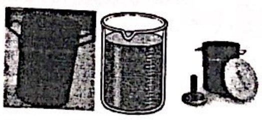
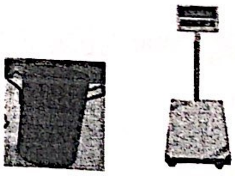
- Balance
- measure (cylinder)
- tamping rod
- straight edge

			
Balance	measure (cylinder)	tamping rod	straight edge

Materials

Coarse aggregate

Procedure

1. Weigh the empty measure (cylinder)  ***(M)***	2. Fill the cylinder to overflowing, discharging the aggregate from a height not to exceed 50mm above the top the cylinder edge. Level the surface of the aggregate with the fingers or straight edge 	3. Determine the weight of the measure plus its contents, and calculate the weight of the aggregate  ***(W LOOSE)***
4. 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. 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 		
5. Determine the weight of the measure plus its contents and calculate the wt. of aggregate by subtracting the empty weight of the cylinder.  ***(W1)***	6. 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. 	7. Determine the weight of the measure full with water, then calculate the weight of water.  ***(W2)***
8. Calculate the volume, V of the measure by dividing the weight of water required to fill the measure by its density. $V = \frac{WATER\ MASS}{WATER\ DENSITY} = \frac{W2-M}{1000}$		

EXAMPLE: <u>Compacted bulk density</u>

W_1: Weight of measure plus aggregate = 20.04g

W_2: Weight of measure filled with water = 15.82 g

M: Weight of measure =5.98 g

ρ_w: Density of water = 1000 kg/m^3

G_s: bulk Specific gravity of coarse aggregate from the experiment = 2.68

Calculations:

1. Volume of aggregate= Volume of measure = $\frac{MASS\ WATER}{DENSITY\ WATER} = \frac{W2-M}{1000} = \frac{15.82-5.98}{1000} = 9.84*10^{-3}m^3$

2. Bulk density of aggregate = $\frac{W1-M}{Agg.vol.} = \frac{20.04-5.98}{9.84*10^{\wedge}-3}$ = 1428.9 kg/m^3

   In Normal Aggregates the Bulk density should be between 1450 –1750 kg/m^3.
   1428.9 belong to (1450 –1750 kg/m^3)→ its ~~ok~~ not ok
   not

3. Voids (%) = $\frac{volume\ void}{volume\ total}$ = 1 - $\frac{bulk\ density}{bulkspecific\ gravity*density\ water}$ = 1 - $\frac{1428.9}{2.65*1000}$ = 46.08%

   Voids: It is the space between the individual particles in a unit volume of the aggregate mass and is not occupied by the solid mineral matter.

   Minimum accepted void ratio is 33%.

   46.08% > 33% → its ok

   If the void content of the aggregate is 33% the angularity of such aggregate is considered 0. If the void is 44%, the angularity number of such aggregate is considered 11.

4. Angularity number = 67 - % solid
   % solid = 100% - void % = 100-46.08 = 53.92
   Angularity number = 67 - % solid = 67% - 53.92% = 13.08%

[redacted]

13.08% > 11 → not ok

ANGULARITY

It is the absence of roundness. An aggregate particle, which is more rounded, is less angular and vice versa.

ANGULARITY NUMBER

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. In road construction angularity number of 7 – 10 is generally preferred.

LOOSE BULK DENSITY

Loose bulk density can be determined by filling the container with dried aggregates until it overflows from the container. Now level the top surface of container by rolling a rod on it. After that, weight the aggregate mass that is inside the container and divide it by the volume of container. This will give you the bulk density of the loose aggregates.

Assuming: Loose bulk density= 0.85*Compacted bulk density

Loose bulk density = 0.85 * 1428.9 = 1214.6 kg/m^3

$$\text{Voids (\%)} = \frac{volume\ void}{volume\ total} = 1 - \frac{loose\ bulk\ density}{bulkspecific\ gravity * density\ water} = 1 - \frac{1214.6}{2.65 * 1000} = 54.17\%$$

Angularity number = 67 - % solid

% solid = 100% - void % = 100-54.17 = 45.83%
Angularity number = 67 - % solid = 67% - 45.83% = 21.17%

21.17% not belong to (7-11) → not ok

Loose angularity number is more accurate than the compacted where the compaction may be effect the shape of aggregate particle.

Compacted angular number gives an indication of more rounded aggregate more than loose, where the void in compacted is less than loss therefore the angular number is less also then its more rounded according to the law below

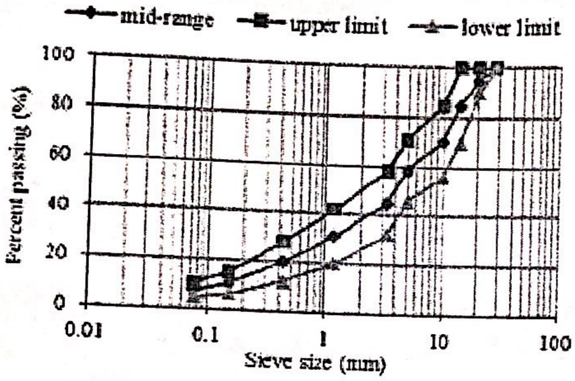
Angularity number = 67 - % solid
Angularity number= 67- (100% - void %)

