CEE 351 – Laboratory 1

Characteristics of Concrete Aggregates

October 5, 2007

Experiment 1: Specific Gravity and Absorption Capacity of Coarse Aggregate

PURPOSE

The purpose of this experiment is to determine both the specific gravity and absorption capacity of coarse aggregate. This information will be used in the proportioning of concrete mixtures. Specific gravity is the characteristic generally used to calculate the volume occupied by aggregate. Absorption capacity describes the change in mass of an aggregate due to water absorbed in the pores.

PROCEDURE

This test is performed in accordance with *ASTM C127: Standard Test Method for Density, Specific Gravity, and Absorption of Coarse Aggregate*. The following materials are required:

- Paper towels
- Shovel/scoop
- Bowl
- Scale
- Water tank
- Wire basket with mesh finer than aggregate particles

Find Saturated Surface Dry (SSD) weight of aggregate:

1. Use shovel to scoop coarse aggregate from the bucket of submerged aggregate. (NOTE: In this test the aggregate was continuously submerged so that all pores are filled, as in the natural state.)[1]
2. Place wet aggregate on paper towels; roll the aggregate particles in the paper towels to remove all visible moisture films and obtain SSD state. NOTE: Do not over dry – this will remove water from the pores, making it not classify as SSD state.
3. Obtain approximately 3 kg of SSD aggregate through the towel drying method; record the actual weight in the data table.

Find weight of aggregate submerged in water:

4. Tare the scale connected to the submerged wire basket, pour the SSD aggregate into the basket and record the weight of submerged aggregate.

Find weight of oven dry aggregate:

5. Find the weight of an empty bowl.
6. Remove the wire basket containing the aggregate from the water. Pour the aggregate into the bowl. Place the bowl in the oven.
7. Dry the sample in an oven; find the weight of the oven dry soil and bowl; record in the data table.

DATA ANALYSIS

Table 1 gives the data from the lab and the appropriate calculations. From this data the Bulk Specific Gravity at the SSD condition (BSG_{SSD}) is 2.57 and the Bulk Specific gravity at the OD condition (BSG_{OD}) is 2.49. The absorption capacity is 3.23%.

Table 1 – Data from Experiment 1 – Specific Gravity and Absorption Capacity of Coarse Aggregate

Weight of SSD aggregate	W_{SSD}	3000.02	g	
Weight of submerged aggregate	W_{sub}	1833.5	g	
Weight of empty bowl	W_{bowl}	221.9	g	
Weight of oven dry aggregate + bowl	$W_{OD+bowl}$	3128.1	g	
Calculations				
Weight of oven dry aggregate	W_{OD}	2906.2	g	$W_{OD} = W_{OD+bowl} - W_{bowl}$
Weight of displaced water	W_{disp}	1166.52	g	$W_{disp} = W_{SSD} - W_{sub}$
Specific gravity of water	SG_w	1.00	--	$SG_w = \rho_w / \rho_w = 1$
Density of water	ρ_w	1.00	g/cm^3	*known*
Volume of aggregate (solids + pores)	V_{total}	1166.52	cm^3	$V_{total} = V_{disp} = \frac{W_{disp}}{\rho_w}$
Volume of pores	V_{pores}	93.82	cm^3	$V_{pores} = \frac{W_{SSD} - W_{OD}}{\rho_w}$
Volume of aggregate (solids)	V_{agg}	1072.7	cm^3	$V_{agg} = V_{total} - V_{pores}$
Density of oven dry coarse aggregate	ρ_{OD}	2.485	g/cm^3	$\rho_{OD} = \frac{W_{OD}}{W_{disp}} \times 0.9975$
Density of SSD coarse aggregate	ρ_{SSD}	2.565	g/cm^3	$\rho_{SSD} = \frac{W_{SSD}}{V_{disp}} \times 0.9975$
Dry bulk specific gravity	BSG_{OD}	2.49	--	$BSG_{OD} = \frac{W_{OD}}{W_{total}}$
SSD Bulk specific gravity	BSG_{SSD}	2.57	--	$BSG_{SSD} = \frac{W_{SSD}}{W_{disp}}$
Apparent specific gravity	ASG	2.71	--	$ASG = \frac{W_{OD}}{W_{disp} - (W_{SSD} - W_{OD})}$
Absorption	A	3.23	%	$A = \frac{W_{SSD} - W_{OD}}{W_{OD}} \times 100\%$

Discussion – Obtaining Reproducible Results

The values of absorption and specific gravity for aggregate that is not oven dried before it is soaked in water can be significantly higher that aggregate that is oven dried. (1) Larger particles, especially those over 75 mm, may be too thick to allow water to penetrate the pores to the center of the aggregate particle. Therefore it is critical that the procedure state if the aggregate was oven dried and, if so, how long it was submerged in the water. In this case, since the data is being found for a concrete mixture (where the aggregate will be in its natural, moist state) the aggregate was continuously submerged.

