

Effects of Fly Ash and Super Plasticiser on Cement Content in M30 Grade Concrete

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ABSTRACT: Concrete is a very common construction material and based on guidelines of IS 456 : 2000 and IS 10262 : 2009 or IRC 44 : 2008 concrete mix is designed. For ordinary Portland cement, maximum cement content (OPC) is limited to 450 kg/m³ of concrete. In design mix M30 grade concrete, chemical admixtures and fly ash were used for reduction in cement content. In M30 grade design mix concrete, cement content was 400.826 kg/m³ and cement content was replaced by fly ash in varying proportion. For 25% cement replacement by fly ash, compressive strength was found satisfactory and reduced cement content was 330.71kg/m³ of concrete. Design mix M30 grade concrete mix samples with 0.5%, 1.0%, 1.5%, 2.0% and 2.5% super plasticiser were tested. Compressive strength for 1.5% use of super plasticiser was found optimal with reduced cement content 328.71 kg/m³ of concrete.

KEYWORDS: Design mix concrete, M30 grade, Fly ash, Super plasticiser

I. INTRODUCTION

Concrete is used in various construction activities like buildings, roads, bridges, hydraulic structures, airport, marine structures etc. Basic ingredients of concrete are cement, fine aggregate (sand), coarse aggregate, water and admixtures, if any. Concrete is produced at construction site or at suitable industrial plants by using cement and locally available ingredients. The ingredients are mixed in known proportions finalised by two ways: based on tradition ratio and as per design of concrete mix. Design mix concrete proportion is finalised by codal provisions, considering properties of ingredients, quality control of concrete production. For such mixes target strength is estimated for probability factor corresponding to 5% failure of test results below expected strength and appropriate standard deviation (SD). In absence of appropriate quality control measures, the values of assumed SD are increased by 1 N/mm² and these SD values are used for designing up to M50 grade concrete mixes.

For the given set of ingredients in concrete mixes, cement content increases in higher grade of concrete. Due to increase in heat of hydration, use of higher cement content needs more curing and results micro / fine crack developments. As per clause 8.2.4.2 (IS 456 : 2000) maximum use of ordinary Portland cement (OPC) in concrete is limited to 450 kg/m³. Accordingly, in higher strength concrete, cement content is to be maintained within permissible limit without compromising strength and durability parameters. Same is achieved either replacing cement content partially by available pozzolanic materials or reducing water content in the mix by using plasticisers / super-plasticisers. IS 456:2000 clause 5.2.1.1 permits use of mineral admixtures like fly-ash (pulverized fuel ash) conforming to grade 1 of IS 3812 for replacing part of ordinary Portland cement provided uniform blending is ensured.

Fly-ash is finely divided residue resulting from the combustion of ground or powdered coal and has pozzolanic properties. This is used as supplementary cementitious material in concrete construction as partial replacement of cement. Fly ash chemically reacts with the by product calcium hydroxide released by the chemical reaction between cement and water to form additional cementitious products that improve many desirable properties of concrete. All fly ashes exhibit cementitious properties to varying degrees depending on the chemical and physical. K. Erdog̃du1 (et.al) studied the effects of effects of fly ash particle size on strength of Portland cement fly ash mortars and found that finer

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the size of a fraction resulted higher compressive strength¹. Compared to cement and water, the chemical reaction between fly ash and calcium hydroxide typically is slower resulting in delayed hardening of the concrete. Use of fly ash in rigid pavement construction was studied by Suryawanshi N T (et.al.) and it was found that 25% replacement of cement by fly ash was optimal for flexural strength². Harison *et al.* (2014) studied the effects of fly ash concrete by replacing 10% to 60% cement content by fly ash and found that strength was comparable up to 30% fly ash content and after that it decreased.³

Use of latex itself reduces the water demand for ordinary concrete and substituting cement by fly ash further reduces water content maintaining similar properties of fresh concrete. Using fly ash in plasticiser mix concrete reduces the total intruded pore volume of hardened latex cement pastes and retains improved pore size distribution pattern. So fly ash mix concrete reduces in chloride permeability. Properties of hardened concrete like compressive strength, flexural strength and dynamic elastic modulus values, shows reduced value initially but on increasing age, these properties are improved. Latex mixed fly- ash paste is denser and has less open-pored than that in plain latex cement paste so the freezing and thawing resistance of latex concrete is not affected adversely.

