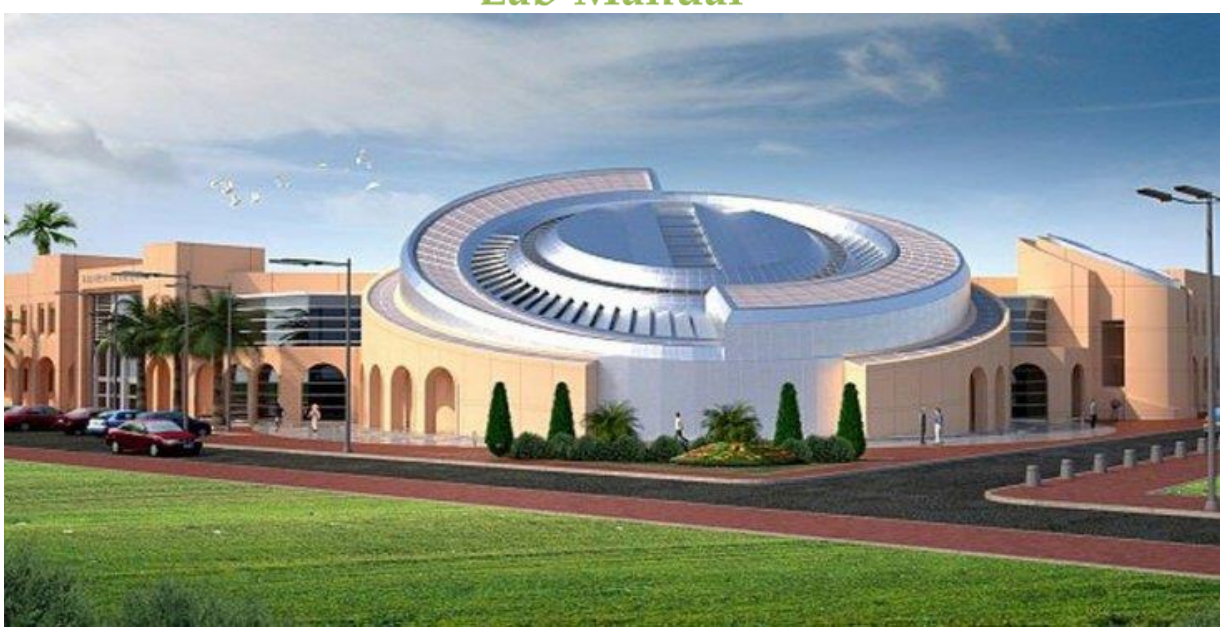
KING FAISAL UNIVERSITY
College Of Engineering

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING

CEE281: Construction Materials Lab.

"Lab Manual"



Prepared By: Eng. Ammar Al-Shayeb

Major Topics covered and schedule in weeks:

Topic	Week #	Courses Covered
SIEVE ANALYSIS OF FINE & COARSE AGGREGATES	1	CEE281& CEE282
UNIT WEIGHT & VOIDS IN AGGREGATE	2	CEE281& CEE282
SPECIFIC GRAVITY & ABSORPTION OF COARSE & FINE AGGREGATES	3	CEE281& CEE282
RESISTANCE TO DEGRADATION OF SMALL-SIZE COARSE AGGREGATE BY ABRASION AND IMPACT IN THE LOS ANGELES MACHINE	4	CEE281& CEE282
TIME OF SETTING OF HYDRAULIC CEMENT AND CONSISTENCY BY VICAT NEEDLE	5	CEE281& CEE282
COMPRESSIVE STRENGTH OF HYDRAULIC CEMENTS MORTARS	6	CEE281& CEE282
CONCRETE MIX DESIGN MAKING AND CURING CONCRETE TEST SPECIMENS IN THE LABORATORY	7	CEE281& CEE282
SLUMP,COMPACTING FACTOR &VEBE-TIME OF HYDRAULIC CEMENT CONCRETE	8	CEE281& CEE282
UNIT WEIGHT, YIELD, AND AIR CONTENT (GRAVIMETRIC) OF CONCRETE	9	CEE281& CEE282
AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE PRESSURE METHOD	10	CEE281& CEE282
COMPRESSIVE STRENGTH OF CYL CONCRETE SPECIMENS	11	CEE281& CEE282
FLEXURAL STRENGTH OF CONCRETE	12	CEE281& CEE282
SPLITTING TENSILE STRENGTH OF CYLINDRICAL CONCRETE SPECIMENS	13	CEE281& CEE282
REBOUND NUMBER OF HARDENED CONCRETE	14	CEE281& CEE282
PULSE VELOCITY THROUGH CONCRETE	15	CEE281& CEE282

Specific Outcomes of Instruction (Lab Learning Outcomes):

1. Identify the characteristics of all concrete ingredients.(1,6)
2. Identify the effect of using admixtures and their influence on concrete properties.(6)
3. Identify ASTM standards and the components of the mix design.(3)
4. Perform fresh and hardened concrete testing.|(5,6)
5. Conduct experiments and employ the various evaluation techniques that are commonly used to determine the mechanical properties of concrete ingredients.|(5,6)
6. Identify the purpose and concrete applications depending on concrete workability. (1)

Student Outcomes (SO) Addressed by the Lab:

z	Outcome Description General Engineering Student Outcomes	Contribution
1.	an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	H
2.	an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	
3.	an ability to communicate effectively with a range of audiences	L
4.	an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	
5.	an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	H
6.	an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	H
7.	an ability to acquire and apply new knowledge as needed, using appropriate learning strategies	

Table of Content

GENERAL POLICIES

1. Attendance:
   - Laboratory attendance is mandatory.
   - The student will not be allowed to submit a report for an experiment in which he has not participated.
   - Students must arrive punctually. If is student is late more than 10 minutes, he will not be allowed to participate in the lab.
   - In case of excused absences, make-up laboratories will be considered on a case-by-case basis.

2. Safety:
   - Safety should be the primary concern when working in any laboratory. Unsafe behavior will not be tolerated in the lab
   - Your laboratory instructor will warn you of potentially dangerous situations which might arise.
   - At all times students will conduct themselves in safe manner.
   - No eating, drinking, or "horseplay" is permitted in the laboratory.
   - Haste causes many accidents. Work deliberately and carefully. Verify your work as you go along. Good planning before coming to the laboratory will promote safety.
   - Disciplinary action will be taken against violators.

3. Reports:
   - Individual reports are required for every experiment.
   - Reports are type written.
   - Reports are due 10 days from the day of the experiment.
   - Late report will be subjected to a penalty of 15% per day. Late reports will be accepted up to 4 days after the due date. No late report will be accepted after that

FORMATS FOR THE WRITTEN LABORATORY REPORTS:

1- Title Page (Cover Page).
2- Abstract.
3- Introduction.
4- Methodology (Experimental Procedure, Methods and Materials or Equipment).
5- Results and Discussion.
6- Conclusion and Comments.
7- References.
8- Appendences

Experiment 1: SIEVE ANALYSIS OF FINE & COARSE AGGREGATES

I. Objective:

This test method covers the determination of the particle size distribution of fine and coarse aggregates by sieving. A weighed sample of dry aggregate is separated through a series of sieves of progressively smaller openings for determination of particle size distribution.

II. Test Standard

ASTM C136

III. Theory:

Maximum Size (of aggregate) - in specifications for, or description of aggregate, the smallest sieve opening through which the entire amount of aggregate is required to pass.

Nominal Maximum Size (of aggregate) - in specifications for, or description of aggregate, the smallest sieve opening through which the entire amount of the aggregate is permitted to pass

IV. Apparatus:

Scale (or balance) - 0.1 g accuracy for fine sieve analysis, 0.5 g accuracy for coarse sieve analysis
Sieves
Mechanical Sieve Shaker
Drying Oven (110 +/- 5 ^{o}C)

V. Procedure:

1) Dry sample to constant weight at a temperature of 110 +/- 5 ^{o}C (230 +/- 9^{o}F).
2) Select suitable sieve sizes to obtain the required information as specified. The following sieves are applicable with reference to ASTM C33:

Coarse Aggregate (in.)	Fine Aggregate
1.5	
1	
¾	
1/2	
3/8	
No. 4 =4.75mm	No. 4
No. 8 =2.36mm	No. 8
No. 16 =1.18mm	No. 16
	No. 30=0.60mm

No. 50=0.30mm
No. 100=0.15 mm
No. 200= 0.075mm

PAN PAN

3) Nest the sieves in order of decreasing size of opening from the top to bottom. Place the pan below the bottom sieve. Place the sample on the top sieve. Place lid over top sieve.

