BATCHERS STUDY GUIDE
USES OF CONCRETE

AAA	- Prestressed Concrete
AA-1	- Precast Concrete as called for on Plans or High Early Strength concrete if approved by the Engineer
AA	- Bridge superstructure concrete or precast concrete as called for on Plans
A	- General Purpose
B	- Massive sections or lightly reinforced sections or miscellaneous non-structural concrete
CS	- To be used as a subbase where required by Plan

Class of Concrete	Coarse Aggr. Size Nos.	Min. [1] Cement Content, lbs/yd^3	Max. Water/Cement Ratio		Slump Acceptance Limits (in) [5]		Ent. Air Acceptance Limits (%)		Min. Comp. Str. @ 28 days (f'c), psi
			gals/yd^3	lbs/lbs	Lower	Upper	Lower	Upper	
AAA	67, 68 [2]	675	35.65	0.440	2	4	2.5	6.0	5000
AA-1	67, 7	675	35.65	0.440	2	4	2.5	6.0	4500
AA	56, 57, 67	635	33.9	0.445	2	4	3.5	7.0	3500
A	56, 57, 67	611	35.9	0.490	2	4	2.5 [3]	6.0	3000
B	56, 57, 67	470	37.2	0.660	2	4	0.0	6.0	2200
CS	56, 57, 67, Graded Aggr.	280	47.1	1.400	-	3	3.0	7.0	1000 [4]

Notes:
1. Portland cement may be partially replaced with fly ash or slag as provided in 500.3.04.D.4 and 5.
2. Specific size of coarse aggregate may be specified for precast/prestressed concrete.
3. Lower limit is waived when air entrained concrete is not required.
4. The mixture will be capable of demonstrating a laboratory compressive strength at 28 days of 1000 psi + 0.18 R*. Compressive strength will be determined based upon result of six cylinders prepared and tested in accordance with AASHTO T 126 and T 22.

   * Where R = difference between the largest observed value and the smallest observed value for all compressive strength specimens at 28 days for a given combination of materials and mix proportions prepared together.

5. Slump limits may be altered by the Laboratory only when Type "F" water reducers are used.

I. Basic Calculations in Concrete and Aggregate Technology:

A. Moisture Content and Absorption of Aggregate

Aggregate used in concrete consists of materials as sand, gravel, crushed stone, stone sand, and lighted aggregates. Usually these materials contain some moisture when they are batched into the mixer. The water can be present in two forms:

(1) Absorbed water in pores or cavities of individual aggregate particles. This water is not visible on the surface of particles and it is not available to contribute to plasticity of fresh concrete. Absorbed water is not included as a portion of the mixing water.

(2) Free water on the surface of individual aggregate particles (see Figure 1). This is the water that is visible on wet aggregates; it makes the particles generally appear shinny. It is free surface moisture that contributes to the mixing water in concrete because it is available to produce slump and to help make the fresh concrete plastic.

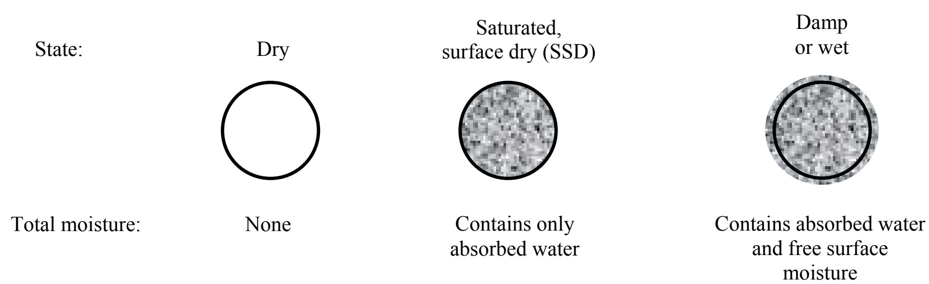

Figure 1

The general formula linking the two kinds of moisture in aggregate is as follows:

Total Moisture = Free (Surface) Moisture + Absorbed Moisture

Our general way of expressing moisture content is as a percentage of SSD aggregate weight. Then when the moisture quantities in kilograms are desired for a known quantity of aggregate, they can be computed by taking a percentage of the SSD weight. Aggregate moisture percentages --% total moisture, % free moisture, and % absorption – are computed from test made on a sample of the aggregate.

