



## Comparative analysis of mix design method of concrete using fly ash

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### Abstract

Concrete is most widely used material which include cement as binding material. Fly Ash an industrial waste is rich in silica and being industrial waste it is difficult to dispose it Fly ash and presence of lime released by Hydration of cement act as binding, material Therefore Fly Ash can replace the cement. More will be Fly Ash used in concrete less will be the burden of pollution on the environment. This study was undertaken with to study available design methods incorporating Fly ash and suggest a most suitable one for future use. In order to achieve this objective the cubes were cast of M20, M25 and M30 of concrete by method of mix design i.e. IS10262: 1982, IS 10262:2009 and research paper by Shantanu Bhanja (January 2015).

**Keywords:** cement, fly ash, strength, mix design

### Introduction

Ordinary Portland Cement (PC) is widely used as a main building material; however, its manufacturing process results in a high emission of carbon dioxide (CO<sub>2</sub>) to the atmosphere (Metz *et al.*, 2007; Sukmak *et al.*, 2013). The production of cement is not environmental friendly as it damage nature in search of limestone and energy involved. Fly ash, also known as "pulverized fuel ash" in the United Kingdom, is a coal combustion product composed of fine particles that are driven out of the boiler with the flue gases. Fly Ash is an industrial waste. In India alone, we produce 75 million tons of fly ash every year, the disposal of which has become a serious environmental problem. The effective use of fly ash in concrete making is therefore attracting serious considerations of concrete technologists and government departments. fly ash

includes substantial amounts of silicon dioxide (SiO<sub>2</sub>) (both amorphous and crystalline), aluminum oxide (Al<sub>2</sub>O<sub>3</sub>) and calcium oxide (Ca O). The more the percentage of amorphous silica high the quality and reactivity of Fly Ash which increase is strength. Therefore Fly Ash can replace the cement. More the Fly Ash used in concrete less will be the burden of pollution on environment.

### Material and Experimental Procedure

#### Material

Fly Ash: The source of fly ash is from the KHEDAR Power Plant in Haryana. The fly ash collected from the precipitators is used in concrete as it is the purest form of Fly Ash compared to other types. The chemical and physical tests were carried out on the Fly Ash sample.

**Table 1:** Chemical composition of Fly Ash

Parameter	Test Method	Results	Units
Chemical Analysis			
Silica content (SiO <sub>2</sub> )	IS 1727:1967	61.86	%
Silicon Dioxide + Aluminum Oxide + Iron Oxide	IS 1727:1967	99.62	%
Magnesium Oxide (MgO)	IS 1727:1967	0.38	%
Sulphuric Anhydroxide (SO <sub>3</sub> )	IS 1727:1967	0.36	%
Sodium Oxide (Na <sub>2</sub> O)	IS 1727:1967	0.17	%
Chloride Content (as Cl)	IS 1727:1967	0.018	%
Loss on Ignition	IS 1727:1967	0.49	%
Reactive Silica	IS 1727:1967	35.32	%
Physical Analysis			
Fineness ( Blaine's Air Permeability )	IS 1727:1967	345	Kg/m <sup>2</sup>
Particle retained on 45 micron IS sieve (By Wet Sieving)	IS 1727:1967	31	%
Lime Reactivity	IS 1727:1967	5.6	N/mm <sup>2</sup>
Compressive Strength at 28 days ( % of the strength of corresponding plain cement mortar cube )	IS 1727:1967	NA	%
Soundness ( Autoclave )	IS 1727:1967	0.07	%
Total Parameters	13		

**Cement**

Ordinary Portland concrete (OPC) of 33 evaluation was utilized as a section of that the structure and properties is in consistence with the Indian standard association. Concrete will be defined as the holding material having strong and glue properties that create it capable to join the various development materials and structure the compacted get together. Standard/Normal Portland concrete is a standout amongst the most broadly utilised kind of Portland cement.

Test performed for cement are as follows

1. Fineness Test

**Table 2:** Fineness (As per IS: 4031- Prat-2) 1988

Sr. No.	Item	Sample 1	Sample 2
1.	Sample taken in gm.	100	100
2.	Passing through IS 90 micron sieve	98.72	99.10
3.	Retained on IS 90 micron sieve	1.28	0.90
4.	Fineness (%)	1.28	0.90
5.	Average		1.09

2. Consistency of cement was found to be 28.5%  
 3. Setting time test

**Table 3:** Setting Time as per (IS 4031 – Part 5) 1988

1.	Initial setting time in minutes	128 mins	30 min. – 600 min.
2.	Final setting time in minutes	245 mins	

**Sand:** The sand was purchased from local market of Sonipat which is generally Yamuna Sand

**Table 4:** Grading of sand (IS 383: 1970)

IS Sieve	Wt. Retained	Cumulative Weight Retained	% Wt.Retained	Ratio
10	0	0	0	100
4.75	60	60	4.29	95.71
2.26	132	192	13.71	86.57
1.18	262	454	32.43	87.57
0.60	330	774	55.23	44.71
0.30	446	1220	87.14	17.86
0.15	132	1352	96.57	8.43