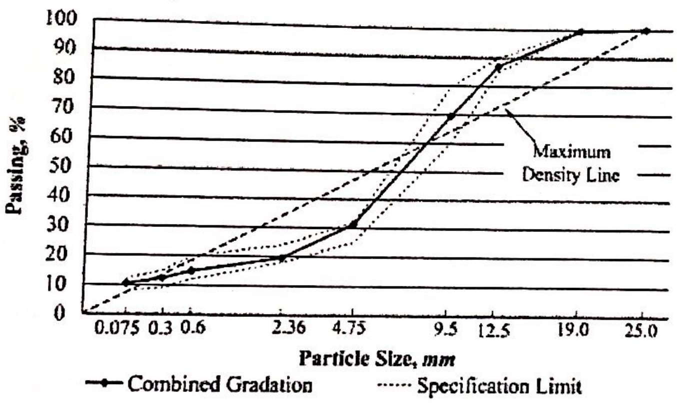
From the experiment performed we came to know that the bulk-density of a material in compacted form is greater than the bulk-density of a material in loose form.

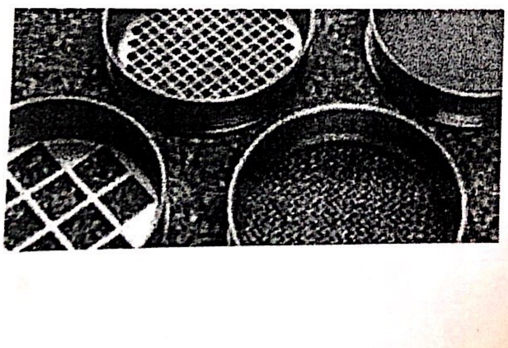
"Sieve Analysis of fine and coarse aggregates"
(ASTM C 136-84a)

Sieve analysis: is the name of the operation of dividing a sample of aggregate into fractions, each consisting of particles of the same size. In practice each fraction contains particles between specific limits, these being the openings of standard test sieves.

Grading Curves: Graphical representation (ordinates represent the cumulative percentage passing and the abscissa the sieve opening plotted to a logarithmic scale)







Some **Standard** test sieves are as follows:

Coarse aggregate	Fine aggregate
37.5mm (1.5 in)	1.18 mm (16 in)
19 mm (0.75 in)	0.6 mm (30 in)
9.5 mm (3/8 in)	0.3 mm (50 in)
4.75mm (4 in)	0.15 mm (100 in)
2.36 mm (8 in)	

Test sieves (Standard & nonstandard) that will be use in material laboratory

Coarse aggregate		Fine aggregate	
sieve size(mm)	sieve No.	sieve size(mm)	sieve No.
37.5	***1 ½"***	***9.5***	***3/8"***
25	1"	***4.75***	***4***
19	***¾"***	***2.36***	***8***
12.5	½"	***1.18***	***16***
9.5	***3/8"***	***0.6***	***30***
4.75	***4***	***0.3***	***50***
2.36	***8***	***0.15***	***100***
1.18	16	0.075	200
0.075	200	pan	
pan			

Fineness modulus: is the sum of the cumulative percentage retained on the sieves of the **standard** test sieves.

Fineness modulus (FM) = (Cum. percent retained / 100)

Limits for FM:

Fine aggregate < 5:
FM < 2 → fine sand
2.2 < FM < 2.8 → medium sand
FM > 3 → coarse sand

Coarse aggregate > 5

Maximum Aggregate Size (M.S): is defined as the smallest sieve size that requires 100% passing.

Nominal Maximum Aggregate (N.M.S):is defined as "one sieve size larger than the first size to retain more than 10%." (one standard sieve size that passes at least 85%) .

Example :
Percent Passing
3/4" : 100%
1/2" : 95%
3/8" : 89%
#4 : 63%
#8 : 39%

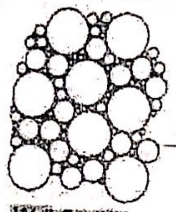
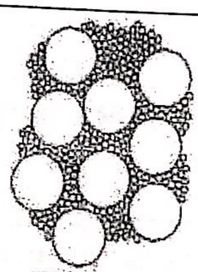
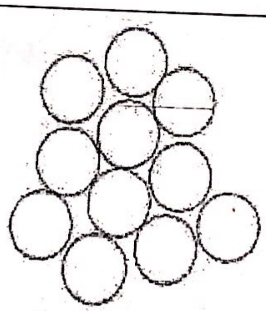
M.S= 3/4"
N.M.S = 3/8 "

