Experimental Study on Developing High Strength Concrete Mixes as per Indian Standard 10262: 2019

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Abstract - *The high strength concrete (HSC) is a special type of concrete, whereas it can resist loads more than that normal strength concrete (NSC) and also, it can increase the speed of construction, early removal of formwork provides early strength and better performance, when compared to NSC.*

In present study attempts to develop M70 grade HSC mixes using IS 10262:2019. Number of trials for HSC mixes were experimented utilizing marginal materials viz. Ground Granulated Blast Slag (GGBS) and Alccofine as filler. The GGBS content, water content and fine to coarse aggregate ratio were maintained; restricting the maximum size of coarse aggregates restricted to 20 mm. The percentage of alccofines (0% to 12%) and GGBS (20%) replace by weight of cement is kept constants for all the mixes. The water content is also kept constant by varying the water to cement ratio accordingly with replacement of alccofines for cement. The fresh properties (slump test) and hardened properties tests compression strength test, split tensile strength test, flexural strength test) on HSC mixes were carried out as per IS codes.

The test result shows that the HSC mixes can be developed by using IS 10262:2019 for given grade of concrete and these developed mixes satisfied both the fresh and hardened properties as per codal provisions. And also results shows that 10% alccofines replacement shows the better workability and strength, when compare to 12% replacement with constant GGBS.

Key Words: Alccofine, Compressive strength, Flexural strength, High Strength Concrete, IS 10262 2019, Split Tensile strength.

1. INTRODUCTION

Concrete is the most used construction material in the world [1]. Now the concrete has transformed itself into advanced type with new innovative ingredients added either singly or in combination. The traditional four ingredients used in mix of concrete are cement, water, fine aggregate, coarse aggregate which is basically followed from past [1]. Basically, the modifications adding new ingredients like chemical and mineral admixtures were meant to increase the features of concrete in the backdrop of rapidly growing concrete construction, rate of urbanization, industrialization, and demand for the requirement of new properties [2]. While in last few decades it has been seen that construction of many high-rise structures, earthquake resistant structures, long-span structures, precast concrete structures etc., they are constructed rapidly and hence require more strong and durable concrete [3].

Whereas high strength concrete (HSC) offers the outstanding engineering properties, such as higher compressive and tensile strengths, higher stiffness, and better durability, when compared to the conventional normal strength concrete (NSC). From a historical point of view, in the middle of the 20th century concrete with characteristic strength (fc) of 30MPa was considered high strength [4] and later in 1980's, 50MPa concrete was considered high strength. Nowadays, technology for producing HSC has sufficiently advanced such that concretes with compressive strengths of up to about 120MPa are commercially available, and strengths much higher than that can be produced in the laboratories. The significant economic advantages of HSC are very well-documented, and evident from the number of recent construction projects where HSC has been used successfully [4]. Generally, HSC is contemplated in structures over 30 stories, and it is a type of special concrete, which has made such projects possible due to load capacity, it has also allowed for the decrease in dimensions of columns and beams. As consequence of lower dead loads it alternately reduces the loads included with foundation design [5,6]. HSC is rarely used in construction of bridges. HSC allows RCC or prestressed concrete girders to span higher in lengths than usual strength concrete girders. Also, the bigger individual girder capacities may assist in decrease of the number of girders needed. Thus, a cost-effective benefit is formed for concrete manufacturers. In the urge of production of concrete with high strength at the same, time to also make it economical [7]. This led to various research begun to produce concrete with higher strength where workability was a major challenge and use of superplasticizer (SP) made it possible and paved way for production of HSC [7].

Though a number of studies have considered the development of a rational or standardized method of concrete mix design for HSC [8], no widely accepted method is currently available. The main requirements for successful and practical HSC are a low water/cement (w/c) ratio combined with high workability and good workability retention characteristics. However, there are very few mix proportion methods are established namely ACI methods and Erntroy and Shacklock's Empirical Graphs methods, towards developing the HSC mixes [8]. In India, recently, Bureau of Indian Standard (BIS) has revised the guidelines IS: 10262-2019 [9] for design and development of concrete mixes and for the first time included the mix design method for HSC.

