

Design of High Strength Concrete with Addition of Mineral and Chemical Admixtures

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ABSTRACT: High Strength Concrete (HSC) is dense, homogeneous and has the improved engineering properties and durability as compare to conventional concrete. In recent years, HSC has gained wide application in the construction industry. Ingredients of HSC are similar as conventional concrete, such as cement, fine aggregate, coarse aggregate and water. The paste of HSC requires high volume of cement content and less water to binder ratio. The high strength and flowability of HSC can be achieved by employment of cement content, mineral admixtures and chemical admixtures. However, increasing the cement content causes high cost, higher heat of hydration and higher drying shrinkage. This can be reduced by employing mineral admixture such as fly ash. In the present investigation, cement content for HSC mix is replaced with fixed percentages of fly ash (10%)

KEYWORDS: High Strength Concrete, Mineral Admixtures, Chemical Admixtures, ACI211.4R-93.

I. INTRODUCTION

High Strength Concrete (HSC) is a special type of concrete that has a specified compressive strength of 60 N/mm² or greater. High strength concrete is a most economic concrete, realized when it is used in the columns of High-Rise Buildings, Parking garages, Bridge decks, and other installations requiring improved compressive strength and density. For HSC usually selected pozzolanic and chemical admixtures are employed, and attainment of a low water to cementitious material ratio is considered essential. Many trial mixtures are often required to generate the data necessary to identify optimum mixture proportions Reported by ACI Committee 211.4R-93 [1].

II. MATERIALS AND EXPERIMENTATION

A. Materials

- **Cement:** Ordinary Portland cement (OPC) (53 grade) with specific gravity of 3.15 and fineness of 292 m²/kg confirming to IS 8112:1989 is being used. The physical properties of cement used are as given in table 1.0
- **Fine aggregate:** The sand used for the experimental program was locally procured and was confirming to zone-III. The specific gravity of fine aggregate was 2.58 and bulk density 1600 kg/m³.
- **Coarse aggregate:** Locally available crushed angular coarse aggregate having maximum size of 12.5 mm was used in the present work. The specific gravity of coarse aggregate was 2.90 and bulk density 1553kg/m³.
- **Mineral Admixture [Fly ash (FA)]:** Fly ash from Raichur thermal power station, Karnataka has been used as cement replacement material with a specific gravity of 2.2 and blains fineness of 229m²/kg. Properties of fly ash used are is shown in table 1.1
- **Water:** Potable tap water was used for the preparation of specimens and for the curing of specimens.
- **Chemical Admixture (Super plasticizer):** The super plasticizer used is Conplast SP430, which is obtained from FOSROC chemicals, Bangalore.

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Table 1.0 Physical properties of cement

Sr. No	Particulars	Experimental result	As per standard
1	Fineness	292 m^2/kg	Not less than 225 m^2/kg
2	Soundness		
a	By Le-Chatelier Expansion(mm)	2.00 mm	Not more than 10 mm
b	By Autoclave Expansion	0.16 %	Not less than 0.80%
3	Setting time (minutes)		
a	Initial	80 minutes	Not less then 30 minutes
b	Final	250 minutes	Not more than 600 minutes
4	Compressive strength (N/mm ²)		
a	3 day	29.32 N/mm ²	Not less than 27 N/mm ²
b	7 day	41.23 N/mm ²	Not less than 37 N/mm ²
c	28 day	57.41 N/mm ²	Not less than 53 N/mm ²
5	Temperature during testing	28 \pm C	27 \pm C=2%

Table 1.1 Properties of fly ash

Particulars	BIS requirements as per IS 3812 (part-1) 2003	Raichur Thermal Power Plant Fly ash
Sp. Surface (m^2/kg)	320 (Min)	329
Lime Reactivity (N/mm^2)	4.5 N/mm^2	4.53
Cement Reactivity (%)	80 % (Min)	85 %
SiO ₂	35 % (Min)	62.1 %
SiO ₂ +Al ₂ O ₃ +Fe ₂ O ₃	70 % (Min)	92.6
MgO	5.0 % (Max)	1.4
LOI	5.0 % (Max)	0.6
Total Alkalis as Na ₂ O	1.5 % (Max)	0.16
Chloride	0.05 % (Max)	0.003 %

