

# **Construction Materials and Equipments**

## **Civil Engineering**

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Comprehensive Theory *with* Solved Examples

**Civil Services Examination**



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**2.1 Introduction**

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- Concrete is a construction material composed of cement, fine aggregates (sand) and coarse aggregates mixed with water which hardens with time.
- Basis requirement of Good Concrete is that it should have good strength in hardened state and remain “fresh” plastic during transportation, placing, compaction.
- In fresh state, consistency of mix should be such that it can be compacted by the desired means without excessive effort and also the mix should be cohesive enough for the methods of transporting, and placing used so as not to cause segregation.

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**2.2 Properties of Cement Concrete**

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1. High compressive strength
2. Free from corrosion and there is no appreciable effect of atmospheric agents on it.
3. It hardens with age and the process of hardening continues for a long time.
4. It is proved to be more economical than steel.
5. It binds rapidly with steel and as it is weak in tension, the steel reinforcement is placed in cement concrete at suitable places to take up the tensile stresses. This is termed as the reinforced cement concrete or simply RCC.
6. It has a tendency to shrink.
7. It forms a hard surface, capable of resisting abrasion.

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**2.3 Manufacturing of Concrete**

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**A. Batching:**

1. Aggregates, cement and water should be measured with an accuracy of  $\pm 3$  per cent of batch quantity and the admixtures by 5 per cent of the batch quantity.

There are two prevalent methods of batching materials are:

- (a) Volume batching
  - (b) Weight batching
2. For most important works weight batching is recommended whereas, volume batching is generally recommended for small jobs only.

**Volume Batching:**

- Amount of each solid ingredient is measured by loose volume (not compacted).  
Example, volume of moist sand in a loose condition weighs much less than the same volume of dry compacted sand.
- Therefore **correction for bulking of sand** is done if volume batching is adopted.

**Weight Batching:**

- Cement is always measured by weight, irrespective of method of batching.
- Water is measured in kg or liters where density of water is  $1 \text{ gm/cm}^3$ .
- **Volume of 1 bag of cement is  $0.035 \text{ m}^3$  (or sometime also said 35 liters)**

**B. Mixing:**

- Objective of mixing is to obtain homogenous, uniform colour and consistent concrete of desired strength.
- **Mixing time depends on the type and capacity of mixer but IS-456 suggest approximately mixing time as 2 minutes.**
- **Generally 20 revolution of concrete in mixture provides sufficient mixing.**
- If mixing time is increased upto 2 minutes the compressive strength of concrete produced is enhanced and beyond this time the improvement in compressive strength is insignificant and prolonged mixing may cause segregation as due to longer mixing periods the water may get absorbed by the aggregates or evaporate resulting in loss of workability and strength.
- The mixing is done in two ways i.e. 1. Hand mixing and 2. Machine mixing (mixture)

**Hand Mixing:**

- Hand mixing is adopted for small jobs where the quantity of concrete involved is small and the approximate time is **2 minutes should never exceed 3 minutes.**

**Machine Mixing:**

- When a large quantity of concrete of the desired quality is to be produced, the machine mixing becomes imperative as Concrete can be produced at a faster rate with better quality.
- Concrete mixers are specified by the volume of mixed concrete discharged after mixing of each batch expressed in  $\text{m}^3$  (such as 0.25, 0.38, 0.57, 0.75, 1.5, 2.25 and  $3 \text{ m}^3$ ).
- Sometimes the total volume of the unmixed ingredients in  $\text{m}^3$  is given as a prefix. i.e. 1.0/0.75 mixer takes  $1 \text{ m}^3$  of unmixed material and gives  $0.75 \text{ m}^3$  of mixed concrete in each batch.
- The machine mixing is done by using 1. Tilting type mixture, 2. Non tilting type mixture, 3. Batching plant.

**1. Tilting type mixture:**

- In this mixed concrete is discharged by tilting the drum about the horizontal axis.
- Tilting mixers are useful for large construction works.
- It gives better results even will **dry concrete.**
- It can be used for **aggregate size more than 75 mm.**
- Tilting mixers are easier to clean and can discharge the mix quickly and with minimum segregation.
- The tilting type mixtures are represented as 85T, 100T, 140T, 200T (where 85, 100, 140 are in liters.)