4) Agitate the sieves by hand or by mechanical apparatus for a sufficient period such that not more than 1% by weight of the residue on any individual sieve will pass that sieve during 1 minute of additional hand sieving. Ten minutes of original sieving will usually accomplish this criteria.

5) Determine the weight of material retained on each sieve. The total retained weights should closely match the original weight of the sample (within 0.3%).

VI. Experimental Work:

1) Calculate percentages passing and total percentages retained to the nearest 0.1% of the initial dry weight of the sample.

2) Calculate the fineness modulus as follows:
Fine aggregate:
F.M. = {Σ (Cumulative % Retained on # 4, 8, 16, 30, 50, and 100 Sieves)}/100
Coarse aggregate:
F.M. = {Σ (Cumulative % Retained on 1-1/2", 3/4", 3/8", Nos. 4, 8, 16, 30, 50, and 100 Sieves)}/100

Standard Test Method for
Sieve Analysis of Coarse Aggregate
ASTM C 136

Construction Materials Laboratory, CEE 281
Department of Civil Engineering
King Faisal University

Project: ____________________

Equipment Used:

Scale I.D.: ____________ Scale S/N: ____________

Sample Material: ____________ Sieve Set I.D.: ____________ Oven Temperature (C): ____________

Sample I.D.: ____________ **Comments:** ____________

Washed Sample per ASTM C117:
NO ☐ YES ☐ Procedure A ☐ B ☐

Weight Original Dry Sample +Tare, (g): ____________
Weight Tare, (g): ____________
Weight Original Dry Sample, B (g): ____________

Weight of Dry Sample + Tare After Washing, (g): ____________
Weight Tare, (g): ____________
Weight of Dry Sample After Washing, C (g): ____________
Washing Loss, (B-C), (g): ____________

Sieve or Screen			Sieve + Material	Retained	% Retained	Cumulative % Retained	Cumulative % Passing	Cumulative % Passing
(1)	Size (mm) (2)	Weight (g) (3)	Weight (g) (4)	Weight (g) (5)	(6)	(7)	(8)	ASTM C33 Course Aggregate Specification (9)
1"	25.0							100
3/4"	19.0							100.0
1/2"	12.5							100.0
3/8"	9.5							100-85
#4	4.75							30.0- 10.0
#8	2.36							10.0-0.0
#16	1.180							5.0-0.0
PAN							N/A	N/A
WASHING LOSS		N/A	N/A			N/A	N/A	N/A
Total Minus #200		N/A	N/A			N/A	N/A	N/A
TOTAL								

% Error =
% Passing #200=

ASTM Criteria (-0.3 L.T.E. %Error L.T.E. 0.3)
ASTM Criteria (L.T.E. 1.0%)

Fineness Modulus =

Calculations:
Col (5) = Col (4) - Col (3)
Col (6) = 100* Col (5) /B
Col (7) = Col (6) + Col (7) of previous line
Col (8) = 100 - Col (7)
W_T = Total Weight Retained
%Error = (W_T - B)*100/B
Fineness Modulus = (Summation of Cum % Retained on 3/4", 3/8", #4, #8, #16, #30, #50, #100)/100
% Passing #200 = (Total Minus #200)*100/B

	Test By:	Calculations By:	Checked By:
Signature:			
Date:			

Standard Test Method for
Sieve Analysis of Fine Aggregate
ASTM C 136

Construction Materials Laboratory, CEE 281
Department of Civil Engineering
King Faisal University

Project: ______

Equipment Used:

Scale I.D.: ______ Scale S/N: ______

Sample Material: ______ Sieve Set I.D.: ______ Oven Temperature (C): ______

Sample I.D.: ______ **Comments:** ______

Washed Sample per ASTM C117:
NO ☐ YES ☐ Procedure A ☐ B ☐

Weight of Dry Sample + Tare After Washing, (g): ______

Weight Original Dry Sample + Tare, (g): ______ Weight Tare, (g): ______

Weight Tare, (g): ______ Weight of Dry Sample After Washing, C (g): ______

Weight Original Dry Sample, B (g): ______ Washing Loss, (B-C), (g): ______

Sieve or Screen (1)	Size (mm) (2)	Weight (g) (3)	Sieve + Material Weight (g) (4)	Retained Weight (g) (5)	% Retained (6)	Cumulative % Retained (7)	Cumulative % Passing (8)	Cumulative % Passing ASTM C33 Fine Aggregate Specification (9)
3/8"	9.5							100
#4	4.75							95 to 100
#8	2.36							80 to 100
#16	1.18							50 to 85
#30	0.600							25 to 60
#50	0.300							10 to 30
#100	0.150							2 to 10
#200	0.075							N/A
PAN							N/A	N/A
WASHING LOSS		N/A	N/A			N/A	N/A	N/A
Total Minus #200		N/A	N/A			N/A	N/A	N/A
TOTAL								

% Error = ASTM Criteria (-0.3 L.T.E. %Error L.T.E. 0.3)

% Passing #200= ASTM Criteria (L.T.E. 3.0%)

Fineness Modulus = ASTM Criteria (2.3 L.T.E. FM L.T.E. 3.1)

Calculations:
Col (5) = Col (4) - Col (3)
Col (6) = 100* Col (5) /B
Col (7) = Col (6) + Col (7) of previous line
Col (8) = 100 - Col (7)
W_T = Total Weight Retained
%Error = (W_T - B)*100/B
Fineness Modulus = (Summation of Cum % Retained on 3/4", 3/8", #4, #8, #16, #30, #50, #100)/100
% Passing #200 = (Total Minus #200)*100/B

	Test By:	Calculations By:	Checked By:
Signature:			
Date:			

References:

ASTM C117   Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

ASTM E11   Specification for Wire-Cloth Sieves for Testing Purposes

AASHTO T27   Sieve Analysis of Fine and Coarse Aggregates

ASTM C33   Standard Specifications for Concrete Aggregates

ASTM C125   Standard Terminology Relating to Concrete and Concrete Aggregates

Experiment 2: UNIT WEIGHT & VOIDS IN AGGREGATE

I. Objective:

Test method covers the determination of unit weight in a compacted or loose condition and calculated voids in fine, coarse, or mixed aggregates based on the same determination. This test method is often used to determine unit weight values that are necessary for use for many methods of selecting proportions for concrete mixtures.

II. Test Standard

ASTM C29

III. Theory:

1) Calculate the unit weight in both the loose and compact (dense) conditions for both the fine and coarse aggregates.

$$\gamma_{bulk} = (G - T) / V$$

where:

γ_{bulk} = unit weight of the aggregate, lb/ft^3
G = mass of the aggregate plus the measure, lb
T = mass of the measure, lb
V = volume of the measure, ft^3

2) Calculate the void content, n (%), in the aggregate (for fine and coarse compact unit weights only)

$$n\ (\%) = [(G_s\,\gamma_w - \gamma_{bulk}) / G_s\,\gamma_w](100)$$

where:

γ_{bulk} = unit weight of the aggregate, lb/ft^3
G_s = bulk specific gravity, dry basis (from ASTM C127 or C128, as applicable)
γ_w = unit weight of water (62.3 lb/ft^3 or 998 kg/m^3)

3) Calculate the void content, n (%), for the compact fine-coarse aggregate combinations as follows

a) $n\ (\%) = [(G_{com}\,\gamma_w - \gamma_{bulk}) / G_{com}\,\gamma_w](100)$

where:

b) $Gcom = 100/[(C/Gc) + (F/Gf)]$

Gcom = the specific gravity of the combined sand-gravel mixture
Gc = the bulk specific gravity of the coarse aggregate
Gf = the bulk specific gravity of the fine aggregate, and

C and F are the fractions (%) of the Coarse and Fine aggregates comprising the sand-gravel mixture, respectively (the sum of C and F must equal 100%).