B. Mix Design

The mix design procedure adopts a M60 grade concrete in accordance with ACI 211.4R-93. The specific gravity of the material used are tabulated in the table 1.2

Table 1.2 specific gravities of material used

Material	Specific gravity
cement	3.15
Fine aggregate	2.58
Coarse aggregate	2.90
Fly ash	2.20

a) Parameters for mix design

The specified compressive strength at 28 days

$$f_{cr} = (9000 \times 6.8) / 1000$$

$$f_{cr} = 61.20 N/mm^2$$

Bulk Specific Gravity (BSG) of fine aggregate based on oven dry weight

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$$BSG_{dry} = 2.58$$

Dry Rodded Unit Weight (DRUW) of fine aggregate per m^3 of concrete is

$$DRUW = 106 \times 0.59$$

$$DRUW = 62.54 \text{ kg}$$

b) Design steps are as follows

Steps 1: Select slump and required concrete strength

The concrete will be designed based on slump of 25-50 mm. from ACI 211.4R-93,

Using Eq, (2.3), the required average strength used for selection of concrete proportions is

$$f'_{cr} = \left[\frac{9000 + 1400}{0.9} \right] \times 6.8$$

$$f'_{cr} = 78.58 \text{ N/mm}^2$$

Target strength for mix proportioning

The required average field compressive strength is

$$f''_{cr} = 0.9 \times 11600 \times 6.8$$

$$f''_{cr} = 71 \text{ N/mm}^2$$

Step 2: Selection of maximum size of coarse aggregate

Based on guideline from ACI211.4R-93, (table 4.3.2), the coarse aggregate used having nominal maximum size of 12.5mm.

Bulk specific gravity (BSD) of coarse aggregate based on the oven dry weight

$$BSG_{dry} = 2.90$$

Dry Rodded Unit Weight (DRUW) of coarse aggregate per m^3 of concrete is

$$DRUW = 97 \times 0.59$$

$$DRUW = 57.23 \text{ kg}$$

Step 3: Selection of optimum coarse aggregate content

The selection of coarse aggregate content, selected from ACI211.4R-93 (Table 4.3.3) is 0.68 per unit volume of concrete.

From the ACI211.4R-93 using Eq, (4.1), the dry weight of coarse aggregate per m^3 of concrete is

$$W_{dry} = 0.68 \times 57.23 \times 27$$

$$W_{dry} = 1050 \text{ kg}$$

Step 4: Estimate the quantity of mixing water and air contents.

Based on the slump on 25 to 50mm and 12.5 mm maximum size coarse aggregate, the required mixing water chosen from ACI 211.4R-93 (Table 4.3.4), per m^3 of concrete is

$$W_{c1} = 295 \times 0.95$$

$$W_{c1} = 174.05 \text{ litres}$$

The entrapped air content is 2.0 percent.

From ACI211.4R-93, using Eq, (4.2) the voids contents of the sand to be used is

$$V = 1 - [106 / (2.58 \times 62.4)] \times 100$$

$$V = 34 \%$$

The mixing water adjustment, calculated from ACI 211.4R-93, using Eq. (4-3), per m^3 of concrete is

$$W_{dry} = 1050 \text{ kg}$$

$$W_{c2} = (V - 35) \times 8$$

$$W_{c2} = (34 - 35) \times 8$$

$$W_{c2} = -8 \times 0.59$$

$$W_{c2} = -4.72 \text{ litres}$$

Then the total mixing water required per m^3 of concrete is

$$WC = W_{c1} + W_{c2}$$

$$WC = 295 - 8$$

$$WC = 287 \times 0.59$$

$$WC = 169 \text{ litres}$$

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Step5: Selection of W/(C+FA) Ratio

From ACI211.4R-93, Table 4.3.5(b), for a 12.5 maximum size coarse aggregate and for the field compression strength 70.72 N/mm². The W/(C+FA) ratio can be calculated by interpolating the respective values.

$$\frac{W}{C + FA} = 0.31$$

Step6: Calculation of cementations material

The weight of cementitious material per m³ of concrete is

$$\begin{aligned} &= WC / \left[\frac{W}{C + FA} \right] \\ &= 287 / 0.31 \\ &= 926 \times 0.59 \\ &= 546 \text{ kg} \end{aligned}$$