## 2. Non-tilting type mixture:

- Non-tilting mixers are suitable for small works.
- Non-tilting mixer is equipped with a drum rotating about a horizontal axis.
- Non-tilting mixers cannot be used when **aggregate size more than 75 mm**.
- Non-tilting mixers are represented as 200 NT, 280 NT, 340 NT, 400 NT, 800 NT.



Sometimes the mixers are specified by two quantities the total volume of ingredients added and the volume of concrete produced for example 285/200-litres mixer takes 285 litres of ingredients and yields 200 liters of concrete.

## C. Transportation:

- Specification states that the process of mixing transporting placing and compacting the concrete **should not take more than initial setting time of cement (30 minutes using OPC)**
- It must also ensure that segregation not took place.
- The transporting of concrete can be done by following methods.
  1. **Pans:** Recommended only for small jobs.
  2. **Power Buggies:** These have sped up to 24 km/h.
  3. **Chutes :** When concrete is to be deposited below ground level at a higher depth, it can be discharged through a steel shaft called chute.
  4. **Concrete Pumps:** It is used commonly for tunnel works and on locations which are not easily accessible where concrete can be pumped for a distance of about 400 m. horizontally and 80 m vertically having slump value 50 mm to 100 mm and the pipe used in concrete pump having diameter 10 cm to 20 cm.
  5. **Transit Mixer:** Transit mixer is a truck on which a concrete mixer is mounted and useful in built-up areas.
  6. **Belt-conveyer:** A belt conveyer is used when the concrete is to be transported continuously and to an inaccessible area.

## D. Placing:

- Research has shown that delayed placing of concrete results in a gain in ultimate compressive strength provided the concrete can be adequately compacted.
- For dry mixes in **hot weather delay of half to one hour** is allowed whereas **for wet mixes** in cold weather it may be several hours.
- **As per IS456 maximum permissible free fall of concrete may be taken as 1.5 m**

## E. Compaction:

- The process of removal of entrapped air and of uniform placement of concrete to form a homogeneous dense mass is termed compaction.
- The density and consequently the strength and durability of concrete depends upon the quality of compaction.
- **The presence of even 5% and 10% voids in hardened concrete left due to incomplete compaction may result in a decreases in compressive strength by about 30% and 60% respectively.**



The various types of vibrators used are:

**1. Internal Vibrators**

- These vibrators consist of a metal rod which is inserted in fresh concrete.
- Skilled and experienced men should handle internal vibrators. These vibrators are more efficient than other types of vibrators.
- These vibrators can compact upto 450 mm from the face but have to be moved from one place to another as concrete progresses.
- The frequency of vibration is about **4000 to 12000 rpm**.
- The needle diameter varies from **20 mm to 75 mm and its length 25 cm to 90 cm**.

**2. Surface Vibrators**

- These vibrators are mounted on platform or screeds.
- They are used to finish concrete surfaces such as bridge floors, road slabs, station platform, etc.
- It is placed directly on the concrete mass for the compaction of shallow elements (where internal vibrators cannot be applied) i.e. depth  $\nless 150$  mm. Ex: Road surfaces, plain concrete floors etc.

**3. Form Vibrators or Shutter Vibrators**

- These vibrators are attached to the framework and external centering of walls, columns, etc. The vibrating action is conveyed to concrete through the framework during transmission of vibrations. Hence they are not generally used.
- But they are very much helpful for concrete sections which are too thin for the use of internal vibrators.

**4. Vibrating Tables**

- It is very efficient in compacting stiff and harsh concrete mixes required for the manufacture of precast elements.

**F. Curing**

- The test specimens should be stored in a place free from vibration in moist air of at least 90% relative humidity and at a temperature of 24- 30°C for 24 hours from the time of addition of water to the dry ingredients.
- After this period the specimens are marked and removed from the moulds and unless required for test within 24 hours immediately submerged in clean fresh water kept there until taken out just prior to test.
- The specimens are not to be allowed to become dry at any time until they have been tested.
- Cement gains strength and hardness because of the chemical action between cement and water.
- The water in a concrete mix takes one of the following three forms as a consequence of hydration are:
  1. **Combined water:** Which combined with hydration products ( $C_3A$ ,  $C_3S$ ,  $C_4AF$ ) its not evaporable.
  2. **Gel water:** The water prevails over cement Gel Surface Area.
  3. **Capillary water:** Which "occupy capillary pores" (Evaporable).

