ACI METHOD OF PROPORTIONING CONCRETE MIXES

The ACI Standard 211.1 is a "*Recommended Practice for Selecting Proportions for Concrete*". The procedure is as follows:

- Step 1. Choice of slump
- Step 2. Choice of maximum size of aggregate
- Step 3. Estimation of mixing water and air content
- Step 4. Selection of water/cement ratio
- Step 5. Calculation of cement content
- Step 6. Estimation of coarse aggregate content
- Step 7. calculation of Fine Aggregate Content
- Step 8. Adjustments for Aggregate Moisture
- Step 9. Trial Batch Adjustments

Step 1. Choice of slump

If slump is not specified, a value appropriate for the work can be selected from the below Table which is reproduced from the text book below*, (note that the table numbers are given from the text book rather than the ACI standard).

Type of Construction	Slump	
	(mm)	(inches)
Reinforced foundation walls and footings	25 - 75	1 - 3
Plain footings, caissons and substructure walls	25 - 75	1 - 3
Beams and reinforced walls	25 - 100	1 - 4
Building columns	25 - 100	1 - 4
Pavements and slabs	25 - 75	1 - 3

Mass concrete	25 - 50	1 - 2

Step 2. Choice of maximum size of aggregate.

Large maximum sizes of aggregates produce less voids than smaller sizes. Hence, concretes with the larger-sized aggregates require less mortar per unit volume of concrete, and of coarse it is the mortar which contains the most expensive ingredient, cement. Thus the ACI method is based on the principle that the **MAXIMUM SIZE OF AGGREGATE SHOULD BE THE LARGEST AVAILABLE SO LONG IT IS CONSISTENT WITH THE DIMENSIONS OF THE STRUCTURE.**

In practice the dimensions of the forms or the spacing of the rebars controls the maximum CA size.

ACI 211.1 states that the maximum CA size should not exceed:

- one-fifth of the narrowest dimension between sides of forms,
- one-third the depth of slabs,
- 3/4-ths of the minimum clear spacing between individual reinforcing bars, bundles of bars, or pre-tensioning strands.

• **Special Note:** When high strength concrete is desired, best results may be obtained with reduced maximum sizes of aggregate since these produce higher strengths at a given w/c ratio.

Step 3. Estimation of mixing water and air content.

The ACI Method uses past experience to give a first estimate for the quantity of water per unit volume of concrete required to produce a given slump.

In general the quantity of water per unit volume of concrete required to produce a given slump is dependent on the

maximum CA size, the shape and grading of both CA and FA, as well as the amount of entrained air.

The approximate amount of water required for average aggregates is given in Table 10.2.

Table 10.2: Approximate Mixing Water and Air Content Requirements for Different Slumps and Maximum Aggregate Sizes.

	Mixing Water Quantity in kg/m³ (lb/yd³) for the listed Nominal Maximum Aggregate Size							
Slump	9.5 mm (0.375 in.)	12.5 mm (0.5 in.)	19 mm (0.75 in.)	25 mm (1 in.)	37.5 mm (1.5 in.)	50 mm (2 in.)	75 mm (3 in.)	100 mm (4 in.)
Non-Air-Entrained								
25 - 50 (1 - 2)	207 (350)	199 (335)	190 (315)	179 (300)	166 (275)	154 (260)	130 (220)	113 (190)
75 - 100 (3 - 4)	228 (385)	216 (365)	205 (340)	193 (325)	181 (300)	169 (285)	145 (245)	124 (210)
150 - 175 (6 - 7)	243 (410)	228 (385)	216 (360)	202 (340)	190 (315)	178 (300)	160 (270)	-
Typical entrapped air (percent)	3	2.5	2	1.5	1	0.5	0.3	0.2
Air-Entrained								
25 - 50 (1 - 2)	181 (305)	175 (295)	168 (280)	160 (270)	148 (250)	142 (240)	122 (205)	107 (180)
75 - 100 (3 - 4)	202 (340)	193 (325)	184 (305)	175 (295)	165 (275)	157 (265)	133 (225)	119 (200)
150 - 175 (6 - 7)	216 (365)	205 (345)	197 (325)	184 (310)	174 (290)	166 (280)	154 (260)	-
Recommended Air Content (percent)								
Mild Exposure	4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0
Moderate Exposure	6.0	5.5	5.0	4.5	4.5	4.0	3.5	3.0
Severe Exposure	7.5	7.0	6.0	6.0	5.5	5.0	4.5	4.0

Step 4. Selection of water/cement ratio.