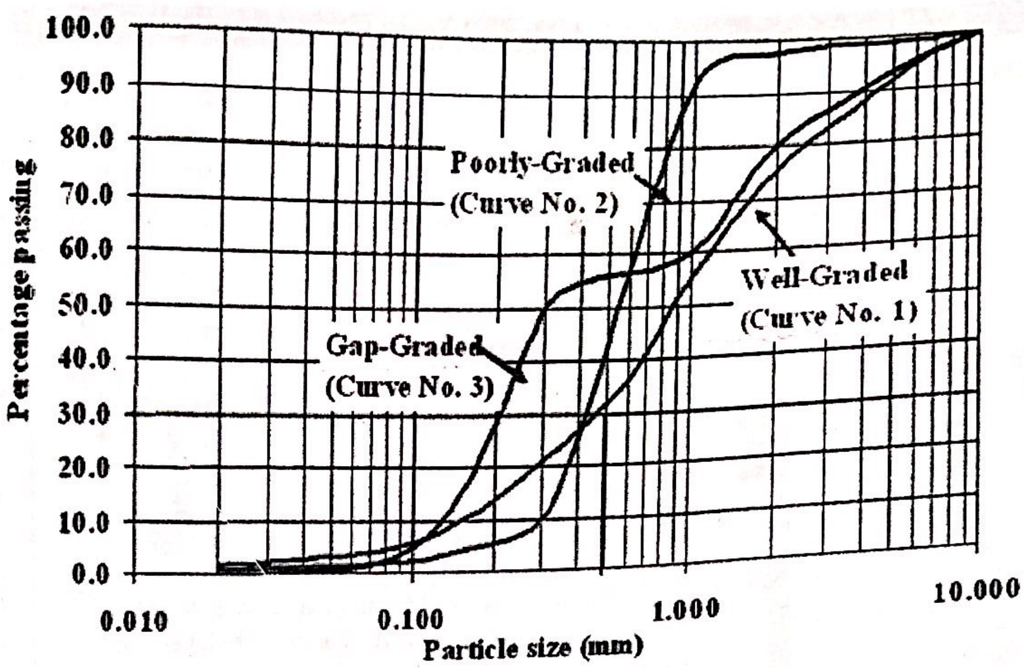
Grading is the process of classifying aggregates into uniform lots based on particle size.

The aggregate classified to:

1. **Single sized**: The entire aggregate lot is of a single specified size.One difference higher than 67% in cumulative passing .
2. **Graded aggregate:** The aggregate lot consists of particles of different sizes ranging between the maximum and minimum specified sizes .and its classified to **well graded, poor graded or gap graded.**

Graded aggregate TYPE

Type of graded	Image	Description	Advantage	Disadvantage
Well Graded Aggregate	 Well Graded	sample that is approximately of equal amounts of various sizes of aggregate.	Low void content Low permeability High stability	Difficult to compact
Gap Graded Aggregate	 Gap Graded	is a kind of grading which lacks one or more intermediate size	more economical concrete(use of less cement) Easy to compact	low strength high permeability Low stability
Poorly graded Aggregate *(uniform graded)*	 Poorly Graded	Sample that not applicable to standard requirement according BS & ASTM		shrinkage excessive amounts of cement paste to fill the voids (uneconomical) High permeability Low stability Difficult to compact



100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Percentage passing
Poorly-Graded
(Curve No. 2)
Well-Graded
(Curve No. 1)
Gap-Graded
(Curve No. 3)
0.010
0.100
1.000
10.000
Particle size (mm)

Apparatus and Equipments

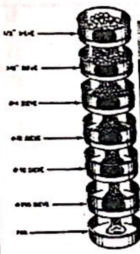
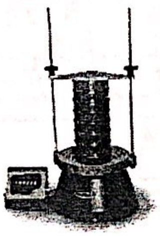
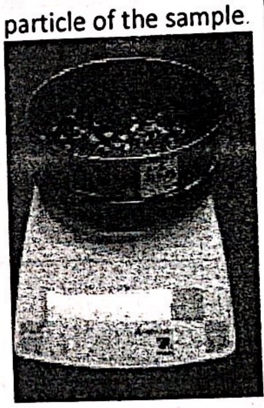
1. Balance
2. Containers to carry the sample.
3. Oven.
4. Mechanical Sieve shaker.
5. Two sets of sieve: -For fine aggregate [No.4, No.8, No.16, No.30, No.50, No.100] For coarse aggregate [37.5mm, 19mm ,9.5mm, No.4, No.8] In addition to a pan and a cover for each set.

				
Balance	Containers	Oven	Mechanical Sieve shaker.	Two sets of sieve(fine, coarse)

Materials

fine aggregate
Coarse aggregate

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.  		

Example: Coarse Aggregates:

sieve size (mm)	sieve No.	sieve wt. (g)	sieve+ret. (g)	Ret. Wt. (g)	Retained (%)	Cum. Ret. (%)	Cum. Pass (%)	Log sieve size
37.5	***1 1/2"***	497	497	0	0	**0.0**	100.0	1.574
25	1"	465	465	0	0.0	0.0	100.0	1.398
19	***3/4"***	468	554	86	8.0	**8.0**	92.0	1.279
12.5	1/2"	460	636	176	16.4	24.4	75.6	1.097
9.5	***3/8"***	469	746	277	25.8	**50.2**	49.8	0.978
4.75	***4***	440	892	452	42.1	**92.3**	7.7	0.677
2.36	***8***	385	460	75	7.0	**99.3**	0.7	0.373
pan		303	311	8	0.7	100.0	0.0	
				1074				

Sample of calculation

@ 37.5 mm→Ret. Wt. = (sieve+ret.) – (sieve wt.) = 497 -497 = 0

@19mm→ %Retained = Ret. Wt./total wt. = 86 /1074*100% = 8

@9.5mm→% Cum. Ret.= 24.4+25.8= 50.2

@19mm→ % Cum. Pass.= 100-8=92

@37.5mm→log37.5=1.574

Fineness modulus (FM) = (Cum. percent retained (standard sieve only) / 100)