- Increase in strength of concrete is very rapid from 3 to 7 days and continues slowly for indefinite period.
- It has observed that moist cured concrete for 7 days is nearly 50% stronger than that which is exposed to dry air for entire period.
- If concrete is cured for one month, strength is nearly double than that of concrete exposed to dry air.

#### Objective of Curing:

- To prevent the loss of moisture from concrete due to evaporation or any other reason supply additional moisture or heat and moisture to accelerate the gain of strength.
- To keep capillary pores saturated to ensure hydration of cement; to increase durability, impermeability of concrete and reduce the shrinkage.
- As per IS: 456 concrete members shall be kept under curing for a minimum period of 7 days for OPC at 90% humidity and at least 10 days where mineral admixtures and blended cements are used.

**NOTE:** Lower temperature reduces the rate of setting and higher temperature reduces the ultimate strength. Therefore curing temperature need to be within 5 to 30°C.

#### Steam Curing:

- For concrete mixes with water cement ratio ranging from 0.3 to 0.7 the increased rate of strength development can be achieved by resorting to steam curing.
- This method of curing is also known as accelerated curing since an increased rate of strength development can be achieved.
- Concrete members are heated by steam at 93°C either at low pressure or high pressure.
- By low pressure steam curing about 70 per cent of the 28 day compressive strength of concrete can be obtained in about 16–24 hours and high pressure steam curing is usually applied to precast concrete members and gives 28 day compressive strength at 24 hours.
- It reduces shear strength of concrete.
- It also results in increased resistance to sulphate action and to freezing and thawing.
- Rate of increase or decrease of temperature should not exceed 10 to 20°C per hour to avoid thermal shocks.
- “Infra-Red Radiation” is also helpful method of curing for Rapid Gain of Strength.

#### G. Finishing:

- Finishing is defined as the process of leveling and smoothing the top surface of freshly placed concrete to achieve the desired appearance is done by as follows:
  1. **Screeching:** Striking off the excess concrete to bring the top surface up to proper grade is called screeching.
  2. **Toweling:** Final operation of finishing be done after all excess water has evaporated by steel float in conical shape giving a very smooth finish.

#### Maturity of Concrete

- The strength of concrete depends on both period of curing (i.e. age) and temperature during curing.
- The product (period × temperature) is called the maturity of concrete
- It is measured in °C hours to °C days.

## 2.4 Proportioning of Concrete

The process of selection of relative proportions of cement, sand, coarse aggregate and water, so as to obtain a concrete of desired quality is known as the proportioning of concrete.

In general, the proportions of coarse aggregate, fine aggregate, cement and water should be such that the resulting concrete has the following properties:

- (i) When concrete is fresh, it should have enough workability so that it can be placed in the framework economically.
- (ii) The concrete must possess maximum density or in other words, it should be the strongest and most watertight.
- (iii) The cost of materials and labour required to form the concrete should be minimum.

### Different methods of proportioning concrete:

#### 1. Arbitrary method :

- The proportions of cement, sand and coarse aggregate are fixed arbitrarily such as 1 : 2 : 4 or 1 : 3 : 6 etc.
- Usually, the fine coarse ratio is 1 : 2
- In this method, there is no rigid control over the strength of the concrete mix.

#### 2. Fineness modulus method :

- The fineness modulus of sand aggregates is determined by the standard tests carried out with a set of ten BIS sieves and dividing the sum by 100.
- It is found from various experiments that certain values of fineness modulus for fine and coarse aggregates and mixed aggregates give better workability with less quantity of cement.
- The aggregates are mixed in such a proportion that the recommended fineness modulus of the combined aggregates is obtained.

#### 3. Minimum Voids Method :

- The voids of coarse aggregate and fine aggregate are determined separately and to get the dense concrete, it is so arranged that : as the quantity of fine aggregate completely fills the voids of the coarse aggregate;
- the quantity of cement completely fills the voids of fine aggregate
- sufficient water is added to make the mix workable.

