A CRITICAL APPRAISAL OF THE PROPERTIES OF SCC WITH BLENDED CEMENT

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ABSTRACT

Concrete is the most important and versatile engineering material and with increase in trend towards the wider use of concrete for a number of applications in construction, there is a growing demand of concrete with higher compressive strength. Advancement in technology demand certain properties of the concrete related to strength and durability to be improved to a greater extent; particularly mineral admixtures are indispensible in production of high strength concrete (HSC) for practical applications. One of the types of concrete now-a-days being used in construction is Self Compacting Concrete (SCC) which is a paramount advancement within concrete technology having a major impact on concrete practices.

In this view, a review was done on various properties of SCC with blended cement. The present paper explores the recent innovations in SCC and the reviewed literature broadly signifies and focuses on use of innovative materials in SCC and their effect on fresh, mechanical, non-destructive, sulphate and chloride attack properties of SCC to find out the advantages and disadvantages of using SCC in practice. The reviewed literature indicates broad variation in behavior and performance of various properties of SCC containing different innovative materials.

Keywords: *Blended cement, Compressive strength, Durability, Self Compacting Concrete, Workability*

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1. INTRODUCTION

Cementitious materials made of Portland cement are the composite materials with utmost significance in the construction industry due to their enormous applications. The increasing world population and tremendous technological & industrial advancement leading to massive infrastructure requirement has further increased the demand of cement. Concrete being one of the most important elements for any kind of construction work; is the only material exclusive to the construction business and hence, it is the beneficiary of a fair proportion of the R&D money from industry. Concrete is a nano-structured, complex, multi-phase, composite construction material composes primarily of aggregate (fine and coarse), cement, water, and additives if any.

One of the types of concrete now-a-days being used in construction is Self Compacting Concrete (SCC) which is a significant advancement within concrete technology having a major impact on concrete practices. As one of the colossal developments in concrete technology, SCC is in the process of casting without imposing additional vibrating forces, and only gravity is necessary to completely fill the mould cavity to form a uniform dense concrete.

The concept of SCC was firstly given in 1986 by Okamura, a scholar from the University of Tokyo in which he pointed out that the reduction of Japanese skilled workers has a negative impact on the durability of the concrete structure, and proposed developing SCC which can avoid the impact of construction quality. SCC is a kind of concrete which is characterized by high workability. Soon after, Ozawa, a scholar from the University of Tokyo,

carried out the study of self-compacting concrete, and made up SCC successfully in 1988 [1-3]. Thus, SCC is widely recognized as a high-performance concrete which introduces benefits in workability, durability, reductions of labor cost and higher strength properties compared to those of normally vibrated concrete. It involves not only high deformability but also resistance to segregation between coarse aggregate and mortar when concrete flow through confined zone of reinforcing bars. Filling ability, passing ability and segregation resistance are the fundamental fresh properties for SCC. It can be used for in-situ applications as well as for precast production. SCC has different proportions as compared to conventional concrete in a way that SCC has more fine aggregates as compared to course aggregates and super plasticizer can be used to enhance the workability. To check the workability of SCC mix various tests are performed such as slump flow, V funnel, U box, L box, and J ring. To ensure high fluidity, resistance to segregation and bleeding problems at some stage in transportation and placing, use of high amount of fine materials and viscosity modifying admixtures(VMA) have been recommended by the researchers. Cement content is decreased to make concrete economical and environment friendly. Supplementary cementitious materials (SCM) are used as its replacement such a fly ash, silica fume, metakaolin, iron slag, rice husk ash, ground granulated blast furnace slag (GGBFS) etc. Therefore, use of these types of mineral additives in SCC will make it possible, not only to decrease the cost of SCC but also to increase its long-term performance.
Basic recommendations to achieve self compactibility are:

(a) Limited coarse aggregate content.
(b) Limited fine aggregate content in mortar.
(c) Low water/powder ratio.
(d) High dosage of super plasticizer.

The EFNARC [4, 6] provides the need for workability which should be satisfied to fall under the category of SCC. According to Mehta et al. [5] the three fundamental elements for supporting an environmentally-friendly concrete technology for sustainable development are the conservation of primary materials, the enhancement of the durability of concrete structures, and a holistic approach to the technology.