(3) Saturated Surface Dry (SSD)

Aggregate is SSD when the following two conditions are met:

(1) The interior pores of the particles are saturated with water and
(2) The particle surfaces are dry.

II. Sampling Fine and Coarse Aggregates:

Procedures for sampling fine and coarse aggregates are given in the Sampling, Testing, and Inspection Manual for sampling off belts, stockpiles, and railroad cars. We feel that you should implore the method in which the most representative sample can be obtained. In our opinion this would be sample taken from a conveyor belt for gradation test and a sample taken near to the weigh hopper for moisture test.

Samples from conveyor belts should be taken by stopping the belt and removing the entire cross-section of material on the belt at three different locations and combining these portions into a composite sample.

III. Determine Moisture Contents of Fine and Coarse Aggregates:

A. % Total Moisture

This must be determined frequently since the total moisture of aggregates can vary a large amount from hour to hour or day to day. Differences may be large within one stockpile or bin compartment. The most direct and accurate way of measuring total moisture is to weigh a sample of the wet aggregate and then dry it completely in an oven or over a burner. The calculations are as follows:

Total Wt. of Water = Wet Wt. of Agg. – Dry Wt. of Agg.

$$\text{\% Total Moisture} = \frac{\text{Total Wt. of Water}}{\text{Dry Wt. of Agg.}} \times 100$$

therefore,

<u>Example No. 1 (Sand):</u>

Wet weight of sample = 847 grams

Dry weight of sample = 792 grams

$$\text{\% Total Moisture} = \frac{847 - 792}{792} \times 100 = \frac{55}{792} \times 100$$

$$= 0.069 \times 100 = 6.9\%$$

Total Wt. of Water = 847 – 792 = 55 grams

B. % Free Moisture.

Free surface moisture is computed by the following method:

% Free Moisture = % Total Moisture - % Absorption

Also,

Wt. of free water = Wt. of Total Water – Wt. of Absorbed Water

<u>Example No. 2 (Stone):</u> If an aggregate has an absorption of 1.5% and the total moisture content of a sample is determined to be 2.5%, what is the % free moisture:

% Free Moisture = 2.5% - 1.5% = 1.0%

For this aggregate how much free water will be batched with the aggregate if the batch weight for an 8 cubic yard load is 14,000 lbs of SSD aggregate?

$$\begin{aligned}\text{Wt. of free water} &= 1.0\% \text{ of } 14{,}000 \text{ lbs}\\ &= 0.01 \times 14{,}000 = 140 \text{ lbs}\end{aligned}$$

Free moisture content is necessary to compute the amount of water on the aggregate which will contribute to mix water in the concrete. The weight of separately added water will be equal to the total mixing water of the batch of concrete minus the total weight of free water present on both fine and coarse aggregate going into the concrete.

C. Determining Free Moisture by Chapman Flask.

1. Fill flask with water to 200 ml. mark. This mark will usually fall between the two bubbles in the flask.

2. Weight 500 grams of wet sand and place in the flask with the 200 ml. of water.

3. Agitate flask to remove entrapped air.

4. Read the water level on the stem.

5. Using the water level reading and the specific gravity of the material you can determine the free moisture content from the Chapman flask chart.

IV. Adjusting Batch Weights for Aggregate Moisture

When batch weights are set up for a specific class of concrete, the aggregate weights will be expressed as saturated-surface-dry weights and the amount of water indicated is the total mixing water. However, since aggregates, as batched into the mixer, are very seldom saturated-surface-dry, adjustments must be made in both the weights of the aggregates and the quantity of water to be added.