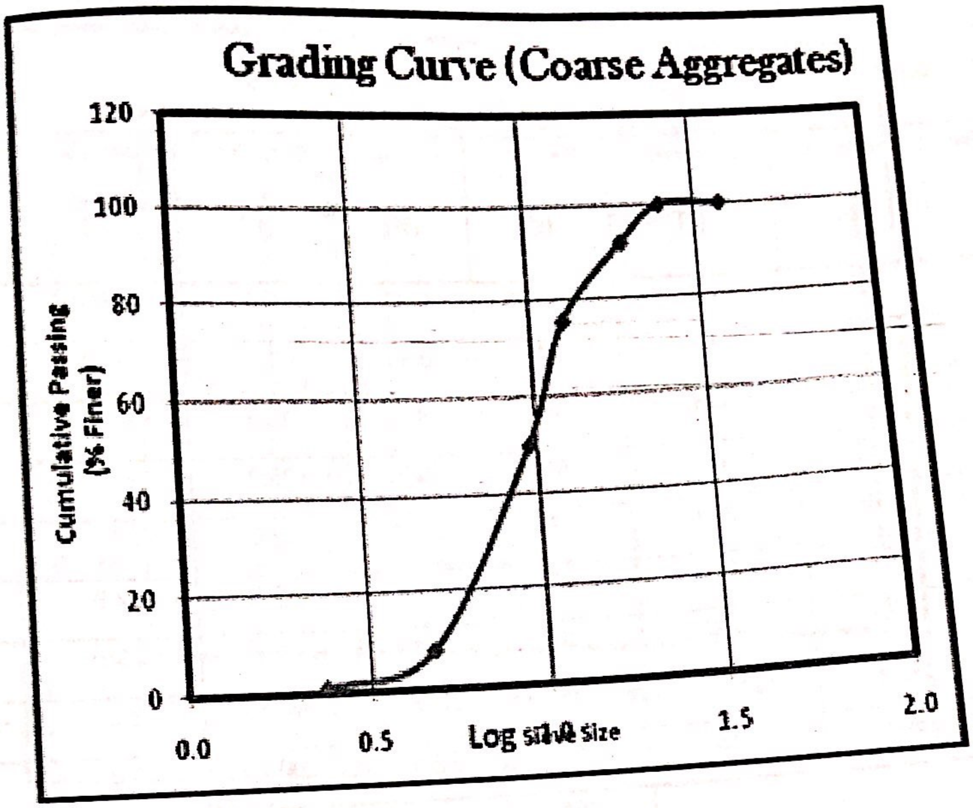
F.M= (0+8+50.2+92.3+99.3+4*100)/100 = 6.5 > 5 → **ok**

Maximum Aggregate Size (M.S): is defined as the smallest sieve size that requires 100%passing

M.S= 25mm

Nominal Maximum Aggregate (N.M.S):is defined as "one sieve size larger than the first size to retain more than 10%." **(one standard sieve size that passes at least 90%)**

N.M.S= 19mm



Grading Curve (Coarse Aggregates)
Cumulative Passing (% Finer)
120
100
80
60
40
20
0
0.0
0.5
1.0
1.5
2.0
Log sieve size

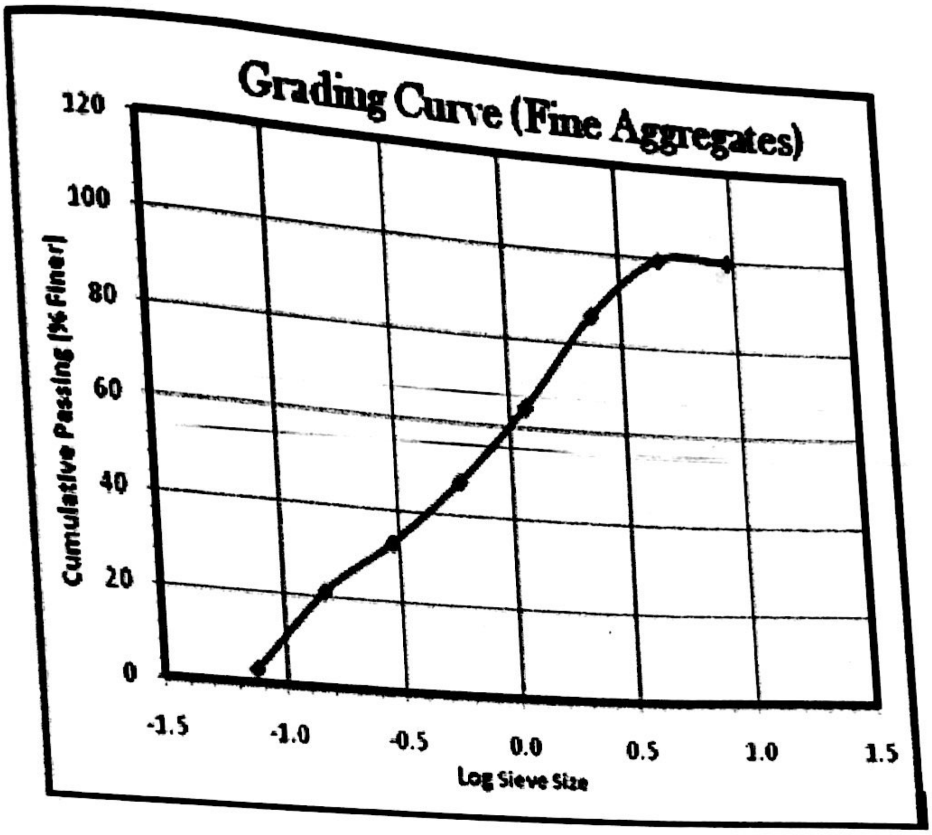
Fine Aggregates:

sieve size (mm)	sieve No.	sieve wt. (g)	sieve+ret. (g)	Ret. Wt. (g)	Retained (%)	Cum. Ret. (%)	Cum. Pass (%)	Log sieve size
9.5	***3/8"***	471	471	0	0.00	0.0	100.0	0.978
4.75	***4***	493	494	1	0.33	0.3	99.7	0.677
2.36	***8***	385	426	41	13.49	13.8	86.2	0.373
1.18	***16***	417	482	65	21.38	35.2	64.8	0.072
0.6	***30***	346	399	53	17.43	52.6	47.4	-0.222
0.3	***50***	365	409	44	14.47	67.1	32.9	-0.523
0.15	***100***	294	330	36	11.84	78.9	21.1	-0.824
0.075	200	245	300	55	18.09	97.0	3.0	-1.125
pan		304	313	9	2.96	100.0	0.0	
				304				

