# CONCRETE MIX DESIGN

**BY**

**Dr. B.N. KRISHNASWAMI**

**Former Faculty,**

**DEPT OF CIVIL ENGG.,**

**NIT, TRICHY**

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## INTRODUCTION

Concrete is the second largest material consumed by human beings after food and water as per WHO. It is obtained by mixing cement, fine aggregate, coarse aggregate and water in required proportions. The mixture when placed in forms and allowed to cure becomes hard like stone. The hardening is caused by chemical action between water and the cement due to which concrete grows stronger with age.

The strength, durability and other characteristics of concrete depend upon the properties of its ingredients, proportion of the mix, the method of compaction and other controls during placing, compaction and curing.

Concrete possess a high compressive strength and is usually more economical than steel and is non corrosive which can be made with locally available materials.

Hence concrete is used widely in all present-day constructions. The concrete is good in compression and bad in tension. Hence liable to be cracked when subjected to tensile load. In situations where tensile stresses are developed concrete is strengthened by steel bars forming a composite construction called Reinforced Cement Concrete (RCC).

## Mix Design

Design of concrete mixes involves determination of the proportions of the given constituents namely, cement, water, coarse aggregate and fine aggregate with admixtures if any.

Workability is specified as the important property of concrete in the fresh state. For hardened state compressive strength and durability will be considered

## Methods of concrete mix design

The mix design methods being followed in different countries are mostly based on empirical relationships, charts and graphs developed from extensive experimental investigations.

Following methods are in practice

1. ACI Mix design method
2. USBR Mix design method
3. British Mix design method
4. Mix design method according to Indian standard

Since ACI Mix design method is an originator for all other methods, including Indian standard method, wherein every table and charts are fully borrowed from ACI, so we follow the ACI Mix design method in practice

## Factors to be considered in Mix design (as per SP23-1982)

The design of concrete mix will be based on the following factors.

(a) **Grade of concrete:** This gives the characteristic strength requirements of concrete. Depending upon the level of quality control available at the site, the concrete mix has to be designed for a target mean strength which is higher than the characteristic strength.

(b) **Type of cement:** The type of cement is important mainly through its influence on the rate of development of compressive strength of concrete as well as durability under aggressive environments ordinary Portland cement(OPC) and Portland Pozzolona cement (PPC) are permitted to use in reinforced concrete construction.

## Table1 GRADES OF CONCRETE

| Grade Designation | Specified Characteristic Compressive Strength In N/mm$^2$ At 28 Days Curing |
|---|---|
| MIO | 10 |
| MI5 | 15 |
| M20 | 20 |
| M25 | 25 |
| M30 | 30 |
| M35 | 35 |
| M40 | 40 |
| M45 | 45 |
| M50 | 50 |
| M55 | 55 |
| M60 | 60 |

**Note:**

In the designation of a concrete mix M refers to the mix and the number to the specified characteristic compressive strength of 15 cm cube at 28 days curing expressed in $N/mm^2$.

MI5 and less grades of concrete may be used for lean concrete bases and simple foundation for masonry walls.

Grades of concrete lower than M20 shall not be used in reinforced concrete structure as per IS 456-2000.

Grades of concrete lower than M30 shall not be used in pre stressed concrete structure

c) **Maximum nominal size of aggregate:** It is found that larger the size of aggregate, smaller is the cement requirement for a particular water cement ratio. Aggregates having a maximum nominal size of 20mm or smaller are generally considered satisfactory.

d) **Minimum water cement ratio:** The minimum w/c ratio for a specified strength depends on the type of cement.

e) **Workability**: The workability of concrete for satisfactory placing and compaction is related to the size and shape of the section to be concreted.

## Out line of mix design procedure

(a) Arrive at the target mean strength from the characteristic strength required.

(b) Choose the water cement ratio for target mean strength.

