

ACI Concrete Mix Design

Weights Method for calculating the Fine Aggregates content

Table 19.10: First estimate of density (unit weight) of fresh concrete as given by ACI 211.1–91 (Reapproved 2002)

Maximum size of aggregate		First estimate of density (unit weight) of fresh concrete			
		Non-air-entrained		Air-entrained	
mm	in.	kg/m ³	lb/yd ³	kg/m ³	lb/yd ³
10	$\frac{3}{8}$	2285	3840	2190	3690
12.5	$\frac{1}{2}$	2315	3890	2235	3760
20	$\frac{3}{4}$	2355	3960	2280	3840
25	1	2380	4010	2285	3850
40	$1\frac{1}{2}$	2415	4070	2320	3910
50	2	2445	4120	2345	3950
70	3	2495	4200	2400	4040
150	6	2530	4260	2440	4110

A more precise estimation of the unit weight of 1 m³ of concrete can be calculated from the following equation:

$$\text{in kg/m}^3: \rho = 10 \gamma_a(100 - A) + C \left(1 - \frac{\gamma_a}{\gamma} \right) - W(\gamma_a - 1) \quad (19.2a)$$

where ρ = density (unit weight) of fresh concrete, kg/m³ (lb/yd³);

γ_a = weighted average bulk specific gravity (SSD) of combined fine and coarse aggregates. Clearly, this needs to be determined from tests;

A = air content, per cent;

C = cement content, kg/m³ (lb/yd³);

γ = specific gravity of cement (generally 3.15¹); and

W = mixing water requirement, kg/m³ (lb/yd³).

Problem (1)

The 28-day target compressive strength should be 25 MPa. The slump should be between 75 mm and 100 mm and the maximum aggregate size should not exceed 20 mm. It is intended to add fly-ash Class C with an amount of 15% of the cement content. The specific gravity of fly-ash Class C is 2.2. To take into consideration the durability issues the **max. water/cement** ratio is 0.50, and the minimum cement content should be 320 kg/1m³ concrete.

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 = 1605 kg/m³; total moisture content = 1.5%
- Fine Aggregate: Bulk specific gravity (SSD) = 2.60; absorption capacity = 2.5%; fineness modulus = 2.70; total moisture content = 1.3%.

Using **Absolute Volumes Method** and then **Weights Method**, calculate the concrete mix proportions?

Solution:

Step 1: **Choice of slump**, Given = (75 _ 100) mm

Step 2: **Choice of MSA** Given = 20 mm

Step 3: **Estimation of mixing water and air content**

From Table 1.0 (choose non-air-entrained concrete) obtain mixing water and air content

Mixing water for MSA = 20 and Slump = (75 – 100), using double interpolation

Mixing water, **W = 203 kg / 1m³ of concrete**

Air content, **A = 1.9 %** for each 1m³ concrete

Step 4: **Selection of (Water/Cement) Ratio**

From Table 2.0 and using interpolation **w/c = 0.611**

From Table 3.0 { Not applicable here }

Note in the question max. w/c ratio = 0.50, then use W/C = 0.50 (Strength is also Satisfied)

Step 5: **Calculation of Cement content.**

$C = 203 / 0.50 = 406 \text{ kg / 1m}^3 \text{ of concrete}$

Check min. cement content: minimum cement content in the problem is 320 kg/1m³ of concrete (satisfied)

Note: If there is no restriction w/c, $C = 203 / 0.68 = 299 \text{ kg / 1m}^3 \text{ of concrete}$

Step 6: Estimation of Coarse Aggregate (CA).

From Table 4.0m FM = 2.7 , MSA = 20 , by interpolation CA = 0.638 per 1m³ of concrete.

Convert the compacted volume of CA into weight by using $\gamma_{dry} = 1605 \text{ kg / m}^3$.

Dry weight of CA = Volume of CA * $\gamma_{dry} = 0.638 * 1605 = 1024 \text{ kg / 1m}^3$ of concrete.

SSD weight of CA = $1024 * (1 + \frac{0.5}{100}) = 1029 \text{ kg / 1m}^3$ of concrete.

Step 7: Estimation of Fine Aggregate (FA)

1- Using Absolute Volumes Method

This method requires converting the obtained weights into their absolute volume as follows:

Note that fly ash should be considered in this stage

	Material	Weight, kg	Specific gravity or unit weight	Calculation	Absolute volume
1	Water	203	1000 kg/ m ³	203 / 1000	0.203 m ³
2	Air	..	...	...	0.019 m ³
3	Cement	406	3150 kg/ m ³	406 / 3150	0.129 m ³
4	CA	1029	2650 kg/ m ³	1029 / 2650	0.388 m ³
5	Fly Ash	0.15*406=60.9	2200 kg/ m ³	60.9 / 2200	0.028 m ³
				$\sum Vol_{abs}$	0.767 m ³
6	FA	?			