**Coarse Aggregate:** The coarse aggregate used in experiments were purchased from local market Kishanganj in Rajasthan

**Table 5:** Grading of coarse aggregate (20 mm)

IS Sieve	Wt. Retained	Cumulative Weight Retained	% Wt. Retained	Ratio
40	0	0	.0	100
20	1210	1246	6.42	58.88
10	15246	16456	27.35	58.65
4.75	2066	18522	92.35	8.65

Specific gravity of Coarse Aggregate (20 mm) = 2.82

**Table 6:** Grading of coarse aggregate (10 mm)

IS Sieve	Wt. Retained	Cumulative Weight Retained	% Wt. retained	Ratio
12.5	0	0	0	100
10	1352	1352	8.13	91.87
4.75	13660	15012	90.32	9.68
2.36	1250	16262	97.88	2.15

Specific gravity of coarse aggregate (10 mm) = 2.67

The proportions of aggregate to be mixed was found to be 60% (20 mm) and 40% (10 mm) to obtain well graded aggregate as per IS 383:1970 requirements

**Methodology**

The first step in methodology was to establish the properties of the material used. Further optimum Fly Ash content was determined so that Fly Ash can be added most efficiently and according to properties. After the determination of optimum Fly Ash content the mix was prepared according to three specified methods.

1. IS 10262:1982
2. IS 10262:2006
3. A research paper “Use of efficiency factor in mix proportioning of concrete” (Santanu Bhanja,2015)

**Determination of Optimum Quantity of Fly Ash**

In order to mix Fly Ash with concrete optimum quantity of Fly Ash was to be determined. The optimum quantity of fly ash was based on compressive testing of fly ash concret cubes at 5%, 15% and 25% were prepared and average compressive strength was noted as shown below. Nominal mix was prepared and was mixed in ratio 1:1:2 (M20). The compression testing was done on 7 days basis.

**Table 7**

Fly Ash	Specimen1	Specimen 2	Specimen3	Average Compressive Strength
5%	9.77	15.11	16.88	13.62
15%	16.88	17.77	15.35	16.66
25%	13.33	15.11	13.33	13.92

From the above results it can be observed that the maximum average compressive strength obtained was 16.66 MPa at 15% replacement of cement with fly ash. Therefore, the optimum quantity of fly ash that could be replaced with cement came to be 15% Further the experiments would be performed on 15% replacement of cement with fly ash.

**Result and Analysis**

The result and calculation include the calculation of various mix design using various methods, there strength and result is analyzed further

Mix

Proportions using IS 10262:2009

Mix Design (M20) [IS 10262:2009]

**1. Stipulation of proportion**

Grade = M20

Type of cement = OPC33

Mineral Admixture = Fly Ash

Max. size of Aggregate = 20 mm

Workability = 100 mm (slump)

Max w/c ratio = 0.45

Exposure = Mild

**2. Test data of Material**

Cement – OPC33 (IS: 269)

**Specific gravity**

1. Cement = 3.15
2. Coarse aggregate = 2.61
3. Fine aggregate = 2.82
4. Fly Ash = 2.2

**Water Absorption**

1. Coarse Aggregate = 0.5%
2. Fine Aggregate = 1%

Zone of fine aggregate = Zone 2 (IS383)

**3. Target Strength of Mix Proportions**

$$F_t = f_{ck} + 1.65D$$

$$F_t = 20 + 1.65 * 4 \text{ (from table IS 10262:2009)}$$

$$F_t = 26.60 \text{ N/mm}^2$$

**4. Selection of W/C Ratio:**

Assuming W/C ratio = 0.45

(Taking value from Fig. 1&2 from IS 10262:2009)

**5. Selection of Water Content**

Max. water content for max. size of 20 mm aggregate = 186 liters

$$\begin{aligned} \text{For 100 mm slump} &= 186 + 6/100 * 186 \\ &= 197 \text{ liters} \end{aligned}$$

**6. Calculation for Cement content**

$$\text{W/C Ratio} = 0.45$$

$$\begin{aligned} \text{Cement + Fly Ash} &= 197/0.45 \\ &= 438 \text{ kg/m}^3 > 320 \text{ kg/m}^3 \quad \text{Hence ok} \end{aligned}$$

Taking optimum quantity of Fly Ash and replacing same with cement

$$\text{Cementitious material content} = 15\% \text{ of } 438 = 66$$

$$\text{Hence, cement content} = 372 \text{ kg/m}^3$$

**7. Proportion of CA and FA contents**

From table 3 (IS 10262:2009)