(c) Arrive at the water content for the workability required

(d) Calculate the cement content

(e) Choose the relative proportion of the fine and coarse aggregate

(f) Arrive at the concrete mix proportions

**Target mean strength:**

Considering the inherent variability of concrete strength during production it is necessary to design the mix to have a target mean strength which is grater than characteristic strength by a suitable margin

$$f_t = f_{ck} + k \times s$$

Where

$f_t$ = Target mean strength

$f_{ck}$= Characteristic strength

k = a constant depending upon the definition of characteristic strength and is derived IS from the mathematics of normal distribution

S = Standard deviation of the particular mix which is available in IS 456-2000

The value of k is equal to 1.65 as per IS 456-2000 where not more than 5% of the test results are expected to fall below the characteristic strength.

## Table 2 Values of statistical constant (K)

| Percentage of result below the characteristic strength | 20 | 10 | 5 | 2.5 | 1 |
|---|---|---|---|---|---|
| Constant k | 0.84 | 1.28 | 1.65 | 1.96 | 2.33 |

## Table 3 Assumed standard deviation (S)

| Grade of concrete | M10 | MI5 | M20 | M25 | M30 | M35 | M40 | M50 |
|---|---|---|---|---|---|---|---|---|
| Standard deviation assumed ($N/mm^2$) | 3 | 3.5 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 |

# MATERIAL TESTING RESULTS

## FINENESS MODULUS TEST COARSE AGGREGATE

| Serial No. | Sieve Opening Size | Weight of soil retained | Cumulative weight of soil retained | Cumulative percentage of soil retained | Percentage of fine aggregate passing |
|---|---|---|---|---|---|
| | (mm) | (g) | (g) | (%) | (%) |
| 1. | 80 | 0 | 0 | 0 | 0 |
| 2. | 40 | 0 | 0 | 0 | 0 |
| 3. | 20 | 1815 | 1815 | 36.3 | 63.7 |
| 4. | 10 | 1738 | 3553 | 71.06 | 28.94 |
| 5. | 4.75 | 1220 | 4773 | 95.46 | 4.54 |
| 6. | 2.36 | 197 | 4970 | 99.4 | 0.6 |
| 7. | 1.18 | 30 | 5000 | 100 | 0 |
| 8. | 0.6 | 0 | 5000 | 100 | 0 |
| 9. | 0.3 | 0 | 5000 | 100 | 0 |
| 10. | 0.15 | 0 | 5000 | 100 | 0 |

Fineness modulus = Cumulative percentage of soil retained/100

= (36.3+71.06+95.46+99.4+100+100+100+100)/100

= 7.02

## FINENESS MODULUS TEST FINE AGGREGATE

| Serial No. | Sieve Opening Size | Weight of soil retained | Cumulative weight of soil retained | Cumulative percentage of soil retained | Percentage of fine aggregate passing |
|---|---|---|---|---|---|
| | (mm) | (g) | (g) | (%) | (%) |
| 1. | 4.75 | 17 | 17 | 3.4 | 96.6 |
| 2. | 2.36 | 28 | 45 | 9 | 91 |
| 3. | 1.18 | 92 | 137 | 27.4 | 72.6 |
| 4. | 0.6 | 81 | 218 | 43.6 | 56.4 |
| 5. | 0.3 | 116 | 334 | 66.8 | 33.2 |
| 6. | 0.15 | 154 | 488 | 97.8 | 2.2 |
| 7. | <0.15 | 12 | 500 | 0 | 0 |

Fineness modulus = Cumulative percentage of soil retained/100

= (3.4+9+27.4+43.6+66.8+97.8+0)/100

= 2.4

## SPECIFIC GRAVITY TEST OF CEMENT

| Serial No. | Observation | Trail | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 1. | Weight of specific gravity bottle ,$W_1$ (g) | 28.5 | 28.5 | 28.5 |
| 2. | Weight of specific gravity bottle and dry soil ,$W_2$ (g) | 55.1 | 54.9 | 55.3 |
| 3. | Weight of specific gravity bottle and soil and water ,$W_3$ (g) | 87.3 | 87.0 | 87.4 |
| 4. | Weight of specific gravity bottle and water ,$W_4$ (g) | 69.2 | 69.2 | 69.2 |
| 5. | Specific gravity of the soil | 3.13 | 3.06 | 3.11 |

