

Concrete Mix Design

- Mean compressive strength?
- Design compressive strength of concrete
 - Or Specified Design strength (US)
 - Or Specified Characteristic strength (UK)
 - Minimum requirement of strength from structural analysis and design
- Concrete mix design aims at a mean strength
- Mean strength > Design strength
 - So that **most of the** concrete strength become stronger than design strength

- Design Engineer tells you Design Strength necessary for the construction
- You need to find Target Mean Strength = ? To design the mix
- You need to use standard deviation to find the mean strength
- Standard deviation comes from previous experience of mix design and/or test results of concrete

Quality Control of Concrete by Testing

- The ACI code specifies that **a pair** of cylinders must be tested for each **150 yd³** of concrete or for **5000 ft²** of surface area actually placed, but not less than **once a day**.
- To ensure adequate concrete strength in spite of such scatter, the ACI code stipulates that concrete quality is **satisfactory** if
 - (1) no individual strength test result (the average of a pair of cylinder tests) falls below the required f_c' by more than **500 psi** when f_c' is 5000 psi or less or by more than **0.10 f_c'** when f_c' is more than 5000 psi, and
 - (2) every arithmetic average of any three (pair) consecutive strength tests equals or exceeds f_c'

σ = standard deviation

f'_c = design compressive strength

f'_{cr} = average compressive strength

$$f'_{cr} = f'_c + 1.34\sigma$$

OR

$$f'_{cr} = f'_c + 2.33\sigma - 500 \text{ for } f'_c \leq 5000 \text{psi}$$

$$f'_{cr} = 0.90f'_c + 2.33\sigma \text{ for } f'_c > 5000 \text{psi}$$

TABLE 5.3.2.2—REQUIRED AVERAGE COMPRESSIVE STRENGTH WHEN DATA ARE NOT AVAILABLE TO ESTABLISH A STANDARD DEVIATION

Specified compressive strength, f_c' , psi	Required average compressive strength, f_{cr}' , psi
Less than 3000	$f_c' + 1000$
3000 to 5000	$f_c' + 1200$
Over 5000	$1.10f_c' + 700$
Specified compressive strength, f_c' , MPa	Required average compressive strength, f_{cr}' , MPa
Less than 21	$f_c' + 7.0$
21 to 35	$f_c' + 8.5$
Over 35	$1.10f_c' + 5.0$

Non-destructive test of concrete (NDT)

- Example – 1: design compressive strength of concrete of a structure is **4000 psi**. the test results of concrete are as follows:
 - Day 1: (2500 psi, 4500psi), (3000 psi, 4680 psi), (4200 psi, 4520 psi)
 - Day 2: (3500 psi, 4050 psi), (3800 psi, 3900 psi)
 - Day 3: (4100 psi, 4360 psi)
 - Day 4: (4500 psi, 4150 psi)
- Are these results **satisfactory**?

Mix Design as per ACI 211.1-91

- ACI = American Concrete Institute
- ACI 211.1-91 is part of ACI Manual published by American Concrete Institute.
- Standard practice for selecting proportions for normal, heavyweight and mass concrete is described here.
- Guide for selecting proportions for high-strength concrete is described in ACI 211.4R-93.
- Mean target strength upto 6000 psi (41 MPa) is considered as normal strength concrete and mean target strength above 6000 psi is considered as high-strength concrete.
- Smaller size aggregates have been shown to provide higher strength potential.

Mix Design as per ACI 211.1-91

- Exposure condition of concrete limits the w/c ratio to ensure durability of concrete in adverse environment.
- Slump value of concrete should be selected based on scope of compaction during casting, for example, to make flowing concrete slump should be in the range of 100 – 150 mm, concrete for cast in situ piles should have slump value in the range of 150-175 mm. In addition, ACI recommended slump values are given below.

Table 6.3.4(b) – Maximum permissible water-cement or water-cementitious material ratios for concrete in severe exposures

Types of structure	Structure wet continuously or frequently and exposed to freezing and thawing*	Structures exposed to sea water or sulfates
Thin sections (railings, curbs, sills, ledges, ornamental work) and Sections with less than 1” clear cover over steel	0.45	0.40**
All other structures	0.50	0.45**
*Concrete should also be air entrained		
**If sulfate resisting cement (Type II or Type V of ASTM C 150) is used, permissible water-cement ratio may be increased by 0.05		