For W/C = 0.45, Zone 2 of FA

$$\text{Volume of coarse aggregate} = 0.62$$

$$\text{Volume of fine aggregate} = 1 - 0.62 = 0.38$$

**8. Mix Calculations**

a) Volume of concrete =  $1 \text{ m}^3$

b) Volume of cement  
 $= \text{mass of cement} / (\text{specific gravity} * 1000)$   
 $= 372 / 3.15 * 1 / 1000 = 0.118 \text{ cum}$

c) Volume of fly ash  
 $= \text{mass of fly ash} / (\text{specific gravity} * 1000)$   
 $66 / 2.2 * 1 / 1000 = 0.03 \text{ cum}$

d) Volume of water  
 $= \text{mass of water} / (\text{specific gravity} * 1000)$   
 $197 / 1000 = 0.197 \text{ cum}$

e) Volume of all aggregate =  $[a - (b + c + d)]$   
 $= [1 - 0.345] = 0.655 \text{ cum}$

f) Mass of coarse aggregate  
 $= e * \text{volume of ca} * \text{sp. gravity} * 1000$   
 $= 0.655 * 0.62 * 2.82 * 1000 = 1084 \text{ kg/m}^3$

g) Mass of fine aggregate  
 $= 0.655 * 0.38 * 2.82 * 1000 = 702 \text{ kg/m}^3$

**9. Mix Proportions**

$$\text{Cement} = 372 \text{ kg/m}^3$$

$$\text{Fly ash} = 66 \text{ kg/m}^3$$

$$\text{Water} = 197 \text{ kg/m}^3$$

$$\text{Fine aggregate} = 702 \text{ kg/m}^3$$

$$\text{Coarse aggregate} = 1084 \text{ kg/m}^3$$

$$\text{W/C Ratio} = 0.45$$

**Mix Design (M25) [IS 10262:2009]**

**1. Stipulations for proportions**

Grade = M25

type of cement = OPC 33

Minerals Admixture = fly ash

Max size of aggregate = 20 mm

Workability = 100 mm (slump)

Max w/c ratio = 0.40

Min cement content 320 kg/m<sup>3</sup>

Exposure = Mild

**2. Test data for Material**

Cement – OPC 33 (IS 269)

Specific gravity

1. Cement = 3.15

2. Coarse aggregate = 2.67

3. Fine aggregate = 2.82

4. Fly ash = 2.2

**Water absorption**

1. Coarse aggregate = 0.5%

2. Fine aggregate = 1%

Zone of fine aggregate = Zone 2

**3. Target strength of mix proportions**

$$F_t = f_{ck} + 1.65D$$

$$F_t = 25 + 1.65 * 4 \text{ [IS 10262:2009]}$$

$$F_t = 25 + 6.60 = 31.60 \text{ N/mm}^2$$

**4. Selection of W/C Ratio**

Assuming W/C ratio = 0.40

(Taking value from Fig. 1&2 from IS 10262:2009)

**5. Selection of Water Content**

Max. Water content for max. Size of 20 mm aggregate = 186 liters

$$\begin{aligned} \text{For 100 mm slump} &= 186 + 6/100 * 186 \\ &= 197 \text{ liters} \end{aligned}$$

**6. Calculations of Cement and Fly Ash**

$$\text{W/C ratio} = 0.4$$

$$\text{Cement + fly ash} = 197/0.40 = 492 \text{ kg/m}^3$$

$$492 \text{ kg/m}^3 > 320 \quad \text{Hence OK}$$

Taking optimum quantity of fly ash and replacing the same with cement

$$\text{Cementitious material content} = 15\% \text{ of } 492 = 74 \text{ kg/m}^3$$

$$\text{Hence cement content} = 418 \text{ kg/m}^3$$

**7. Proportion of CA and FA Content**

From table 3 (IS 10262:2009)

For W/C = 0.45, Zone 2 of FA

Volume of coarse aggregate = 0.62  
 Volume of fine aggregate = 1-0.62 = 0.38

**8. Mix Calculations**

- a. Volume of concrete = 1m<sup>3</sup>
- b. Volume of cement = mass of cement/(specific gravity\*1000) 418/3.15\*1/1000 = 0.133 cum
- c. Volume of fly ash = mass of fly ash/(specific gravity\*1000) 74/2.2\*1/1000 = 0.033 cum
- d. Volume of water = mass of water/(specific gravity\*1000) 197/1\*1/1000 = 0.197 cum
- e. Volume of all aggregate = [a-(b+c+d)] = 1 - 0.363 = 0.637 cum
- f. Mass of coarse aggregate = e\* volume of ca\* sp. gravity\* 1000 0.637\*0.62\*2.67\*1000 = 1054 kg/m<sup>3</sup>

**9. Mix Proportions**

Cement = 418 kg/m<sup>3</sup>  
 Fly ash = 74 kg/m<sup>3</sup>  
 Water = 197 kg/m<sup>3</sup>  
 Fine aggregate = 682 kg/m<sup>3</sup>  
 Coarse aggregate = 1054 kg/m<sup>3</sup>  
 W/C Ratio 0.40

**Mix Design (M30) [IS10262:2009]**

**1. Stipulations for proportions**

Grade = M25  
 Type of cement = OPC 33  
 Minerals Admixture = fly ash  
 Max size of aggregate = 20 mm  
 Workability = 100 mm (slump)  
 Max w/c ratio = 0.40  
 Min cement content 320 kg/m<sup>3</sup>  
 Exposure = Mild