F.M= (0+0+0+0.3+13.8+35.2+52.6+67.1+78.9)/100 = 2.48 < 5→**ok** (medium sand)

M.S= 9.5mm

[redacted]



The aggregate that has passing sieve #100 → don't put it in concrete.

Jordanian sand (Sweileh sand) contain very fine aggregate → coating between aggregate & cement .therefore the sieve #200 was added although its not standard where the American sand not contain very fine particles (ASTM specification) .

Materials passing by sieve 200 should not exceed 5%

Table 3.9: **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 to 5 mm (1½ in. to $\frac{3}{16}$ in.)	20 to 5 mm (¾ in. to $\frac{3}{16}$ in.)	14 to 5 mm (½ in. to $\frac{3}{16}$ in.)	40 mm (1½ in.)	20 mm (¾ in.)	14 mm (½ in.)	10 mm (⅜ in.)	5 mm ($\frac{3}{16}$ in.)
50.0	2	100	–	–	100	–	–	–	–
37.5	1½	90–100	100	–	85–100	100	–	–	–
20.0	¾	35–70	90–100	100	0–25	85–100	100	–	–
14.0	½	–	–	90–100	–	–	85–100	100	–
10.0	⅜	10–40	30–60	50–85	0–5	0–25	0–50	85–100	100
5.00	$\frac{3}{16}$	0–5	0–10	0–10	–	0–5	0–10	0–25	50–100
2.36	No. 7	–	–	–	–	–		0–5	0–30

Table 3.10: **Some of the grading requirements for coarse aggregate according to ASTM C 33–03**

Sieve size		Percentage by mass passing sieve				
		Nominal size of graded aggregate			Nominal size of single-sized aggregate	
mm	in.	37.5 to 4.75 mm (1½ to $\frac{3}{16}$ in.)	19.0 to 4.75 mm (¾ to $\frac{3}{16}$ in.)	12.5 to 4.75 mm (½ to $\frac{3}{16}$ in.)	63 mm (2½ in.)	37.5 mm (1½ in.)
75	3	–	–	–	100	–
63.0	2½	–	–	–	90–100	–
50.0	2	100	–	–	35–70	100
38.1	1½	95–100	–	–	0–15	90–100
25.0	1	–	100	–	–	20–55
19.0	¾	35–70	90–100	100	0–5	0–15
12.5	½	–	–	90–100	–	–
9.5	⅜	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 3.10: Some of the grading requirements for coarse aggregate according to ASTM C 33–03

Sieve size		Percentage by mass passing sieve				
		Nominal size of graded aggregate			Nominal size of single-sized aggregate	
mm	in.	37.5 to 4.75 mm (1½ to $\frac{3}{16}$ in.)	19.0 to 4.75 mm (¾ to $\frac{3}{16}$ in.)	12.5 to 4.75 mm (½ to $\frac{3}{16}$ in.)	63 mm (2½ in.)	37.5 mm (1½ in.)
75	3	–	–	–	100	–
63.0	2½	–	–	–	90–100	–
50.0	2	100	–	–	35–70	100
38.1	1½	95–100	–	–	0–15	90–100
25.0	1	–	100	–	–	20–55
19.0	¾	35–70	90–100	100	0–5	0–15
12.5	½	–	–	90–100	–	–
9.5	⅜	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	–	–

Specification coarse aggregate

Sieve size	Cum. Pass(%)	The difference
37.5mm (1.5")	100	100-100=0
25 (1")	100	100-92=8
19(3/4")	92	92-75.6=16.4
12.5(0.5")	75.6	75.6-49.8=25.8
9.5(3/8")	49.8	49.8-7.7=42.1
4.75(3/16")(#4)	7.7	7.7—0.7=7
2.36(#8)	0.7	

All difference < 67 → not single size → its **graded** aggregate

N.M.S=19mm

Sieve size mm(in)	Nominal size 20 to 5 mm (3/4"to3/16")	Cum. Pass(%)	BS
50 (2)	-		
37.5(1.5)	100	100	OK
20(3/4)	90-100	92	OK
14(0.5)	-	75.6	OK
10(3/8)	30-60	49.8	OK
5(3/16)	0-10	7.7	OK
2.36(No.7)	-	0.7	OK

In **BS** →the sample(coarse) is accepted & **well graded** .

Sieve size mm(in)	Nominal size 19 to 4.75 mm (3/4"to3/16")	Cum. Pass(%)	ASTM
75(3)	-		
63(2.5)	-		
50 (2)	-		
38.1(1.5)	-	100	OK
25(1)	100	100	OK
19(3/4)	90-100	92	OK
12.5(0.5)	-	75.6	OK
9.5(3/8)	20-55	49.8	OK
4.75(3/16)	0-10	7.7	OK
2.36(No.8)	0-5	0.7	OK

In **ASTM** →the sample(coarse) is accepted & **well graded** .