Table 6.3.1 – Recommended slumps for various types of construction

Types of construction	Slump, in.	
	Maximum	Minimum
Reinforced foundation walls and footings	3	1
Plain footings, caissons and substructure walls	3	1
Beams and reinforced walls	4	1
Building columns	4	1
Pavements and slabs	3	1
Mass concrete	2	1

* For cast in situ concrete piling, slump value is 6" to 8"

Mix Design Example

- ACI method
- Composite cement
- Ready mixed concrete will be cast by pumping
- Admixture (Super Plasticizer) will be used to make flowing concrete
- Concrete will remain under sea water (i.e. offshore structure)
- Design strength of concrete is 35 MPa
- All necessary data are given in the following tables

Table 1: Properties of fine aggregate

Sl. No.	Property	Test Method	Value	Unit
1	Bulk Specific Gravity (OD basis)	ASTM C127	2.54	-
2	Apparent Specific Gravity (OD basis)	ASTM C127	2.60	-
3	Absorption Capacity	ASTM C127	1.34	%
4	Dry Rodded Unit Weight	ASTM C29	1590	kg/m ³
5	Moisture Content of FA in Laboratory	-	4.00	%
6	Fineness Modulus (FM)	ASTM C136	2.62	

Table 2: Properties of coarse aggregate

Sl. No.	Property	Test Method	Value	Unit
1	Bulk Specific Gravity (OD basis)	ASTM C127	2.66	-
2	Apparent Specific Gravity (OD basis)	ASTM C127	2.68	-
3	Absorption Capacity	ASTM C127	0.69	%
4	Dry Rodded Unit Weight	ASTM C29	1550	kg/m ³
5	Moisture Content of CA in Laboratory	-	0.38	%
6	Maximum Size	-	20	mm

Table 3: Propertie of cement

Sl. No.	Property	Test Method	Value	Unit
1	Brand name		Supercrete (composite)	-
2	Clinker		80	%
3	Fly ash		20	%
4	Compacted Unit Weight		1400	kg/m ³
5	Loose Unit Weight	-	1100	kg/m ³
6	Specific gravity of clinker		3.15	
7	Specific gravity of fly ash		2.40	

Table 4: Properties of water reducing admixture

Sl. No.	Property	Test Method	Value	Unit
1	Brand name		Megaflow230	-
2	Recommended dose		500-1500 ml per 100 kg cement	
3	Expected water reduction		15-20	%
4	Specific gravity		1.2	-

Table 5: ACI recommended w/c ratio for normal strength concrete

Mean target strength		w/c ratio
psi	MPa	
6000	41	0.41
5000	34	0.48
4000	28	0.57
3000	21	0.68
2000	14	0.82

$$\frac{w}{c} = 1.1734e^{-0.0259 f_c'}$$

f_c' in MPa

Table 6: ACI recommended dry rodded bulk volume of coarse aggregate per unit volume of concrete

max size of agg	FM of fine aggregate			
	2.40	2.60	2.80	3.00
mm				
9.5	0.50	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
19	0.66	0.64	0.62	0.60
25	0.71	0.69	0.67	0.65
37.5	0.75	0.73	0.71	0.69
50	0.78	0.76	0.74	0.72
75	0.82	0.80	0.78	0.76
150	0.87	0.85	0.83	0.81

Table 7: First estimate of density of fresh concrete

nominal max size	Density of fresh concrete (kg/m ³)
9.5	2280
12.5	2310
19	2345
25	2380
37.5	2410
50	2445
75	2490
150	2530

Table 8: ACI recommended mixing water content for 1 m³ fresh concrete

Max size of aggregate (mm)	10	12.5	20	25	40	50	70	150
Slump value (mm)	Amount of mixing water in kg per 1 m ³ concrete							
25 to 50	207	199	190	179	166	154	130	113
75 to 100	228	216	205	193	181	169	145	124
150 to 175	243	228	216	202	190	178	160	-
Entrapped air (%)	3	2.5	2	1.5	1	0.5	0.3	0.2

Table 9: Properties of aggregates in site

Sl. No.	Property	Test Method	Value	Unit
1	Moisture content of fine aggregate		5.0	%
2	Moisture content of coarse aggregate		1.0	%
3	Loose Unit Weight of fine aggregate		1280	kg/m ³
4	Loose Unit Weight of coarse aggregate		1330	kg/m ³
5	Loose Unit Weight of Cement		1100	kg/m ³

Table 10: First trial mix result

Water added	0.3 kg more water was added than calculated for first trial mix
Slump measured	100 mm
Measured density of fresh concrete	2390 kg/m ³

Step 1: Selection of slump value

To make flowing concrete, slump = 100 - 150 mm

Step 2: Selection of maximum size of coarse aggregate

- (a) Nominal maximum size of coarse aggregate should be the largest possible which is economically available.
- (b) Maximum size of coarse aggregate should be less than
- One-fifth of the narrowest dimension of the structure
 - One-third of the depth of slab
 - Three-fourth of minimum clear spacing between bars
 - Clear cover

Here, we have no information about size of structure and maximum size of available aggregate is 20 mm.