#### 4. Maximum density method :

- It is based on the principle that the densest concrete is achieved by proportioning its aggregates in such a manner that the heaviest weight of concrete for same volume is obtained.
- A box is filled with varying proportions of fine and coarse aggregates. The proportion which gives heaviest weight is then adopted.

#### 5. Water-cement ratio method :

- The lower water content produces stiff paste having greater binding property and hence the lowering of water-cement ratio within certain limits results in the increased strength.
- The higher water content increases the workability. But it is not useful for the chemical action. The excess water evaporates leaving pores in the concrete. Thus the increased water-cement ratio lowers the strength of concrete.
- Thus optimum water-cement ratio for the concrete of required compressive strength is decided from graphs and expressions developed from various experiments.

## 2.5 IS Code method of Concrete Mix Design

Concrete mix design procedure for a particular grade of concrete depends on the following requirements,

- (i) Characteristic Strength of the concrete ( $F_{ck}$ ) required.
- (ii) Degree of workability required.
- (iii) Specific gravity and bulk density of cement.
- (iv) Grading zone of fine aggregate (sand) and size of coarse aggregates.
- (v) Specific gravity and bulk density of coarse and fine aggregates.
- (vi) Moisture Content, i.e. water absorption of coarse and fine aggregates.

### 2.5.1 Steps for Concrete Mix Design as per IS Code Method

IS 10262 : 2009 gives guidelines for concrete mix proportioning.

**Step-1: Target mean strength and standard deviation:**

- Cubes made of same concrete show slightly different strengths. IS 456 : 2000 recommends that standard deviation for each concrete grade should be determined separately. Further, it states that not less than 30 samples are to be tested.
- In the absence of sufficient test result, Table 1 of IS 10262 : 2009 and also IS 456 : 2000 suggests the following standard deviation:
- The target mean strength is then determined as,

$$f_{ck}' = f_{ck} + kS$$

Where  $S$  = Standard deviation

$k$  = A constant which is as per IS code is 1.65

The target mean strength

$$f_{ck}' = f_{ck} + 1.65 S$$

**Step-2: Selection of water-cement ratio:**

- Cl 4.1 of IS 10262 : 2009 specifies guidelines for selection of water cement ratio. For the same water-cement ratio, the strength of concrete obtained may be different because of difference in the cement quality and difference in shape, size and grade of aggregate.
- It is important to establish the relationship between water-cement ratio and strength of concrete. In the absence of this relationship. Table 5 of IS 456 : 2000, gives free water-cement ratio for different grades of concrete.

*Table : Maximum free water-cement ratio v/s minimum grade of concrete.*

Exposure	Plain concrete		Reinforced concrete	
	Max. free w/c ratio	Min. concrete grade	Max. free w/c ratio	Min. concrete grade
Mild	0.6	—	0.55	M20
Moderate	0.6	M15	0.5	M25
Severe	0.5	M20	0.45	M30
Very severe	0.45	M20	0.45	M35
Extreme	0.40	M25	0.40	M40

**Step-3: Selection of water content:**

- Cl. 4.2 of IS 10262 : 2009 states about selection of water content. Table 2 of IS 10262 : 2009 gives maximum water content per cubic meter of concrete for angular coarse aggregates and for 25-50 mm slump.
- Water content as arrived at corresponds to saturated and surface dry aggregates.

**Connections:**

- The so computed maximum water content is reduced if aggregates used are:  
Sub angular aggregates – 10 kg/m<sup>3</sup>  
Gravel with certain crushed particles – 20 kg/m<sup>3</sup>  
Rounded gravels – 25 kg/m<sup>3</sup>
- For slump of than 25-50 mm, increase the water content by 3% for each additional 25 mm slump.

**Step-4: Calculation of cementations material content:**

- Cl. 4.3 of IS 10262 : 2009 recommends to compute the cement and supplementary cementations material content per unit volume of concrete from free water-cement ratio i.e.,

$$\text{Cementations material, } C = \frac{\text{Water content used}}{\text{Water-cement ratio}}$$

- From durability considerations, the above computed value of cementations material (C) should not be less than the values as given in Table.