**2. Test data for Material**

Cement – OPC 33 (IS 269)  
 Specific gravity  
 1. Cement = 3.15  
 2. Coarse aggregate = 2.67  
 3. Fine aggregate = 2.82  
 4. Fly ash = 2.2  
 Water absorption  
 1. Coarse aggregate = 0.5%  
 2. Fine aggregate = 1%  
 Zone of fine aggregate = Zone 2

**3. Target strength of mix proportion**

$F_t = f_{ck} + 1.65D$  [IS 10262:2009]  
 $F_t = 30 + 1.65*5 = 38.25$  N/mm<sup>2</sup>

**4. Selection of W/C Ratio**

Assuming W/C ratio = 0.35  
 (Taking value from Fig. 1&2 from IS 10262:2009)

**5. Selection of water content**

Max. Water content for max. Size of 20 mm aggregate = 186 liters  
 For 100 mm slump = 186+6/100\*186 = 197 liters

**6. Calculations of cement content**

W/C ratio = 0.4  
 Cement + fly ash = 197/0.40 = 492 kg/m<sup>3</sup>  
 492 kg/m<sup>3</sup> > 320 Hence OK  
 Taking optimum quantity of fly ash and replacing the same with cement  
 Cementitious material content = 15% of 492 = 74 kg/m<sup>3</sup>  
 Hence cement content = 418 kg/m<sup>3</sup>

**7. Proportion of CA and FA Content**

From table 3 (IS 10262:2009)  
 For W/C = 0.35, Zone 2 of FA  
 Volume of coarse aggregate = 0.62  
 Volume of fine aggregate = 1-0.62 = 0.38

**8. Mix Calculations**

- a. Volume of concrete = 1m<sup>3</sup>
- b. Volume of cement = mass of cement/(specific gravity\*1000) 478/3.15\*1/1000 = 0.15 cum
- c. Volume of fly ash = mass of fly ash/(specific gravity\*1000) 85/2.2\*1/1000 = 0.03 cum
- d. Volume of water = mass of water/(specific gravity\*1000) 197/1\*1/1000 = 0.197 cum
- e. Volume of all aggregate = [a-(b+c+d)] = 1 - 0.377 = 0.623 cum
- f. Mass of coarse aggregate = e\* volume of ca\* sp. gravity\* 1000 0.623\*0.62\*2.67\*1000 = 1031 kg/m<sup>3</sup>
- g. Mass of fine aggregates 0.623\*0.38\*2.82\*1000 = 668 kg/m<sup>3</sup>

**9. Mix Proportions**

Cement = 478 kg/m<sup>3</sup>  
 Fly ash = 85 kg/m<sup>3</sup>  
 Water = 197 kg/m<sup>3</sup>  
 Fine aggregate = 668 kg/m<sup>3</sup>  
 Coarse aggregate = 1031 kg/m<sup>3</sup>  
 W/C Ratio 0.35

**Table 8:** Quantity of material

Mix	Cement	Fly Ash	Coarse aggregate	Fine aggregate	Water
M20	372	66	1084	702	197
M25	418	74	1054	682	197
M30	478	85	1031	668	197

## IS 10262 : 2009 Results

Table 9: The following results were obtained from compressive strength test

Designation	Specimen 1 (MPa)	Specimen 2 (Mpa)	Specimen 3 (MPa)	Average Compressive Strength (MPa)
M 20	21.33	20.66	21.33	21.10
M 25	26.66	27.77	26.22	26.88
M 30	35.33	37.33	37.55	36.69

**Mix Proportion Using IS 10262:1986****Mix design for concrete of M20 Grade****1. Design stipulation**

- Characteristics compressive strength required in field at 28 days = 20 N/mm<sup>2</sup>
- Maximum size of aggregate = 20 mm
- Degree of workability = 0.9 compacting factor
- Degree of quality control = Good
- Type of exposure = Mild

**2. Test data for material**

- Cement used = OPC 33 grade
- Specific gravity:
  - Cement = 3.15
  - Coarse aggregate = 2.67
  - Fine aggregate = 2.82
- Water absorption
  - Coarse aggregate = 0.5%
  - Fine aggregate = 1%

Zone of fine aggregate = Zone 2

**3. Target strength of mix proportion**

$$F_t = f_{ck} + 1.65$$

$$F_t = 20 + 1.65 \times 4.6 = 27.6 \text{ N/mm}^2$$

**4. Selection of W/C Ratio**

From fig. 1 the W/C ratio required for target mean strength of 27.6 MPa is 0.50

(This is lower than maximum value of 0.65 prescribed for 1978 t. Mild Exposure)

**5. Selection of water & sand content**

From table 4 for 20 mm nominal maximum size aggregate and sand conforming to zone 2, water content per cubic meter of concrete = 197 kg

Sand content by volume = 35% of total aggregate

**6. Determination of cement and fly ash content**

$$W/C \text{ Ratio} = 0.50$$

$$\text{Cement} = 186/0.5 = 372 \text{ kg/m}^3$$

(The cement content is adequate for mild exposure Acc. To Appendix A of IS 456)