Another important procedural point that must be followed to assure reproducible results: The experimenter should assure the aggregate is fully submerged when finding the weight in water.

Experiment 2: Specific Gravity and Absorption Capacity of Fine Aggregate

PURPOSE

The purpose of this experiment is to find both the specific gravity and absorption capacity of the fine aggregate. This information will be used in the proportioning of concrete mixtures. Specific gravity is the characteristic generally used to calculate the volume occupied by aggregate. Absorption capacity describes the change in mass of an aggregate due to water absorbed in the pores.

PROCEDURE

This test is performed in accordance with *ASTM C128: Standard Test Method for Density, Specific Gravity, and Absorption of Coarse Aggregate*. The following materials are required:

- Pycnometer
- Scale
- Mold and tamper
- Bowl
- Hair dryer
- Squirt water bottle

Prepare SSD condition of fine aggregate:

1. Obtain approximately 1 kg of fine aggregate that has been continuously submerged to assure that all pores are full; place sample on a large tray.
2. Use a gently moving current of air (the hair dryer) to dry the aggregate to SSD condition. Stir the aggregate frequently to assure homogeneous drying. When the specimen approaches a free flowing condition, continue to the next step.
3. Use the mold and tamper to test for surface moisture. Place the mold on the tray, with the larger opening down. Fill the mold with aggregate to overflowing. Drop the tamper from a height of 5 mm above the aggregate 25 times, adjusting the drop height to be 5 mm from the lowered aggregate level. Remove soil from surrounding area and remove the mold. Slight slumping indicates the aggregate is at SSD condition. If it retains the shape of the mold, repeat step 2.

Find weight-volume ratios using Gravimetric Procedure:

4. Record the weight of the dry, empty pycnometer.
5. Fill the pycnometer to the tip of the cone; record the weight.
6. Empty and dry the pycnometer, add approximately 500 g of SSD aggregate, prepared in the previous section. Record the weight of the pycnometer and aggregate.
7. Fill the aggregate pycnometer with water to the tip of the cone; record the weight.
8. Record weight of empty bowl.
9. Pour aggregate-water mixture into the bowl. Use a spray bottle to remove all aggregate from pycnometer.
10. Place bowl in oven to dry; record oven dry temperature of the aggregate in the bowl.

DATA ANALYSIS

Table 2 gives the data from the lab and the appropriate calculations. From this data the Bulk Specific Gravity at the SSD condition (BSG_{SSD}) is 2.684 and the Bulk Specific gravity at the OD condition (BSG_{OD}) is 2.669. The absorption capacity is 0.553%.

Table 2 – Data from Experiment 2 – Specific Gravity and Absorption Capacity of Fine Aggregate

Weight of dry, empty pycnometer	W_p	423.1	g	
Weight of pycnometer + water	W_{p+w}	1448.7	g	
Weight of pycnometer + fine aggregate	W_{p+s}	923.15	g	
Weight of pycnometer + fine aggregate + water	W_{p+s+w}	1762.9	g	
Weight of empty bowl	W_{bowl}	223.0	g	
Weight of bowl + oven dry fine aggregate	$W_{OD+bowl}$	720.3	g	
Calculations				
Weight of oven dry aggregate	W_{OD}	497.3	g	$W_{OD} = W_{OD+bowl} - W_{bowl}$
Weight of SSD aggregate	W_{SSD}	500.05	g	$W_{SSD} = W_{p+s} - W_p$
Weight of displaced water	W_{disp}	186.3	g	$W_{disp} = (W_{SSD} + W_{p+w}) - W_{p+s+w}$
Specific Gravity of water	SG_w	1.0	g/cm^3	$SG_w = 1$
Volume of fine aggregate	V_{total}	186.3	cm^3	$V_{total} = V_{disp} = \frac{W_{disp}}{\rho_w}$
Volume of pores	V_{pores}	2.75	cm^3	$V_{pores} = \frac{W_{SSD} - W_{OD}}{\rho_w}$
Volume of impermeable aggregate	V_{agg}	183.55	cm^3	$V_{agg} = V_{total} - V_{pores}$
Density of oven dry fine aggregate	ρ_{OD}	2.66	g/cm^3	$\rho_{OD} = \frac{W_{OD}}{W_{disp}} \times 0.9975$
Density of SSD fine aggregate	ρ_{SSD}	2.68	g/cm^3	$\rho_{SSD} = \frac{W_{SSD}}{W_{disp}} \times 0.9975$