Berry and Malhotra cited two cases in which 30% fly ash substitution for cement was found to reduce the water requirement for constant slump by about 7%.⁴ Based on his results, Kokubu conducted tests on 20 different fly ashes available in Japan and found that these fly ashes produced water reduction ranged from 4% to 11% when they were used at a replacement level of 25%.⁵ When fly ash was substituted for cement on an equal volume basis, Brown reported a reduction in water demand ranged from 3% to 4%.⁶

Jiei, hosek stated that in general the polymer emulsion is acting as a hydrocarbon retarder and delaying both the beginning and the end of the hydration process.⁷ Latex modified mortar and concrete show appreciable increase in tensile and flexural strength but decreases in compressive strength as compared with cement mortar and concrete. Gubezhenet found that compared with reference cement paste made on 0.25 w/c ratio, the super-plasticizers paste containing alaphene-condensate had less water of hydration.⁸ In addition, they found that 7 and 28 days compressive strength of super-plasticized concrete was higher by 5 to 10% and test on 7 month old specimens showed that the strength disappeared in them. Mac Pherson found that the lignosulfonate admixture increases bond strength about 15-20% and reduces the slip between reinforcing bar and concrete at a given stress.⁹ The effect is ascribed to the decrease in w/c ratio, consequently the reduction in bleeding and shrinkage can be contributing to better adhesion and hence improve bond strength.

II. RELATED WORK

For M30 grade concrete 53 grade ordinary Portland cement (OPC), 20 mm maximum nominal size graded crushed angular aggregate and zone III sand were used. Specific gravity of coarse and fine aggregate was 2.78 and 2.71 respectively. Concrete mix was designed for moderate exposure condition with normal workability as 25 – 50 mm slump value. Locally available fly ash with specific gravity 2.3 was used for cement replacement in different percentages. Adcrete Super-101, a Sulphonated Nephthalene Formaldehyde (SNF) based super plasticiser, available in local market with specific gravity 1.05, was used for this work. Based on the codal provisions of IS 456 : 2000 and IS 10262 : 2009, proportion of trial mix I for design mix M30 grade concrete was calculated in the following steps:

Target strength for mix proportioning: $f_t = f_{ck} + 1.65 * s$, where, f_t = target average compressive strength at 28 days, f_{ck} = characteristic compressive strength at 28 days, and s = standard deviation. From Table-1 of IS: 10262:2008 pg. 2, for standard deviation $s = 5 \text{ N/mm}^2$; $f_t = 30 + 1.65 * (5) = 38.25 \text{ N/mm}^2$

Selection of water-cement ratio and water content for Trail Mix-II: From table-5 of IS 456: 2000, maximum free water-cement ratio 0.45 is adopted. From table 2 of IS 10262:2009, maximum water content for 20 mm angular aggregate and 25 to 50 mm slump is 186 kg/m^3 of concrete

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Calculation of cement content: For free water cement ratio 0.45 and water content 186 kg/m^3 , cement content is 413.33 kg/m^3 which is higher than minimum cement content 300 kg/m^3 for “moderate” exposure conditions.

Proportion of volume of coarse aggregate and fine aggregate content: From IS 10262 : 2009, table no. 3, pg. 3, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (zone III) for water cement ratio 0.50 is 0.64. For water-cement ratio is 0.45, volume of coarse aggregate and fine aggregate content is to be adjusted. For lower value of water-cement ratio from 0.50 by 0.10, volume of coarse aggregate is increased by 0.02 (at the rate of ± 0.01 for every ± 0.05 change in water cement ratio. Corrected proportion of volume of coarse aggregate and fine aggregate, for water-cement ratio of 0.45, is 0.65 and 0.35 respectively.