Replacements of cement by 15% fly ash

$$\text{Hence fly ash} = 56 \text{ kg/m}^3$$

$$\text{Final cement content} = 316 \text{ kg/m}^3$$

**7. Determination of coarse and fine aggregate**

From table 3 for specified maximum size of aggregate of 20mm the amount of entrapped air in wet concrete is 2%

$$V = W + \frac{c}{S_c} + \frac{1}{P} * \frac{F_a}{S_{fa}}$$

$$0.98 = [186 + 372/3.15 + 1/0.35 * F_a/2.82] * 0.001$$

$$F_a = 667 \text{ kg/m}^3$$

$$V = W + \frac{c}{S_c} + \frac{1}{1-P} * \frac{Ca}{S_{ca}}$$

$$0.98 = [186 + 372/3.15 + 1/0.65 * Ca/2.67]$$

$$Ca = 1173 \text{ kg/m}^3$$

**8. Mix Proportion**

- Cement = 316 kg/m<sup>3</sup>
- Fly Ash = 56 kg/m<sup>3</sup>
- Sand = 667 kg/m<sup>3</sup>
- Coarse aggregate = 1173 kg/m<sup>3</sup>
- Water = 197 kg/m<sup>3</sup>

**Mix design for concrete of M20 Grade****1. Design stipulation**

- Characteristics compressive strength required in field at 28 days = 25 N/mm<sup>2</sup>
- Maximum size of aggregate = 20 mm
- Degree of workability = 0.9 compacting factor
- Degree of quality control = Good
- Type of exposure = Mild

**2. Test data for material**

- Cement used = OPC 33 grade
- Specific gravity:
  - Cement = 3.15
  - Coarse aggregate = 2.67
  - Fine aggregate = 2.82
- Water absorption
  - Coarse aggregate = 0.5%
  - Fine aggregate = 1%

Zone of fine aggregate = Zone 2

**3. Target strength of mix proportion:**

$$F_t = f_{ck} + 1.65D$$

$$F_t = 25 + 1.65 * 5.3 = 33.74 \text{ N/mm}^2$$

**4. Selection of W/C Ratio**

From fig. 1 the W/C ratio required for target mean strength of 33.74 MPa is 0.40

(This is lower than maximum value of 0.65 prescribed for 1978 t. Mild Exposure)

**5. Selection of water & sand content**

From table 4 for 20 mm nominal maximum size aggregate and sand conforming to zone 2, water content per cubic meter of concrete = 197 kg

Sand content by volume = 35% of total aggregate

**6. Determination of cement and fly ash content**

W/C Ratio = 0.40

Cement = 186/0.4 = 465 kg/m<sup>3</sup>

(The cement content is adequate for mild exposure Acc. To Appendix A of IS 456)

Replacements of cement by 15% fly ash

Hence fly ash = 70 kg/m<sup>3</sup>

Final cement content = 395 kg/m<sup>3</sup>

**7. Determination of coarse and fine aggregate**

From table 3 for specified maximum size of aggregate of 20mm the amount of entrapped air in wet concrete is 2%

$$V = W + \frac{c}{Sc} + \frac{1}{P} * \frac{Fa}{Sfa}$$

0.98 = [186+395/3.15+1/0.35\*FA/2.82]\*0.001

Fa = 660 kg/ m<sup>3</sup>

$$V = W + \frac{c}{Sc} + \frac{1}{1 - P} * \frac{Ca}{Sca}$$

0.98 = [186+395/3.15+1/0.65\*Ca/2.67]

Ca = 1160 kg/m<sup>3</sup>

**8. Mix Proportion**

- a) Cement = 395 kg/ m<sup>3</sup>
- b) Fly Ash = 70 kg/ m<sup>3</sup>
- c) Sand = 660 kg/ m<sup>3</sup>
- d) Coarse aggregate = 1160 kg/ m<sup>3</sup>
- e) Water = 197 kg/ m<sup>3</sup>

**Mix design for concrete of M30 Grade**

**1. Design stipulation**

- a. Characteristics compressive strength required in field at 28 days = 30 N/mm<sup>2</sup>
- b. Maximum size of aggregate = 20 mm
- c. Degree of workability = 0.9 compacting factor
- d. Degree of quality control = Good
- e. Type of exposure = Mild

**2. Test data for material**

- a. Cement used = OPC 33 grade
- b. Specific gravity:
  - 1. Cement = 3.15
  - 2. Coarse aggregate = 2.67
  - 3. Fine aggregate = 2.82
- c. Water absorption
  - 1. Coarse aggregate = 0.5%
  - 2. Fine aggregate = 1%

**Results (IS 10262:1982)**

**Table 11:** The following results were obtained in compressive strength test

Designation (MPa)	Specimen 1 (MPa)	Specimen 2 (MPa)	Specimen 3 (MPa)	Average compressive strength
M20	20.83	20.03	19.77	20.20
M25	24.84	25.50	25.70	25.33
M30	34.66	36.66	35.77	35.14

