

BUILDING DIGEST

CENTRAL BUILDING RESEARCH INSTITUTE, INDIA



PROPORTIONING OF FLY ASH CONCRETE MIX

Introduction

Fly ash is a finely divided residue resulting from the combustion of pulverised coal in boilers. It is transported from the boiler by flue gases and collected by means of electrical precipitators or mechanical collectors or a combination of both. It is a pozzolanic material and consists of small spheres of glassy phase of complex chemical composition together with small quantities of quartz, mullite, haematite, magnetite and unburnt carbon. It is generally finer than portland cement and has been, therefore, used at the construction sites for replacing a part of the cement in mass concrete constructions.

When fly ash is used as a part replacement of cement, as is normally done in mass concrete, the strength of the concrete at 28 days is lower than that of the corresponding normal portland cement concrete without fly ash. It is only at later ages that the strength becomes equal. While this pattern of strength development can be tolerated in mass

concrete construction, it is not acceptable in building works where concrete is designed on the basis of a minimum 28 days strength requirement. Investigations carried out at the CBRI have shown, that equal strengths at 28 days can be attained by properly proportioning fly ash concrete mix. The properties of Indian fly ashes and the method of proportioning fly ash concrete mix for attaining equal 28 days strength are described in this digest. The recommended mix proportion of different fly ash concrete mixes are also listed.

Properties of Indian Fly Ashes

IS:3812 (Part I) 1966 "Specifications for fly ash Part I, For use as Pozzolana" has laid down chemical and physical requirements for fly ash for use as a pozzolana as part replacement of cement. Tests carried out at CBRI have shown that most of the Indian fly ashes pass the specified requirements and can be used to replace upto 20 per cent cement by weight. Test data on some of the Indian fly ashes are shown in Table 1.

Table 1

Properties of some Indian Fly Ashes

Properties	Test Results Range	Specified requirements as per IS:3812 (Part I)-1966	
Chemical Composition	percent by weight		
SiO ₂ + Al ₂ O ₃ + Fe ₂ O ₃	76.90—91.91	70.0	Minimum
SiO ₂	46.0 —62.0	35.0	Minimum
MgO,	0.2 — 2.0	5.0	Maximum
SO ₃ ,	traces-- 0.3	3.0	Maximum
Loss on ignition	0.81—10.8	12.0	Maximum
Physical Properties.			
(i) Fineness—Specific surface in Cm ² /g by Blaine's permeability method.	3267—6842	3200	Minimum
(ii) Reactivity,			
(a) Lime reactivity strength, Kg/cm ²	47.4—83.5	40	Minimum
(b) Compressive strength of cement mortar cubes at the age of 28 days using mixture B*	80.4—94.5	Not less than 80 percent of the strength of corresponding plain cement mortar cubes.	
(iii) Drying shrinkage at 28 days, using mixture B* percent.	0.1—0.2	0.15	Maximum
(iv) Soundness by autoclave test—expansions of specimens prepared using mixture B, percent	0.02—0.07	0.8	Maximum

Method of Proportioning

(a) Structural concrete mix

The concrete mix should be proportioned on absolute volume basis. The proportions of different ingredients are then adjusted as follows:—

- (i) Substitute 20 percent of cement with 27.5 percent of fly ash, by weight.
- (ii) Reduce the quantity of sand in the concrete mix by an amount equal to the weight of fly ash.
- (iii) Increase the quantity of coarse aggregate in the concrete mix by an amount equal to the weight of fly ash added.

(iv) Add water 8 per cent less than the water required to keep water/cement plus fly-ash ratio equal to the water/cement ratio decided for the corresponding straight cement concrete without fly ash. Any correction for moisture content of the sand and coarse aggregate should also be applied for determining the quantity of water.

(v) Place the concrete by vibration. If vibration is not possible use admixtures such as viscolox, Bondex, Celex, Retardex produced in the country.

The mix proportions of different fly ash concrete mixes corresponding to different grade of plain cement concrete mixes are shown in Table 2. These are recommended for use in building construction.

Table 2

Mix Proportions of Some Structural Concrete Mixes with Flyash

Grade of Concrete	Quantities of Materials (in Kg) for cubic meter of concrete				
	Cement	Fly ash	Sand	Coarse Aggregate	Water
M 150	247.2	85.0	680.00	1190.0	168.0
M 200	312.5	108.3	515.5	1202.0	194.6
M 250	433.0	148.8	314.0	1200.0	214.0

Note:—For calculating the nominal mix proportions by volume determine the loose bulk density of flyash, sand and coarse aggregate at site and then divide the batch mix by loose bulk density to find the mix proportion by volume. The bulk density of cement may be taken as 90 lb/cft. (1442 kg/cum).