So, maximum size of CA = 20 mm

Step 3: Estimation of mixing water content and air content

Usually for concrete structures exposed to severe weathering, air-entrained concrete is needed. As air-entraining admixture is expensive and not readily available in Bangladesh, non air-entrained concrete will be used.

Using Table 8, for slump = 100 - 150 mm and maximum size of CA = 20 mm,

$$\text{Mixing water} = \frac{205 + 216}{2} = 210.5 \text{ kg per } 1 \text{ m}^3 \text{ fresh}$$

concrete

Entrapped air content = 2 % (Table 8)

Super plasticizer **Megaflow230** will be used to increase workability. Megaflow230 can reduce mixing water content upto 20% depending on its dose.

If we use the dose of Megaflow230 = 1000 ml per 100 kg cement and assume that it would reduce water content by 15%,

So, Mixing water = $210.5 \times 0.85 = 179$ kg per 1 m^3 fresh concrete

Step 4: Selection of w/c ratio

(a) Considering durability of concrete which is exposed to sea water, maximum permissible w/c ratio is 0.45 (see Table 6.3.4(b) of ACI 211.1-91)

$$\text{So, } \frac{w}{c} \leq 0.45$$

(b) Considering strength of concrete

Design compressive strength	= 35.0 MPa
<u>Safety margin</u>	<u>= 8.5 MPa</u>
Target Mean Strength	= 43.5 MPa

For 41 MPa

w/c ratio = 0.41

For 34 MPa

w/c ratio = 0.48

For 7 MPa difference in strength, diff in w/c ratio
= 0.07

For (43.5-41.0 =) 2.5 MPa diff in strength, diff in w/c
ratio = $\left(\frac{0.07}{7}\right) \cdot (2.5) = 0.025$

So, for 43.5 MPa, w/c ratio = 0.41 - 0.025 = 0.385 =
0.38

i.e. $\frac{w}{c} \leq 0.38$ (governs)

or , to avoid interpolation or
extrapolation, we can use following
formula to get w/c ratio

$$\frac{w}{c} = 1.1734e^{-0.0259 f_c}$$

Step 5: Calculation of cement content and admixture

$$\text{Cementitious material or binder} = \frac{w}{w/c} = \frac{179}{0.38} = 471 \text{ kg}$$

Where, clinker = $471 \times 0.8 = 377 \text{ kg}$

 Fly ash = $471 \times 0.2 = 94 \text{ kg}$

Here, let us use 700 ml Megaflo230 per 100 kg cement

So, amount of admixture = $\frac{700}{100}(471) \text{ ml per } 1 \text{ m}^3$

concrete

$$\begin{aligned} &= 3297 \text{ ml} = 3297 \text{ cm}^3 = 3297(1.2) \text{ gm} \\ &= 3956 \text{ gm} = 3.956 \text{ kg} \end{aligned}$$

Admixture is generally water based solution. Amount of mixing water will be changed

$$\text{Mixing water} = 179 - 4 = 175 \text{ kg}$$

Step 6: Estimation of coarse aggregate content

Using Table 6,

Dry rodded bulk volume of *CA* = 0.64 m³ per 1 m³ concrete

$$\begin{aligned}\text{Dry mass of } CA &= 0.64 \times 1550 \text{ kg} \\ &= 992 \text{ kg per } 1 \text{ m}^3 \text{ concrete}\end{aligned}$$

$$\begin{aligned}\text{SSD mass of } CA &= 992 \left(1 + \frac{0.69}{100} \right) \\ &= 999 \text{ kg}\end{aligned}$$

Step 7: Calculation of fine aggregate content

Fine aggregate content can be calculated using mass method or volume method.

