ACI Mix Design Example

Concrete is required for an exterior column located above ground where substantial freezing and thawing may occur. The 28-day compressive strength should be 5,000 lb./in^2. The slump should be between 1 and 2 in. and the maximum aggregate size should not exceed ¾ in.

The properties of the materials are as follows:

- Cement : Type I, specific gravity = 3.15
- Coarse Aggregate: Bulk specific gravity (SSD) = 2.70; absorption capacity = 1%; dry-rodded unit weight = 100 lb./ft.^{3}; surface moisture = 0%
- Fine Aggregate: Bulk specific gravity (SSD) = 2.65; absorption capacity = 1.3%; fineness modulus = 2.70; surface moisture = 3%

ACI Mix Design Example

Step 1. Required material information (already given).

Step 2. Choice of slump. The slump is given, consistent with Table 1.

Concrete construction	Slump, mm (in.) Maximum*	Slump, mm (in.) Minimum
Reinforced foundation walls and footings	75 (3)	25 (1)
Plain footings, caissons, and substructure walls	75 (3)	25 (1)
Beams and reinforced walls	100 (4)	25 (1)
Building columns	100 (4)	25 (1)
Pavements and slabs	75 (3)	25 (1)
Mass concrete	75 (3)	25 (1)

Step 3. Maximum aggregate size. Given: ¾ inches

ACI Mix Design Example

Step 4. Estimation of mixing water and air content. Since freezing and thawing is important, the concrete must be air-entrained.

	Maximum aggregate size (in.)							
Slump(in)	0.375	0.5	0.75	1	1.5	2	3	6
1 to 2	305	295	280	270	250	240	225	180
3 to 4	340	325	305	295	275	265	250	200
6 to 7	365	345	325	310	290	280	270	-
Air Content								
Mild	4.5%	4.0%	3.5%	3.0%	2.5%	2.0%	1.5%	1.0%
Moderate	6.0%	5.5%	5.0%	4.5%	4.5%	4.0%	3.5%	3.0%
Extreme	7.5%	7.0%	6.0%	6.0%	5.5%	5.0%	4.5%	4.0%

From Table 2, the recommended air content is 6%; the water requirement is 280 lb./yd.^{3}

ACI Mix Design Example

Step 5. Water/cement ratio. From Table3, the estimate for required *w/c* ratio to give a 28-day strength of 5,000 psi.

28-day Compressive Strength (psi)	Non-AE	AE
2,000	0.82	0.74
3,000	0.68	0.59
4,000	0.57	0.48
5,000	0.48	0.40
6,000	0.41	0.32
7,000	0.33	---

The *w/c* ratio to give a 28-day strength of 5,000 psi is 0.40

ACI Mix Design Example

Step 6. Calculation of cement content. Based on steps 4 and 5, the required cement content is:

$$\textit{weight of cement} = \frac{280\ ^{lb}\!/_{yd.^3}}{0.4} = 700\ ^{lb}\!/_{yd.^3}$$

ACI Mix Design Example

Step 7. Estimation of coarse aggregate content. Interpolating Table 4 for the fineness modulus of the fine aggregate of 2.70

	Fineness Modulus						
Max Aggregate (in.)	2.4	2.5	2.6	2.7	2.8	2.9	3
0.375	0.50	0.49	0.48	0.47	0.46	0.45	0.44
0.500	0.59	0.58	0.57	0.56	0.55	0.54	0.53
0.750	0.66	0.65	0.64	0.63	0.62	0.61	0.60
1.000	0.71	0.70	0.69	0.68	0.67	0.66	0.65
1.500	0.75	0.74	0.73	0.72	0.71	0.70	0.69
2.000	0.78	0.77	0.76	0.75	0.74	0.73	0.72
3.000	0.82	0.81	0.80	0.79	0.78	0.77	0.76
6.000	0.87	0.86	0.85	0.84	0.83	0.82	0.81

ACI Mix Design Example

- The coarse aggregate will occupy:

$$0.63 \times 27\,\text{ft.}^3/\text{yd.}^3 = 17.01\,\text{ft.}^3/\text{yd.}^3$$

(Value from Table 4)

- The OD weight of the coarse aggregate

$$17.01\,\text{ft.}^3/\text{yd.}^3 \times 100\,\text{lb.}/\text{ft.}^3 = 1{,}701\,\text{lb.}/\text{yd.}^3$$

(Dry-Rodded Unit Weight)

ACI Mix Design Example

Step 8. Estimation of fine aggregate content by the absolute volume method.