Use of Efficiency factor in Mix Proportioning of Fly Ash”  
 Research Paper by Santanu Bhanja

Zone of fine aggregate = Zone 2

**3. Target strength of mix proportion**

Ft = fck + 1.65D

Ft = 30 + 1.65\*6 = 39.9 N/mm<sup>2</sup>

**4. Selection of W/C Ratio**

From fig. 1 the W/C ratio required for target mean strength of 39.9 MPa is 0.37

(This is lower than maximum value of 0.65 prescribed for 1978 t. Mild Exposure)

**5. Selection of water & sand content**

From table 4 for 20 mm nominal maximum size aggregate and sand confirming to zone 2, water content per cubic meter of concrete = 197 kg

Sand content by volume = 35% of total aggregate

**6. Determination of cement and fly ash content**

W/C Ratio = 0.37

Cement = 186/0.37 = 503 kg/m<sup>3</sup>

(The cement content is adequate for mild exposure Acc. To Appendix A of IS 456)

Replacements of cement by 15% fly ash

Hence fly ash = 75 kg/m<sup>3</sup>

Final cement content = 428 kg/m<sup>3</sup>

**7. Determination of coarse and fine aggregate**

From table 3 for specified maximum size of aggregate of 20mm the amount of entrapped air in wet concrete is 2%

V=W+c/Sc+1/P\*Fa/Sfa

0.98 = [186+428/3.15+1/0.35\*FA/2.82]\*0.001

Fa = 650 kg/ m<sup>3</sup>

V=W+c/Sc+1/(1-P)\*Ca/Sca

0.98 = [186+428/3.15+1/0.65\*Ca/2.67]

Ca = 1142 kg/m<sup>3</sup>

**8. Mix Proportion**

- a. Cement = 428 kg/ m<sup>3</sup>
- b. Fly Ash = 76 kg/ m<sup>3</sup>
- c. Sand = 650 kg/ m<sup>3</sup>
- d. Coarse aggregate = 1142 kg/ m<sup>3</sup>
- e. Water = 197 kg/ m<sup>3</sup>

**Table 10:** Quantity of material

Mix	Cement	Fly Ash	Coarse aggregate	Fine aggregate	Water
M20	316	56	1173	667	197
M25	395	70	1160	660	197
M30	438	75	1142	650	197

The efficiency factor (k – value) is defined as part of pozzolonic material which can be considered as equivalent to Portland cement having the same properties as the concrete without pozzolonic material (k = 1 for Portland cement)

### Mix Design M20 [Research Paper by Dr. Santanu Bhanja]

#### 1. Stipulation for Proportion

Type of Cement = OPC 33  
 Minerals Admixtures = Fly Ash  
 Max. size of aggregate = 20 mm  
 Workability = 100 mm (slump)  
 Exposure = Mild

#### 2. Test Data for Material

Cement – OPC33 (IS: 269)

Specific gravity:

1. Cement = 3.15
2. Coarse aggregate = 2.61
3. Fine aggregate = 2.82
4. Fly Ash = 2.2

Water Absorption

1. Coarse Aggregate = 0.5%
2. Fine Aggregate = 1%

Zone of fine aggregate = Zone 2 (IS383)

#### 3. Target Strength of Mix Proportions

$$F_t = f_{ck} + 1.65D$$

$$F_t = 20 + 1.65 \times 4 \text{ (from table IS 10262:2009)}$$

$$F_t = 26.60 \text{ N/mm}^2$$

#### 4. Selection of W/C Ratio

Assuming W/C ratio = 0.45

(Taking value from Fig. 1&2 from IS 10262:2009)

#### 5. Selection of Water Content

Max. water content for max. size of 20 mm aggregate = 186 liters

$$\text{For 100 mm slump} = 186 + 6/100 \times 186$$

$$= 197 \text{ liters}$$

#### 6. Calculation for Cement content

W/C Ratio = 0.45

$$\text{Cement + Fly Ash} = 197/0.45$$

$$= 438 \text{ kg/m}^3 > 320 \text{ kg/m}^3 \quad \text{Hence ok}$$

Taking optimum quantity of fly ash and replacing same with cement

Cementitious material content = 14.31%

$$14.31 \times 438/100 = 63 \text{ kg/m}^3$$

$$\text{Hence cement} = 375 \text{ kg/m}^3$$

#### 7. Proportion of CA and FA contents

From table 3 (IS 10262:2009)