(a) Mass method

Using Table 7, approximate density of fresh concrete
= 2345 kg/m³

So SSD mass of FA

$$\begin{aligned} &= 2345 - W - C - CA(SSD) - Adm \\ &= 2345 - 175 - 471 - 999 - 4 \\ &= 696 \text{ kg} \end{aligned}$$

$$\text{OD mass of FA} = \frac{696}{1 + \frac{1.34}{100}} = 687 \text{ kg}$$

(b) Volume method

Total volume of concrete is 1 m^3 which must be equal to sum of solid volumes of all ingredients.

$$\frac{W}{1000} + \frac{C}{(3.15)1000} + \frac{\text{FlyAsh}}{(2.40)1000} + \frac{FA_{(OD)}}{(BSG_{FA-OD})1000} + \frac{CA_{(OD)}}{(BSG_{CA-OD})1000} + \frac{Adm}{(SG)1000} + \frac{A}{100}(1) = 1$$

$$\frac{175}{1000} + \frac{377}{(3.15)1000} + \frac{94}{(2.40)1000} + \frac{FA_{(OD)}}{(2.54)1000} + \frac{992}{(2.66)1000} + \frac{3.956}{(1.2)1000} + \frac{2}{100}(1) = 1$$

$$FA (OD) = 686 \text{ kg}$$

$$FA (SSD) = 686 \left(1 + \frac{1.34}{100} \right) = 695 \text{ kg}$$

Volume method does not require assumption of density of fresh concrete, so it is more rational than mass method

$$\begin{aligned} \text{So, } FA (OD) &= 686 \text{ kg} \\ FA (SSD) &= 695 \text{ kg} \end{aligned}$$

Basic mix design is complete here.

Mix proportion for 1 m³ fresh concrete

Water	= 175 kg
Cement	= 471 kg
FA (SSD)	= 695 kg
CA (SSD)	= 999 kg
<u>Megaflow230</u>	<u>= 3.956 kg</u>
Total	= 2344 kg

Step 8: Adjustment and First Lab Trial Mix

Surface moisture or

$$\text{free moisture in FA} = 686 \left(\frac{4.0 - 1.34}{100} \right) = 18.2 \text{ kg}$$

Surface moisture or

$$\text{free moisture in CA} = 992 \left(\frac{0.38 - 0.69}{100} \right) = -3.1 \text{ kg}$$

$$\text{Adjusted mixing water} = 175 - 18.2 - (-3.1)$$

$$= 159.9 \text{ kg} = 160 \text{ kg}$$

$$\text{Adjusted FA} = 695 + 18.2 = 713.2 \text{ kg} = 713 \text{ kg}$$

$$\text{Adjusted CA} = 999 - 3.1 = 995.9 \text{ kg} = 996 \text{ kg}$$

Mix proportion for 1 m³ fresh concrete

	SSD mass (kg)	Adjusted wet mass (kg)
Water	175	160
Cement	471	471
Fine Aggregate	695	713
Coarse Aggregate	999	996
<u>Megaflow230</u>	<u>3.956</u>	<u>3.956</u>
Total	2344	2344

$$\text{Volume of 3 cylinders} = 3 \left(\frac{\pi}{4} (0.150)^2 (0.300) \right) = 0.0159 \text{ m}^3$$

Consider 25% loss during handling,

So, volume of fresh concrete needed for first
lab trial mix = $1.25 * 0.0159 = 0.0199 \text{ m}^3 = 0.02$
 m^3

Mix proportion for 0.02 m³ fresh concrete

	Adjusted wet mass (kg)	Adjusted wet mass (kg)
Water	$160 \times 0.02 =$	3.20
Cement	$471 \times 0.02 =$	9.42
Fine Aggregate	$713 \times 0.02 =$	14.26
Coarse Aggregate	$996 \times 0.02 =$	19.92
Megaflow230	$3.956 \times 0.02 =$	0.079

All the ingredients as calculated above are mixed in mixer machine. From visual observation it seems that more water is necessary to get required slump. 0.3 kg more water is added and concrete is mixed again. Freshly mixed concrete is taken out of mixer machine and slump test is performed.

Slump value = 100 mm found from slump test.