Specific gravity, $G_s$ = (W2-W1)/((W4-W1)-(W3-W2))

= (55.1-28.5)/((69.2-28.5)-(87.3-55.1))

= 3.13

## SPECIFIC GRAVITY TEST OF COARSE AGGREGATE

| Serial No. | Observation | Trail | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 1. | Weight of specific gravity bottle ,$W_1$ (g) | 625 | 625 | 625 |
| 2. | Weight of specific gravity bottle and one-third aggregate,$W_2$ (g) | 1016 | 1021 | 1019 |
| 3. | Weight of specific gravity bottle and one-third aggregate and water ,$W_3$ (g) | 1718 | 1728 | 1725 |
| 4. | Weight of specific gravity bottle and water ,$W_4$ (g) | 1477 | 1477 | 1477 |
| 5. | Specific gravity of the soil | 2.68 | 2.73 | 2.69 |

Specific gravity, $G_s$ $= (W_2-W_1)/((W_4-W_1)-(W_3-W_2))$

$= (1016-625)/((1477-625)-(1728-1021))$

$= 2.7$

## SPECIFIC GRAVITY TEST OF FINE AGGREGATE

| Serial No. | Observation | Trail | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 1. | Weight of specific gravity bottle ,$W_1$ (g) | 21 | 21 | 21 |
| 2. | Weight of specific gravity bottle and one-third aggregate,$W_2$ (g) | 48 | 52 | 51 |
| 3. | Weight of specific gravity bottle , one-third aggregate and water ,$W_3$ (g) | 88 | 91 | 89 |
| 4. | Weight of specific gravity bottle and water ,$W_4$ (g) | 71 | 71 | 71 |
| 5. | Specific gravity of the soil | 2.62 | 2.68 | 2.65 |

Specific gravity, $G_s$ $= (W_2-W_1)/((W_4-W_1)-(W_3-W_2))$

$= (48-21)/((71-21)-(88-48))$

$= 2.65$

## BULK DENSITY OF COARSE AGGREGATE

| Serial No. | Observation | Trail | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 1. | Weight of the container and coarse aggregate ,$W_1$ (g) | 6915 | 6921 | 6918 |
| 2. | Weight of the container ,$W_2$ (g) | 3885 | 3885 | 3885 |
| 3. | Weight of coarse aggregate,$W_3$ (g) | 3030 | 3036 | 3033 |
| 4. | Volume of the container ,V ($cm^3$) | 1853.4 | 1853.4 | 1853.4 |
| 5. | Bulk Density of coarse aggregate | 1.635 | 1.638 | 1.636 |

Weight of coarse aggregate = 6915-3885

= 3030 kg

Volume of container = $(\Pi/4) \times 11.65^2 \times 18.5$

= 1853.4 $cm^3$

Bulk Density = 3030/1853.4

= 1.635 $g/cm^3$

= 1635 $kg/m^3$

## ACI METHOD OF MIX DESIGN

### The American Concrete Institute mix design method

The methods suggested by the ACI Committee 211 [1969] are widely used in the USA. One method is based on the estimated weight of the concrete per unit volume. The other method is based on calculation of the absolute volume occupied by concrete ingredients. The ACI methods take into consideration the requirements for workability, consistency, strength and durability. In the following section, step-by-step operation involved in the first method as suggested by the ACI is presented.

**ACI Mix design Procedure**

(a) The W/C ratios selected from curve for the target mean strength.

(b) The water content is selected from table 4 for the desired workability and maximum size of aggregate

(c) The cement content is calculated from the water content and W/C ratio

(d) The coarse aggregate content is estimated from the table 5 for the maximum size of aggregate and fineness modulus of sand.