Dry bulk specific gravity	BSG_{OD}	2.67	--	$BSG_{OD} = \frac{W_{OD}}{W_{disp}}$
SSD Bulk specific gravity	BSG_{SSD}	2.68	--	$BSG_{SSD} = \frac{W_{SSD}}{W_{disp}}$
Apparent specific gravity	ASG	2.72	--	$ASG = \frac{W_{OD}}{W_{p+w} + W_{OD} - W_{p+w+s}}$
Absorption	A	0.553	%	$A = \frac{W_{SSD} - W_{OD}}{W_{OD}} \times 100\%$

Discussion – Description of SG types (a), Obtaining Reproducible Results (b)

(a) Bulk dry specific gravity, bulk SSD specific gravity, and apparent specific gravity are all calculated in experiments 1 and 2. The key concept to understanding these terms is understanding the concept of pores in aggregate particles. A single particle of aggregate has a total volume that includes solids and pores. At the SSD condition the pores are filled with water and at the OD condition the pores are filled with air.

Bulk dry specific gravity is $\frac{weight\ of\ oven\ dry\ aggregate}{total\ volume\ of\ aggregate \times density\ of\ water}$

Bulk SSD specific gravity is $\frac{weight\ of\ SSD\ aggregate}{total\ volume\ of\ aggregate \times density\ of\ water}$

Apparent specific gravity is $\frac{weight\ of\ oven\ dry\ aggregate}{volume\ of\ aggregate\ (solids\ only) \times density\ of\ water}$

From these equations, these bulk and apparent specific gravities can be compared. In general $ASG > BSG_{SSC} > BSG_{OD}$.

(b) Reproducible Results: In order to produce reproducible results, an accurate SSD condition needs to be obtained. It is critical that this is performed correctly, because the basis of all calculations relies on the appropriate SSD weight.

Experiment 3: Gradation Analysis of Coarse and Fine Aggregates

PURPOSE

The purpose of this experiment is to determine the particle size distribution for fine and coarse aggregates using the sieve method. This data will be used to select proportions for concrete mixtures.

PROCEDURE

This test is performed in accordance with *ASTM C136: Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*. The following materials are required:

- Scales (readable to 0.1g)
- Sieve set (one for coarse, one for fine)
- Mechanical sieve shaker

Perform gradation analysis of coarse aggregate:

1. Place a bowl on the scale; tare the scale to set it at zero.
2. Record the sieve sizes and corresponding sieve openings in the data sheet. For simplicity, start with the largest sieve opening (smallest Sieve No.) on the top.
3. Pour approximately 10 k g of the dry coarse aggregate sample into the coarse sieve stack; mechanically agitate for 10 minutes.
4. Remove the sieve set after the 10 minute agitation period.
5. For each sieve, pour retained soil into the bowl. Record weight of retained soil for each sieve. (NOTE: If quantity of soil retained is too large to fit in the bowl, split the sample into two separate measurements.

Perform gradation analysis of fine aggregate:

6. Perform as in steps 1-5, using smaller sieves and appropriate sieve shaker.

DATA ANALYSIS

Tables 3 and 4 give data from experiment 3. Table 3 gives the sieve gradation analysis for coarse aggregate. Table 4 gives the sieve gradation analysis for fine aggregate. Figures 1 and 2, following the data charts, show the particle distribution graphically. As both the tables and figures demonstrate, both the fine and coarse aggregates do not meet ASTM specifications at some point in the distribution.

Table 3 – Data from Experiment 3 – Gradation Analysis of Coarse and Fine Aggregates

Coarse Aggregate Gradation Analysis						
	Weight Retained (g)	Retained (%)	Cumulative Retained (%)	Cumulative Passing (%)	ASTM Spec. (%)*	Meet Specs (Y/N)
37.5 mm (1.5")	0	0.00%	0.00%	100.00%	100%	Y