A. Example 1: What is the equivalent weights for 1200 lbs of saturated-surface-dry sand if in a wet condition it has an absorption = 1.5% and total moisture = 7.0%. How many gallons would the total mixing water be reduced for the conditions described above?

Solution: We are only interested in the amount of free water contained in the sand because this is the water which contributes to consistency.

Free Moisture = Total Moisture – Absorption

Free Moisture = 7.0 – 1.5 = 5.5%

$$\text{Express \% moisture as decimal} = \frac{5.5}{100} = 0.055$$

$$\text{Equivalent Wt.} = 1200\,\text{lbs} \times 1.055 = 1266\ \text{lbs}$$

$$\text{Water Reduction} = 1266 - 1200 = 66\,\text{lbs}$$

$$\frac{66\ \text{lbs}}{8.33\ \text{lbs/gal}} = 7.9\ \text{gals.}$$

B. Example 2: The following is a Class A mix which meets the Department of Transportation Specifications. The batch weights are given in SSD condition for a one cubic yard batch. What actual weights should be used if the sand and stone are wet?

Cement	611	lbs
Sand	1150	lbs
Stone	1820	lbs
Total Mixing Water	34.2	gals
Air Content	4	%

Wet Sand (Total Moisture = 5.5%; Absorption = 1.5%)

Wet Stone (Free Moisture = 1.0%; Absorption = 0.5%)

Solution:

We now calculate the amount of free moisture in the aggregates since the batch weights are expressed in SSD. The necessary aggregate weight and water adjustments for this free moisture must be made.

Sand: Free Moisture = Total Moisture – Absorption

Free Moisture = 5.5% - 1.5% = 4.0%

Water and Water Adjustment:

Convert % free moisture to its decimal equivalent

$$\frac{4.0}{100} = 0.040$$

$$\text{Adjusted Sand Wt.} = 1150\,\text{lbs} \times 1.040 = 1196\ \text{lbs}$$

$$\text{Water Adjustment} = \frac{1196 - 1150}{8.33\ \text{lbs/gal}} = \frac{46}{8.33} = 5.5\ \text{gals.}$$

Stone: In this example the stone is already expressed as a percent free moisture so no conversion is necessary.

Convert % Free Moisture to its decimal equivalent.

$$\frac{1.0}{100} = 0.01$$

Adjustment in stone weight for corresponding % moisture =

$$1820\ \text{lbs} \times 1.01 = 1838\ \text{lbs}$$

$$\text{Adjustment for water} = 1838 - 1820 = 18\ \text{lbs}$$

$$\text{Convert pounds of water to gallons} = \frac{18\ \text{lbs}}{8.33\ \text{lbs/gals}} = 2.2\ \text{gals.}$$

Since these aggregates contain free moisture that will contribute to the consistency of the concrete, the total mixing water will be reduced by the amount of free moisture in the aggregates expressed in gallons.

Free water in the sand	=	5.5 gals
Free water in the stone	=	2.2 gals
Total Free Water	=	7.7 gals

Actual Mixing Water = Total mixing water – total free water

Actual Mixing Water = 34.2 gals – 7.7 gals = 26.5 gals

Your actual batch weights for one cubic meter which would be as follows:

Cement	611	lbs
Sand	1196	lbs
Stone	1838	lbs
Water	26.5	gals

What would be the actual batch weights of a 5 cubic yard batch?

$$\text{Cement} = 611 \text{ lbs}/\text{yd}^3 \times 5 \text{ yd}^3 = 3055 \text{ lbs}$$

$$\text{Sand} = 1196 \text{ lbs}/\text{yd}^3 \times 5 \text{ yd}^3 = 5980 \text{ lbs}$$

$$\text{Stone} = 1838 \text{ lbs}/\text{yd}^3 \times 5 \text{ yd}^3 = 9190 \text{ lbs}$$

$$\text{Water} = 26.5 \text{ gals}/\text{yd}^3 \times 5 \text{ yd}^3 = 132.5 \text{ gals}$$

C. Example 3: If the 5 cubic yard weights in the previous example were actually batched and produced a zero slump, how many gallons of water could be added without exceeding the maximum gallons for its class?