2. Mix Proportioning of High Strength Concrete as per IS 10262:2019

A brief procedure for mix proportioning of HSC is as per revised code is discussed here. Based on the required grade of concrete to be proportioned, a target strength of HSC is determined (cl. 4.2). Depending on the maximum size of aggregate, air content is determined (cl. 6.2.3). The water content is selected from the Table 7of IS Code (cl. 6.2.4) which is based on size of coarse aggregate. The water content is selected from a particular range and further may be reduced based on use of SP. The SP content may be determined using Marsh cone test. The cement content is determined by using the water/cementitious ratio (Table 8 of IS Code) and further the filler may be used to replace cement based on the type of filler. Based on the type of filler, the code provides percentage of replacement by replacement of cement (Table 9 of IS code). Then determine the volume of coarse and fine aggregates, starts the trial mixes.

3. EXPERIMENTAL PROGRAM

3.1 Materials

The list of constituent materials and their corresponding properties are tabulated in Table 1.

Table 1: Material properties

Materials	Specific Gravity	Specific Surface (m^2/kg)	Water Absorption (%)	Remarks
Cement	3.14	290	-	OPC-53 grade; (conforming IS:12269-2013 [10])
Fine aggregate	2.70	-	3.00	Manufacturing sand used as fine aggregates; (confirming Zone-II - IS 383-2016 [11])
Coarse aggregate	2.65	-	0.90	Crushed angular coarse aggregate passing 20 mm and 12.5mm downsize.
GGBS	2.90	425	-	Confirming to IS 16714-2018[12]
Alccofine (AF)	2.87	1000	-	-
Superplasticizer (SP)	1.09	-	-	Polycarboxylic Ether (PCE) based: (confirming to IS 9103 [13])
Water	1.00	-	-	Portable water – pH 7.7 (Conforming to IS 456 – 2000 [14])

All the materials were procured from a single source in sufficient quantity to ensure enough availability of material throughout the experimental program and stored in air-tight containers. The natural coarse aggregate used was crushed granite stone which was angular and all marginal materials were procured form nearby market place. The maximum size of the aggregates used was 20mm. Manufactured sand confirming zone-II requirements was used as a fine aggregate and its gradation curve is presented in Figure 1.

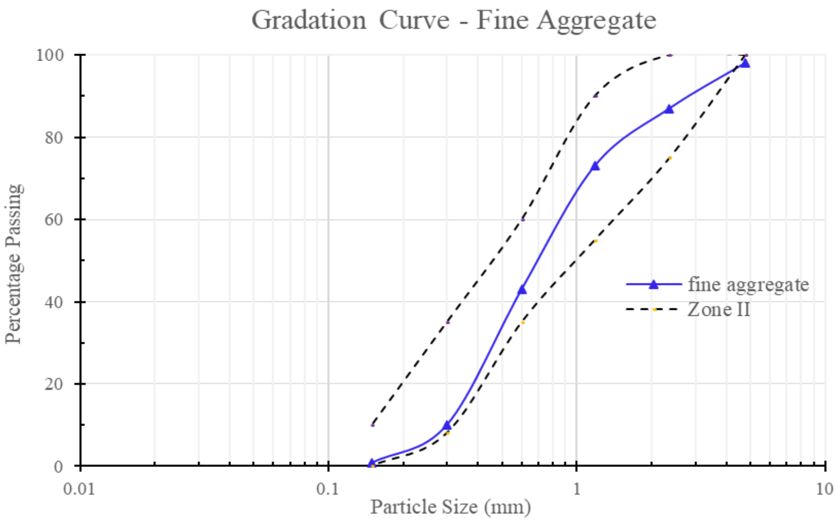

Figure 1. Grading curve of fine aggregate

3.2 Mix Design

The M70 grade of HSC mix has been designed based on Indian standard IS: 10262-2019 [9]. The details are presented through the flow chart (Figure 2) and brief discussion below.