(e) The fine aggregate content is determined by subtracting the sum of the absolute volume of coarse aggregate, cement, water and air content from the unit volume of concrete.

**Step 1**

Determine the slump depending on the degree of workability and placing condition. A concrete of the stiffest consistency (lowest slump) that can be placed efficiently should be used.

**Step 2**

Determine the maximum size of coarse aggregate that is economically available and consistent with dimensions of the structure.

**Step 3**

Determine the amount of mixing water for the given slump and maximum size of coarse aggregate from Table 4. This table also indicates approximate amount of entrapped air.

**Step 4**

Determine the minimum water-cement ratio from the curve.

## Table 4 Approximate water requirement for different slumps and maximum size of coarse aggregate

| Slump (mm) | Water, kg/m$^3$ of concrete for maximum size of coarse aggregate(mm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 10 | 12.5 | 20 | 25 | 40 | 50 | 70 | 150 |
| **Non air entrained concrete** | | | | | | | | |
| 30-50 | 205 | 200 | 185 | 180 | 160 | 155 | 145 | 125 |
| 80-100 | 225 | 215 | 200 | 195 | 175 | 170 | 160 | 140 |
| 150-180 | 240 | 230 | 210 | 205 | 185 | 180 | 170 | - |
| Approximate % of entrapped air content | 3 | 2.5 | 2 | 1.5 | 1 | 0.5 | 0.3 | 0.2 |
| **Air entrained concrete** | | | | | | | | |
| 30-50 | 180 | 175 | 165 | 160 | 145 | 140 | 135 | |
| 80-100 | 200 | 190 | 180 | 175 | 160 | 155 | 150 | |
| 150-180 | 215 | 205 | 190 | 185 | 170 | 165 | 160 | |
| Recommended percent of average total air | 8 | 7 | 6 | 5 | 4.5 | 4 | 3.5 | |

**Step 5**

Determine the amount of cement per unit volume of concrete from steps3 and 4. This cement content should not be less than the cement content required based on durability or some other criterion.

**Step 6**

Determine the amount of coarse aggregate required for a unit volume of concrete from Table 5. The value thus obtained is multiplied by the dry rodded unit weight if the aggregate to get the required dry weight.

## Table 5 Bulk volume of coarse aggregate

| Maximum size of coarse aggregate (mm) | Bulk volume of dry-rodded coarse aggregate per unit volume of concrete | | | |
|---|---|---|---|---|
| | Fineness modulus of fine aggregate | | | |
| | 2.4 | 2.6 | 2.8 | 3.0 |
| 10 | 0.50 | 0.48 | 0.46 | 0.44 |
| 12.5 | 0.59 | 0.57 | 0.55 | 0.53 |
| 20 | 0.66 | 0.64 | 0.62 | 0.60 |
| 25 | 0.71 | 0.69 | 0.67 | 0.65 |
| 40 | 0.76 | 0.74 | 0.72 | 0.70 |
| 50 | 0.78 | 0.76 | 0.74 | 0.72 |
| 70 | 0.81 | 0.79 | 0.77 | 0.75 |
| 150 | 0.87 | 0.85 | 0.83 | 0.81 |

**Step 7**

Determine the amount of fine aggregate. At completion of step 6, all ingredients of the concrete have been estimated except the fine aggregate. If the weight of concrete per unit volume is assumed, the required weight of fine aggregate is simply the difference between the weight of fresh concrete and the total weight of all other ingredients. An estimate of weight of fresh concrete can be made either by using Eq. 1 or Table 6

$$W_m = 10\rho_A(lOO\text{-}A)+\gamma_c(1\text{-} \rho_A/ \rho C) -\gamma_w(\rho_A - 1) \qquad (1)$$

where

$W_m$ = weight of fresh concrete, kg/n.