Specification fine aggregate:

Sieve size	Cum. Pass(%)	The difference
10 mm (3/8 in)	100.0	100-99.7=0.3
5mm (4 in)	99.7	99.7-86.2=13.5
2.36 mm (8 in)	86.2	86.2-64.8=21.2
1.18 mm (16 in)	64.8	64.8-47.4=17.4
0.6 mm (30 in)	47.4	47.4-32.9=14.5
0.3 mm (50 in)	32.9	32.9-21.1=11.8
0.15 mm (100 in)	21.1	

All difference < 67 → not single size → its **graded** aggregate

Sieve size mm(in)	Overall limits	Cum. Pass(%)	BS	C	M	F
10 mm (3/8 in)	100	100.0	ok	-	-	-
5mm (4 in)	89-100	99.7	OK	-	-	-
2.36 mm (8 in)	60-100	86.2	OK	60-100	65-100	80-100
1.18 mm (16 in)	30-100	64.8	OK	30-90	45-100	70-100
0.6 mm (30 in)	15-100	47.4	OK	15-54	25-80	55-100
0.3 mm (50 in)	5-70	32.9	OK	5-40	5-48	5-70
0.15 mm (100 in)	0-15	21.1	Not OK	-	-	-

In **BS** →the sample (fine) is not accepted &**POOR graded** .

م. هيفاء ناصر
مختبر مواد البناء

EXP# 7: Workability of Concrete

ASTM C143 / C143M - 15a

Concrete workability is a broad and subjective term describing how easily freshly mixed concrete can be mixed, placed, consolidated and finished with minimal loss of homogeneity.

Workability is a property that directly impacts strength, quality, appearance, and even the cost of labor for placement and finishing operations.

Factors Affecting Workability:

- Water/Cement Ratio
- Aggregate Size and Shape
- Admixtures

Tests used to check the workability of concrete

- **Slump Test**
- **Vebe Test**
- **Flow Table Test**
- **Compacting Factor Test**
- **Kelly ball (ball penetration test)**

Materials

BATCH (35 Kg):
~~**Cement 6.4 kg**~~
Water 3.5 kg
Coarse aggregate 12.8 kg
Fine aggregate 11.7 kg

Tests Apparatus and Equipment

Slump Test

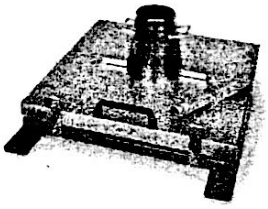
				

balance	mixer	Cone(slump test)	rod	Meter or (ruler)

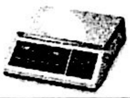
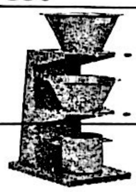
Vebe Test

		
balance	mixer	**Vebe Consistometer**

Flow Table Test

				
balance	mixer	**Flow Table**	Slump cone shaped mold	Wooden tamping bar

Compacting Factor Test

			
balance	mixer	COMPACTING FACTOR TEST APPARATUS	**Vibrating table**

Kelly ball (ball penetration test)

		
balance	mixer	Kelly ball test APPARATUS

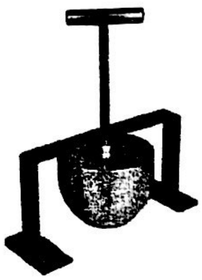
Mixing procedure:

1. Coarse aggregate
2. (1/3) water
3. sand
4. cement gradually
5. Water gradually

Mixing **3 minute** → **stop 3 minute** → Mixing **3 minute**

Procedure

Kelly ball (ball penetration test)



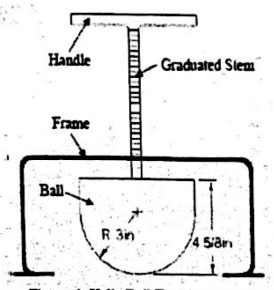
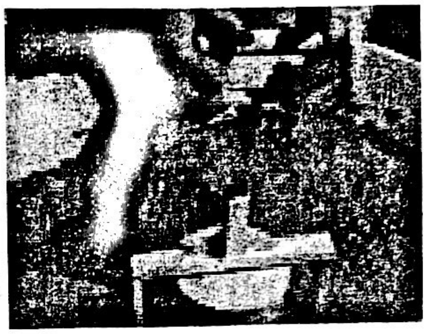


Figure 6: Kelly Ball Test Apparatus



The test apparatus consists of a 6 inch diameter, 30 pound ball attached to a stem, as shown in Figure 6. The stem, which is graduated in ¼ inch increments, slides through a frame that rests on the fresh concrete. To perform the test, the concrete to be tested is stuck off level. The ball is released and the depth of penetration is measured to the nearest ¼ inch. At least three measurements must be made for each sample.

Typically, the value of slump is 1.10 to 2.00 times the Kelly ball test reading.

Advantages:

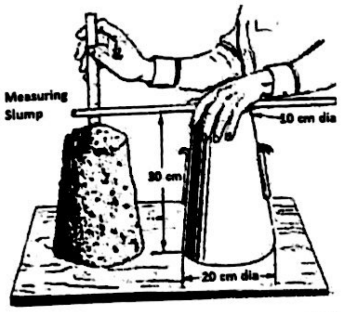
- The test is faster than the slump test and can be preformed on in-place concrete to obtain a direct result quickly.
- It has been claimed that the Kelly ball test provides more accurate results than the slump test.