Solution:

Go to "Uses of Concrete" chart and find the maximum water per cubic meter for a Class "A" mix, which is 35.9 galsyd^3.

Actual total mixing water in Example = 34.2 gals/yd^3.

The water which could be added to a one cubic yard batch without exceeding the maximum is equal to the maximum minus the actual.

Maximum	=	35.9 gals/yd^3
Actual	=	34.2 gals/yd^3
Addable water	=	1.7 gals/yd^3

V. Water Cement Ratio:

The water-cement ratio of a batch of concrete is the ratio of mix water (lbs) to cement (lbs). This calculation is a simple one and can be accomplished by dividing the pounds of water by the pounds of cement.

A. Example 1: What is the water/cement ratio of the following mix?

Cement	611	lbs
Sand	1150	lbs
Stone	1838	lbs
Total Mixing Water	34.2	gals
Air Content	4	%

Convert 34.2 gallons of water to pounds:

$$34.2 \text{ gals} \times 8.33 \text{ lbs/gal} = 284.9 \text{ lbs}$$

$$\text{Water/cement ratio} = \frac{284.9}{611} = 0.47$$

CHAPMAN FLASK MOISTURE CHART
Per Cent Moisture in Sand

Volume	Bulk Specific Gravity, SSD basis																				
	2.55	2.56	2.57	2.58	2.59	2.60	2.61	2.62	2.63	2.64	2.65	2.66	2.67	2.68	2.69	2.70	2.71	2.72	2.73	2.74	2.75
382																					0.1
383																				0.2	0.4
384																		0.1	0.3	0.5	0.7
385																	0.2	0.4	0.6	0.8	1.0
386															0	0.3	0.5	0.7	0.9	1.1	1.3
387														0.1	0.4	0.6	0.8	1.0	1.3	1.5	1.7
388												0	0.2	0.4	0.7	0.9	1.1	1.4	1.6	1.8	2.0
389											0.1	0.3	0.5	0.8	1.0	1.2	1.5	1.7	1.9	2.1	2.3
390									0	0.2	0.4	0.6	0.9	1.1	1.3	1.6	1.8	2.0	2.2	2.4	2.6
391							0	0	0.3	0.5	0.7	1.0	1.2	1.4	1.7	1.9	2.1	2.3	2.5	2.7	3.0
392						0	0.1	0.4	0.6	0.8	1.1	1.3	1.5	1.8	2.0	2.2	2.5	2.6	2.8	3.1	3.3
393				0	0	0.2	0.5	0.7	0.9	1.2	1.4	1.6	1.9	2.1	2.3	2.6	2.8	3.0	3.2	3.4	3.7
394			0	0.1	0.3	0.6	0.8	1.0	1.3	1.5	1.7	2.0	2.2	2.4	2.7	2.9	3.1	3.3	3.5	3.8	4.0
395		0	0.1	0.4	0.6	0.8	1.1	1.4	1.6	1.8	2.1	2.3	2.5	2.8	3.0	3.3	3.4	3.7	3.9	4.1	4.3
396	0	0.2	0.5	0.7	1.0	1.2	1.5	1.7	1.9	2.2	2.4	2.6	2.9	3.1	3.4	3.6	3.8	4.0	4.2	4.4	4.7