Step7: Proportion basic mixture with cement only

1. Cement content per m³ = 546 kg
2. The volumes per m³ of all materials, except sand are as follows

Table 1.3: the volume per m³ of all material except sand

Cementitious material	926 / (3.15 X 62.4)	4.71/3.281	1.43 m ³
Coarse aggregate	170 / (2.90 X 62.4)	9.84/3.281	2.99 m ³
Water	287 / 62.4	4.60/3.281	1.40 m ³
Air	0.02 X 27	0.54/3.281	0.164 m ³
Total volume		19.69/3.281	6.00 m ³

Then the required volume of sand per m³ of concrete is

$$\begin{aligned} &= 27 - 19.69 \\ &= 7.31/3.281 \\ &= 2.23 \text{ m}^3 \end{aligned}$$

Then the required weight of sand per m³ of concrete is

$$\begin{aligned} &= 7.31 \times 62.4 \times 2.58 \\ &= 1177 \times 0.59 \\ &= 694 \text{ kg} \end{aligned}$$

Table 1.4: proportion of basic mixture

Cementitious material	546 kg
Fine aggregate	694 kg
Coarse aggregate	1050 kg
Water	169 liters

Step 8: Proportion companion mixtures using cement and fly ash

From ACI 211.4R-93 Table 4.3.6 the fly ash can be replaced with different percentage

The trial mixtures for different percentage of fly ash are the follows.

Trial 1: for 10% replacement of fly ash

$$\begin{aligned} &\text{Fly ash content} \\ &= 546 \times (10/100) \\ &= 54 \text{ kg/m}^3 \end{aligned}$$

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Cement content
= 546 – 54
= 492 kg/m³
Supper plasticizers = 1.5% by weight of cementations materials
= (1.5/100) x 546
= 8.19 litres

Table 1.5 proportions companion mixtures using cement by fly ash

Cement	492 kg
Fine Aggregate	694 kg
Coarse Aggregate	1050 kg
Fly ash	54 kg
Water	169 litres
Super Plasticizer	8.19 litres

Step 9: The mix proportion obtained using cement and fly ash are as shown in the table 1.6

Table 1.6 Mix Proportions

Cement	Fine Aggregate	Coarse Aggregate	Fly ash	Water Content	Super Plasticizer
492 kg/m ³	694kg/m ³	1050kg/m ³	54kg/m ³	169 litres	8.19 litres
1.00	1.41	2.13	0.10	0.31 (w/c ratio)	1.50 %

C. Testing

Hardened properties were determined by conducting compressive strength on cubes, splitting tensile strength and modulus of elasticity on cylinders, flexural strength and load deflection response on beams. The compressive strength test on cube specimens is conducted as per IS 516-1959. Split tensile test is carried out on compression testing machine as per IS 5816-1999. Modulus of elasticity test is carried out on universal testing machine as per IS 5816-1999. To determine flexural properties of concrete beams two point loading system is adopted and testing is carried out by as per IS 516-1959.

D. Hardened properties

a) Compressive strength

Figure 1 represents the compressive strength for a mix proportion of a HSC (M60 Grade of concrete).

b) Split tensile strength

Figure 1 represents the split tensile strength for a mix proportion of a HSC (M60 Grade of concrete).

c) Flexural strength

Figure 1 represents the flexural strength for a mix proportion of a HSC (M60 Grade of concrete).

d) Modulus of elasticity

Figure 2 represents the modulus of elasticity for a mix proportion of a HSC (M60 Grade of concrete).

e) Load deflection response under flexural loading

Figure 3 represents the Load deflection response under flexural loading for a mix proportion of a HSC (M60 Grade of concrete).

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III. TEST RESULTS

Table 4: Hardened properties of designed HSC

Hardened properties	Compressive Strength (N/mm ²)	Split Tensile Strength (N/mm ²)	Flexural strength (N/mm ²)	Modulus of elasticity (N/mm ²)	Deflection (mm)
Designed HSC for M60 Grade of concrete	61.49	7.08	5.12	37722	1.55