Absolute volume of FA = $1.0 \text{ m}^3 - 0.767 = 0.223 \text{ m}^3$.

SSD weight of FA = $0.223 * 2600 = 605.8 \text{ kg / m}^3$.

Note: 2600 is specific gravity of (FA) with units (2.6*1000(water density))

Therefore, SSD weights of mix proportions

Water, kg	Cement, kg	FA, kg	CA, kg
203	406	605.8	1029

2- Using weight method

The weight of fresh concrete density (unit weight) is to be estimated. ACI gives Table 19.10 to obtain the first estimate of the fresh concrete unit weight

1- First estimate: From 19.10 $\rho_{\text{fresh concrete}} = 2355 \text{ kg / 1m}^3$ of concrete.

Then,

FA = $2355 - (203 + 406 + 1029 + 60.9) = 656.1 \text{ kg / 1m}^3$ of concrete.

ACI gives the following equation to revise the estimated unit weight of 1m³ of concrete

2- Second estimate of $\rho_{\text{fresh concrete}}$

$$\rho = 10 \times \gamma_a (100 - A) + (1 - \frac{\gamma_a}{\gamma}) - W * (\gamma_a - 1), \text{ where } \gamma = \text{Specific Gravity for Cement} = 3.15,$$

γ_a = weighted average of combined GS (FA & CA)

$$\gamma_a = \frac{2.60 \times 656.1 + 2.65 \times 1029}{656.1 + 1029} = 2.631$$

$$\rho = 10 * 2.631 * (100 - 1.9) + 406 * (1 - \frac{2.631}{3.15}) - 203 (2.631 - 1)$$

= 2316.8 kg /1m³ of concrete.

Based on the obtained FA=656.1kg/1m³ of concrete based, the revised $\rho_{\text{fresh concrete}}$:

$$FA = 2316.8 - (203 + 406 + 1029 + 60.9) = 617.9 \text{ kg / 1m}^3 \text{ of concrete.}$$

3- Third estimate of $\rho_{\text{fresh concrete}}$

$$\gamma_a = \frac{2.60 \times 617.9 + 2.65 \times 1029}{617.9 + 1029} = 2.631 \text{ Since no change in the value of } \gamma_a \text{ no need for further calculations}$$

Step 8: Adjustment for aggregate weights and mixing water

we will use the results of the Absolute Volumes Method

1- Aggregate weights

- Coarse Aggregate weight , wet condition as water content (1.5%) > absorption moisture (0.50%). The surface water = 1.5% - 0.5% = 1.0%

$$\text{Adjusted CA weight} = 1029 * (1 + \frac{1}{100}) = 1039.3 \text{ kg}$$

- Fine Aggregate weight , Air dry condition , effective absorption effective absorption = 2.5 – 1.3 = 1.2 %

$$\text{Adjusted FA weight} = 605.8 * (1 - \frac{1.2}{100}) = 598.5 \text{ kg}$$

- Mixing water

$$\begin{aligned} \text{Adjusted mixing water} &= 203 - (1029 * \frac{1}{100}) + 605.8 * \frac{1.2}{100} \\ &= 199.98 \text{ (200 kg / 1m}^3 \text{ of concrete)} \end{aligned}$$

Final mix proportions for making 1m³ of concrete

	Water, kg	Cement, kg	Fine Agg,kg	Coarse Agg, kg
SSD case	203	406	605	1029
Site condition	200	406	600	1040

Problem (2)

Repeat Problem (1) if the given strength (25 MPa) is the characteristic strength, the accepted level of quality is 10%, the standard deviation of enough previous results is 3.5MPa.

(Hint: Target strength = $25 + 1.28 \times 3.5 = 29.50$ MPa)

Problem (3)

Repeat Problem (1) but with MSA 25mm and compare the results. 37.5mm

Problem (4)

Repeat Problem (1) with with Slump 40mm.

Problem (5)

For an entrained concrete, the 28-day characteristic compressive strength should be 30 MPa, the accepted level of quality (risk factor is 2.5%) and the standard deviation of previous tests is 4.5MPa. The slump should be between 160 mm and the maximum aggregate size should not exceed 25 mm. It is intended to replace 15% of the cement content with fly-ash Class C. The specific gravity of fly-ash Class C is 2.1., and the minimum cement content should be 300 kg/m³ concrete.

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 = 1.5%; dry-rodded unit weight = 1605 kg/m³; total moisture content = 0.5%
- Fine Aggregate: Bulk specific gravity (SSD) = 2.60; absorption capacity = 2.30%; fineness modulus = 2.70; total moisture content = 3.5%.

Using [Absolute Volumes Method](#) and then [Weights Method](#), calculate the concrete mix proportions?