For W/C = 0.45, Zone 2 of FA

Volume of coarse aggregate = 0.62

Volume of fine aggregate =  $1 - 0.62 = 0.38$

#### 8. Mix Calculations

a. Volume of concrete =  $1 \text{ m}^3$

b. Volume of cement =

$$\text{mass of cement}/(\text{specific gravity} \times 1000)$$

$$= 372/3.15 \times 1/1000 = 0.119 \text{ cum}$$

c. Volume of fly ash =

$$\text{mass of fly ash}/(\text{specific gravity} \times 1000)$$

$$66/2.2 \times 1/1000 = 0.03 \text{ cum}$$

d. Volume of water =

$$\text{mass of water}/(\text{specific gravity} \times 1000)$$

$$197/1000 = 0.197 \text{ cum}$$

e. Volume of all aggregate =  $[a - (b + c + d)] = [1 - 0.346]$

$$= 0.654 \text{ cum}$$

f. Mass of coarse aggregate =

e. \* volume of ca \* sp. gravity \* 1000

$$= 0.654 \times 0.62 \times 2.82 \times 1000 = 1083 \text{ kg/m}^3$$

#### 9. Mix Proportions

Cement = 375 kg/m<sup>3</sup>

Fly ash = 63 kg/m<sup>3</sup>

Water = 197 kg/m<sup>3</sup>

Fine aggregate = 701 kg/m<sup>3</sup>

Coarse aggregate = 1083 kg/m<sup>3</sup>

W/C Ratio 0.45

### Mix Design M25 Research Paper by Dr. Santanu Bhanja

#### 1. Stipulation for Proportion

Type of Cement = OPC 33

Minerals Admixtures = Fly Ash

Max. size of aggregate = 20 mm

Workability = 100 mm (slump)

Exposure = Mild

#### 2. Test Data for Material

Cement – OPC33 (IS: 269)

Specific gravity:

1. Cement = 3.15
2. Coarse aggregate = 2.61
3. Fine aggregate = 2.82
4. Fly Ash = 2.2

Water Absorption

1. Coarse Aggregate = 0.5%
2. Fine Aggregate = 1%

Zone of fine aggregate = Zone 2 (IS383)

#### 3. Target Strength of Mix Proportions

$$F_t = f_{ck} + 1.65D$$

$$F_t = 25 + 1.65 \times 4 \text{ (from table IS 10262:2009)}$$

$$F_t = 31.60 \text{ N/mm}^2$$

#### 4. Selection of W/C Ratio:

Assuming W/C ratio = 0.40

(Taking value from Fig. 1&2 from IS 10262:2009)

#### 5. Selection of Water Content

Max. water content for max. size of 20 mm aggregate = 186 liters

$$\text{For 100 mm slump} = 186 + 6/100 \times 186$$

$$= 197 \text{ liters}$$

#### 6. Calculation for Cement content

W/C Ratio = 0.40

$$\text{Cement + Fly Ash} = 197/0.40$$

= 492 kg/m<sup>3</sup> >320 kg/m<sup>3</sup> Hence ok  
 Taking optimum quantity of fly ash and replacing same with cement  
 Cementitious material content = 14.17%  
 $14.17 \times 492 / 100 = 74 \text{ kg/m}^3$   
 Hence cement = 418 kg/m<sup>3</sup>

### 7. Proportion of CA and FA contents

From table 3 (IS 10262:2009)  
 For W/C = 0.40, Zone 2 of FA  
 Volume of coarse aggregate = 0.62  
 Volume of fine aggregate =  $1 - 0.62 = 0.38$

### 8. Mix Calculations

- Volume of concrete = 1m<sup>3</sup>
- Volume of cement =  $\frac{\text{mass of cement}}{\text{specific gravity} \times 1000} = \frac{418}{3.15 \times 1/1000} = 0.133 \text{ cum}$
- Volume of fly ash =  $\frac{\text{mass of fly ash}}{\text{specific gravity} \times 1000} = \frac{74}{2.2 \times 1/1000} = 0.03 \text{ cum}$
- Volume of water =  $\frac{\text{mass of water}}{\text{specific gravity} \times 1000} = \frac{197}{1000} = 0.197 \text{ cum}$
- Volume of all aggregate =  $[a - (b + c + d)] = [1 - 0.363] = 0.637 \text{ cum}$
- Mass of coarse aggregate =  $e \times \text{volume of ca} \times \text{sp. gravity} \times 1000 = 0.637 \times 0.62 \times 2.82 \times 1000 = 1054 \text{ kg/m}^3$

### 9. Mix Proportions

Cement = 418 kg/m<sup>3</sup>  
 Fly ash = 74 kg/m<sup>3</sup>  
 Water = 197 kg/m<sup>3</sup>  
 Fine aggregate = 683 kg/m<sup>3</sup>  
 Coarse aggregate = 1054 kg/m<sup>3</sup>  
 W/C Ratio 0.40

### Mix Design M30 [Research Paper by Dr. Santanu Bhanja]

#### 1. Stipulation for Proportion

Type of Cement = OPC 33  
 Minerals Admixtures = Fly Ash  
 Max. size of aggregate = 20 mm  
 Workability = 100 mm (slump)  
 Exposure = Mild

#### 2. Test Data for Material

Cement – OPC33 (IS: 269)  
 Specific gravity:  
 1. Cement = 3.15  
 2. Coarse aggregate = 2.61  
 3. Fine aggregate = 2.82  
 4. Fly Ash = 2.2

#### Water Absorption

- Coarse Aggregate = 0.5%
- Fine Aggregate = 1%

Zone of fine aggregate = Zone 2 (IS383)