*Table : Maximum cement content for normal weight aggregates of 20 mm*

Exposure	Plain concrete (kg/m <sup>3</sup> )	Reinforced concrete (kg/m <sup>3</sup> )
Mild	220	300
Moderate	240	300
Severe	250	320
Very severe	260	340
Extreme	280	360

*Table : Adjustment to cement content*

Nominal size of aggregate (mm)	Adjustment to minimum cement content
10	+ 40 kg/m <sup>3</sup>
20	0
40	– 40 kg/m <sup>3</sup>

**Step-5: Estimate of coarse aggregates:**

- Cl. 4.4 of IS 10262 : 2009 states about the estimation of coarse aggregates per unit volume of concrete. Table 3 of IS 10262 : 2009 gives volume of coarse aggregates per unit volume of concrete for different zones of fine aggregates.

**Table :** Volume of coarse aggregates per unit volume of concrete for different zones of fine aggregates (i.e., sand)

Nominal max. size of aggregate (in mm)	Volume of coarse aggregates per unit volume of concrete for different zones of fine aggregates (kg/m <sup>3</sup> )			
	Zone-1	Zone-2	Zone-3	Zone-4
10	0.50	0.48	0.46	0.44
20	0.66	0.64	0.62	0.60
40	0.75	0.73	0.71	0.69

The above value are based on saturated and surface dry aggregates condition.

#### Step-6: Estimation of mass of coarse aggregates:

- After arriving at the masses of cement and water, the volume of total aggregate is computed as:

$$V_A = 1 - \left[ \frac{C}{S_c} + \frac{W}{1} \right] \times \frac{1}{1000}$$

where  $C$  = Mass of cement,  $S_c$  = Specific gravity of cement,  $W$  = Mass of water

- If other materials like fly ash, chemical admixtures are also added, air-entrainment is also incorporated then the volume of all these materials must be subtracted from unity in order to get the volume of total aggregates as,

$$V_A = 1 - \left[ \frac{C}{S_c} + \frac{W}{1} + \frac{F}{S_f} + \frac{P}{S_p} \right] \times \frac{1}{1000} - v$$

where  $F$  = Mass of fly ash,  $P$  = Mass of plasticizer,  $S_f$  = Specific gravity of fly ash

$S_p$  = Specific gravity of plasticizer,  $v$  = Volume of entrained air (in fraction)

- From the percentage of coarse aggregate ( $p$ ) as found in step 5 above, the mass of coarse aggregate is computed as:

Mass of coarse aggregate

$$= p V_A S_{CA} \times 1000$$

where,  $S_{CA}$  = Specific gravity of coarse aggregate

Similarly, mass of fine aggregate is given by,

$$\text{Mass of fine aggregate} = (1 - p) V_A S_{FA} \times 1000$$

where,  $S_{FA}$  = Specific gravity of fine aggregate

#### Step-7: Correction for actual site conditions:

- Often the available coarse and fine aggregates available at site are not in saturated and surface dry conditions.
- If there is some moisture content already present in the free state then reduce the amount of water required to that extent and increase the amount of aggregate by the same extent.
- If aggregates absorb moisture then definitely it will pose a deficiency in water required for concrete. So increase the water content by that extent and decrease the mass of aggregate by the same extent.

#### Fineness Modulus of Aggregate

- The term fineness modulus is used to indicate an index number which is roughly proportional to the average size of the particle in the entire quantity of aggregate.

Let  $p$  be the designed fineness modulus for a concrete mix of fine and coarse aggregates.

Then 
$$R = \frac{p_2 - p}{p - p_1} \times 100$$

where  $R$  = proportion of fine aggregate to the combined aggregate by weight

$p_1$  = fineness modulus of fine aggregate

$p_2$  = fineness modulus of coarse aggregate

### Fineness Modulus

- The fineness modulus of an aggregate is an index number which is roughly proportional to the average size of the particles in the aggregate. The coarser the aggregate, the higher is the fineness modulus.
- Fineness modulus is obtained by adding the percentage of the weight of the material retained on a total of 10 numbers of IS sieves (of sieve opening between 80  $\mu\text{m}$  to 150  $\mu\text{m}$ ) and dividing it by 100.