IV. Apparatus:

Scale (or balance, 0.1 lb (0.05 kg))
Tamping Rod - a round, straight steel rod, 5/8 in. in diameter and approximately 24 in. in length, having one end rounded to a hemispherical tip of the same diameter as the rod.
Measure - a cylindrical metal watertight measure (nominal 1/3 ft^3 for coarse aggregate and 1/10 ft^3 for fine aggregate)
Scoop

V. Procedure:

Measure Calibration

1) Determine weight of dry measure.
2) Fill the measure completely full with water and determine the weight of measure plus water.
3) Calculate the weight of water by taking the difference between the measurements obtained in (1) and (2) above.
4) Calculate the volume of the container

$$V = W_w / \gamma_w$$

where Ww is the weight of water used to fill the container and □w is the unit weight of water (62.3 lb/ft3 or 998 kg/m3). The computed volume should be close to the nominal value state in the apparatus section.

The following loose and compact unit weight procedures are to be performed on both the coarse and fine aggregates.
Loose Unit Weight (shoveling procedure)

1) Fill the measure to overflowing by means of a scoop, discharging the aggregate from a height not to exceed 2 in. (50 mm) above the top of the measure.
2) Level the surface of the aggregate with a straightedge.
3) Determine the weight of the measure plus content, and the weight of the measure alone, recording values to the nearest 0.1 lb (0.05 kg).

Compact Unit Weight (rodding procedure)

1) Fill the measure one third full and level the surface with the fingers.
2) Rod the layer of aggregate with 25 strokes of the tamping rod evenly distributed over the surface.

3) Add additional aggregate to the measure to the two thirds full level, level with the fingers, and rod again with 25 strokes of the tamping rod.
4) Finally, add additional aggregate to overflowing and rod again using 25 strokes of the tamping rod.
5) Level the surface of the aggregate with a straightedge.
6) Determine the weight of the measure plus content, and the weight of the measure alone, recording values to the nearest 0.1 lb (0.05 kg).

Note: When rodding the first layer, do not allow the rod to strike the bottom of the measure. When rodding the subsequent layers, do not force the rod into the previous layer of aggregate.

Compact Unit Weights (rodding procedure) of sand and gravel mixtures (coarse & fine aggregate mixtures)
1) Each group will determine the compact (dry rodded) unit weight of an assigned sand gravel mixture.
2) Mix the fine and coarse aggregate in a large mixing pan.
3) Determine the unit weight using the Compact Unit Weight procedure (steps 1-6) above

VI. Experimental Work:

1) Report the loose and dense unit weights for both the fine and coarse aggregates to the nearest 1 lb/ft3 .
2) Report the results of the void content to the nearest 1% for both the loose and dense unit weights.
3) Plot class curve of the unit weight vs. % sand.
4) Plot class curve of the void content vs. % sand.

References:

ASTM C127 Specific Gravity and Absorption of Coarse Aggregate
ASTM C128 Specific Gravity and Absorption of Fine Aggregate
ASTM C125 Terminology Relating to Concrete and Concrete Aggregates
AASHTO T19 Unit Weight and Voids in Aggregates

Experiment 3: SPECIFIC GRAVITY & ABSORPTION OF COARSE & FINE AGGREGATES

I. Objective:

Test method C127 covers the determination of specific gravity and absorption of coarse aggregate. The specific gravity may be expressed as bulk specific gravity, saturated surface dry bulk specific gravity (SSD), or apparent specific gravity.

Test method C128 covers the determination of bulk, SSD specific gravity, and apparent specific gravity, and absorption of fine aggregate. The bulk and apparent specific gravity are defined according to ASTM E12, while absorption is defined in ASTM C125.

II. Test Standard

ASTM C127

ASTM C128.

III. Theory:

(Coarse Aggregate)

Bulk Sp. Gr. = A/(B-C)
Bulk Sp. Gr. (SSD) = B/(B-C)
Apparent Sp. Gr. = A/(A-C)

where:
A = weight of oven dried test sample in air, g
B = weight of SSD sample in air, g
C = weight of saturated sample in water, g

Absorption, % = [(B-A)/A] *100

(Fine Aggregate)

Bulk Sp. Gr. = A/(B+S-C)
Bulk Sp. Gr. (SSD) = S/(B+S-C)
Apparent Sp. Gr. = A/(B+A-C)

where:
A = weight of oven dried test sample in air, g
B = weight of pycnometer filled with water to calibration mark, g
S = weight of SSD sample in air, g (prior to placement in pycnometer)
C = weight of pycnometer with specimen and water to calibration mark, g.

Absorption, % = [(S-A)/A] *10

NOTE
The following inequality must be satisfied for absorbing aggregates:
Bulk Specific Gravity $\leq$ Bulk Specific Gravity (SSD) $\leq$ Apparent Specific Gravity

IV. Apparatus:

(Coarse Aggregate)

Scale (or balance)
Sample Container (wire basket)
Water Tank
Sieves (No. 4)
Drying Oven

(Fine Aggregate)

Scale (2 kg)
Pycnometer - A flask or other suitable container into which the fine aggregate test sample can be readily introduced and in which the volume content can be reproduced within 0.1 cm3.
Mold - A metal mold in the form of a frustum of a cone with dimensions of 40 mm top diameter, 90 mm bottom diameter, and 75 mm height.
Tamper - A metal tamper weighing 340 g and having a flat circular tamping face of 25 mm diameter.
Drying Oven

V. Procedure:

(Coarse Aggregate)

1) Sieve dry material and reject all material finer than a number four sieve.
2) Obtain approximately 3 kg of the water soaked material and roll it in a large absorbent cloth until all visible films of water are removed. Wipe large particles individually as required to achieve a SSD condition. Weigh the test sample in his SSD condition to the nearest 0.5 g or 0.05% of the sample weight, whichever is greater.
3) Subsequently, place this SSD sample in the sample container and determine its weight in water. Be sure to tare out the sample container (wire basket) prior to placing the sample. Remove all air before weighing by shaking the basket while immersed.

4) Dry the sample to constant weight in an oven at 110 C, then allow to cool to room temperature. Weigh this dry sample of coarse aggregate

(Fine Aggregate)
1) Obtain approximately 1 kg of the water soaked material by the following process. Decant excess water from the pan in which the fine aggregate has been soaking, being careful to avoid loss of fines.

2) Spread sample on a flat nonabsorbent surface exposed to a gently moving current of warm air, stirring frequently to ensure uniform drying.
3) Follow the cone test for surface moisture, subsequently described; this cone test determines whether or not surface moisture is present on the fine aggregate particles. The first trial of the cone test must be made with some surface water present in the sample. Continue drying with constant stirring of the sample and cone tests at frequent intervals until the cone test indicates that the fine aggregate has reached a saturated-surface-dry condition.
4) Cone Test - Place mold, large side down, on a dry nonabsorbent surface. Place a portion of the partially dried sample loosely in the mold by filling it to overflowing. Lightly tamp the sample into the mold with 25 light drops of the tamper (each drop should start about 5 mm (0.2 in.) above the top surface of the aggregate). The tamper should free fall under gravity during each drop. Distribute the 25 drops over the surface of the sample. Remove loose sand from around the outside base and lift the mold vertically. If surface moisture is still present, the sand cone will retain its molded shape. When the molded shape slightly slumps, a saturated-surface-dry condition has been reached.
5) Partially fill the pycnometer with water. Immediately introduce 500 g of saturated-surface-dry fine aggregate prepared as above. Record the weight of this SSD fine aggregate placed in the pycnometer. Fill the pycnometer to 90% of capacity. Roll, invert, and agitate the pycnometer to eliminate all air bubbles (this can take 15 to 20 min). Bring the pycnometer to its calibrated capacity. Determine the total weight of the pycnometer, specimen, and water. Note: Use distilled gas-free water in the pycnometer.
6) Remove the fine aggregate from the pycnometer and dry to constant weight in an oven at 110 C, then cool to room temperature, and weigh.
7) Determine the weight of the pycnometer filled to its calibration capacity with water.

VI. Experimental Work:

1) Report specific gravity results to the nearest 0.001.

2) Report corresponding densities to the nearest 0.1 lb/ft3.

3) Report the absorption to the nearest 0.1%.