Temperature, °F	Density, lb./ft.^{3}
60	62.368
65	62.337
70	62.302
75	62.261
80	62.216
85	62.166

62.4 lb./ft.^{3}

ACI Mix Design Example

Step 8. Estimation of fine aggregate content by the absolute volume method.

water (ft^3)	$\frac{water\,(lb)}{62.4\,\frac{lb}{ft^3}}$
Cement (ft^3)	$\frac{cement\,(lb)}{3.15 \times 62.4\,\frac{lb}{ft^3}}$
Coarse Aggregate (ft^3)	$\frac{coarse\ aggregate\,(lb)}{SG_{CA} \times 62.4\,\frac{lb}{ft^3}}$
Air (ft^3)	$air\,(\%) \times 27\,\frac{ft^3}{yd^3}$

ACI Mix Design Example

Step 8. Estimation of fine aggregate content by the absolute volume method.

Water:	280 lb./62.4 lb./ft.^{3}	= 4.49 ft.^{3}
Cement:	700 lb./(3.15 x 62.4 lb./ft.^{3})	= 3.56 ft.^{3}
Coarse Aggregate:	1,701 lb./(2.70 x 62.4 lb./ft.^{3})	= 10.10 ft.^{3}
Air:	6% x 27ft.^{3}/yd.^{3}	= 1.62 ft.^{3}
Total		**19.77 ft.^{3}**

Class ACI Mix Design Example

- Therefore, the fine aggregate must occupy a volume of:

$$27\,\text{ft.}^3 - \boxed{Volume}\,\text{ft.}^3 = \boxed{Volume_{FA}}\,\text{ft.}^3$$

- The SSD weight of the fine aggregate is:

$$\boxed{Volume_{FA}}\,\text{ft.}^3 \times \boxed{SG_{FA}} \times 62.4\,\text{lb.}/\text{ft.}^3 = \boxed{FA_{SSD}}\,\text{lb.}$$

(Specific Gravity of Fine Aggregate) (Unit Weight of Water)

ACI Mix Design Example

- Therefore, the fine aggregate must occupy a volume of:

$$27\,\text{ft.}^3 - 19.77\,\text{ft.}^3 = 7.23\,\text{ft.}^3$$

- The OD weight of the fine aggregate is:

$$7.23\,\text{ft.}^3 \times 2.65 \times 62.4\,\text{lb.}/\text{ft.}^3 = 1{,}196\,\text{lb.}$$

(Specific Gravity of Fine Aggregate) (Unit Weight of Water)

ACI Mix Design Example

Step 9. Adjustment for moisture in the aggregate.

- Since the moisture level of the fine aggregate in our storage bins can vary, we will apply a simple rule to adjust the water required.
- Decrease the amount of water required by surface moisture content of the weight of the fine aggregate
- Increase the amount of aggregate by the amount equal to the surface moisture

ACI Mix Design Example

Step 9. Adjustment for moisture in the aggregate.

The weight of aggregate from the stock pile is:

$$Weight_{Stock\ Pile} = Weight_{OD}\left(1 + MC\right)$$

The change in the weight water due to the moisture of the aggregate from the stock pile is:

$$\Delta Weight_{Water} = Weight_{OD}\left(SM\right)$$

$$Adjusted\,Weight_{Water} = Weight_{Water} - \Delta Weight_{Water}$$

ACI Mix Design Example

Step 9. Compute stockpile weight based on moisture content

- Fine aggregate required from the stockpile is:

1,196 lb. (1 + 0.043) = 1,247.4 lb./yd.^{3} or 1,247 lb./yd.^{3}

Moisture Content 4.3%

Moisture Content 1%

- Coarse aggregate required from the stockpile is:

1,701 lb. (1 + 0.01) = 1,718 lb./yd.^{3}

ACI Mix Design Example

Step 9. Adjust the amount of water based on moisture content

The required mixing water required is:

280 lb. - 1196 lb. (0.043 – 0.013) ← fine aggregate

Moisture Content 4.3% Absorption Capacity 1.3%

- 1,718 lb. (0.01 – 0.01) ← coarse aggregate

= 244.1 lb./yd.^{3} or 244 lb./yd.^{3}

ACI Mix Design Example

Thus the estimated batch weights per yd.^{3} are:

Water	= 244 lb.
Cement	= 700 lb.
Coarse aggregate	= 1,718 lb.
Fine aggregate (wet)	= 1,247 lb.
Total	**= 3,909 lb./yd.^{3}**
	= 144.8 lb./ft.^{3}