## 2.6 Durability of Concrete

- A durable concrete is one that performs satisfactorily under anticipated exposure conditions for its stipulated life.
- Various factors affecting durability of concrete are as follows:

### 1. Permeability

- Ingress of water leads concrete susceptible to chemical attack, forest action, rusting of steel etc.
- We can reduce permeability by
  - (i) Providing high grade of concrete
  - (ii) Using well-graded dense aggregate
  - (iii) Using low water-cement ratio, adequate cement and effective curing.
  - (iv) Using appropriate admixtures
  - (v) Achieving maximum compaction
  - (vi) The above parameter is giving thrust to the concrete of **Dense Mix** to reduce **Permeability**.

### 2. Frost action

- The Le Chatelier's
- Concrete is be affected due to being permeable or by temperature below  $0^\circ\text{C}$ .
- Because of expansion of absorbed water on freezing ice builds up in large pores causing large expansion in local areas the others being dry cause disintegration.
- Low temperatures increasing the extent of migration of water resulting in freezing to greater depths in the concrete.

### 3. Sulphate attack

- Sulphate attack is a chemical reaction between the products of hydration of cement and solution containing sulphate of calcium, Magnesium and sodium (water).
- These sulphates reacts with  $\text{C}_3\text{A}$  and formed calcium sulphotoaluminate (ettringite) which expands and causes disruption of concrete.
- Magnesium sulphate has the most severe descriptive action.





- (i) **Repair:** The main purpose of repairs is to bring back the architectural shape of the building so that all services start working and the functioning of building is resumed quickly. Repair does not pretend to improve structural strength of building e.g. Patching up of defects such as cracks.
- (ii) **Restoration:** It is the restitution of strength the building had before the damage occurred. The main purpose is to carry out structural repairs to load bearing elements. It may involve cutting portions of elements and rebuilding them, inserting temporary supports, etc. e.g. injecting epoxy like material, which is strong in tension, into the cracks, in walls etc.
- (iii) **Rehabilitation:** Rehabilitation methods, in addition to restoring structural integrity and shape, mitigate or stop the process responsible for the damage, because rehabilitation includes addressing the cause of the problem itself, the repairs last significantly longer.



### EXAMPLE : 2.1

Calculate the quantities of cement, sand and coarse aggregate required to produce one cubic meter of concrete for mix properties of 1 : 10 : 2.80 (by volume) with water-cement ratio of 0.18 (by mass) Bulk densities of cement, sand and coarse aggregates are 11.7, 16.66 and 18.68 kN/m<sup>3</sup> respectively. Percentage of entrained air is 2.0. Specific gravities of cement, sand and coarse aggregate are 3.15, 2.6 and 2.5 respectively.

#### Solution:

Cement : F.A. : CA

$$x\text{m}^3 : 1.4 \times \text{m}^3 : 2.85 \times \text{m}^3 \quad \frac{\text{Weight of water}}{\text{Weight of cement}} = 0.48$$

$$\frac{\text{Weight}}{\text{Volume}} = \text{Absolute density } (e_s) = \frac{W_s}{V_s}$$

$$e_{\text{bulk cement}} = 14.7 \text{ kN/m}^3$$

$$e_{\text{bulk F.A.}} = 16.66 \text{ kN/m}^3$$

$$e_{\text{bulk CA}} = 15.68 \text{ kN/m}^3$$

$$\frac{\text{Weight}}{\text{Volume}} = \frac{\text{Weight of solid}}{V_s + V_{\text{air}}} = \text{Bulk density}$$

$$\therefore \text{Cement : FA : CA} = (14.7 \times \text{kN}) : (1.4 \times 16.66 \times \text{kN}) : (15.68 \times 2.8x)$$

$$\text{Weight of water} = 0.48 \times \text{weight of cement} = 0.48 \times 14.7 \times \text{kN}$$

$$\text{Volume of water} = \frac{0.48 \times 14.7x}{\gamma_w} \text{m}^3 \quad \text{Vol. of air} = 0.02 \text{ m}^3$$

$$\therefore \frac{14.7x}{3.15\gamma_w} + \frac{1.4 \times 16.66x}{2.6\gamma_w} + \frac{15.68 \times 2.8x}{2.5\gamma_w} + \frac{0.48 \times 14.7x}{\gamma_w} + 0.02 \text{ m}^3$$

$$x = 0.257 \text{ m}^3$$

Now, Weight of cement =  $14.7 x = 3.777 \text{ kN} = 377.7 \text{ kg}$  [1 kN = (100 kg)]