To measure density of fresh concrete, 3 empty cylinders are weighed, filled with concrete, compacted, leveled and cleaned outside of mold. Then filled up molds are weighed. Density of concrete is calculated as follows.

	weight of cylinder	weight of cylinder + concrete	weight of concrete	diameter (mm)	height (mm)	volume mold (m ³)	density (kg/m ³)	average density (kg/m ³)
Cylinder1	11.00	24.50	13.50	155	305	0.005755	2345.7	2390
Cylinder2	10.99	24.67	13.68	153	305	0.005608	2439.6	
Cylinder3	10.88	24.60	13.72	155	305	0.005755	2384.0	

Measured density of fresh concrete = 2390 kg/m³

Mass of water added = 3.20 + 0.30 = 3.50 kg

Mass of ingredients mixed

= 3.50 + 9.42 + 14.26 + 19.92 + 0.079

= 47.179 kg

$$\text{So, yield of trial mix} = \frac{47.179}{2390} = 0.01974 \text{ m}^3$$

Surface moisture in 14.26 kg FA = ?

$$\text{OD mass of FA} = \frac{14.26}{1 + \frac{4}{100}} = 13.71 \text{ kg,}$$

$$\text{Surface moisture in FA} = 13.71 \left(\frac{4 - 1.34}{100} \right) = 0.365 \text{ kg}$$

Surface moisture in 19.92 kg CA = ?

$$\text{OD mass of CA} = \frac{19.92}{1 + \frac{0.38}{100}} = 19.845 \text{ kg}$$

$$\text{Surface moisture in CA} = 19.845 \left(\frac{0.38 - 0.69}{100} \right) = -0.062 \text{ kg}$$

So, mixing water in first lab trial mix

$$= 3.50 + 0.365 - 0.062 + 0.079$$

$$= 3.882 \text{ kg for } 0.0197 \text{ m}^3 \text{ concrete}$$

For 0.0197 m^3 concrete, mixing water = 3.882 kg

$$\text{For } 1 \text{ m}^3 \text{ concrete, mixing water} = \frac{3.882}{0.01974} = 197 \text{ kg}$$

Step 9: Revision of mix proportion based on First Lab Trial Mix result

ACI suggests that if the slump of the trial mix does not satisfy the requirement, increase or decrease the re-estimated water content by 2 kg/m^3 for each increase or decrease of 10 mm slump.

$$\text{Slump required} = (100+150)/2 = 125 \text{ mm}$$

$$\text{Slump found} = \underline{\hspace{10em}} = 100 \text{ mm}$$

$$\text{Slump to be increased} = 25 \text{ mm}$$

$$\text{Water to be increased} = \left(\frac{2}{10}\right)25 = 5 \text{ kg}$$

$$\text{So, modified mixing water} = 197 + 5 = 202 \text{ kg}$$

To get target mean strength or same durability, we have to keep the w/c ratio constant as calculated in step 4,

$$\text{So, modified cement content} = \frac{202}{0.38} = 532 \text{ kg}$$

$$\text{CA (wet) for } 1 \text{ m}^3 \text{ concrete} = \frac{19.92}{0.01974} = 1009 \text{ kg}$$

$$\text{CA (OD) for } 1 \text{ m}^3 \text{ concrete} = \frac{1009}{1 + \frac{0.38}{100}} = 1005 \text{ kg}$$

$$\text{CA (SSD) for } 1 \text{ m}^3 \text{ concrete} = 1005 \left(1 + \frac{0.69}{100} \right) = 1012 \text{ kg}$$

$$\text{Surface water in wet CA} = 1009 - 1012 = -3 \text{ kg}$$

$$\begin{aligned} \text{FA (SSD)} &= 2390 - 202 - 532 - 1012 \\ &= 652.48 = 644 \text{ kg} \end{aligned}$$

$$\text{FA (OD)} = \frac{644}{1 + \frac{1.34}{100}} = 635 \text{ kg}$$

$$\text{FA (wet)} = 635 \left(1 + \frac{4}{100} \right) = 660 \text{ kg}$$

$$\text{Surface water in wet FA} = 660 - 644 = 16 \text{ kg}$$

$$\text{Mixing water} = 202 - 4 = 198$$

$$\begin{aligned} \text{Mixing water in adjusted wet masses} \\ &= 198 - 16 + 3 \\ &= 185 \end{aligned}$$

Modified mix proportion for 1 m³ fresh concrete after first lab trial

	SSD mass (kg)	Adjusted wet mass (kg)
Water	198	185
Cement	532	532
Fine Aggregate	644	660
Coarse Aggregate	1012	1009
<u>Megaflow230</u>	<u>3.956</u>	<u>3.956</u>
Total	2390	2390

Step 10: Final trial mix to confirm strength and slump

We need 9 cylinders to cast. If we use 4" diameter and 8" height cylinder,

$$\text{Volume of 9 cylinders} = 9 \left(\frac{\pi}{4} (0.100)^2 (0.200) \right) = 0.0141 \text{ m}^3$$

Consider 25% loss during handling,

$$\begin{aligned} \text{Volume of fresh concrete needed for final trial mix} \\ = 1.25 * 0.0141 = 0.0176 \text{ m}^3 \end{aligned}$$

This is very small amount of mix which may lead to significant errors due to errors in measurement and loss in mixing. For this reason, it is wise to make at least 0.025 m³ concrete for final trial mix.

