ACI Mix Design Example #3

- Consider the following example: The 28-day compressive strength should be 6,000 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. This application will be in an moderate exposure environment.
- The properties of the materials are as follows:
  - Cement : Type I, specific gravity = 3.15
  - Coarse Aggregate: Bulk specific gravity (SSD) = 2.65; absorption capacity = 0.5%; dry-rodded unit weight = 96 lb./ft.^{3} surface moisture = 0.5%
  - Fine Aggregate: Bulk specific gravity (SSD) = 2.60; absorption capacity = 1.1%; fineness modulus = 2.70; surface moisture = 2.0%

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.

Class ACI Mix Design Example

Step 4. Estimation of mixing water and air content. From Table 2, the recommended air content is 4.5%; the water requirement is 295 lb./yd.^{3}.

	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%**

Class 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 6,000 psi is 0.32.

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**	---

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

$$weight\ of\ cement = \frac{295\ \text{lb./yd.}^3}{0.32} = 922\ \text{lb./yd.}^3$$

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

	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**

Class ACI Mix Design Example

- The coarse aggregate will occupy:

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

Value from Table 4

- The OD weight of the coarse aggregate

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

Dry-Rodded Unit Weight

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

$$18.36\ \text{ft.}^3/\text{yd.}^3 \times 96\ \text{lb.}/\text{ft.}^3 = 1{,}763\ \text{lb.}/\text{yd.}^3$$

Dry-Rodded Unit Weight

Class ACI Mix Design Example

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

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

Class ACI Mix Design Example

- **Step 8**. Estimation of fine aggregate content by the absolute volume method.
  - Water: 295 lb./62.4 lb./ft.^{3} = 4.73 ft.^{3}
  - Cement: 922 lb./(3.15 x 62.4 lb./ft.^{3}) = 4.69 ft.^{3}
  - Coarse Aggregate: 1,763 lb./(2.65 x 62.4 lb./ft.^{3}) = 10.66 ft.^{3}
  - Air: 4.5% x 27ft.^{3}/yd.^{3} = 1.22 ft.^{3}

Total **21.30 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

Class ACI Mix Design Example

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

$$27\ \text{ft.}^3 - 21.30\ \text{ft.}^3 = 5.70\ \text{ft.}^3$$

- The SSD weight of the fine aggregate is:

$$5.70\ \text{ft.}^3 \times 2.60 \times 62.4\ \text{lb.}/\text{ft.}^3 = 925\ \text{lb.}$$

Specific Gravity of Fine Aggregate

Unit Weight of Water

Class 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:

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

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

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Step 9. Compute fine aggregate weight

- Fine aggregate required from the stockpile is:

  925 lb. (1 + 0.031) = 954 lb./yd.^{3}

  Moisture Content 3.1%

- Coarse aggregate required from the stockpile is:

  1,763 lb. (1 + 0.01) = 1,781 lb./yd.^{3}

  Moisture Content 1%

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

The required mixing water required is:

295 lb. - 925 lb. (0.02) ← fine aggregate

Surface moisture 2.0%

- 1,763 lb. (0.005) ← coarse aggregate

= 268 lb./yd.^{3}

Surface moisture 0.5%

Class ACI Mix Design Example

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

Water	=	268 lb.
Cement	=	922 lb.
Coarse aggregate (wet)	=	1,781 lb.
Fine aggregate (wet)	=	954 lb.
Total	**=**	**3,925 lb./yd.^{3}**
	=	**145.4 lb./ft.^{3}**