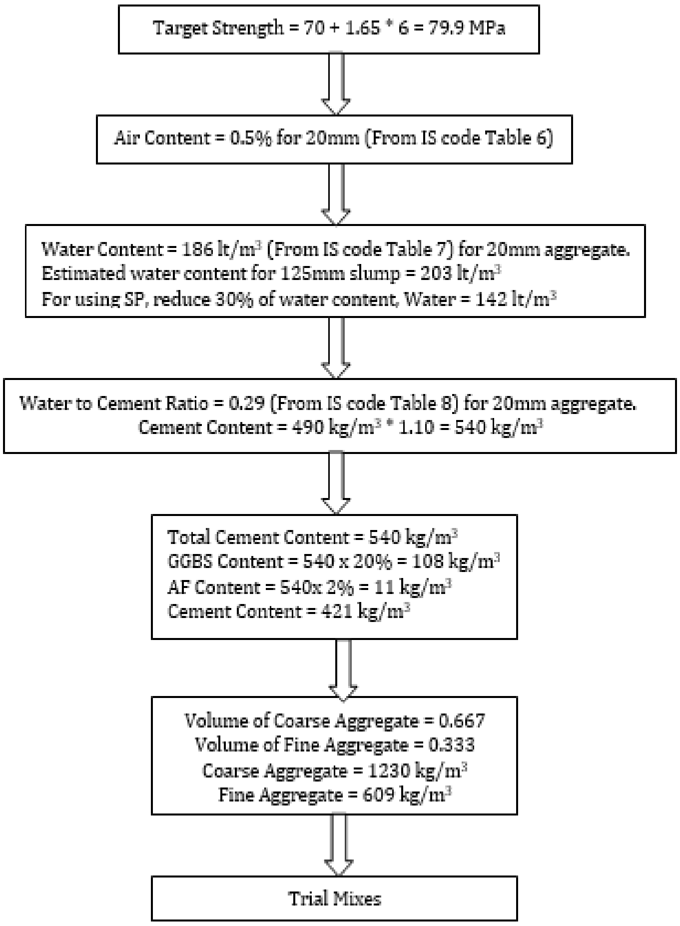

Figure 2. Flow chart representing the mix design for M70 grade HSC

Based on the IS code procedure, there are about Twelve different trial mixes were developed to obtain desired slump value. The Table 2 shows trial mix proportion details.

Table 2: Details of Trial Mixes (by Mass)

Mixes	Cement (kg/m³)	GGBS (kg/m³)	AF (kg/m³)	Fine Aggregate (kg/m³)	Coarse Aggregate (kg/m³)	Water (lt/m³)	SP (%)	Slump (mm)
TM1	431	108 (20%)	-	609	1230	142	0.60	90
TM2	420	108 (20%)	11 (2%)	609	1230	142	0.55	0
TM3	301	216 (40%)	22 (4%)	609	1230	142	0.55	80
TM4	431	108(20%)	-	609	1230	142	0.00	0
TM5	431	108(20%)	-	609	1230	142	0.20	40
TM6	420	108(20%)	11(2%)	609	1230	142	0.30	0
TM7	420	108(20%)	11(2%)	609	1230	150	0.40	20
TM8	409	108(20%)	22(4%)	609	1230	150	0.55	60
TM9	301	216(40%)	22(4%)	609	1230	142	0.55	20
TM10	420	108(20%)	11(2%)	609	1230	142	0.55	80
TM11	448	81 (15%)	11(2%)	609	1230	142	0.52	25
TM12	448	81 (15%)	22(4%)	609	1230	142	0.52	0.00

Based on the trial mixes, varying the percentage of alccofines from 0% to 12% by weight of cement. The GGBS content is keep (20% replace by cement) constant for all the mixes. The water content is also kept constant by varying the W/C ratio accordingly with replacement of alccofines for cement. The reference mix details are given in Table 3.

Table 3: Details of Mix Proportions of HSC mixes (by Mass)

Mixes	Cement (kg/m³)	GGBS (kg/m³)	AF (kg/m³)	Fine Aggregate (kg/m³)	Coarse Aggregate (kg/m³)	Water (lt/m³)	SP (%)	w/c
M1	431	108 (20%)	0	609	1230	142	0.60	0.330
M2	420	108 (20%)	11 (2%)	609	1230	142	0.55	0.338
M3	409	108 (20%)	22 (4%)	609	1230	142	0.55	0.347
M4	398	108 (20%)	33 (6%)	609	1230	142	0.55	0.356
M5	387	108 (20%)	44 (8%)	609	1230	142	0.55	0.367
M6	376	108 (20%)	55 (10%)	609	1230	142	0.55	0.377
M7	365	108 (20%)	66 (12%)	609	1230	142	0.55	0.389

3.3 Test Details

The fresh properties of HSC mixes were ascertained by slump test and flow table test as per IS 1199: 1959 [15]. The hardened properties tests like compressive strength test on cube and cylinder specimen, split tensile test and flexural test were conducted as per IS 516-1959 and IS 5816-1999[16,17].