References:

ASTM C127	Specific Gravity and Absorption of Coarse Aggregate
ASTM C128	Specific Gravity and Absorption of Fine Aggregate
ASTM E12	Definitions of Terms Relating Density and Specific Gravity of Solids, Liquids, and Gases
ASTM C125	Terminology Relating to Concrete and Concrete Aggregates
ASTM C29	Unit Weight and Voids in Aggregate
ASTM C566	Total Moisture Content of Aggregate by Drying

Experiment 4: RESISTANCE TO DEGRADATION OF SMALL SIZE COARSE AGGREGATE - BY ABRASION AND IMPACT IN THE LOS ANGELES MACHINE

I. Objective:

This test method covers a procedure for testing sizes of coarse aggregate smaller than 1-1/2 inch (37.5 mm) for resistance to degradation using the Los Angeles testing machine.

II. Test Standard

ASTM C131

III. Theory:

L.A. Abrasion Loss (%) = (Original Weight – Final Weight)*100/(Original Weight)

IV. Apparatus:

Los Angeles testing machine
Sieves
Balance – accurate within 0.1% of range required for test
Charge – the charge shall consist of steel spheres averaging approximately 46.8 mm in diameter and each weighing between390 and 445 g. The charge, depending upon the grading of the test sample, shall be as follows:

Grading	Number of Spheres	Weight of Charge, g
A	12	5000 +/- 25
B	11	4584 +/- 25
C	8	3330 +/- 20
D	6	2500 +/- 15

V. Procedure:

1) Wash the coarse aggregate test sample, per ASTM C136, and oven-dry (105 to 115 °C) to substantially constant weight. Separate into individual size fractions, and recombine to the grading (Table 1) most nearly corresponding to the range of sizes in the aggregate as originally furnished. The weight of the sample prior to test shall be recorded to the nearest 1 g.
2) Place the test sample and the charge in the Los Angeles testing machine
3) Rotate the machine at a speed of 30 to 33 rpm for 500 revolutions.
4) Discharge the material from the L.A. abrasion machine and separate the sample on a No. 12 sieve (1.70 mm).
5) Weigh the material coarser than the No. 12 sieve and record this as the final weight.

Table 1. Gradings of Test Samples

		Weight of Indicated Sizes, g			
Sieve Size (Square Openings)		Grading			
Passing	Retained on	A	B	C	D
37.5 mm (1-1/2 in.)	25.0 mm (1 in.)	1250 +/- 25			
25.0 mm (1 in.)	19.0 mm (3/4 in.)	1250 +/- 25			
19.0 mm (3/4 in.)	12.5 mm (1/2 in.)	1250 +/- 25	2500 +/- 10		
12.5 mm (1/2 in.)	9.5 mm (3/8 in.)	1250 +/- 25	2500 +/- 10		
9.5 mm (3/8 in.)	6.3 mm (1/4 in.)			2500 +/- 10	
6.3 mm (1/4 in.)	4.75 mm (No. 4)			2500 +/- 10	
4.75 mm (No. 4)	2.36 mm (No. 8)				5000 +/- 10
Total		5000 +/- 10	5000 +/- 10	5000 +/- 10	5000 +/- 10

VI. Experimental Work:

Calculate the L.A. abrasion loss as the difference between the original weight and the final weight of the test sample as a percentage of the original weight of the test sample

Compare your results with maximum allowable abrasion loss for concrete coarse aggregate as specified in ASTM C33, Standard Specifications for Concrete Aggregates

References:

ASTM C136 Sieve Analysis of Fine and Coarse Aggregate

ASTM C535 Resistance to Degradation of Large Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

ASTM E11 Specification for Wire Cloth Sieves for Testing Purposes

Experiment 5: TIME OF SETTING OF HYDRAULIC CEMENT AND CONSISTENCY BY VICAT NEEDLE

I. Objective:

This test method covers the determination of the time of setting of hydraulic cement and consistency by means of the Vicat needle.

II. Test Standard

ASTM C191

III. Theory:

Initial setting time more than 30 minutes
Final setting time less than 10 hours

IV. Apparatus:

Vicat apparatus – Consists of a frame, a movable rod weighing 300 g with a 10 mm plunger on one end and a 1 mm removable needle on the other end.
Conical Ring
Glass Plate
Balance – 0.01g resolution.
Timer – 0.5s resolution.

V. Procedure:

A- Normal Consistency
1) Mix 500 g of cement with the required amount of clean mixing water to obtain a paste of normal consistency (C187 & C305).
a) Place all the mixing water in the mixing bowl.
b) Add the cement to the water and allow 30 s for the absorption of water.
c) Start the mixer and mix at slow speed (140 rpm) for 30 s.
d) Stop the mixer for 15 s; during this rest period scrap down into the batch any paste that may have collected on the sides of the bowl.
e) Start the mixer at medium speed (285 rpm) and mix for 1 minute.

Note: Approximately 125 g of mixing water (25%) is a good starting point to determine the normal consistency of the cement.

2) Transfer the paste immediately and fill the mould placed on the base-plate, remove the excess by a gentle sawing motion with a straight –egged implement in such a way as to leave the paste filling the mould and having a smooth upper surface within3-5 minutes from adding water to cement

3) Center the paste specimen under the 10 mm end of the Vicat apparatus. Lower the movable rod until the 10 mm end makes contact with the paste. Release the movable rod. Record the scale reading. A “normal consistency” is obtained when the scale reading (5-7)mm

4) Repeat this process, using fresh cement, with varying percentages of water until the normal consistency is obtained, then record the water content of the paste to the nearest 0.5% as the water for standard consistency.

B- Initial Setting Time

1) Prepare a normal consistency paste, using the previously determined amount of water. Mix and place the paste specimen in the mold using the procedure outlined in Steps 1 through 3 above.

Note: start the stop watch at moment you add water to cement

2) Remove the plunger and replace it by the needle.
3) Transfer the mould under the needle of the vicat apparatus
4) Lower the needle gently until it is in contact with the paste
5) Release the moving part quickly and allow the needle to penetrate into the paste
6) Repeat the penetration on the same specimen at conveniently time intervals, clean the needle after each penetration
7) Initial setting time is obtained from zero time until the scale reading (5+0.5)

C-Final Setting Time

1) Fit the needle with ring attachment of diameter approximately 5mm
2) Invert the filled mold(used for initial setting time) on its base-plate so that the tests for final set are made on the face of the specimen originally in contact with the base plate
3) Gently apply the needle on the specimen, if the outer ring make an impression repeat the test on the specimen at conveniently spaced position at conveniently spaced intervals of time
4) Final setting time is obtained from the zero time (you add water to cement) until the needle only has impression on the sample without the outer ring

VI. Experimental Work:

1) Record the water content of the paste to nearest 0.5% as water for standard consistency
2) Report the initial setting time to the nearest 5 minutes.
3) Report the final setting time to the nearest 5 minutes.

References:

ASTM C187 Normal Consistency of Hydraulic Cement
ASTM C305 Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

Experiment 6: COMPRESSIVE STRENGTH OF HYDRAULIC CEMENTS MORTARS

I. Objective:

This test method covers the determination of the compressive strength of hydraulic cement mortars using 2 inch (50 mm) cube specimens

.II. Test Standard

ASTM C109

III. Theory:

Compressive Strength (pa) , (psi)= maximum load / cross sectional area

IV. Apparatus:

Scale (2000 g)
Specimen Molds
Mixer, Mixing Bowl, Mixing Paddle, & Scraper
Flow Table and Flow Mold
Tamper
Trowel
Testing Machine, Forney 400 kip testing machine

V. Procedure:

Mortar Composition - The proportions of materials for the standard mortar shall be one part of cement to 2.75 parts of graded standard sand by weight. Use a water-cement ratio of 0.485 for all Portland cements and 0.460 for all air-entraining Portland cements. The water-cement ratio for other than Portland and air-entraining Portland cements shall be such as to produce a flow of 110 +/- 5.

Batch the following, which is sufficient for 6 samples:

Cement, g	500
Sand, g	1375
Water, g	
Portland (w/c=0.485)	**242**

Note: use 3different W/c ratios

(Air-entraining portland (w/c=0.460)	*230*
Non-portland	*(As required for flow of 110))*

Specimen Mold Preparation - Apply a thin coating of mold release to the interior surfaces of the molds and base plates. Wipe surfaces with a cloth to remove any excess.

Mortar Mixing Procedure (ASTM C305) - Place dry paddle and dry bowl in the mixing position of the mixer. Introduce the materials into the bowl in the following manner:

1) Place all the mixing water in the bowl.