Results of various tests made in fly ash concrete mixes at CBRI have shown that small difference in the relative fineness and content of unburnt fuel in various Indian fly ashes do not affect the attainment of equal strengths at 28 days and the flyash concrete compares favourably in strength with the corresponding plain cement concrete at later ages also.

(b) Lean concrete mixes

Lean concrete mixes are used in laying sub-

base under floors and foundations. Due to lack of fines these mixes generally have poor workability which leads to bleeding of mixing water and segregation of aggregates. Addition of fly ash as a part replacement of sand by weight in these mixes has been found to eliminate these defects and decrease water requirement for the same workability. The latter results in an increase in strength, which can be advantageously utilised in using still leaner mixes. The mix proportions of lean concrete mixes with fly ash recommended for use in place of some commonly used mix proportions are shown in Table 3.

Table 3

Mix Proportions of Some Lean Concrete Mixes with Fly ash

Commonly used mix proportions, by volume			Equivalent mixes with fly ash, by volume			
Cement	Sand	Gravel	Cement	Fly ash	Sand	Gravel
1	3	6	1	1.5	3.0	7
1	4	8	1	2.0	3.5	9
1	5	10	1	2.5	4.0	11

Example

It is proposed to replace 20 percent cement in M150 grade concrete mix (roughly corresponding to 1:2:4 concrete).

1.5 cubic meter of dry loose materials are normally required to produce 1 cubic meter compacted concrete. Quantity of cement required in 1:2:4 nominal concrete mix

$$= \frac{1.5}{7} = 0.214 \text{ cum.}$$

Assuming water/cement ratio of 0.55, sand of fineness modulus 2.63 and maximum size of the coarse aggregate 20 mm, the mix proportions per cubic meter of concrete, determined according to ACI:613-54 is

Cement	309 kg
Sand	787 kg
Gravel	1135 kg
Water	170 kg

With 20 percent of cement by weight replaced by fly ash, the proportions of different ingredients in the fly ash concrete mix would be as follows:

- i. Substituting 20 percent of the cement with 27.5 percent fly ash,

$$\text{Cement} = 309 \times 0.80 = 247.2 \text{ kg}$$

$$\text{Fly ash} = 309 \times 0.275 = 85 \text{ kg}$$

- ii. Adjust the water requirements so that it is 8 percent less than the amount of water required to keep water/cement + fly ash ratio equal to the water/cement ratio.

The quantity of water required

$$\begin{aligned} \text{Water} &= (247.2 + 85) \times 0.55 \times 0.92 \\ &= 168 \text{ kg.} \end{aligned}$$

Calculating the absolute volume of the materials,

$$\text{Cement} = \frac{247.2}{3.15 \times 10^3} = 0.0785 \text{ cum}$$

$$\text{Fly ash} = \frac{85}{2.12 \times 10^3} = 0.0401 \text{ cum}$$

$$\text{Water} = \frac{168}{10^3} = 0.1680 \text{ cum}$$

$$\text{Air} = \frac{0.01 \times 1}{(1\% \text{ assumed})} = 0.0100 \text{ cum}$$

$$\text{Total} = 0.2966 \text{ cum}$$

Total (coarse and fine) aggregate = $1 - 0.2966 = 0.7034 \text{ cum}$. In the corresponding plain cement concrete mix, the ratio of sand to total aggregate by weight

$$= \frac{787}{787 + 1135} = 0.4087$$

∴ Specific gravity of mixed aggregate

$$= 2.67 \times 0.4087 + 2.65 \times 0.5913 = 2.658 = 2.66 \text{ (say)}$$

∴ Weight of mixed aggregate

$$= 0.7034 \times 2.66 \times 10^3 = 1870 \text{ kg.}$$

weight of sand

$$= 1870 \times 0.4087 = 765 \text{ kg.}$$

- (iii) Reduce the quantity of sand and increase the quantity of coarse aggregate in the concrete mix by a quantity equal to weight of fly ash added.

Weight of sand required in the fly ash concrete mix

$$= 765 - 85 = 680 \text{ kg.}$$

$$\begin{aligned} \text{Weight of coarse aggregate} &= 1870 - 680 \\ &= 1190 \text{ kg} \end{aligned}$$

Estimated batch quantities per cubic meter of fly ash concrete corresponding to M150 grade plain cement concretes.

Cement	=	247.2 kg
Flyash	=	85 kg
Sand	=	680 kg
Coarse aggregate	=	1190 kg
Water	=	168 kg or litres

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