Mix proportion for 0.025 m³ fresh concrete

	Adjusted wet mass (kg)	Adjusted wet mass (kg)
Water	$185 \times 0.025 =$	4.63
Cement	$532 \times 0.025 =$	13.30
Fine Aggregate	$660 \times 0.025 =$	16.50
Coarse Aggregate	$1009 \times 0.025 =$	25.23
Megaflow230	$3.956 \times 0.025 =$	0.099

Date of Casting: 1-Jul-09

Trial Mix No.: ASHA-01

w/c: 0.38

Target Mean Strength: 43.5 MPa (C35)

Brand Name of Cement: Supercrete (Composite)

Name of Admixture: Megaflo 230

Fine and Coarse Aggregate: Sylhet sand and Stone chips

COMPRESSIVE STRENGTH OF TRIAL MIX CONCRETE CYLINDERS

	3-days strength			7-days strength			28-days strength		
Sl. No	Crushing strength (psi)	Crushing strength (MPa)	Type of Failure	Crushing strength (psi)	Crushing strength (MPa)	Type of Failure	Crushing strength (psi)	Crushing strength (MPa)	Type of Failure
1	3720	25.6	Mortar	5140	35.4	Combined	6700	46.2	Combined
2	3350	23.1	Mortar	4990	34.4	Combined	6780	46.7	Combined
3	3570	24.6	Mortar	5210	35.9	Combined	6550	45.1	Combined
Mean	3550	24.5	-	5100	35.1	-	6700	46.2	-

4-Jul-09

56%

8-Jul-09

81%

29-Jul-09

106%

Materials requirement for 1 m³ of fresh concrete:

Water:	198	kg
Cement:	532	kg
Fine Aggregate (SSD):	644	kg
Coarse Aggregate (SSD):	1012	kg
Admixture*:	3.96	kg

Initial setting time = - minutes

* (0.74 % of cement mass)

Slump:	140	mm
--------	-----	----

Step 11: Adjustment for casting in site

From table 9,

Moisture content in FA = 5%

Moisture content in CA = 1%

FA (OD) = 635 kg,

CA (OD) = 1005 kg

$$\text{Surface moisture in FA} = 635 \left(\frac{5 - 1.34}{100} \right) = 23.2 \text{ kg}$$

$$\text{Surface moisture in CA} = 1005 \left(\frac{1 - 0.69}{100} \right) = 3.1 \text{ kg}$$

Adjusted mixing water

$$= 198 - 23.2 - 3.1 = 171.7 \text{ kg} = 172 \text{ kg}$$

$$\text{Adjusted FA} = 644 + 23.2 = 667 \text{ kg}$$

$$\text{Adjusted CA} = 1012 + 3.1 = 1015 \text{ kg}$$

Mix proportion for 1 m³ fresh concrete in site

	SSD mass (kg)	Adjusted wet mass (kg)
Water	198	172
Cement	532	532
Fine Aggregate	644	667
Coarse Aggregate	1012	1015
<u>Megaflow230</u>	<u>3.956</u>	<u>3.956</u>
Total	2390	2390

Step 12: Conversion to volumetric ratio

	SSD Mass (kg)	Moisture content (%)	Adjusted wet mass (kg)	Loose unit weight (kg/m ³)	Bulk volume (m ³)	Volumetric ratio
water	198	<i>N/A</i>	172	1000	0.172	0.36
cement	532	<i>N/A</i>	532	1100	0.484	1.00
FA (field)	644	5.00	667	1280	0.521	1.08
CA (field)	1012	<i>1.00</i>	1015	1330	0.763	1.58
adm	4.0	<i>N/A</i>	4	1200	-	-

Note that generally

1 bag cement

= 50 kg cement mass

= 1.25 cft compacted bulk volume of cement

= 1.60 cft loose bulk volume of cement

However, among practicing engineers in Bangladesh, 50 kg cement = 1.25 cft bulk volume of cement is known and used for calculating volumetric ratio.

Volumetric ratios like 1:1.5:3 or 1:2:4 which are very familiar to practicing engineers in Bangladesh have no rational basis. This kind of ratios should not be used any more.