2) Add the cement to the water; then start the mixer and mix at slow speed (140 rpm) for 30 s.

3) Add sand slowly over a 30 s period, while continued mixing at slow speed.

4) Stop the mixer, change to medium speed (285 rpm), and mix for an additional 30 s.

5) Stop the mixer and let the mortar stand for 1.5 minutes. During the first 15 s, quickly scrape down into the batch any mortar that may have collected on the side of the bowl; then for remainder of the interval, cover with the lid.

6) Finish mixing for 1 minute at medium speed (285 rpm).

7) Determine flow of mortar as follows:
   a) Wipe table clean and dry and place flow mold at center
   b) Place a layer of mortar about 1 inch thickness in the mold and tamp 20 times.
   c) Then fill the mold and tamp this second layer 20 times.
   d) Cut mortar flush with top of mold with a trowel, held perpendicular to the mold, using a sawing motion.
   e) Wipe table around mold clean of all mortar and dry; then remove mold.
   f) Drop table through ½ inch height 25 times in 15 s.

g) Use calipers to measure the diameters along the 4 scribed lines on the table. The sum of the four readings is the flow (the percent increase in the original diameter). Record this flow value.

8) Following flow test, return all mortar to the mixing bowl. Scrap down the sides and remix for 15 s at medium speed (285 rpm).

Molding Test Specimens - Start molding within 2 minute and 30 s after completion of the original mixing of the mortar.

1) Place a layer of mortar about 1 in. (25 mm) (approximately one half of the depth of the mold) in all of the cube compartments.

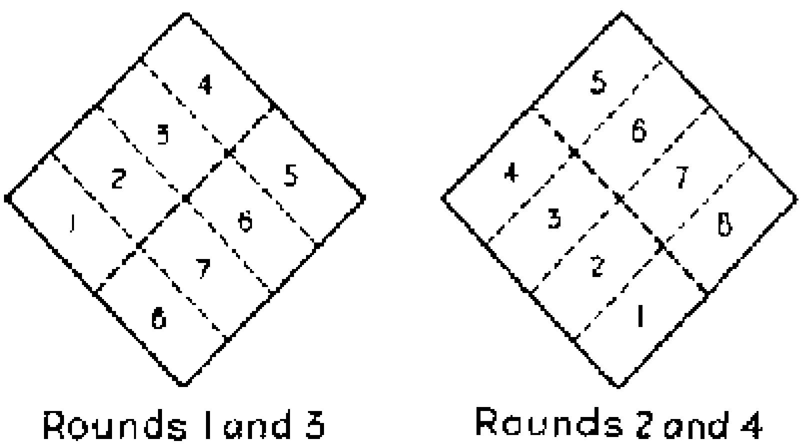


Figure 1. Order of Tamping in Molding of Test Specimens.

2) Tamp the mortar in each cube compartment 32 times in about 10 s in four (4) rounds, each round to be at right angles to the other and consisting of eight adjoining strokes over the surface of the specimen (see Figure 1).

3) Fill the compartments with the remaining mortar and tamp as specified for the first layer. During tamping of the second layer, bring in the mortar forced out onto the tops of the molds after each round of tamping using gloved finger and the tamper. On completion of the tamping, the tops of all cubes should extend slightly above the top of the mold.

4) Trowel mortar of each cube both laterally and longitudinally. Cut off mortar to a plane surface with the top of the mold by drawing the straight edge of the trowel, held perpendicular to the mold, with a sawing motion over the length of the mold.

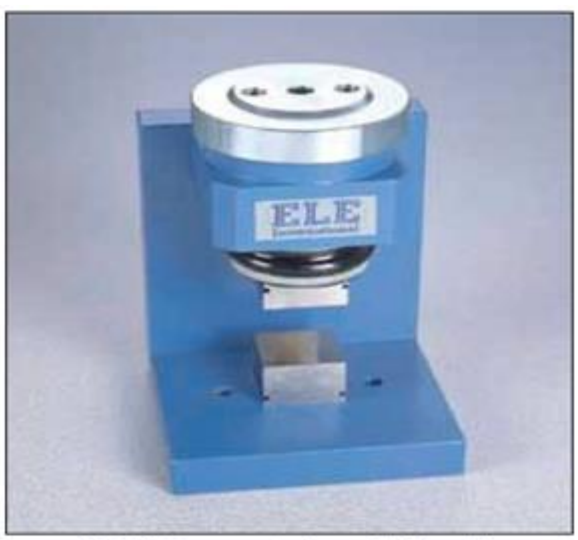
5) Place molded specimens in a moist room for 24 hours. Keep specimens in their molds for this initial curing period. After 24 hours remove specimens from the molds and immerse in a saturated lime water curing tank.

Compressive Strength Determination Test all specimens according to the specified testing schedule. 3, 7, and 28 day strengths will be obtained to ascertain the strength gain as a function of time.

1) Remove specified test specimen from the curing tank. Wipe to a surface dry condition and remove any loose sand grains or incrustations for test surfaces. Determine the unit weight of the specimen by carefully weighing, and measuring the dimensions of, each cubical specimen.

2) Apply the load to specimen faces that were in contact with the true plane surfaces of the mold. Check the straightness of these faces with a straight edge. Note that grinding is required if the surfaces have appreciable curvature. Select opposing surfaces which have the straightest profiles.

3) Place specimen below the center of the upper bearing block of the testing machine. Ascertain that this spherically seated block is free to tilt. Test at a loading rate such that the peak load will be reached in a period of 20 s to 80 s. Make no adjustments in the controls of the testing machine while specimen is yielding prior to failure.



39-5600 Compression Frame Jig Assembly
with Accessories

4) Schematically show how the specimen failed.

5) Record the total maximum load as indicated by the testing machine. Calculate the compressive strength of the specimen in pounds per square inch (psi). Express this strength in Pascals (Pa).

6) Calculate the average of all like specimens and report to the nearest 10 psi (70 kPa).

VI. Experimental Work:

After testing at 1, 3, and 7 days, generate curves, using all group data for each cement type, of compressive strength vs. time of testing. Show all data points and plot an average curve. Plot the ASTM C150 Specifications.

References:

ASTM C109 Compressive Strength of Hydraulic Cement Mortars

ASTM C778 Specification for Standard Sand

ASTM C150 Specification for Portland cement

ASTM C305 Mechanical Mixing of Hydraulic Cement Pastes & Mortars of Plastic Consistency

ASTM C230 Specification for Flow Table for Use in Tests of Hydraulic Cements

Experiment 7: MAKING AND CURING CONCRETE TEST SPECIMENS IN THE LABORATORY

I. Objective:

This ASTM 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.

II. Test Standard

ASTM C192

III. Theory:

This practice also makes reference to typical plastic concrete tests such as the a) slump test, b) the unit weight, yield, and air content by gravimetric means, and c) the air content by pressure meter.

IV. Apparatus:

Concrete Mixer, power driven
Tamping Rods
    5/8” diameter for 6 inch diameter cylinders
    3/8” diameter for 3 inch and 4 inch diameter cylinders
Shovel, hand scoop, trowel
Mallet - rubber, weighing approximately 1.25 lb
Molds - cylinders, 3” diameter by 6”, 4” diameter by 8”, & 6” diameter by 12”, and beams, 6” by 6” by 21”
Vibratory Table

V. Procedure:

1) Dampen entire inside of mixer drum and drain.
2) Add coarse aggregate, some of the mixing water, and admixture solution to the mixer
3) Start mixer.
4) Add fine aggregate, cement, and the balance of the water while the mixer is running.
5) Mix for 3 minutes followed by a 3 minute rest (turn mixer off). Final mix for an additional 2 minutes.
6) Tilt the mixer while it is running and pour the concrete into a clean and wet wheelbarrow.
7) Remove any concrete stuck in the mixer using a scoop or trowel.
8) Remeix concrete in the wheelbarrow using a shovel.
9) Measure the slump per procedure below.
10) Determine the unit weight, yield, and air content per procedure below.
11) Sample Preparation:

CYLINDERS

a) Place the concrete in the cylindrical molds, using hand trowel or scoop, in three layers, each approximately one-third the volume of the mold. For the final layer, place sufficient concrete to just fill mold after compaction (rodding).
b) Rod each layer, 25 times, with the appropriate rounded tamping rod. Rod the bottom layer throughout it's entire depth. Distribute the strokes uniformly across the cross section of the mold. Rod the upper layers allowing the rod to penetrate the underlying layer about 1 inch.
Note: Use the 5/8" rod for the 6 inch diameter cylinders and the 3/8" rod for the 3 inch & 4 inch diameter cylinders.
c) After each layer is rodded, tap the outside of the mold lightly 15 times with the mallet. Use an open hand, in lieu of the mallet, for light gauge single use molds.
d) Finish by troweling off top surface flush with top of mold.

