Journal of Civil Engineering and Environmental Technology
Print ISSN: 2349-8404; Online ISSN: 2349-879X; Volume 2, Number 7; April-June, 2015 pp. 630-634

http://www.krishisanskriti.org/jceet.html

Cost Deduction Analysis on High Strength Concrete

S. Purushothaman[1], G. Harri[2] and S. Lokesh[3]

[1,2,3]PG Student, Department of Civil Engineering Dhirajlal Gandhi College of Technology Salem
E-mail: [1]purushothamanb6@gmail.com, [2]sudharsann.92@gmail.com, [3]lokeshselvam@hotmail.com

Abstract—*The advancement of materials technology has led to production of higher grades of concrete strength. The application of High Strength Concrete in Civil Engineering structures has increased significantly, with economy, superior strength, increased stiffness and greater durability being the principal reasons for its popularity. This paper describes the way of developing high strength concrete (M60) in an economical way with water–cement ratio of 0.32 and total cementitious materials not less than 450kg. A polycarboxylate ether based super plasticizer was used with a dosage of 0.8% of total cementitious material was used. Cement was replaced by Silica Fume, Fly Ash and GGBS. Fine aggregate was replaced by M-sand, Crusher Dust and Granite powder. Mix designs were performed to achieve compressive strength of 60MPa with the above replacements. A mix design which satisfies both strength and cost were declared as economical. A total of 19 mix designs with 6 cubes (150mm x 150mm x 150mm) for each mix were tested.*

1. INTRODUCTION

Concrete was generally classified as Normal Strength Concrete (NSC), High Strength Concrete (HSC) and Ultra High Strength Concrete (UHSC). There was no clear cut boundary for the above classification. Indian Standard Recommended Methods of Mix Design denotes the boundary of 35 MPa between NSC and HSC. They did not talk about UHSC. But elsewhere in the international forum, about thirty years ago, the high strength label was applied to concrete having strength above 40 MPa. More recently, the threshold rose to 55 MPa as per IS 456-2000.

High strength concrete has been widely used in civil engineering in recent years. This was because most of the rheological, mechanical and durability properties of these materials were better than those of conventional concretes. High strength was made possible by reducing porosity, inhomogeneity and micro cracks in concrete and the transition zone. This can be achieved by using superplasticizers and supplementary cementing materials such as fly ash, silica fume, granulated blast furnace slag, and natural pozzolan. Fortunately, most of these materials were industrial by-products and help in reducing the amount of cement required to make concrete less costly, more environmental friendly, and less energy intensive.

Owing to numerous advantages, usage of HSC has been increasing day by day. It leads to the necessity of designing an economical HSC by using various Mineral and Chemical admixtures available locally. Cement and fine aggregates occupies greater cost in concrete. So we go for replacements. In this project cement was replaced by silica fume, fly ash and Ground granulated blast furnace slag. And fine aggregate was replaced by granite powder, manufactured sand and quarry dust. Mix proportions were designed by using above replacements. Cost analysis for each mix was performed and the economical one was found out.

2. LITERATURE BACKGROUND

Use of quality materials, smaller water-binder ratio, larger ratio of coarse aggregate (CA) to fine aggregate (FA), smaller size of coarse aggregate, and suitable admixtures with their optimum dosages were found necessary to produce HSC [1]. High strength concrete cannot be produced with the help of admixtures. Compressive strengths of 60 MPa, 70 MPa and 110 MPa at 28days were obtained by using 10 percent replacement of cement with SF[2]. Various combinations of a local natural pozzolan and silica fume were used to produce workable high to very high strength mortars and concretes with a compressive strength in the range of 69 to 110 MPa. Use of silica fume at 15% of the weight of cement was able to produce relatively the highest strength increase in the presence of about 15% pozzolan than without pozzolan [3].

High strength concrete with a 28-day compressive strength of 80 MPa was obtained with a w/b ratio of 0.24, and with a fly ash content of 45% [4]. Fly ash mortars with 40% cement replacement shows around 14% higher compressive strength than OPC mortar after 90 days curing. The corresponding increase in tensile strength was reported to be around 8%. Cement replacement level up to 50% exhibited satisfactory results for both compressive and tensile strength [5].

The compressive strength of concrete mixtures containing GGBS increased as the amount of GGBS increase. After an optimum point, at around 55% of the total binder content, the addition of GGBS does not improved the compressive strength [6]. The strength development of GGBS concrete was affected by the curing temperature. Low curing temperature would result in low early strength of GGBS concrete. For high temperature curing at 75◦C, the 28-day strengths all fell short of their design strength and there may be a need to limit the peak temperature of concrete in mass pours in practice. The

GGBS concrete would require a longer curing period than that of Portland cement concrete [7].

Granite powder contributed in the development of concrete industry as a replacement material. The mix with 25% granite powder enhances the compressive strength. When the ratio was increased beyond 25%, the strength got decreased gradually [8].

