

# Optimum Cement Content Requirement in Cast In-situ Concrete Wall Construction

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**ABSTRACT:** Locally available sand and river shingles are common ingredients of concrete used in construction of compound walls and enclosure of semi-permanent houses upto sill level. High slump concrete is favoured for more concrete placing height. For the same, M20 grade high slump concrete was designed and cement content was found 437.78 kg/m<sup>3</sup>. Designed concrete mix was showing excessive segregation and bleeding. To minimise the same recommended quantity of Sika plastocrete – modified lignosulphate polymer was used in concrete and cement content was reduced to 372.11 kg/m<sup>3</sup>. Further replacement of cement content by fly ash @ 15%, 20%, 25%, 30% and 35% was studied. For 25% of fly ash replacement, 28 days compressive strength was found optimal and for the same required cement content was found 306.99 kg/m<sup>3</sup>.

**KEYWORDS:** High slump concrete, Design mix M20 grade concrete, Cement content, Fly ash, Sika plastocrete – modified lignosulphate

## I. INTRODUCTION

Concrete produced by using locally available sand conforming to zone IV and 20 mm graded angular / river shingles aggregate of nominal size is used in construction of thin walls. Construction height of such walls in one stage is limited and compaction in such thin section becomes difficult. Cement-sand mortar with higher workability is used for casting Moladi house wall units up to full height at one time only. Similarly, by using high workability concrete mix, construction height at one time will increase. For given water cement ratio (w/c) in concrete mix, higher water content with more cement content results higher workability with escalating cost. Further increasing water content has higher possibility of segregation and bleeding. This increases capillary pores and air voids which adversely affect the various properties of hardened concrete especially moisture movement and durability. To minimising the adverse effects of high workability concrete, chemical admixtures are used to reduce the water content, fly ash is added to reduce cement content and more fines are mixed to controls segregation and bleeding. Water proofing and workability improving admixtures increases slump values in fresh stage and improves pore structures, impermeability etc. in hardened stage.

Steven et.al. (2003) used water reducing admixtures, plasticisers or superplasticisers in concrete for reducing water content for higher workability and to minimize the chance of segregation and bleeding at higher workability. Reduction in water-cementing materials ratio, cementing materials content, water content, paste content and improvement in the workability of a concrete without changing the water-cementing materials ratio was found.<sup>1</sup> Compatibility of plasticizer or super plasticizer with the given ingredients is necessary for optimal result. Super plasticisers are found to be compatible with retarders, water reducers, accelerators and air entraining agents along with mineral admixtures such as silica fumes and fly ashes.<sup>2</sup> Ravindrarajah et. al. (2003) found increase in slump flow with the increase of the superplasticiser dosage, nearly same flow values for superplasticiser dosage more than 0.25% and significant improvement in bleeding capacity for flowing and self-compacting concretes.<sup>3</sup>

Use of mineral admixtures and pozzolanic materials is suggested for reducing cement content in concrete. Malagavelli et. al. (2012) studied the effects of super plasticisers on workability and strength of concrete. Increased workability and strength of concrete was found up to 30% replacement of cement by fly ash. Optimal result is suggested for 20%

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

replacement of cement..<sup>4</sup> Mittal et. al. (2012) undertook an experimental study on use of fly ash in concrete to see the various changes in the properties of the finished concrete mix and concluded that using cementitious materials 450 kg/m<sup>3</sup> to 500 kg/m<sup>3</sup> of concrete, partial replacement of cement upto 40% has good result.<sup>5</sup> It was further concluded that development of strength for 20%, 30% and 40% fly ash for total cementitious content of 450 kg/m<sup>3</sup> and 500 kg/m<sup>3</sup>, beyond 28 days increased by 111%, 117%, 129% and 142% respectively. Mishra et.al (2015) studied the effects of cement replacement by fly ash and use of superplasticiser in M30 grade concrete. Based on 28 days compressive strength test result, optimal use of fly ash was found for 25% cement replacement and saving of cement was reported 70.12 kg/m<sup>3</sup> of concrete. For optimal use (1.5%) of plasticizer, reduction cement content was found from 400.83 kg/m<sup>3</sup> to 328.71 kg/m<sup>3</sup> in M30 gradeconcrete.<sup>6</sup>