Mix Calculation: Required ingredient per unit volume of concrete was as

$$\text{Volume of cement} = \frac{\text{mass of cement}}{\text{specific gravity of cement}} \times \frac{1}{1000} = \frac{413.33}{3.15} \times \frac{1}{1000} = 0.131 \text{ m}^3$$

$$\text{Volume of water} = \frac{\text{mass of water}}{\text{specific gravity of water}} \times \frac{1}{1000} = 186/1 \times 1/1000 = 0.186 \text{ m}^3$$

$$\text{Volume of all in aggregate (e)} = 1 - (\text{volume of cement} + \text{vol. of water}) = 1 - (0.1312 + 0.186) = 0.683 \text{ m}^3$$

$$\text{Mass of coarse aggregate} = e \times \text{volume of coarse agg} \times \text{sp.gr of coarse agg} \times 1000$$

$$= 0.683 \times 0.65 \times 2.74 \times 1000 = 1305.21 \text{ kg}$$

$$\text{Mass of fine aggregate} = e \times \text{volume of fine aggregate} \times \text{sp.gr. of fine agg.} \times 1000$$

$$= 0.683 \times 0.35 \times 2.706 \times 1000 = 646.86 \text{ kg}$$

Fresh concrete was prepared and workability was found as 33 mm slump value. On satisfying workability requirements, trial mix I was designated as trial mix II, cube samples were casted for 28 days strength. Trial III and IV were calculated by keeping water content constant and changing w/c ratio $\pm 10\%$ and cube samples for both trial mixes were casted. (Table I) after 28 days water curing cubes were tested and a graph was plotted between compressive strength and water cement ratio (Figure 1). For required target strength, water cement ratio was obtained and final proportion was calculated (Table-1). As per annexure B of IS 10262, cement content of the final mix proportion was replaced by fly ash in 15%, 20%, 25%, 30% and 35% (Table 2), test samples were casted and tested for all mixes. Similarly mix proportions were calculated by adding super plasticiser (0.5%, 1.0%, 1.5%, 2.0 and 2.5%) and taking account of reduction in water content Table 3). For all mixes, cube samples were casted and tested after 28 days curing.

III. EXPERIMENTAL RESULTS AND DISCUSSION

Mean compressive strength of trial mix II, III and IV samples were 40.00 N/mm^2 , 34.25 N/mm^2 and 45.00 N/mm^2 respectively. From the graph between w/c and compressive strength of trial mixes (Figure 1), for target strength 38.25 N/mm^2 , w/c was found 0.464. For the same w/c, mass of cement, fine aggregate and coarse aggregate in final mix proportion was 400.86 kg/m^3 , 655.62 kg/m^3 and 1217.82 kg/m^3 respectively. On using fly ash replacement of cement content in final mix by 15%, 20%, 25%, 30% and 35%, cement content in respective mixes reduced to 374.81 kg/m^3 , 352.76 kg/m^3 , 330.71 kg/m^3 , 308.66 kg/m^3 and 286.62 kg/m^3 . After 28 days curing compressive strength was lowest (26.14 N/mm^2) for 35% replacement of cement. Average compressive strength of samples with 30% cement replacement level was found 17.50% and 29.75% higher after 60 days and 90 days under water curing.

For the specified workability, reduction in water content by using chemical admixture 0.5%, 1.0%, 1.5%, 2.0% and 2.5% was 7%, 13%, 18%, 23% and 26.5% respectively. For 2.5% of dose of admixture, cement content reduced to 294.63 kg/m^3 and average compressive strength of same mix samples was 38.11 N/mm^2 . On increasing dose of

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admixture, density of concrete showed an increasing trend. Maximum density 25.41 kN/m^3 was found at 2.5% admixture.

