ACI Mix Design Example #1

- Consider the following example: The 28-day compressive strength should be 4,000 psi. The slump should be between 3 and 4 in., and the maximum aggregate size should not exceed 1 in. The coarse and fine aggregates in the storage bins are wet.
- 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 = 1.1%; dry-rodded unit weight = 105 lb./ft.^{3} surface moisture = 1%
  - Fine Aggregate: Bulk specific gravity (SSD) = 2.67; absorption capacity = 1.3%; fineness modulus = 2.70; surface moisture = 1.5%

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Class ACI Mix Design Example

- **Step 1**. Required material information (already given).
- **Step 2**. The slump is given, consistent with Table 1.

Concrete construction	Slump, mm (in.) Maximum*	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: 1 in.

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Class ACI Mix Design Example

Step 4. Estimation of mixing water and air content.

Slump(in)	Maximum aggregate size (in.) 0.375	0.5	0.75	1	1.5	2	3
1 to 2	350	335	315	300	275	260	220
3 to 4	385	365	340	325	300	285	245
5 to 6	400	375	350	330	305	290	255
6 to 7	410	385	360	340	315	300	270
Air Content	3.0%	2.5%	2.0%	1.5%	1.0%	0.5%	0.3%

From Table 2, the recommended air content is 1.5%; the water requirement is 325 lb./yd.^{3}.

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Class ACI Mix Design Example

Step 5. Water/cement ratio.

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	0.34	<0.33

From Table 3, the estimate for required w/c ratio to give a 28-day strength of 4,000 lb./in.^{2} is 0.57.

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Class ACI Mix Design Example

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

$$\textit{weight of cement} = \frac{325 \text{ lb./yd.}^3}{0.57} = 570 \text{ lb./yd.}^3$$

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Class 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

Max Aggregate (in.)	Fineness Modulus 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

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Class ACI Mix Design Example

- The coarse aggregate will occupy:

$$\boxed{} \times 27\ \text{ft.}^3/\text{yd.}^3 = \boxed{}\ \text{ft.}^3/\text{yd.}^3$$

Value from Table 4

- The OD weight of the coarse aggregate

$$\boxed{}\ \text{ft.}^3/\text{yd.}^3 \times \boxed{}\ \text{lb.}/\text{ft.}^3 = \boxed{}\ \text{lb.}/\text{yd.}^3$$

Dry-Rodded Unit Weight

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Class ACI Mix Design Example

- The coarse aggregate will occupy:

$$0.68 \times 27\ \text{ft.}^3/\text{yd.}^3 = 18.36\ \text{ft.}^3/\text{yd.}^3$$

Value from Table 4

- The OD weight of the coarse aggregate

$$18.36\ \text{ft.}^3/\text{yd.}^3 \times 105\ \text{lb.}/\text{ft.}^3 = 1{,}928\ \text{lb.}/\text{yd.}^3$$

Dry-Rodded Unit Weight

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Class ACI Mix Design Example

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

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

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Class ACI Mix Design Example

- **Step 8**. Estimation of fine aggregate content by the absolute volume method.
  - Water: 325 lb./62.4 lb./ft.^{3} = 5.21 ft.^{3}
  - Cement: 570 lb./(3.15 x 62.4 lb./ft.^{3}) = 2.90 ft.^{3}
  - Coarse Aggregate: 1,928 lb./(2.70 x 62.4 lb./ft.^{3}) = 11.44 ft.^{3}
  - Air: 1.5% x 27ft.^{3}/yd.^{3} = 0.41 ft.^{3}

Total **19.96 ft.^{3}**

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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

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Class ACI Mix Design Example

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

$$27\ \text{ft.}^3 - 19.96\ \text{ft.}^3 = 7.04\ \text{ft.}^3$$

- The SSD weight of the fine aggregate is:

$$7.04\ \text{ft.}^3 \times 2.67 \times 62.4\ \text{lb.}/\text{ft.}^3 = 1{,}173\ \text{lb.}$$

Specific Gravity of Fine Aggregate

Unit Weight of Water

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Class ACI Mix Design Example

- **Step 9**. Adjustment for moisture in the aggregate.

The weight of aggregate from the stockpile is:

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

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

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

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

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Class ACI Mix Design Example

- **Step 9**. Compute stockpile weight based on moisture content
- Fine aggregate required from the stockpile is:

1,173 lb. (1 + 0.028) = 1,206 lb./yd.^{3}

Moisture Content 2.8%

- Coarse aggregate required from the stockpile is:

1,928 lb. (1 + 0.021) = 1,968 lb./yd.^{3}

Moisture Content 2.1%

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Class ACI Mix Design Example

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

The required mixing water required is:

325 lb. - 1173 lb. (0.015) ← fine aggregate

Surface moisture 1.5%

- 1,928 lb. (0.01) ← coarse aggregate

Surface moisture 1%

= 288 lb./yd.^{3}

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Class ACI Mix Design Example

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

Water	= 288 lb.
Cement	= 570 lb.
Coarse aggregate (wet)	= 1,968 lb.
Fine aggregate (wet)	= 1,206 lb.
Total	**= 4,031 lb./yd.^{3}**
	= 149.3 lb./ft.^{3}

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