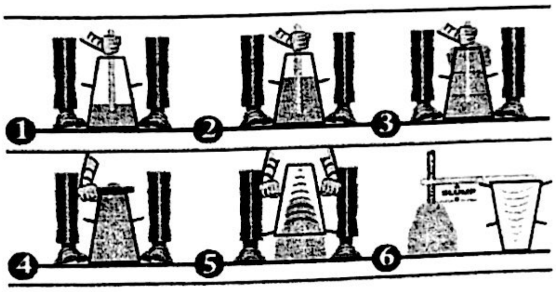
Disadvantages:

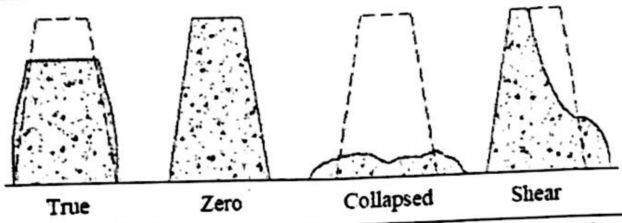
- Like the slump test, the Kelly ball test is a static test.
- The test must be performed on a level concrete surface.
- The test is no longer widely used.
- Large aggregate can influence the results.

Typically, the value of slump is 1.10 to 2.00 times the Kelly ball test reading.

Slump Test







1. Clean the internal surface of the mold and apply oil.	2. Place the mold on a smooth horizontal non- porous base plate.
3. Fill the mold with the prepared concrete mix in 3 approximately equal layers.	4.Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mold. For the subsequent layers, the tamping should penetrate (1-1.5cm) into the underlying layer.
5.Remove the excess concrete and level the surface with a trowel.	6. Clean away the concrete or water leaked out between the mold and the base plate.
7.Raise the mold from the concrete immediately and slowly in vertical direction during (3 seconds).	8.Measure the slump as the difference between the height of the mold and that of height point of the specimen being tested.

Types of Concrete Slump Test Results

- **True Slump** – True slump is the only slump that can be measured in the test. The measurement is taken between the top of the cone and the top of the concrete after the cone has been removed as shown in

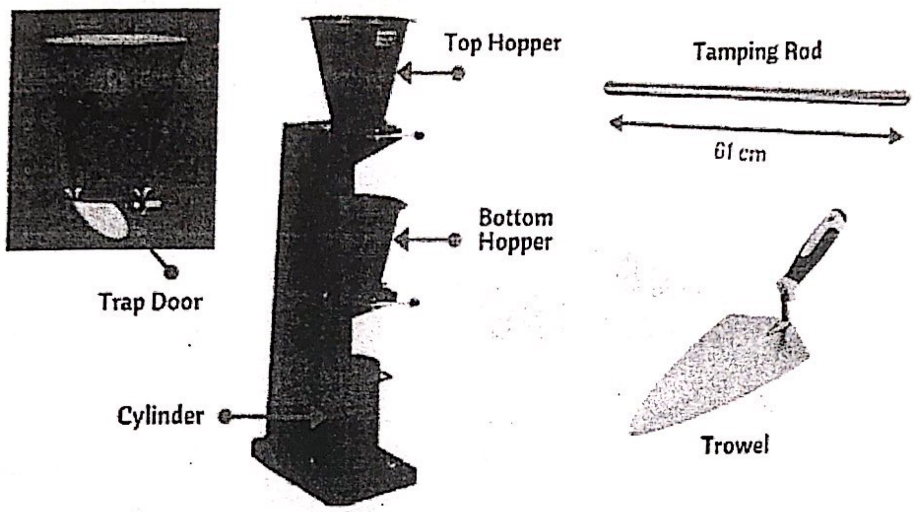
- **Zero Slump** – Zero slump is the indication of very low water-cement ratio, which results in dry mixes. These type of concrete is generally used for road construction.

- **Collapsed Slump** – This is an indication that the water-cement ratio is too high, i.e. concrete mix is too wet or it is a high workability mix, for which a slump test is not appropriate.

- **Shear Slump** – The shear slump indicates that the result is incomplete, and concrete to be retested.

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

Compacting Factor Test



1. The sample of concrete is placed in the upper hopper up to the brim.	2. The trap-door is opened so that the concrete falls into the lower hopper.	3. The trap-door of the lower hopper is opened and the concrete is allowed to fall into the cylinder.
4.The excess concrete remaining above the top level of the cylinder is then cut off with the help of plane blades.	5.The concrete in the cylinder is weighed. This is known as weight of partially compacted concrete.	6. The cylinder is filled with a fresh sample of concrete and vibrated to obtain full compaction. The concrete in the cylinder is weighed again. This weight is known as the weight of fully compacted concrete.

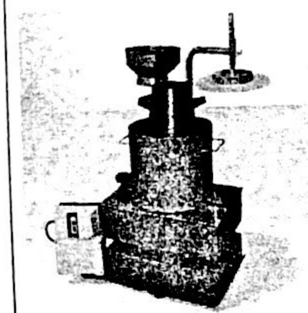
Calculation of Compaction Factor Value

The compaction factor is defined as the ratio of the weight of partially compacted concrete to the weight of fully compacted concrete. It shall normally to be stated to the nearest second decimal place.

$$\text{Compaction factor} = \frac{\text{weight of partially compacted concrete}}{\text{weight of fully compacted concrete}} \text{ should be} < 1$$