IV RECOMMENDATIONS

By using fly ash replacement 35% or 2.5% dose of chemical admixture, minimum cement content reduced to 286.62 kg/m^3 and 294.63 kg/m^3 respectively. Fly ash being from locally available sources is not considered for minimum cement content requirement. For M30 grade concrete with the ingredients used in this study, use of fly ash should be less than 35% as cement replacement and chemical admixture up to 2% for meeting the durability aspects. Use of fly ash replacement (20%) and chemical admixture (1%) in M30 grade concrete with same ingredients showed reduced cement content requirement to 300 kg/m^3 and hence use of both in the same mix was not found justifiable from economic considerations. Use of chemical admixture and fly ash replacement with appropriate doses is recommended for higher grade of design mix concrete.

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Particulars of ingredients		Water (kg)	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	Compressive strength (N/mm ²)
Trial mix II	per m ³ of concrete	186.00	413.33	646.66	1216.04	40.00
	proportion	0.450	1.000	1.565	2.942	
Trial mix III	per m ³ of concrete	186.00	375.76	674.88	1220.15	34.25
	proportion	0.495	1.000	1.796	3.247	
Trial mix IV	per m ³ of concrete	186.00	459.26	616.58	1206.55	45.00
	proportion	0.405	1.000	1.343	2.627	
Final mix	per m ³ of concrete	186.00	400.86	655.62	1217.82	38.25
	proportion	0.464	1.000	1.636	3.038	

Fly ash used for replacement of cement	Water (kg)	Cement (kg)	Fly ash (kg)	Fine aggregate (kg)	Coarse aggregate (kg)
15%	186	374.81	66.14	637.00	1198.74
20%	186	352.76	88.19	634.53	1194.09
25%	186	330.71	110.24	632.05	1189.43
30%	186	308.66	132.28	629.58	1184.78
35%	186	286.62	154.33	627.11	1180.12

Super plasticizer used for reducing water content	Water (kg)	Cement (kg)	Super plasticiser (l)	Fine aggregate (kg)	Coarse aggregate (kg)
0.5%	172.98	372.80	1.96	675.85	1271.86
1.0%	161.82	348.75	3.66	692.35	1302.89
1.5%	152.52	328.71	5.18	706.01	1328.60
2.0%	143.22	308.66	6.48	719.85	1354.65
2.5%	136.71	294.63	7.73	729.25	1372.33

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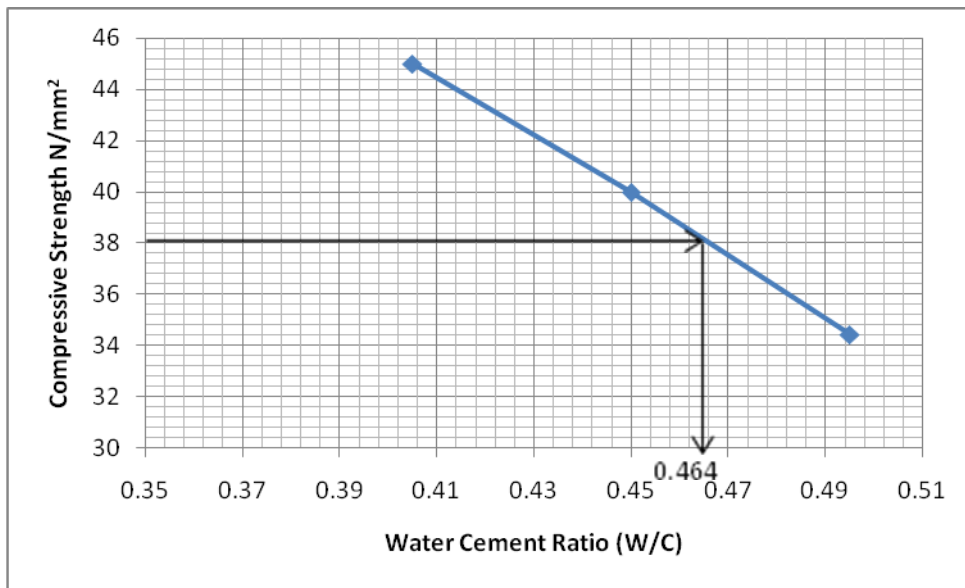


Figure 1 Variation of compressive strength and water cement ratio