BEAMS

a) Place the concrete in the beam molds, using a hand trowel or scoop. Fill using the trowel and tamping rod as necessary so that the mold will not be overfilled by more than ¼".
b) Place filled beam on vibration table and vibrate sufficiently. Usually sufficient vibration has been applied as soon as the surface of the concrete has become relatively smooth. Over-vibration may cause segregation of the aggregates.
c) Finish the top surface by adding only enough concrete with a trowel to overfill the mold by about 1/8". Work this additional concrete into the surface with trowel and strike off the excess with the trowel.

12) Curing: Cover the prepared cylinders and beams with impervious plastic sheeting. After 24 hours, remove the specimens from their molds and cure, by immersion, in the water storage tanks.

VI. Experimental Work:

References:

ASTM C192 Making and Curing Concrete Test Specimens in the Laboratory
ASTM C143 Slump of Hydraulic Cement Concrete
ASTM C138 Unit Weight, Yield, and Air Content (Gravimetric) of Concrete
ASTM C231 Air Content of Freshly Mixed Concrete by the Pressure Method

Experiment 8: SLUMP OF HYDRAULIC CEMENT CONCRETE

I. Objective:

To determine the degree of concrete workability

II. Test Standard

ASTM C143

III. Theory:

Concrete workability depends on concrete applications in the site

IV. Apparatus:

Slump mold w/base plate (see photo)

Tamping Rod (5/8” diameter)

Scale (tape measure)

Shovel, hand scoop

V. Procedure:

1) Start the test within 5 min. after obtaining the final portion of the mixed concrete sample.

2) Dampen the mold (inside) and place on the dampened base plate.

3) Hold the mold firmly in place during the filling and rodding operation (by the operator standing on the two foot pieces).

4) Fill the mold in three layers, each approximately one-third the volume of the mold.

5) Rod each layer with 25 strokes of the tamping rod. During filling and rodding the top layer, heap the concrete above the mold before rodding is started.

6) Strike off the surface by a screeding and a rolling motion of the tamping rod.

7) Remove the mold immediately by raising it in a vertical direction. (steps 2 through 7 should be completed in less than 2.5 minutes).

8) Place the empty mold (inverted) adjacent to the concrete sample and measure the vertical difference between the top of the mold and the displaced original center of the sample. This is the slump. (See photo)

VI. Experimental Work:

Record the slump in inches to the nearest ¼ in.

References:

Experiment 9: UNIT WEIGHT, YIELD, AND AIR CONTENT (GRAVIMETRIC) OF CONCRETE

I. Objective:

To determine unit weight, yield & air content (Gravimetric)of concrete

II. Test Standard

ASTM C138

III. Theory:

Yield - volume of concrete produced per batch, cubic yard, or cubic meter

Air content - percentage of air voids by volume in concrete

IV. Apparatus:

Measure - a cylindrical metal watertight measure, a yield bucket (nominal 1/3 ft^3)
Tamping Rod (5/8" diameter)
Scale (0.01 lb accuracy)
Mallet - rubber, weighing approximately 1.25 lb
Flat trowel

V. Procedure:

1) Weigh the empty measure.
2) Fill the measure with freshly mixed concrete in three layers of approximately equal volume. Rod each layer with 25 strokes of the tamping rod.
3) After each layer is rodded, tap the sides of the measure *smartly* 15 times with the mallet (this procedure is required to release any large trapped air bubbles). After consolidation, the measure must not contain any excess of concrete protruding above (approximately 1/8") the top of the yield bucket.
4) Strike off the top surface with a sawing motion of the flat trowel (using little vertical pressure).
5) Clean all excess concrete from the exterior of the measure (use a dampened towel if necessary, and then dry).
6) Weigh the measure with concrete.
7) Calculate the unit weight of concrete as the ratio between net weight of concrete and measure volume:

$\gamma_{concrete} = W_{concrete} / V_{measure}$
where: $\gamma_{concrete}$ = unit weight of concrete (lb/ ft^3)
$W_{concrete}$ = net weight of concrete (lb)
$V_{measure}$ = volume of measure (ft^3)

8) Calculate the total weight of all materials batched, i.e., the sum of the weights of the cement, fine aggregate (sand), coarse aggregate (gravel), the mixing water, and any admixture:
$W_1 = W_c + W_s^* + W_g^* + W_w^* + W_a$
where: W_c , W_s^* , W_g^* , W_w^* and W_a are the weights of cement, sand, gravel, water, and admixture, respectively. (Note: W_s^* , W_g^* , and W_w^* are adjusted weights for absorption and moisture content).
9) Calculate the yield, in yd^3 /batch as:

$\text{Yield} = W_1 /(27\ \gamma_{concrete})$
10) Calculate the theoretical unit weight of concrete (on an air-free basis):
$\gamma_{theoretica} = W_1/V$
where: V = the total absolute volume of the component ingredients in the batch (ft^3);
$V = [(W_c /G_c) + (W_s /G_s) + (W_g /G_g) + (W_w /G_w) + (W_a /G_a)]/ \gamma_w$
where: G_c is the specific gravity of cement (=3.15)
G_s , and G_g , are the bulk specific gravities (dry) of sand, and gravel, respectively,
G_a is the specific gravity of the admixture,
G_w is the specific gravity of water (=1.00),
γ_w is the unit weight of water, 62.4 lb/ ft^3, and
W_s , W_g , and W_w , are the weights of sand, gravel, and water (unadjusted for absorption and moisture).
11) Calculate the air content as
$\% \text{Air} = 100(\gamma_{theoretical} - \gamma_{concrete})/ \gamma_{theoretical}$

VI. Experimental Work:
1) Report the value of unit weight to the nearest 0.1 lb/ft^3.
2) Report the value of theoretical unit weight to the nearest 0.1 lb/ft^3.
3) Report the air content to the nearest 0.1%.
4) Report the yield to the nearest 0.01 yd^3.

References:

Experiment 10: AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE PRESSURE METHOD

I. Objective:

This test method covers the determination of the air content of freshly mixed concrete made with dense aggregate (non-lightweight aggregate). A suitably designed air meter employing the principle of Boyle's law is used to determine the air content of the plastic concrete.

II. Test Standard

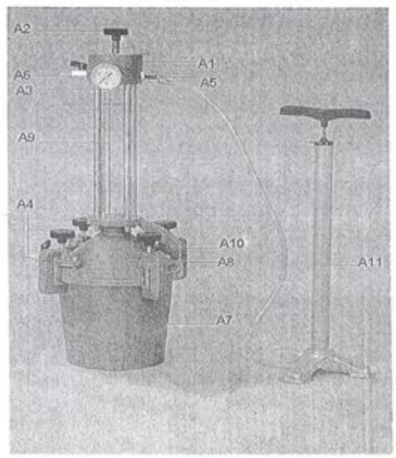
ASTM C231

III. Theory:

A suitably designed air meter employing the principle of Boyle's law is used to determine the air content of the plastic concrete

IV. Apparatus:

Air Meter Type A
(see photo) – consists of a measuring bowl (capacity of 5 liters) and cover
Tamping Rod (5/8" diameter)
Scale (0.01 lb accuracy)
Mallet - rubber, weighing approximately 1.25 lb
Strike off bar



V. Procedure:

1) Dampen the interior of the bowl and place on a flat, level, firm surface.

2) Using a scoop, place the concrete in the measuring bowl in the required number of layers, moving the scoop around the perimeter of the bowl opening to ensure an even distribution of the concrete. For the first layer:

A- Fill the bowl to approximately 1/3 of its volume

B- Rod the layer 25 times throughout its depth but not forcibly striking the bottom of the measure. Distribute the roddings uniformly over the cross section of the bowl.

C- Tap the outside of the bowl smartly 10 to 15 times with the mallet to close voids by tamping rod.