### II. MATERIALS AND RELATED WORK

River sand conforming zone IV (FA), angular graded aggregate of nominal size 20 mm (CA), 43 grade ordinary Portland cement (OPC), fly-ash procured from local steel plant and Sika plastocrete super (modified ligno sulphonate) were used for M20 grade design mix high slump concrete. Specific gravity (Sp. Gr.) of CA, FA and fly ash was 2.72, 2.76 and 1.92 respectively. Properties of Sika plastocrete super was as brown colour liquid, specific gravity 1.05 at 30°C. For mild exposure condition maximum free water cement ratio and minimum cement content were kept as 0.55 and 300 kg/m<sup>3</sup> respectively. For high workability of mix, slump value range, as required for pumpable concrete, 100 - 125 mm was selected for this design.

Based on provisions of IS 456 : 2000 and IS 10262 : 2009, proportions of ingredients for trial mixes II, III and IV were calculated (Table 1). Cube samples were casted and tested after 28 days under water curing. Average compressive strength for trial mix II, III and IV samples were 20.7 N/mm<sup>2</sup>, 17.3 N/mm<sup>2</sup> and 23.8 N/mm<sup>2</sup> respectively. A graph was plotted between compressive strength and w/c of trial mixes (Figure 1) and for target strength (26.6 N/mm<sup>2</sup>) of design mix w/c was found as 0.45. Using same values of w/c, final mix proportion was calculated and cement content for the same was 438.13 kg/m<sup>3</sup>.

Segregation and bleeding was observed in final mix. For minimizing the same, mix was redesigned with 0.2% Sika plastocrete super, for assumed reduction in water content as 10%, 15% and 20%; resulted slump value as 145 mm, 115 mm and 85 mm respectively (Table 2). As per required workability, 0.2% use of superplasticiser resulting 15% reduction in water content was selected. In the same design mix concrete cement content was reduced to 372.11 kg/m<sup>3</sup>.

Design calculation for the same is given at appendix-1.

Properties of materials and design stipulations are grade designation of concrete - M20; type of cement - OPC 43 grade; maximum nominal size of aggregate - 20 mm; minimum cement content - 300 kg/m<sup>3</sup>, maximum water cement ratio - 0.55; workability - 100 - 125 mm (slump); Exposure condition – moderate; degree of supervision – good; type of aggregate - river singles, maximum cement content - 450 kg/m<sup>3</sup>, specific gravity of coarse and fine aggregates - 2.72 and 2.76 respectively, specific gravity of cement plasticizer and fly-ash - 3.15, 1.05 and 1.92 respectively.

**Target strength ( $f_t$ ):** For design mix proportioning  $f_t$  is correlated to characteristics compressive strength ( $f_{ck}$ ) and assumed standard deviation (s) as  $f_t = f_{ck} + 1.65*s$ . For characteristic compressive strength at 28 days 20 MPa and assumed standard deviation (from Table-1 of IS 10262:2008 pg. no.-2) 4 MPa, value of target strength is 26.6 N/mm<sup>2</sup>.

**Selection of water-cement ratio and water content:** Water cement ratio for final mix was (Figure 1) was 0.45 and maximum water content for 20 mm aggregate and 25 to 50 mm slump was 186 kg/m<sup>3</sup> of concrete (Table 2, IS 10262 : 2009). Adjusted water content for 100 mm slump (186 \*1.06) was 197.11 kg/m<sup>3</sup> of concrete. Reduction in water content by super plasticizers was 15% and final water content reduced to 167.45 kg/m<sup>3</sup> of concrete.

**Calculation for cement and fly ash content:** For water-cement ratio (0.450) and water content 167.45 kg/m<sup>3</sup>, cement content was 372.11 kg/m<sup>3</sup>, higher than minimum cement content (300 kg/m<sup>3</sup>) for moderate exposure condition (Table 5, IS 456 : 2000). For using fly ash as partial cement replacement, cementitious content was increased by 10% and

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

same increased to 409.32 kg/m<sup>3</sup>. Cement and fly ash content was 347.922 kg/m<sup>3</sup> and 61.398 kg/m<sup>3</sup> resulting 24.19 kg/m<sup>3</sup> saving of cement.