### 3. Target Strength of Mix Proportions

$F_t = f_{ck} + 1.65D$   
 $F_t = 30 + 1.65 \times 5$  (from table IS 10262:2009)  
 $F_t = 38.25 \text{ N/mm}^2$

### 4. Selection of W/C Ratio

Assuming W/C ratio = 0.35  
 (Taking value from Fig. 1&2 from IS 10262:2009)

### 5. Selection of Water Content

Max. water content for max. size of 20 mm aggregate = 186 liters  
 For 100 mm slump =  $186 + 6/100 \times 186 = 197 \text{ liters}$

### 6. Calculation for Cement content

W/C Ratio = 0.35  
 Cement + Fly Ash =  $197 / 0.35 = 563 \text{ kg/m}^3 > 320 \text{ kg/m}^3$  Hence ok  
 Taking optimum quantity of fly ash and replacing same with cement  
 Cementitious material content = 13.8%  
 $13.8 \times 563 / 100 = 78 \text{ kg/m}^3$   
 Hence cement = 485 kg/m<sup>3</sup>

### 7. Proportion of CA and FA contents

From table 3 (IS 10262:2009)  
 For W/C = 0.35, Zone 2 of FA  
 Volume of coarse aggregate = 0.62  
 Volume of fine aggregate =  $1 - 0.62 = 0.38$

### 8. Mix Calculations

- Volume of concrete = 1m<sup>3</sup>
- Volume of cement =  $\frac{\text{mass of cement}}{\text{specific gravity} \times 1000} = \frac{478}{3.15 \times 1/1000} = 0.152 \text{ cum}$
- Volume of fly ash =  $\frac{\text{mass of fly ash}}{\text{specific gravity} \times 1000} = \frac{85}{2.2 \times 1/1000} = 0.038 \text{ cum}$
- Volume of water =  $\frac{\text{mass of water}}{\text{specific gravity} \times 1000} = \frac{197}{1000} = 0.197 \text{ cum}$
- Volume of all aggregate =  $[a - (b + c + d)] = [1 - 0.387] = 0.613 \text{ cum}$
- Mass of coarse aggregate =  $e \times \text{volume of ca} \times \text{sp. gravity} \times 1000 = 0.613 \times 0.62 \times 2.82 \times 1000 = 1014 \text{ kg/m}^3$

### 9. Mix Proportions

Cement = 485 kg/m<sup>3</sup>  
 Fly ash = 78 kg/m<sup>3</sup>  
 Water = 197 kg/m<sup>3</sup>  
 Fine aggregate = 656 kg/m<sup>3</sup>  
 Coarse aggregate = 1014 kg/m<sup>3</sup>  
 W/C Ratio 0.35

**Table 12:** Quantity of material

Mix	Cement	Fly Ash	Coarse aggregate	Fine aggregate	Water	Efficiency factor k
M20	316	56	1083	701	197	0.51
M25	395	70	1054	683	197	0.61
M30	438	75	1014	656	197	0.57

Result by method suggested by S. Bhanja

**Table 13:** Compressive strength of sample as follows

Designation	Specimen 1	Specimen 2	Specimen 3	Avg. Compressive Strength
M20	22	21.33	20.88	23.70
M25	27.33	28.44	27.77	27.84
M30	37.33	35.77	37.55	36.88

### Analysis of Result

From the above three findings it can be seen that highest compressive strength is obtained through the mix design procedure suggested by Dr. Santanu Bhanja (2015). In this method properties of fly ash has been considered before designing the mix which is not in either of two design methods by Indian Standard i.e. IS 10262:2009 and IS 10262:1982.

From the result presented above it is obvious that compressive strength of concrete increase with increase of grade in all three methods. However, the compressive strength of cube is proportioned by IS 10262:2009 was higher by 4.50% for M20, 6.11% for M25 and 1.52% for M30 as compared to IS 10262:1982.

The increase in strength of cubes proportioned by the method suggested by Bhanja had higher compressive strength by 12.32% for M20, 3.57% for M25 and 0.49% for M30 as compared to IS10262:2009. Moreover, the compressive strength was higher by 17.38% for M20, 9.90% M25 and 2.04% for M30 when compared to IS 10262:1982.

It is therefore obvious that method suggested by Bhanja provided best result. As discussed by Singhal et.al 2013 IS 10262:1982 was best method when compared with COST (computer Optimization and software tool and ACI (American Concrete Institute Method)

Therefore all these possible methods were tried with inclusion of fly ash. The cubes proportioned by the methods suggested by Bhanja had higher compressive strength since this method includes the property of fly ash as binding material which other method did not. It is therefore obvious that this method will be best to mix design concrete with fly ash.

### Conclusion

Based on the observations and discussion made in study following conclusion can be derived upon:

1. The mix proportion by IS 10262:2009 had better compressive strength than IS 10262:1982
2. The mix proportion IS 10262:2009 is therefore better than IS 10262:1982 method ACI method and COST method.
3. The method suggested by Bhanja is the best for mix proportioning of concrete which includes the properties fly ash in terms of efficiency factor.

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