3) For the second layer:
A- Fill the bowl to approximately 2/3 of its volume.
B- Rod the layer 25 times, penetrate the first layer about 1inch (25mm), evenly distribute the roddings over the cross section of the bowl.
C- Tap the outside of the bowl smartly 10 to 15 times with the mallet to close voids by tamping rod.

4) For the third layer:
A- Add concrete in a manner to avoid excessive overfilling.
B- Rod the layer 25 times, penetrate the second layer about 1inch(25mm),evenly distribute the roddings over the cross section of the bowl.

C- Tap the outside of the bowl smartly 10 to 15 times with the mallet to close voids by tamping rod.

5) Strike- off the top layer of the concrete:

A – <u>if using a strike –off plate:</u>

i) Cover 2/3 of the top surface of the concrete with plate. Withdraw the plate using a sawing motio while keeping the plate level.

ii) Place the plate over the original area covered in step 5a. Advance the plate completely across the top surface of the concrete again using a sawing motion, with a downward pressure, and keeping the plate level

iii) Holding the plate in an inclined position, and using the edge of the plate, use several final strokes to produce a smooth finished surface.

B- <u>if using a strike –off bar:</u> Strike –off the top surface by sliding the strike-off bar across the top flange or rim of the measuring bowl with a sawing motion until the bowl is just level full.

6) Thoroughly clean the flange/rim of the bowl and cover assembly

7) Clamp the cover to the bowl ensuring a pressure tight seal.

8) Add water over the concrete by means of the tube until rises to about the halfway mark in the standpipe

9) Incline the apparatus assembly about 30degrees from vertical and using the bottom of the bowl as a pivot , describe several complete circles with the upper end of the column, simultaneously tapping the cover lightly to remove any entrapped air bubbles above the sample

10) Return the apparatus assembly to a vertical position and fill the water column slightly above the zero mark, while lightly tapping the sides of the bowl

11) Bring the water level to the zero mark of the graduated tube before closing the vent at the top of the water column.

12) Apply more than the desired test pressure by means of the small hand pump, relieving local restrains by tapping the sides of the measure sharply.

13)When the pressure gauge indicates the exact test pressure ,read the water level and record to the nearest division or half – division on the gauge of the standpipe.

14) Gradually release the air pressure through the vent at the top of the water column and tap the sides of yhe bowl lightly for about 1 min.

VI. Experimental Work:

1) Record the water level to the nearest division or half- division on the gauge of the standpipe.
2) Calculate the apparent air content by subtracting the initial gauge reading from the gauge reading at zero pressure after release of pressure.

$A_1 = h_1 - h_2$

3) Report the air content to the nearest 0.1% using the aggregate correction factor (or to the nearest 1/2 scale division if the gauge reading exceeds 8%).

References:

Experiment 11: Compressive Strength of Cylindrical Concrete Specimens

I. Objective:

This ASTM test method covers the determination of the unconfined compressive strength of cylindrical concrete specimens. The test method consists of applying a compressive axial load to molded cylinders (or cores) at a rate which is within a prescribed range until failure occurs

II. Test Standard

ASTM C39

III. Theory:

The compressive strength of the specimen is calculated by dividing the maximum load attained during the test by the cross-sectional area of the specimen.

IV. Apparatus:

Compression Test Machine

V. Procedure:

1) Maintain the specimen in a moist condition up to the time of compression testing. Compression tests are made as soon as practicable after removal from moist storage. The specimens are tested in this cured moist condition.

2) Wipe clean the bearing surfaces of the upper and lower platens of the compression testing machine. Also, wipe clean both end caps of the test specimen.

3) Center the specimen on the lower platen of the testing machine.

4) Carefully align the axis of the specimen with the center of thrust of the spherically seated upper platen.

5) Bring the upper platen to bear on the specimen, adjusting the load to obtain uniform seating of the specimen.

6) Apply the load at a loading rate of 20 to 50 psi/s (140 to 350 lb/s for 3” diameter cylinders, 250 to 630 lb/s for 4” diameter cylinders, 560 to 1400 lb/s for 6” diameter cylinders). The time to failure for 3000 psi concrete is 1 to 2.5 minutes.
7) Apply the load at the prescribed loading rate until the specimen fails. Record the maximum load (lb). Note the type of failure and the appearance of the concrete (see Figure 1).

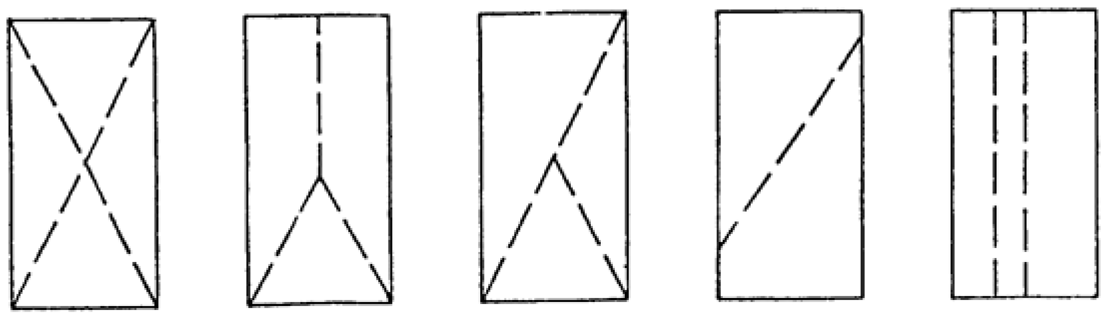


Figure 1. Types of Concrete Fracture

VI. Experimental Work:

1) Report the size (diameter and length) and the age of the specimen.
2) Record the maximum load to the nearest 10 lb.
3) Report the type of failure and appearance of the concrete.
4) Calculate the unconfined compressive strength of the specimen by dividing the maximum load by the cross-sectional area of the specimen. Report this strength to the nearest 10 psi.
5) Plot the results for all data generated by the class (both sections if applicable), showing unconfined compression strength (y-axis) versus time in days (x-axis). Calculate average strength values from the above data and plot.
6) For purposes of design of concrete structures, the 28 day strength is typically used. What is f_{cr}' based on the acquired test results?
7) Calculate the standard deviation for 7, 14, and 28 days. Assume that the standard deviation at 28 days is based on a sample size greater than 30 specimens.

References:

ASTM C39 Compressive Strength of Cylindrical Concrete Specimens
ASTM C192 Making and Curing Concrete Test Specimens in the Laboratory

Experiment 12: FLEXURAL STRENGTH OF CONCRETE

I. Objective:

This ASTM test method covers the determination of the flexural strength of concrete using a simple beam with third point loading. The results are calculated and reported as the modulus of rupture.

II. Test Standard

ASTM C78

III. Theory:

Modulus of Rupture (MOR) - the tensile strength of a material determined using a flexural specimen

1) If the fracture (rupture) occurs in the tension surface (the bottom surface) outside the middle third of the span length by more than 5% of the span length, discard the result of the test.
2) Calculate the modulus of rupture (MOR), neglecting the beam weight, as follows:

a) When fracture initiates in the tension surface (i.e., the bottom surface) within the middle third of the beam,

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

where *P* is the maximum load at failure in pounds, *l* is the span length, *d* is the depth of the beam, and *b* is the width of the beam. All dimensions are in inches.

b) If fracture initiates in the tension surface (i.e., the bottom surface) outside the middle third of the beam by not more than 5% of the span length,

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

Where *a* is the average distance, in inches, between the line of fracture and the nearest support measured on the tension surface of the beam

3) An empirical relation for the MOR, according to your textbook, is

$$MOR \cong 8.75\sqrt{f_c^{'}}$$

IV. Apparatus:

Compression Testing Machine

Loading Apparatus - Third-point loading mechanism

V. Procedure:

1) Position the specimen in the testing machine. Center the loading apparatus in relation to the applied axial force.

2) Bring the load-applying block in contact with the upper surface of the specimen at the third points between the lower supports. The span distance between the lower supports is 12 in.