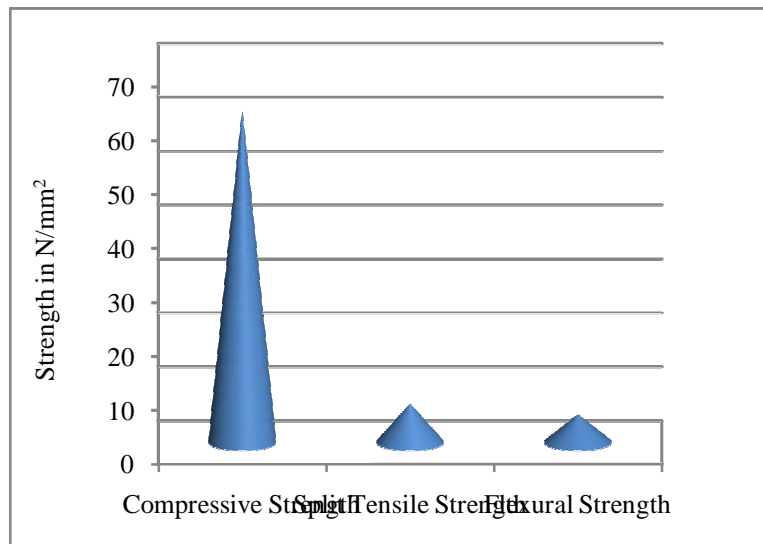


Fig.1. Compressive, Split Tensile & Flexural Strength

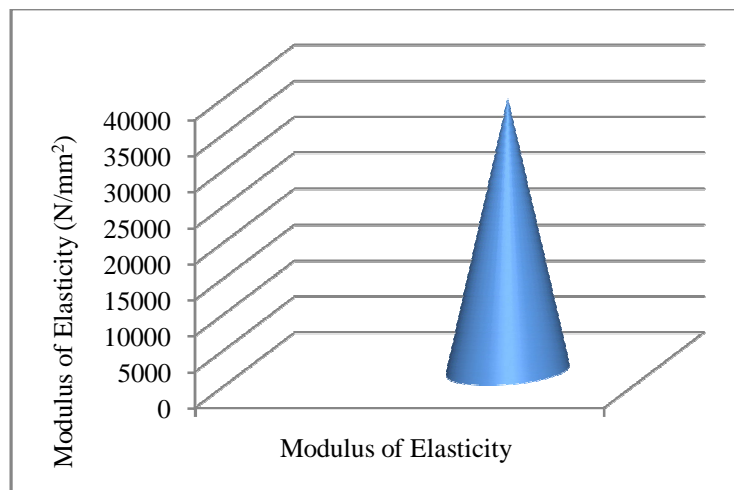


Fig.2. Modulus of Elasticity

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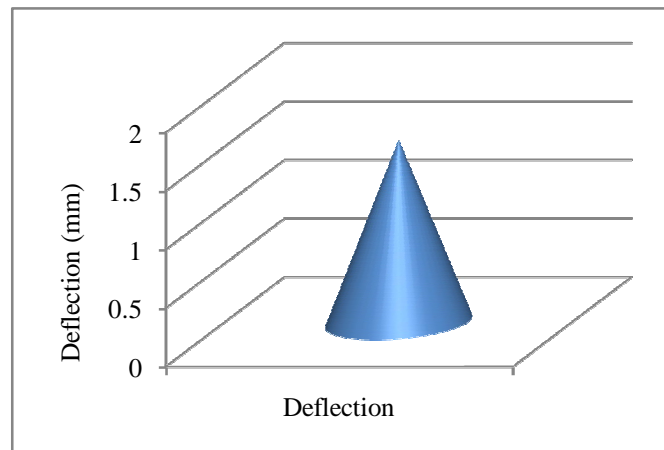


Fig.3. Load deflection response

IV. CONCLUSION

Since as per the design mix(ACI 211.4R-93) we got satisfied results for the High Strength Concrete (HSC). Hence HSC is a dense, homogeneous and having improved engineering properties and durability as compare to conventional concrete. As per results the use of chemical and mineral admixtures in HSC having significant effects and HSC is a most economic concrete when it is designed by using ACI Committee 211.4R-93 with locally available normal ingredients. HSC can be used in the columns of High-Rise Buildings, Parking Garages, Bridge decks, and other installations requiring improved compressive strength and density. For HSC usually selected pozzolanic and chemical admixtures are employed, and attainment of a low water to cementitious material ratio is considered essential. Many trial mixtures are often required to generate the data necessary to identify optimum mixture proportions Reported by ACI Committee 211.4R-93.

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