$\rho_A$ = weighted average specific gravity of combined fine and coarse aggregate

$\rho_C$ = specific gravity of cement (= 3:15)

$\gamma_c$ = cement requirement, kg/m3

$\gamma_w$ = mixing water requirement, kg/m3

A = air content, percent

**Table 6 First estimate of weight of fresh concrete**

| Maximum size of coarse Aggregate (mm) | First estimate of concrete weight ($Kg/m^3$) | |
|---|---|---|
| | Non-air entrained concrete | Air-entrained Concrete |
| 10 | 2285 | 2190 |
| 12.5 | 2315 | 2235 |
| 20 | 2355 | 2280 |
| 25 | 2375 | 2315 |
| 40 | 2420 | 2355 |
| 50 | 2445 | 2375 |
| 70 | 2465 | 2400 |

**Step 8**

Adjust the mixing water quantity based on the moisture content in the aggregate.

**Step 9**

Check the calculated mix proportions by means of trial batches prepared and tested in accordance with the relevant IS specifications and make another trial, if necessary.

**CALCULATIONS AS PER ACI MIX DESIGN METHOD**

| | | |
|---|---|---|
| Specific Gravity of Cement | = | 3.10 |
| Specific Gravity of Fine Aggregate | = | 2.65 |
| Specific Gravity of Coarse Aggregate | = | 2.70 |
| Dry Density of Coarse Aggregate | = | 1560 kg/$m^3$ |
| Water Cement Ratio | = | 0.403 |
| Volume of dry-rodded Coarse Aggregate per unit volume of concrete | = | 0.64 |
| Fineness Modulus of Fine Aggregate | = | 2.40 |
| Fineness Modulus of Coarse Aggregate | = | 7.20 |

Trail mix was prepared for,

| | | |
|---|---|---|
| Workability | = | Medium |
| Compaction Factor | = | 0.85 to 0.92 |
| Slump | = | 50mm to 75mm |
| Approximate amount of entrained air | = | 2% |
| Mean Target Compressive $f_t$ | = | $f_{ck}$ + k . s |
| Strength of concrete , | = | 35 + 1.65 x 5 |
| | = | 43.25 N/$mm^2$ |
| Water required for 50-75mm slump using | = | 200 l |
| 53 grade cement as per sp23-1982, | | |
| Water Cement Ratio | = | 0.403 |
| Quantity of cement per $m^3$ of concrete | = | 200 /.403 |
| | = | 496.3 kg |
| Quantity of coarse aggregate required | = | 0.6264 x1560 |
| for 1$m^3$ of concrete | = | 977.2 kg |

Quantity of materials required for 1 m3 of concrete,

| W | C | F.A | C.A | |
|---|---|---|---|---|
| --- | --- | ----- | ----- | |
| 200 | 496.3 | sand | 977.2 | |
| ----- | ------- | ------ | ------- | = 980 litres |
| 1 | 3.10 | 2.65 | 2.7 | |

Therefore quantity of sand required for 1m3 of concrete = 683.6 kg

Quantity of materials for 1 bag of cement,

| W | C | F.A | C.A |
|---|---|---|---|
| --- | --- | ----- | ----- |
| 20.1l | 50 kg | 68.9 kg | 98.4kg |

Mix proportions by weight,

1 : 1.377 : 1.969

# MIX DESIGN REPORT AS PER ACI METHOD

| Grade of Concrete | Slump (mm) | Quantity per $m^3$ of Concrete (kg) | | | | Quantity per Bag of Concrete (kg) | | | | Proportions by weight | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (litre) | Cement | Sand | Aggregate | Water (litre) | Cement | Sand | Aggregate | Cement | Sand | Aggregate |
| M35 | 0-25 | 188 | 466.5 | 740.9 | 977.2 | 20.1 | 50 | 79.4 | 104.7 | 1 | 1.588 | 2.094 |
| | 25-50 | 194 | 481.4 | 712.3 | 977.2 | 20.1 | 50 | 74 | 101.5 | 1 | 1.48 | 2.03 |
| | 50-75 | 200 | 496.3 | 683.6 | 977.2 | 20.1 | 50 | 68.9 | 98.4 | 1 | 1.377 | 1.969 |
| | 75-100 | 206 | 511.2 | 655 | 977.2 | 20.1 | 50 | 64.1 | 95.6 | 1 | 1.281 | 1.912 |