The compressive, flexural strength and Durability Studies of concrete made of Quarry Rock Dust are nearly 10% more than the conventional concrete [28].

3. MATERIALS USED

3.1 Cement

Cement used here was Ordinary Portland Cement of 53 grade (Dalmia Superoof). Specific gravity was found to be 3.15. Physical and chemical properties were confirming to IS: 12269–1987. Properties were given in Table 1.

3.2 Silica Fume

Silica fume (SF) has been recognized as a pozzolanic admixture that was effective in enhancing the mechanical properties to a great extent. In this study SF was obtained from M/s ELKEM Pvt Ltd, Mumbai, confirming to ASTM C1240. Properties of silica fume were given in Table 1, confirming to IS: 15388-2003.

3.3 Fly Ash

Fly ash (FA) class F in a dry powder form obtained from Thermal power plant, Mettur, confirming to IS: 3812-2013 was used in this project. Properties of FA were given in Table 1.

3.4 Ground Granulated Blastfurnace Slag

Ground granulated blast furnace slag (GGBS) was one such pozzolanic material which can be used as a cementitious ingredient in either cement or concrete composites. GGBS used in this project were confirming to BS: 6699- 1992 and their properties were given in Table 1.

3.5 Sand

Clean and dry river sand from Karur was used in this project. Sand passing through WAS 4.75 mm sieve was used for casting all the specimens. Specific gravity and fineness modulus was 2.49 and 2.75 respectively. Other properties were shown in Table 2.

3.6 Crusher Dust

Crusher dust obtained from local resource RG quarry, Salem was used in this project. Properties of crusher dust were shown in Table 2.

3.7 Granite Powder

Granite powder obtained from local granite stone cutting industry was used here. Their specific gravity and other properties are shown in Table 2.

3.8 Manufactured sand

M-Sand obtained from Namakkal was used in this project. They were used as a replacement for sand and their properties were shown in Table 2.

3.9 Coarse Aggregate

Crushed aggregate of 20mm and 12 mm obtained from local crusher were used in this project. Their properties were shown in Table 3.

3.10 Water

Locally available portable drinking water was used in this project which was free from impurities confirming to IS: 456–2000.

3.11 Super Plasticizer

As per Indian standards, the dosage of super plasticiser should not exceed 2% by weight of the cement. Polycarboxylate Ether based super plasticizer was used in this project. Auramix 400 from FOSROC combined the properties of water reduction and workability retention. It allows the production of high performance concrete and/or concrete with high workability.

Table 1: Properties of Cement, SF, FA and GGBS

Properties	Materials			
	Cement	SF	FA	GGBS
Specific gravity	3.15	2.21	2.08	
Silicon di oxide	19.5%	54%	92%	36%
Aluminium oxide	5.6%	23%	0.55%	21%
Ferric oxide	5.4%	4.6%	0.4%	0.2%
Calcium oxide	61%	3.5%	0.4%	33%
Magnesiumoxide	0.9%	2/8%	0.9%	9.3

Table 2: Properties of Fine Aggregates

Properties	Materials			
	sand	Crusher dust	M-Sand	Granite powder
Specific gravity	2.49	2.49	2.75	2.5
Fineness modulus	2.75	2.78	2.84	2.4
Density (kg/m3)	1600	2000	1750	2600
Absorption	1%	1.3	1.8%	0.7%

Table 3: Properties of Coarse Aggregate

Property	20mm	12mm
Specific gravity	2.87	2.66
Fineness modulus	4.1	3.98

4. MIX DESIGN

Mix designs were performed according to IS: 10269–2009 and IS: 456–2000 to achieve the target mean strength of 68MPa. Water–cement ratio of 0.32 and total cementitious content not less than 450kg and Super plasticizer of dosage 0.8% of weight of cement was maintained. Percentage of replacements were selected based upon the detailed study on literatures. M1 was a control mix without any replacements. In M2, M3 and M4, sand was replaced by 40%, 50% and 60% of crusher dust respectively. In M5, M6 and M7, sand was replaced by 50%, 75% and 100% of M- Sand respectively. In M8, M9 and M10, sand was replaced by 10%, 15% and 20% of granite powder respectively. In M11, M12 and M13, cement was replaced by 5%, 7.5% and 10% of silica fume respectively. In M14, M15 and M16, cement was replaced by 30%, 40% and 50% of GGBS respectively. In M17, M18 and M19, cement was replaced by 15%, 20% and 25% of fly ash respectively. Detailed mix proportions are given in Table 4