397	0.3	0.6	0.8	1.1	1.3	1.5	1.8	2.0	2.3	2.5	2.7	3.0	3.2	3.5	3.7	4.0	4.1	4.3	4.6	4.8	5.0
398	0.7	0.8	1.1	1.4	1.6	1.9	2.1	2.4	2.6	2.8	3.1	3.3	3.6	3.8	4.1	4.3	4.5	4.7	4.9	5.1	5.4
399	1.0	1.2	1.5	1.7	2.0	2.2	2.5	2.7	2.9	3.2	3.4	3.7	3.9	4.2	4.4	4.6	4.8	5.0	5.3	5.5	5.7
400	1.3	1.6	1.8	2.1	2.3	2.6	2.8	3.0	3.3	3.6	3.8	4.0	4.3	4.5	4.7	4.9	5.2	5.4	5.6	5.8	6.1
401	1.7	1.9	2.2	2.4	2.6	2.9	3.1	3.4	3.7	3.9	4.2	4.4	4.6	4.8	5.1	5.3	5.5	5.8	6.0	6.2	6.4
402	2.0	2.2	2.5	2.7	3.0	3.2	3.5	3.8	4.0	4.3	4.5	4.7	5.0	5.2	5.5	5.7	5.9	6.1	6.3	6.5	6.8
403	2.4	2.6	2.8	3.1	3.3	3.6	3.9	4.1	4.4	4.6	4.8	5.1	5.3	5.6	5.8	6.0	6.2	6.5	6.7	6.9	7.1
404	2.7	2.8	3.2	3.4	3.7	4.0	4.2	4.5	4.7	4.9	5.2	5.4	5.7	5.9	6.2	6.4	6.6	6.8	7.0	7.3	7.5
405	3.0	3.3	3.5	3.8	4.0	4.3	4.6	4.8	5.1	5.3	5.5	5.8	6.0	6.3	6.5	6.7	7.0	7.2	7.4	7.7	7.9
406	3.4	3.6	3.9	4.2	4.4	4.7	4.9	5.2	5.4	5.7	5.9	6.1	6.4	6.6	6.9	7.1	7.3	7.5	7.8	8.0	8.2
407	3.8	4.0	4.2	4.5	4.8	5.0	5.3	5.5	5.8	6.0	6.3	6.6	6.7	7.0	7.2	7.5	7.7	7.9	8.1	8.4	8.6
408	4.1	4.3	4.6	4.9	5.1	5.4	5.6	5.9	6.1	6.4	6.7	6.9	7.1	7.3	7.6	7.8	8.1	8.3	8.5	8.7	9.0
409	4.4	4.7	5.0	5.2	5.5	5.7	6.0	6.3	6.5	6.8	7.0	7.3	7.5	7.7	8.0	8.2	8.4	8.6	8.9	9.1	
410	4.8	5.1	5.3	5.6	5.8	6.1	6.4	6.6	6.9	7.1	7.4	7.7	7.8	8.1	8.3	8.6	8.8	9.0	9.3		
411	5.2	5.4	5.7	6.0	6.2	6.5	6.7	7.0	7.2	7.5	7.8	8.0	8.2	8.5	8.7	9.0	9.2				
412	5.6	5.8	6.1	6.3	6.6	6.8	7.1	7.4	7.6	7.9	8.1	8.3	8.6	8.8	9.1	9.3					
413	5.9	6.2	6.4	6.7	7.0	7.2	7.5	7.7	8.0	8.3	8.5	8.7	9.0	9.2							
414	6.3	6.5	6.8	7.1	7.3	7.6	7.8	8.1	8.4	8.7	8.8	9.1									
415	6.7	6.9	7.2	7.4	7.7	8.0	8.2	8.5	8.8	9.0	9.2	9.5									
416	7.0	7.3	7.6	7.8	8.1	8.4	8.6	8.9	9.1	9.4	9.6										
417	7.4	7.7	7.9	8.2	8.5	8.7	9.0	9.2													
418	7.8	8.0	8.3	8.6	8.8	9.1	9.4														
419	8.2	8.4	8.7	9.0	9.2	9.5															
420	8.6	8.8	9.1	9.4																	
421	8.9	9.2																			
422	9.3																				

$$\text{Per Cent moisture} = \frac{V - (500/\text{specific gravity}) - 200}{200 + 500 - V}$$

where V = flask reading
specific gravity = bulk specific gravity, SSD basis