## ACI MIX DESIGN METHOD

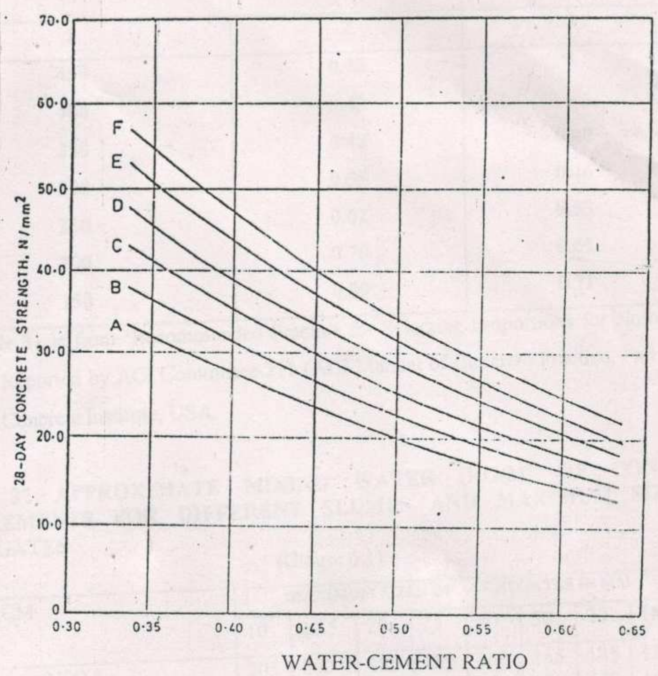
## COMPRESSIVE STRENGTH TEST RESULTS

| Serial No. | Identification | Date of casting | Date of Receipt | Date of Testing | Size (mm) | Area ($mm^2$) | Proportions of mix | Grade | Age (days) | Weight of cube (Kg) | Crushing load (KN) | Compressive Strength ($N/mm^2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | BE 01 | 12.09.05 | 19/9/05 | 19/9/05 | 150 * 150 * 150 | 22500 | 1:1.377:1.969 | M20 | 7 | 8.5 | 600.075 | 26.67 |
| 2. | BE 02 | 12.09.05 | 19/9/05 | 19/9/05 | | | 1:1.377:1.969 | | 7 | 8.5 | 580.05 | 25.78 |
| 3. | BE 03 | 12.09.05 | 19/9/05 | 19/9/05 | | | 1:1.377:1.969 | | 7 | 8.5 | 540.00 | 24 |

## CONCLUSION

In this regard, The New Method is found to be better than ACI because the limitations of the code (SP23-1982) such as the maximum cement content for 1 m3 of concrete will be limited to 530 kg has been well considered in the New method. Hence it gives better results than other methods.

SP :23 – 1982




28-Day Strength of Cement, Tested According to IS : 4031-1968

| | | |
|---|---|---|
| A-31.9-36.8 | N/mm$^2$ | (325-375 kg/cm$^2$) |
| B-36.8-41.7 | N/mm$^2$ | (375-425 kg/cm$^2$) |
| C-41.7-46.6 | N/mm$^2$ | (425-475 kg/cm$^2$) |
| D-46.6-51.5 | N/mm$^2$ | (475-525 kg/cm$^2$) |
| E-51.5-56.4 | N/mm$^2$ | (525-575 kg/cm$^2$) |
| F-56.4-61.3 | N/mm$^2$ | (575-625 kg/cm$^2$) |

Fig. 47 Relationship Between Free Water-Cement Ratio and Concrete Strength for Different

**Curve**

# THANK YOU