3) Apply the load continuously at a rate that increases the extreme fiber stress 125 to 275 psi/minute until rupture occurs. Note the peak load at failure

VI. Experimental Work:

1) Report the type of concrete, unit weight, and unconfined compressive strength.
2) Report the modulus of rupture to the nearest 5 psi.
3) What is the ratio of the modulus of rupture strength to the unconfined compressive strength?
4) How does the modulus of rupture flexural tensile strength compare with the strength obtained from the splitting tensile test (ASTM C496, Splitting Tensile Strength of Cylindrical Concrete Specimens)? Express as a ratio of the split tensile strength to the MOR.

References:

ASTM C78 Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
ASTM C496 Splitting Tensile Strength of Cylindrical Concrete Specimens
ASTM C39 Compressive Strength of Cylindrical Concrete Specimens
ASTM C192 Making and Curing Concrete Test Specimens in the Laboratory

Experiment 13: SPLITTING TENSILE STRENGTH OF CYLINDRICAL CONCRETE SPECIMENS

I. Objective:

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

.II. Test Standard

ASTM C496

III. Theory:

This method consists of applying a diametral compressive force along the length of a cylindrical specimen. This loading induces tensile stresses on the plane containing the applied load. Tensile failure occurs rather than compressive failure. Plywood strips are used so that the load is applied uniformly along the length of the cylinder. The maximum load is divided by appropriate geometrical factors to obtain the splitting tensile strength

The splitting tensile strength as follows:

$$f'_{st} = \frac{2P}{\pi \ ld}$$

where P is the maximum load at failure in pounds, and l and d are the length and diameter of the cylindrical specimen, respectively, in inches.

IV. Apparatus:

Compression Testing Machine

Bearing Strips - 2 each, 1/8 in. thick plywood strips, 1 in. wide (the length shall be slightly longer that that of the specimens). The bearing strips are placed between the specimen and the upper and lower bearing blocks of the testing machine (or between the specimen and supplementary bearing bars if used).

Supplementary Bearing Bars - Steel bar 2 in. wide, 3 in. thick, and 12 in. long

V. Procedure:

1) Draw diametral lines on each end of the specimen so that they are in the same axial plane.
2) Center one of the plywood strips along the center of the lower bearing block.
3) Place the specimen on the plywood strip and align so that the lines marked on the ends are vertical and centered over the plywood strip
4) Place the second plywood strip and the bearing bar so that they are lengthwise on the cylinder, centered on the previously marked lines on the ends.
5) Apply the load continuously at a constant rate of 100 to 200 psi/minute of splitting tensile stress until failure occurs (the load rate is 11000 to 22000 lb/minute for 6"diameter by 12" long specimens).
6) Record the maximum load at failure.

VI. Experimental Work:

1) Report the type of concrete, unit weight, and unconfined compressive strength.
2) Report the splitting tensile strength to the nearest 5 psi.
3). What is the ratio of the splitting tensile strength to the unconfined compressive strength?
4) How does the splitting tensile strength compare with the strength obtained from the Modulus of Rupture tests (ASTM C78, Flexural Strength of Concrete)? Express as a ratio of the split tensile strength to the MOR.

References:

ASTM C496 Splitting Tensile Strength of Cylindrical Concrete Specimens
ASTM C39 Compressive Strength of Cylindrical Concrete Specimens
ASTM C78 Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
ASTM C192 Making and Curing Concrete Test Specimens in the Laboratory

Experiment 14: REBOUND NUMBER OF HARDENED CONCRETE

I. Objective:

This ASTM test method covers the determination of the rebound number of hardened concrete using a spring driven steel hammer.

II. Test Standard

ASTM C805

III. Theory:

This test method may be used to assess the in-place uniformity of concrete, to delineate regions in a structure of poor quality or deteriorated concrete, and to estimate in-place strength development. To use this method to estimate strength development requires establishment of a relationship between strength and rebound number for a given concrete mixture.

IV. Apparatus:

Rebound Hammer – a spring-loaded steel hammer which when released strikes a steel plunger in contact with the concrete surface.

Test anvil – a 6 inch diameter by 6 inch long high-carbon steel cylinder hardened to Rockwell 65-67 C.

Abrasive stone – silicon carbide of medium grain texture.

V. Procedure:

1) Firmly hold the instrument in a position that allows the plunger to strike vertically downward against the test anvil and verify that the rebound hammer provides the rebound number specified. Be sure to follow the same procedure as for testing the subsequent concrete test surface. Note that the test anvil shall be placed on a solid surface, e.g., concrete floor.
2) Grind and clean the concrete surface using the abrasive stone.
3) Firmly hold the instrument in a position that allows the plunger to strike perpendicularly to the concrete test surface.
4) Gradually increase the pressure on the plunger until the hammer impacts.
5) Examine the impression; if the impact crushes or breaks through a near surface void, discard the reading.

VI. Experimental Work:

1) Report the test date, type of concrete, and estimated unconfined compressive strength.
2) Hammer orientation, i.e., downward, upward, horizontal, or at a specific angle.
3) Average rebound number to the nearest whole number.

Test Date:	
Concrete Type:	
Estimated Strength (psi):	
Hammer Orientation:	
Rebound Numbers:	
Reading #1	
Reading #2	
Reading #3	
Reading #4	
Reading #5	
Reading #6	
Reading #7	
Reading #8	
Reading #9	
Reading #10	
Average Rebound Number	

References:

Experiment 15: PULSE VELOCITY THROUGH CONCRETE

I. Objective:

This ASTM test method covers the determination of the pulse velocity of propagation of compressional waves in concrete. The pulse velocity V is related to the physical properties of a solid by the equation:

$$V^2 = (K)\frac{E}{\rho}$$

where:

$K =$ a constant,
$E =$ the modulus of elasticity, and
$\rho =$ the mass density.

This test method does not apply to the propagation of other vibrations within the concrete

II. Test Standard

ASTM C597

II. Theory:

Pulses of compressional waves are generated by an electro-acoustical transducer that is held in contact with one surface of the concrete under test. After traversing through the concrete, the pulses are received and converted into electrical energy by a second transducer located a distance L from the transmitting transducer. The transit time T is measured electronically. The pulse velocity is calculated by dividing L by T.

IV. Apparatus:

1)Ultra Sonic Tester- The testing apparatus, shown schematically in Figure1, consist of a pulse generator, a pair of transducer (transmitter and receiver),an amplifier, a time measuring circuit, a time display unit, and connecting cables. The PUNDIT ultrasonic concrete tester incorporates all of the above – described features.
2) Calibration bar- a reference bar for which the transit time is accurately known.

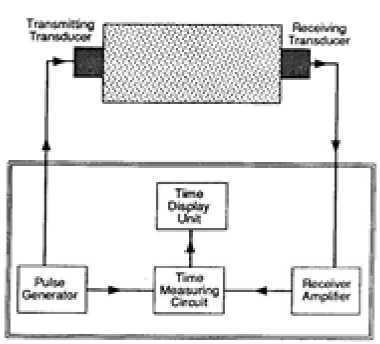


Figure1 Schematic of Pulse Velocity Circuit

V. Procedure:

1) Check the accuracy of the transmit time measurement against the calibration bar. Use an appropriate coupling agent (e.g., vacuum grease, petroleum jelly, or other viscous material) between the transducers and the ends of the calibration bar. Adjust the PUNDIT ultrasonic tester so that the transit time is the same as that stamped on the calibration bar.
2) Measure the length of the concrete specimen.
3) Determine the mass of the concrete specimen.
4) Apply the appropriate coupling agent to the transducers and the test surfaces (the ends of the cylindrical specimen) in order to avoid entrapped air between the contact surface of the transducers and the concrete surface.
5) Press the faces of the transducers against the surfaces of the concrete (cylindrical ends) assuring good contact.
6) Measure the transit time

VI. Experimental Work:

1) Calculate the pulse velocity as follows:

$$V = L / T$$

Where:

$V =$ Pulse velocity, m/s,
$L =$ Distance between transducers, m, and
$T =$ Transit time, s.

2) Calculate the modulus of elasticity as follows:

$$E = \frac{\rho V^2}{K}$$

where:

$E =$ the modulus of elasticity, Pa (N/m^2),
$V =$ pulse velocity, m/s,
$\rho =$ the mass density, kg/m^3, and
$K =$ 1 (for a cylindrical specimen tested as above).

References:

ASTM C215 Standard Test Method for Fundamental Transverse, Longitudinal, and Torsional Frequencies of Concrete Specimens

ASTM C805 Standard Test Method for Rebound Number of Hardened Concrete