Table 4: Mix Proportions

Materials	Cement	SF	FA	GGBS	20mm	12mm	NRS	CD	M- Sand	Granite powder	Water	Admixture
M1	456	-	-	-	794	490	618	-	-	-	146	3.65
M2	456	-	-	-	794	490	371	247	-	-	146	3.65
M3	456	-	-	-	794	490	309	309	-	-	146	3.65
M4	456	-	-	-	794	490	247	371	-	-	146	3.65
M5	456	-	-	-	794	490	309	-	341	-	146	3.65
M6	456	-	-	-	794	490	155	-	512	-	146	3.65
M7	456	-	-	-	794	490	-	-	682	-	146	3.65
M8	456	-	-	-	794	490	556	-	-	62	146	3.65
M9	456	-	-	-	794	490	525	-	-	93	146	3.65
M10	456	-	-	-	794	490	494	-	-	124	146	3.65
M11	433	23	-	-	794	490	618	-	-	-	146	3.65
M12	422	34	-	-	794	490	618	-	-	-	146	3.65
M13	410	46	-	-	794	490	618	-	-	-	146	3.65
M14	319	-	-	137	794	490	618	-	-	-	146	3.65
M15	274	-	-	182	794	490	618	-	-	-	146	3.65
M16	228	-	-	228	794	490	618	-	-	-	146	3.65
M17	388	-	68	-	794	490	618	-	-	-	146	3.65
M18	365	-	91	-	794	490	618	-	-	-	146	3.65
M19	**342**	**-**	**114**		**794**	**490**	**618**	**-**	**-**	**-**	**146**	**3.65**

5. EXPERIMENTAL INVESTIGATION

5.1 Compression Test

The experimental investigation consisted of making M60 grade of concrete by using above mentioned mix proportions to determine the compressive strength of the concrete. The required materials were weighed and machine mixed. Cube specimen of sized 150mm x 150mm x150mm were casted. Six cubes for each mix proportions were casted. The specimens were de- molded after 24 hours of casting and cured in a tank for 28 days. Compression testing was done in Structural Engineering Laboratory of Dhirajlal Gandhi College of Technology using compression testing machine.

5.2 Cost Analysis

Cost analysis was done for each mix proportions by finding their rates per cubic meter. Control mix was compared with remaining mixes to found the economical one. Cost analysis for all mixes were given in Table 5.

Table 5: Cost Analysis

Mix design	Cost per m3 in Rupees
M1	5207.27
M2	5106
M3	5080.58
M4	5055.16
M5	5156.78
M6	5132.09
M7	5106.29
M8	5177.51
M9	5162.63
M10	5147.75
M11	5529.27
M12	5683.27
M13	5851.27
M14	5892.27
M15	6117.27
M16	6347.27
M17	4287.75
M18	4512.03
M19	4336.31

6. RESULTS AND DISCUSSIONS

Compression test results for all the mixes are graphically represented in Fig. 1. From the results of compression testing and cost analysis, we concluded that

- In the production of HSC, industrial wastes played a predominant role in replacement of cement and fine aggregates.
- For sand replacement, granite powder was proved economical and satisfied strength factor.
- For cement replacement, fly ash was economical and satisfied the strength factor.
- Overall replacement of cement with fly ash proved to be an economical way of developing M60 High strength concrete.

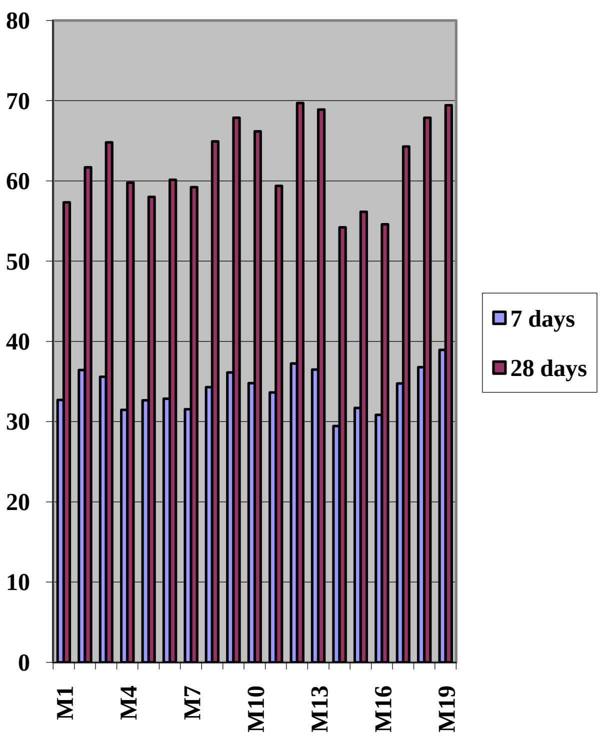

Fig. 1: Compression test Results

7. ACKNOWLEDGEMENTS

I have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals and organizations. I would like to extend my sincere thanks to all of them. I am highly indebted to Mr.G.Suresh, Assistant Professor, Dhirajlal Gandhi College of Technology, for his guidance and constant supervision as well as for providing necessary information regarding the project & also for his support in completing the project.

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