25 mm (1")	695.71	7.15%	7.15%	92.85%	95-100%	N
19 mm (3/4")	2513.71	25.85%	33.01%	66.99%	--	--
12.5 mm (1/2")	4520.42	46.49%	79.50%	20.50%	25-60%	N
9.5 mm (3/8")	1413.5	14.54%	94.03%	5.97%	--	--
4.75 mm (#4)	440.1	4.53%	98.56%	1.44%	0-10%	Y
2.36 (#8)	--	--	--	--	--	--
Pan	140.01	1.44%	100.00%	0.00%	--	--
Total	9723.45	100.00%	412%	288%	--	--
Initial	10000					
% Error	3%					
FM	4.12					

*Nominal maximum size = 1"

Table 4 – Data from Experiment 3 – Gradation Analysis of Coarse and Fine Aggregates

Fine Aggregate Gradation Analysis						
	Weight Retained (g)	Retained (%)	Cumulative Retained (%)	Cumulative Passing (%)	ASTM Spec. (%)	Meet Specs (Y/N)
9.5 mm (3/8")	0	0.00%	0.00%	100.00%	100%	Y
4.75 mm (#4)	1.39	0.28%	0.28%	99.72%	95-100%	Y
2.36 mm (#8)	20.95	4.23%	4.51%	95.49%	80-100%	Y
1.18 mm (#16)	86.06	17.37%	21.88%	78.12%	50-85%	Y
0.6 mm (#30)	101.8	20.54%	42.42%	57.58%	25-60%	Y
0.3 mm (#50)	131.98	26.63%	69.05%	30.95%	5-30%	N
0.15 mm (#100)	93.33	18.83%	87.89%	12.11%	0-10%	N
Pan	60.02	12.11%	100.00%	0.00%	--	--
Total	495.53	100.00%	326.02%	473.98%	--	--
Initial	500					
% Error	1%					
FM	3.26					