The required water/cement ratio is determined by strength, durability and finishability. The appropriate value is chosen from prior testing of a given system of cement and aggregate or a value is chosen from Table 10.3 and/or Table 10.4.

Table 10.3: Water-Cement Ratio and Compressive Strength Relationship

28-Day Compressive Strength in MPa (psi)	Water-cement ratio by weight	
	Non-Air-Entrained	Air-Entrained
41.4 (6000)	0.41	-
34.5 (5000)	0.48	0.40
27.6 (4000)	0.57	0.48
20.7 (3000)	0.68	0.59
13.8 (2000)	0.82	0.74

TABLE 10-4 MAXIMUM PERMISSIBLE WATER/CEMENT RATIOS FOR CONCRETE IN SEVERE EXPOSURES

Type of Structure	Structure wet continuously or fequently exposed to freezing & thawing*	Structure exposed to seawater
Thin sections (railings, curbs, sills, ledges, ornamental work) & sections with less than 1-inch cover over steel	0.45	0.40
All other structures	0.50	0.45

* Concrete should also be air-entrained.

Step 5. Calculation of cement content.

The amount of cement is fixed by the determinations made in Steps 3 and 4 above.

$$weight\ of\ cement = \frac{weight\ of\ water}{w/c}$$

Step 6. Estimation of coarse aggregate content.

The most economical concrete will have as much as possible space occupied by CA since it will require no cement in the space filled by CA.

Table 10.5: Volume of Coarse Aggregate per Unit Volume for Different Fine aggregate Fineness Moduli

Nominal Maximum Aggregate Size	Fine Aggregate Fineness Modulus			
	2.40	2.60	2.80	3.00

9.5 mm (0.375 inches)	0.50	0.48	0.46	0.44
12.5 mm (0.5 inches)	0.59	0.57	0.55	0.53
19 mm (0.75 inches)	0.66	0.64	0.62	0.60
25 mm (1 inches)	0.71	0.69	0.67	0.65
37.5 mm (1.5 inches)	0.75	0.73	0.71	0.69
50 mm (2 inches)	0.78	0.76	0.74	0.72

Notes:

1. These values can be increased by up to about 10 percent for pavement applications.
2. Coarse aggregate volumes are based on oven-dry-rodded weights obtained in accordance with ASTM C 29.

The ACI method is based on large numbers of experiments which have shown that for properly graded materials, the finer the sand and the larger the size of the particles in the CA, the more volume of CA can be used to produce a concrete of satisfactory workability.

Step 7. Estimation of Fine Aggregate Content.

At the completion of Step 6, all ingredients of the concrete have been estimated except the fine aggregate. Its quantity can be determined by difference if the "absolute volume" displaced by the known ingredients-, (i.e., water, air, cement, and coarse aggregate), is subtracted from the unit volume of concrete to obtain the required volume of fine aggregate.

Then once the volumes are know the weights of each ingredient can be calculated from the specific gravities.

Step 8. Adjustments for Aggregate Moisture.

Aggregate weights. Aggregate volumes are calculated based on oven dry unit weights, but aggregate is typically batched based on actual weight. Therefore, any moisture in the aggregate will increase its weight and stockpiled aggregates almost always contain some moisture. Without correcting for this, the batched aggregate volumes will be incorrect.

Amount of mixing water. If the batched aggregate is anything but saturated surface dry it will absorb water (if oven dry or air dry) or give up water (if wet) to the cement paste. This causes a net change in the amount of water available in the mix and must be compensated for by adjusting the amount of mixing water added.

Step 9. Trial Batch Adjustments.

The ACI method is written on the basis that a trial batch of concrete will be prepared in the laboratory, and adjusted to give the desired slump, freedom from segregation, finishability, unit weight, air content and strength.