4. RESULTS AND DISCUSSION

4.1 Fresh Properties

Workability of concrete is determined by slump test and flow table test as per IS 1199: 1959 [15]. Table 4 shows the different values of slump for different mix proportion.

Table 4: Fresh Properties of HSC Mixes

Mixes	Cement (kg/m³)	GGBS (kg/m³)	AF (kg/m³)	Fine Aggregate (kg/m³)	Coarse Aggregate (kg/m³)	Water (lt/m³)	SP (%)	w/c	Slump (mm)	Flow (mm)
M1	431	108	0	609	1230	142	0.60	0.330	90	120
M2	420	108	11	609	1230	142	0.55	0.338	0	100
M3	409	108	22	609	1230	142	0.55	0.347	50	90
M4	398	108	33	609	1230	142	0.55	0.356	30	120
M5	387	108	44	609	1230	142	0.55	0.367	60	110
M6	376	108	55	609	1230	142	0.55	0.377	75	130
M7	365	108	66	609	1230	142	0.55	0.389	50	120

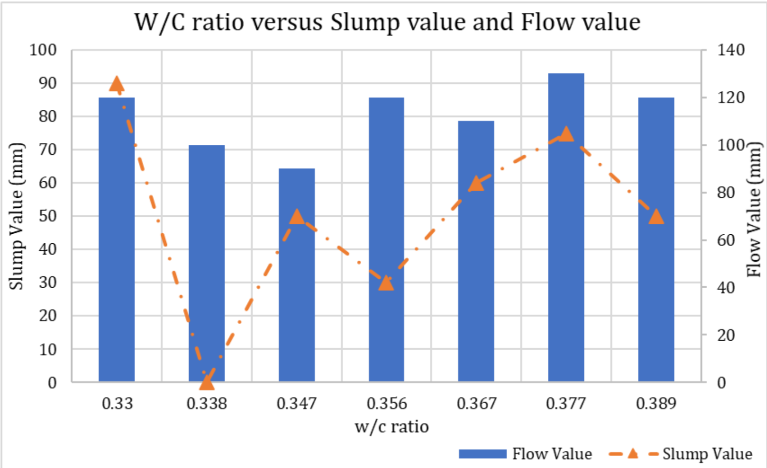

Figure 3. Relationship between W/C ratio versus slump & Flow values

Figure 3 shows the relation between W/C ratio versus slump and flow values for HSC mixes. It can be observed that mix M1 have lower w/c ratio, it exhibits maximum slump value about 90mm and 120mm flow value. It is clearly showing the affect of alccofines and SP on fresh properties of concrete. When replacing the alccofines the slump value gradually decreases, it can be observed from the Figure 3. The mix M6 showing a better workability when compare to the other mixes.

4.2 Compressive Strength Test

Compression strength test were performed on compression testing machine of 2000 KN capacity. Cube and cylinder specimens casted to determine compressive strength at the age of 7 and 28days. The specimens were de-moulded 24 hours after casting and were cured under water at 27 ± 2°C until the test age. The tests were conducted as per the codal provisions of IS 516-1959[16]. Table 5 shows the cube compressive strength at different ages of curing period of 7 and 28 days respectively.