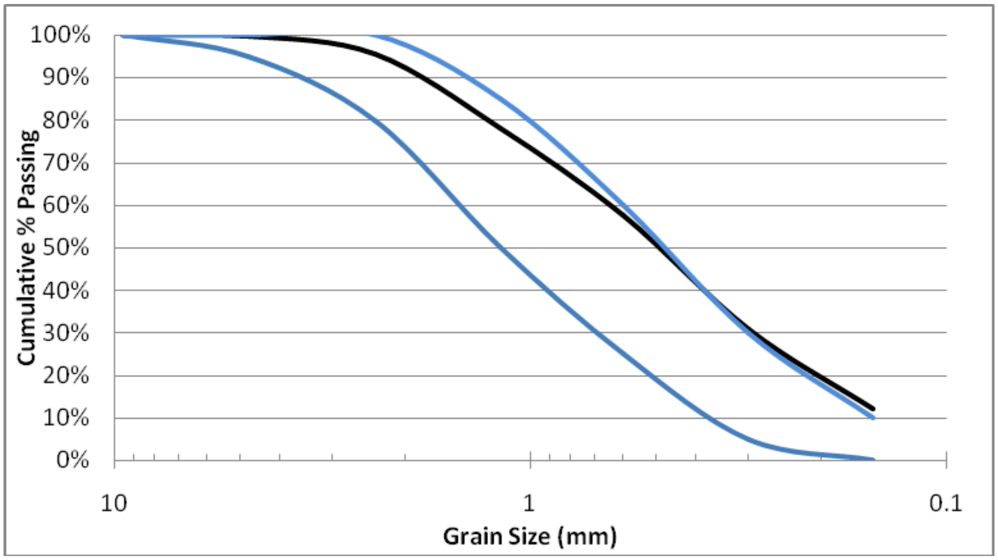

Figure 1: Cumulative Percent Passing vs. Grain Size for Coarse Aggregate

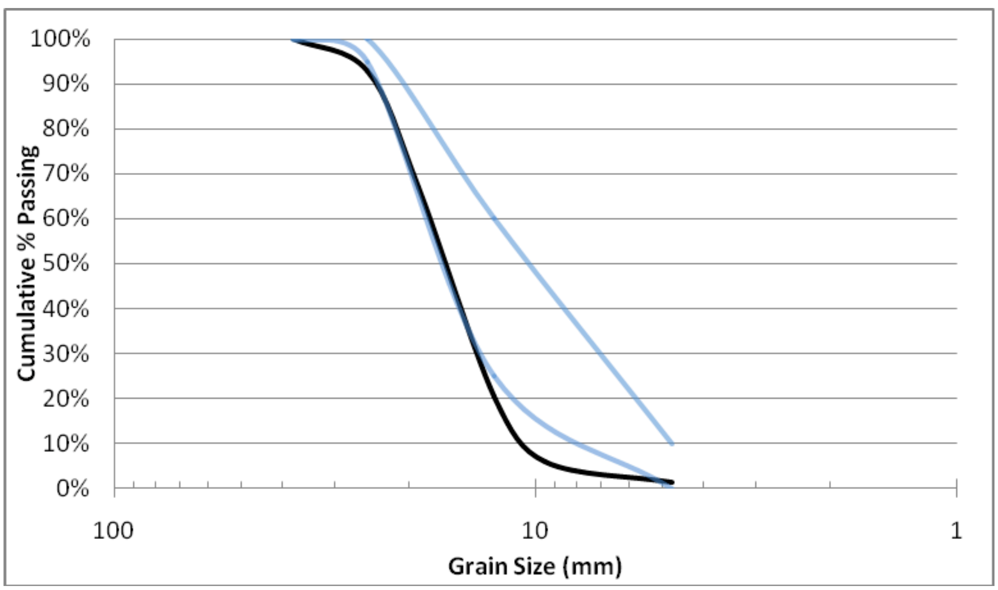

Figure 2: Cumulative Percent Passing vs. Grain Size for Fine Aggregate

Discussion – Meeting ASTM Standards (a), and Obtaining Reproducible Results

(a) In figures 1 and 2 the upper and lower limits for the ASTM standards are plotted in the lighter color. As demonstrated, both the coarse and fine aggregates do not fully meet ASTM specifications. The coarse aggregate does not fall in the range specified by ASTM standards for 3 of 4 given standards. The fine aggregate meets specifications for all sieves besides the #50 and #100 sieves. This tells us that both specimens are not appropriate for use in construction.

(b) In order to obtain reproducible results it is crucial that the aggregate is agitated for the appropriate amount of time. It is also necessary to weigh *all* aggregate sample retained in a sieve. Loss of any particles causes error in the calculations.

Experiment 4: Unit Weight of Coarse Aggregate

PURPOSE

The purpose of this laboratory is to determine the minimum and maximum unit weights of coarse aggregate. This data will be used to select proportions for concrete mixtures.

PROCEDURE

This experiment is performed in accordance with ASTM C 29: *Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate*. The following materials are required:

- Unit weight bucket
- Oven dry coarse aggregate
- Tamping rod, 16 mm diameter
- Stiff straight edge
- Scale/balance
- Shovel

Record container data that will be necessary for calculations:

1. Weigh the dry, empty unit weight bucket using the scale; record the weight in the data table.
2. Record the volume of the unit weight bucket used.

Find the weight of the dry rodded aggregate using the rodding procedure described in ASTM C 29:

3. Fill the bucket approximately 1/3 full with oven-dried coarse aggregate.
4. Rod the aggregate with 25 strokes of the tamping rod, evenly distributed on the surface of the aggregate.
5. Place another layer (about 1/3 of the bucket) and repeat step 4.
6. Fill the bucket to overflowing and repeat step 4.
7. Use a straight edge to level aggregate with the brim of the bucket. Try to adjust so that any particles above the brim are equal to the voids in the surface below the brim.
8. Record the mass of the bucket full with rodded aggregate; dispose of rodded aggregate.

Find the weight of the loose aggregate using the shoveling procedure described in ASTM C 29:

9. Fill the bucket to overflowing using a shovel to pour dry aggregate into the unit bucket; do not pour from a height above the surface greater than 50 mm (2 in).
10. Level the aggregate as in step 7, but in this case be sure not to compact the aggregate.
11. Record the mass of the bucket full with loose aggregate.

DATA ANALYSIS

Table 5 demonstrates the data obtained in the lab, as well as the resulting calculations of specific gravity. From this data the rodded unit weight (γ_{rodded}) is 1424 kg/m^3 and the loose unit weight (γ_{loose}) is 1328 kg/m^3.

Table 5 - Data from Experiment 4 - Unit Weight of Coarse Aggregate

Weight of dry and empty unit weight bucket	W_b	3.565	kg
Weight of bucket full with rodded aggregate	$W_{b+rodded}$	13.646	kg
Weight of bucket full with loose aggregate	$W_{b+loose}$	12.967	kg
Volume of bucket $(1\ ft^3 = 0.0283\ m^3)$	V_b	0.00708	m^3
Calculations			
Weight of rodded aggregate	W_{rodded}	10.081	kg
Weight of loose aggregate	W_{loose}	9.402	kg
Rodded Unit Weight	γ_{rodded}	1423.870	kg/m^3
Loose Unit weight	γ_{loose}	1327.966	kg/m^3