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

Vebe test



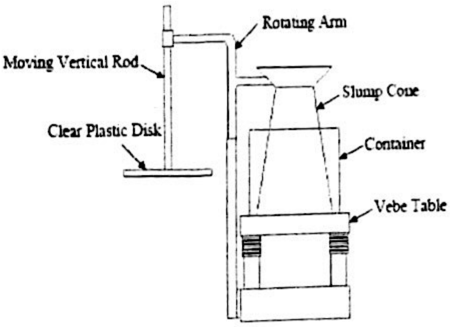


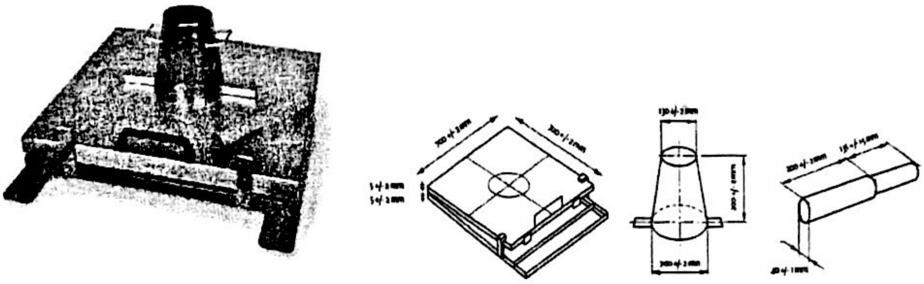
Figure 10: Vebe Consistometer

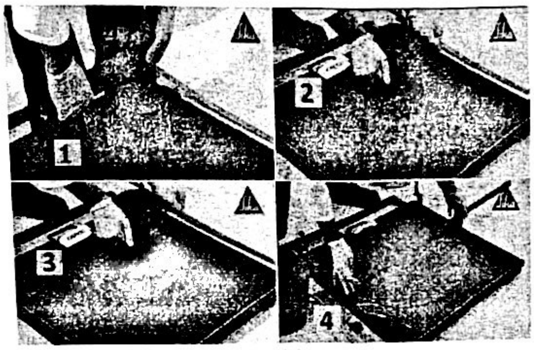
The apparatus is paced on top of a vibrating table. The fresh concrete is compacted into a conical slump mould(3 layers(25 stokes)). The mould is removed and a clear plastic disc is placed on the top of the concrete. The vibrating table is started and the time taken for the transparent disc to be fully in contact with the concrete (the Vebe time), is measured.

The main advantage of this test is that it is a dynamic test and can be used on concretes that are too stiff for a slump test.

Degree of Workability	Vebe Time (sec)
very low	20-40
Low	10-20
Medium	7-10
High	3-7
Very High	1-3

flow table test





Flow Table Test

1. Place the **flow table** on a leveled surface	2. Clean the top of the table and inner surface of the mould using a damp cloth.
3. Place the slump cone centrally on the table.	4. Fill the slump cone with concrete in two equal layers and tamp each layer 15 times with the help of wooden tamping bar.
5. After filling the mould, the concrete is struck off flush with the upper edge of the slump cone an the free area of the table top cleaned off.	6. Half a minute after striking off the concrete, slowly raise the cone vertically using the handles.
7. Then raise the table top by handle and allow it to fall 15 times in 15 seconds. The concrete spreads itself out.	8. Measure the diameter of spread concrete in two dimensions parallel to the table edges.

Flow factor = $\frac{df-20}{20} * 100\ \%$

Df= (d1+d2)/2

Flow Table:

500 mm High workability

400 mm Medium Workability

300 mm Low workability

<u>Admixtures :</u> are the special ingredients which are added during concrete mixing to enhance the properties and performance of fresh concrete. Various types of admixtures are available in the market which is used in construction work.

Types Of admixtures:

1. Accelerating Admixtures:

This admixture is added in concrete or mortar for increasing the rate of hydration of hydraulic cement

and for shortening the setting time. ***Calcium chloride ($CaCl_2$)*** is the most widely used accelerating admixture.

2. Retarding Admixtures:

Retarding admixtures delay the initial rate of hydration of cement and extend the setting time of cement paste. This admixture can be used in high temperature and where the concrete has to be transported to a long distance. It is also suitable for using in grouting oil wells.

3. Air-Entraining Admixtures:

Air entraining admixtures help to produce a certain amount of air bubbles in the concrete mixture. The main goal of this admixture is to increase the resistance against freeze-thaw degradation and cohesion. It also improves the workability of fresh concrete without changing the setting or the rate of hardening.

4. Water Reducing Admixtures:

As the name suggest, water reducers are added to a concrete mixture, mortar or grout to increase the flowability without increasing the water content.

Advantages Of Water Reducing Admixtures:

1. The rate of concrete placement is faster.
2. Strength, durability, density etc. are significantly improved.
3. Segregation, permeability, and cracking are reduced.

Special admixtures:

1. Superplasticizing admixtures.
2. Corrosion-inhibiting admixtures.
3. Grouting admixtures.
4. Coloring admixtures etc.

Superplasticizer (high range water reducing admixture)
Admixture which permits a high reduction in the water content of a given mix without affecting the consistence, or which increases the slump/flow considerably without affecting the water content; or produces both effects simultaneously.

The percentage of *water cement* is equal when using both mixtures *Without admixture* & *With admixture.*

The percentage of *cement /sand* and the ratio of *cement / coarse aggregate* is *constant* even with *admixture*

Compaction factor *increase* → The workability *increase*

Flow factor *increase* → The workability *increase*

Vebe time *increase* → The workability *decrease*

slump *increase* → The workability *increase*