2. BLENDED CEMENT

Blended cement is a uniform blend obtained by mixing OPC with mineral admixtures or additives like fly ash, slag or silica fumes. Blended cements are now being considered superior as compared to conventional OPC category of cements. They are being manufactured and used at a large scale in many countries including India. Presently in India, about 30% of the total production is blended cement. With the advanced applications there are various advantages of blended cement which can be summarized as follows:

- It reduces water demand thereby reducing the w/c ratio.
- It improves workability for the same water content.
- The blended cements are finer as compared to the OPC and have improved durability and reduced permeability in concrete.
- Blended cements are obtained by adding admixtures or other additives to OPC and the energy is being saved to large extend during this process of production.
- By using the industrial wastes and other resources, the natural minerals like lime, stone, clay, silica, etc are conserved.
- By reducing the production of cement; pollution is controlled as cement is an energy intensive product. It has been estimated that 7% of total present pollution is only due to cement production which can proportionately be reduced if more blended cement is used.

3. GGBFS (ALCCOFINE)

Alccofine is a specially processed product based on slag of high glass content with high reactivity obtained through the process of controlled granulation. The raw materials are composed primary of low calcium silicates. The processing with other select ingredients results in controlled particle size distribution (PSD). The computed blain value based on PSD is around 12000cm^2/gm and is truly ultra-fine. Due to its unique chemistry and ultra-fine particle size, alccofine provides reduced water demand for a given workability, even up to 70% replacement level as per requirement. Alccofine also consumes by product calcium hydroxide from the hydration of cement to form additional C-S-H gel, similar to pozzolans.

4. LITERATURE REVIEW

4.1 Fresh Properties

Boukendakdji et al. (2012) examined the inclusion of granulated blast furnace slag by substitution to cement and found it to be very beneficial for fresh self-compacting concrete. Five mixes were prepared with 0%, 10%, 15%, 20%, and 25% cement replacement by blast furnace slag and two types of super plasticizer were added. One was polycarboxylate based super plasticizer (SP1) and another was naphthalene sulphonate based super plasticizer (SP2). Tests were conducted for fresh properties such as flowability, passing ability and segregation resistance. The fresh concrete compositions are shown in Table 1 [7].

Table 1: Fresh Concretes Compositions [7]

Mixture	SCC1	SCC2	SCC3	SCC4	SCC5
Cement	465	420	397	374	352
Slag (%)	0	10	15	20	25
(kg/m^3)	0	44	66	88	110
Coarse aggregate (3/8) (kg/m^3)	280	280	280	280	280
Coarse aggregate (8/15) (kg/m^3)	560	560	560	560	560
Fine aggregate (kg/m^3)	867	867	867	867	867
Water (kg/m^3)	186	185	185	185	185
Super Plasticizer SP1 (%)	1.6	1.6	1.6	1.6	1.6
(kg/m^3)	7.44	7.42	7.40	7.39	7.38
SP2 (%)	1.8	1.8	1.8	1.8	1.8
(kg/m^3)	8.37	8.35	8.33	8.32	8.32

Note: SP1: polycarboxylate based super plasticizer
SP2: naphthalene sulphonate based super plasticizer.

With the experiments conducted, it was predicted that SP1 gave more workability and acceptable values of all fresh properties as suggested by EFNARC [6] at all ages to concrete mixes than SP2. The optimum content of blast furnace slag was found to be 15%.

Khaleel et al. (2011) studied the effect of coarse aggregate properties on self-compacting concrete. They used three types of coarse aggregates namely crush gravel, uncrushed gravel and crush limestone. Slump flow, U-Box, V-Funnel and L-Box tests were performed to determine workability of concrete mix [8]. Twelve various mixes were prepared as shown in Table 2.

Table 2: Mixes involved in the study [8]

Mix No.	C (kg/m^3)	MK (kg/m^3)	W(kg/m^3)	SP (% of cement weight)	S(kg/m^3)	CA(kg/m^3)	CA type	CA max. size
CU10	500	0	170	0.85	865	885	uncrushed	**10**
CU20	500	0	170	0.80	865	885	uncrushed	**20**
C10	500	0	172	0.95	865	885	crushed	**10**
C20	500	0	172	0.90	865	885	crushed	**20**
CL10	500	0	172	1.00	865	885	limestone	**10**
CL20	500	0	172	0.95	865	885	limestone	**20**
MU10	450	0	175	1.70	865	885	uncrushed	**10**
MU20	450	0	175	1.65	865	885	uncrushed	**20**
MC10	450	0	175	1.85	865	885	crushed	**10**

MC20	450	0	175	1.80	865	885	crushed	**20**
ML10	450	0	173	1.80	865	885	limestone	**10**
ML20	450	0	173	1.75	865	885	limestone	**20**

Note: W is water that is used in the mixes.