Weight of FA =  $1.4 \times 16.66 x = 5.994 \text{ kN} = 59.4 \text{ kg}$

Weight of CA =  $15.68 \times 2.8 x = 11.283 \text{ kN} = 1128.3 \text{ kg}$

Weight of water =  $0.48 \times 14.7 x = 0.48 \times 377.7 = 181.296 \text{ kg}$



**EXAMPLE : 2.2**

Estimate the quantities of cement, fine aggregate and coarse aggregate per cubic meter of concrete if the void ratio in cement is 62% fine aggregate is 11% and coarse aggregate is 45%.

The material properties are as follows:

Mix : 1 : 2 : 4 with a w/c of 0.55, one bag of cement contains 50 kg of cement and its density is 14.10 kg/m<sup>3</sup>. The density of fine aggregate is 1700 kg/m<sup>3</sup> and coarse aggregate is 1600 kg/m<sup>3</sup> respectively. One bag of cement is equal to 34.7 liters.

**Solution:**

When the mix proportion is given line 1 : 2 : 4 and it is not mentioned whether it is by volume or by weight, we should always take it as by weight like 1 kg cement : 2 kg fine aggregate : 4 kg coarse aggregate. Also bulk density or simply density of cement means

$$\text{Bulk density or density of cement} = \frac{\text{Mass of cement}}{\text{Vol. of cement}}$$

on the other hand, absolute density or mass density means.

$$\text{Absolute density or mass density of cement} = \frac{\text{Mass of cement}}{\text{Vol. of cement solid}}$$

$$\text{Mass density} = \frac{W_s}{V_s}$$

$$\text{Bulk density} = \frac{W_s}{V} = \frac{W_s}{V_s \cdot V_v} = \frac{W_s / V_s}{1 + \frac{V_v}{V_s}}$$

$$\text{Bulk density} = \frac{\text{Mass density}}{1 + e}$$

where,  $e_{\text{cement}} = 0.62$ ,  $e_{\text{fine aggregate}} = 0.41$ ,  $e_{\text{coarse aggregate}}$

$$\text{Bulk density of cement} = 1440 \text{ kg/m}^3$$

$$\text{Bulk density of fine aggregate} = 1700 \text{ kg/m}^3$$

$$\text{Bulk of coarse aggregate} = 1600 \text{ kg/m}^3$$

$$\text{Mass density of cement, } \rho = (\text{Bulk density of cement}) \times (1 + e_s)$$

$$\rho = 1440 \times 1.62 = 2332.8 \text{ kg/m}^3$$

$$\rho = 1700 \times 1.40 = 2391 \text{ kg/m}^3$$

$$\rho = 1600 \times 1.45 = 2320 \text{ kg/m}^3$$

Let the volume of air in 1 m<sup>3</sup> of concrete = 0.02 m<sup>3</sup>

$$\text{Sum of vol. of all ingredients} = \text{Vol. of concrete}$$

Let the mass of cement in 1 m<sup>3</sup> of concrete be  $x$  kg

$x$  kg of cement is to be mixed with  $2x$  kg fine aggregate and  $4x$  kg coarse aggregate and as W/C ratio is 0.55, wt. of water is  $0.55x$ .

$$\frac{x}{2332.8} + \frac{2x}{2397} + \frac{4x}{2320} + \frac{0.55}{1000} + 0.02 = 1$$

$$x = 27.06 \text{ kg}$$

$$\text{Wt. of cement for 1 m}^3 \text{ concrete} = 277.06 \text{ kg}$$

$$\text{Wt. of F.A. for 1 m}^3 \text{ concrete} = 554.12 \text{ kg}$$

$$\text{Wt. of C.A. for 1 m}^3 \text{ concrete} = 1108.24 \text{ kg}$$

$$\text{Wt. of water for 1 m}^3 \text{ concrete} = 152.383 \text{ kg}$$