**Proportion of volume of coarse and fine aggregate content:** From Table-3 (IS 10262:2009) volume of coarse aggregate to all in one aggregate corresponding to 20 mm size aggregate and fine aggregate (zone IV) for water-cement ratio of 0.50 was 0.66. For water-cement ratio is 0.45, volume of coarse aggregate adjusted by increasing 0.01 (at the rate of +/- 0.01 for every +/- 0.05 change in the water-cement ratio). Adjusted proportion of volume of coarse aggregate for the water-cement ratio of 0.45 was found 0.67. For high slump or pumpable concrete, proportion of volume of coarse aggregate was reduced by 10 % and final proportion of volume of coarse and fine aggregate was 0.603 and 0.397 respectively.

**Mix calculations:** For unit volume of concrete, volume of cement - 0.110 m<sup>3</sup>; volume of fly-ash - 0.032 m<sup>3</sup>; volume of water - 0.167 m<sup>3</sup>; volume of admixture (@ 0.2% by mass of cementitious material) - 0.00071 m<sup>3</sup>; volume of all in aggregate - [1 - (0.110 + 0.032 + 0.167 + 0.00071)] 0.691 m<sup>3</sup>; mass of coarse aggregate - (0.691 × 0.603 × 2.72 × 1000) 1133.350 kg and mass of fine aggregate - (0.691 × 0.397 × 2.76 × 1000) 757.14 kg

Similarly design mix proportions for 20%, 25%, 30% and 35% cement replacement by fly ash were calculated and required ingredients are given in Table 3.

### III. CONCLUSION

Water and cement content for high slump (100-120 mm) M20 grade design mix concrete were 197.16 l kg/m<sup>3</sup> and 438.13 kg/m<sup>3</sup> respectively. To minimise the water content, 0.2% Sika plastocrete – modified lignosulphate was used in the mix and same workability (115 mm) was achieved at 85% water content. Cement content for the same mix was reduced by 66.02 kg/m<sup>3</sup> of concrete. On 15% replacement of cement content by fly ash optimal result was found. In final mix of M20 grade high slump concrete mix, water and chemical admixture, Sika plastocrete super (modified ligno sulphonate) content per cu-m of concrete were 167.45 l and 744 ml respectively. Cementitious material content in same concrete was 306.99 kg/m<sup>3</sup> cement with 102.33 kg/m<sup>3</sup> fly ash resulting total 131.36 kg/m<sup>3</sup> saving in cement content.

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## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

Particulars	Ingredients	Water	Cement	Sand	CA	Density
Trial Mix II	kg/m <sup>3</sup>	197.16	358.47	789.23	1096.40	2441.26
	proportion	0.550	1.000	2.202	3.059	
Trial Mix III	kg/m <sup>3</sup>	197.16	325.88	820.72	1094.03	2437.79
	proportion	0.605	1.000	2.518	3.357	
Trial Mix IV	kg/m <sup>3</sup>	197.16	398.30	755.71	1094.00	2445.17
	proportion	0.495	1.000	1.897	2.747	
Final Mix	kg/m <sup>3</sup>	197.16	438.13	732.78	1088.66	2456.73
	proportion	0.450	1.000	1.673	2.485	

Ingredients with assumed reduction in water content	Water	Cement	Admixture	Fine aggregate	Coarse Aggregate	Slump Value
	(litre)	(kg)	(ml)	(kg)	(kg)	(mm)
10%	177.3	394	750.47	763.716	1143.191	145
15%	167.45	372.11	709.52	781.248	1169.434	115
20%	157.6	350.22	701	800.971	1198.956	85

Fly ash replacement	Ingredients	Water	Cement	Fly-Ash	Admixture (ml)	Sand	CA
15%	kg/m <sup>3</sup>	167.45	347.922	61.398	744	757.14	1133.35
	proportion	0.481	1.000	0.235	0.0021	2.176	3.257
20%	kg/m <sup>3</sup>	167.45	327.456	81.864	744	751.33	1124.65
	proportion	0.511	1.000	0.250	0.0022	2.294	3.434
25%	kg/m <sup>3</sup>	167.45	306.99	102.33	744	746.77	1117.83
	proportion	0.545	1.000	0.330	0.0024	2.432	3.641
30%	kg/m <sup>3</sup>	167.45	286.524	122.524	744	742.21	1111.01
	proportion	0.584	1.000	0.427	0.0026	2.59	3.877
35%	kg/m <sup>3</sup>	167.45	266.058	143.262	744	737.65	1104.17
	proportion	0.629	1.000	0.538	0.0028	2.772	4.150

# International Journal of Innovative Research in Science, Engineering and Technology

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