Table 5: Average Compressive Strength of Cubes and Cylinder at 7 and 28 days

Mix No	W/C Ratio	Cube Compressive Strength (MPa)		Cylinder Compressive Strength (MPa)	
		7 days	28 days	7 days	28 days
M1	0.330	57	71	45	60
M2	0.338	52	64	42	51
M3	0.347	56	73	45	53
M4	0.356	58	75	47	55
M5	0.367	60	78	48	59
M6	0.377	63	80	52	66
M7	0.389	55	68	43	52

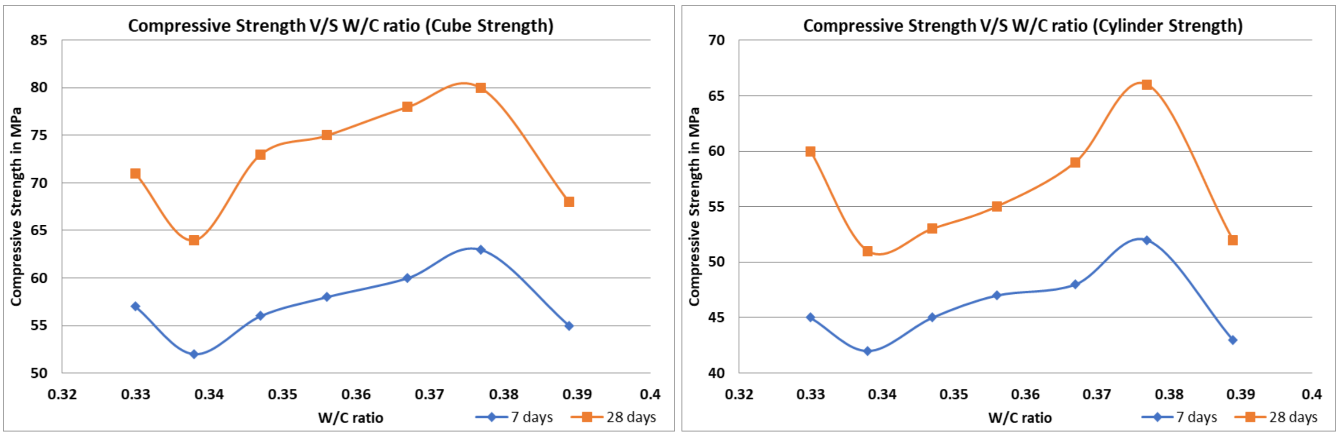

Figure 4. Relationship between W/C ratio versus compressive strength of HSC mixes

It was observed that from the Figure 4, the 7 days compressive strength is varying from 56 MPa to 63 MPa and value decrease to 52MPa. The same observation can be seen from Figure 4, for 28 days the compressive strength value varying from 71MPa to 80MPa, then the value decrease to 64MPa. This may be due to the optimum values of alccofines above 10% it does not contribute strength. The same trend also seen in some of the published literatures [5,7].

4.3 Split Tensile Strength Test

The tests were conducted as per the codal provisions of IS 5816-1999 [17]. Table 4 shows the split tensile strength of HSC mixes at 28 days.

Table 4: Average Split Tensile Strength Values at 28 days

Mix No	W/C Ratio	Split Tensile Strength (MPa)
M1	0.330	3.6
M2	0.338	5.0
M3	0.347	4.7
M4	0.356	4.2
M5	0.367	4.5
M6	0.377	4.0
M7	0.389	4.1

The Table 4 shows, it can be noticed that even though for mix M2 shows maximum tensile strength when compare to other mixes. It clearly indicates that there is an increase in tensile strength of concrete up to 10% replacement of alccofine and replacing above 10% will the tensile strength values decreases.

4.4 Flexural Strength Test

The tests were conducted as per the codal provisions of IS 516-1959 [16]. Table 5 shows the flexural strength of mixes at 28 days.

Table 5: Average Flexural Strength Values at 28 days

Mix No	W/C Ratio	Split Tensile Strength (MPa)
M1	0.330	5.8
M2	0.338	5.2
M3	0.347	5.5
M4	0.356	6.0
M5	0.367	6.2
M6	0.377	6.3
M7	0.389	5.4

From the Table 5, it clearly indicates that there is an increase in flexural strength of concrete up to 10% replacement of alccofine and replacing above 10% will the flexural strength values decreases.

5. CONCLUSIONDING REMARKS

The test result shows that the HSC mixes can be developed by using IS 10262:2019 for given grade of concrete and developed mixes satisfied both the fresh and hardened properties as per codal provisions. The 10% alccofines replacement shows the better workability and strength, when compare to 12% replacement with constant GGBS.

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