Various figures 1, 2, 3 and 4 indicate T50 time, V-Funnel time, blocking ratio and U-Box height difference.

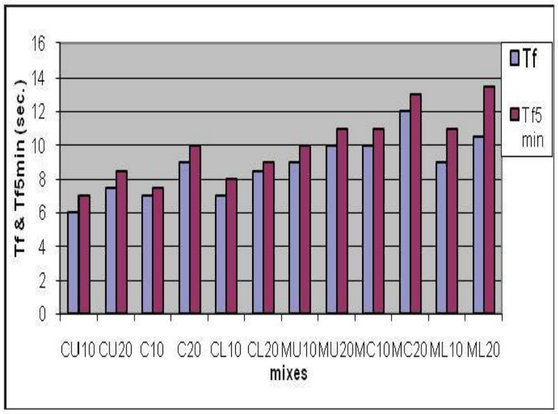

Fig.1: Tf and Tf5 min (sec.) for all mixes

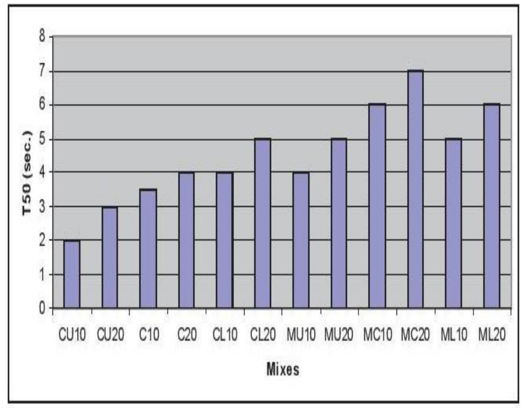

Fig.2: Time required passing (50 cm Dia.) Circle

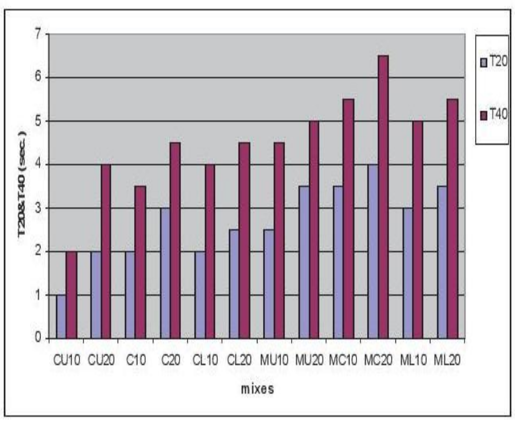

Fig.3: Tf and Tf5 min (sec.) for all mixes

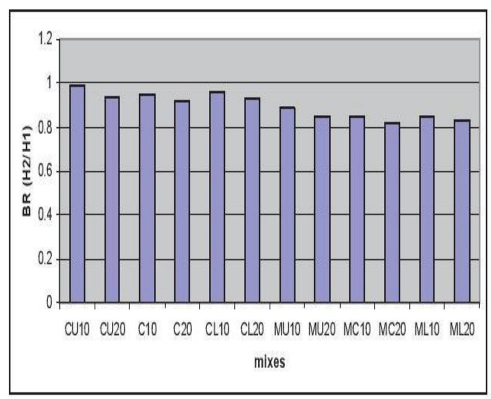

Fig.4: Results of BR for all mixes

It has been concluded that flowability decreases with the use of crushed aggregates and increasing the maximum size of coarse aggregate with the same dose of superplasticizer and water-powder ratio. A partial replacement of cement by 10% metakaolin leads to a decrease in flowability and an increase in viscosity.

Siddique (2011) prepared a report on results of various fresh properties of SCC. The various tests like Slump flow, U-Box, L-Box, V-Funnel and j-ring were performed on five mixes of concrete. Class F Fly ash was used as a supplementary cementitious material with 15%, 20%, 25%, 30%, and 35% cement replacement by weight. A polycarboxylic ether based superplasticizer complying to ASTM C 494 type F was used. Slump flow time (T50 time) for all mixes was less than 4.5 seconds. All the other properties were acceptable as per EFNARC standard. The various results were given as in the Table 3 [9].

Table 3: Fresh Properties of SCC mixes [9]

Mix	**Slump Flow**		**J-Ring**		**V-Funnel**		**L-Box**			**U-Box**	
	Dia. (mm)	**T_{50cm} (s)**	**Dia. (mm)**	**h_2-h_1 (mm)**	**T_{10s} (s)**	**T_{5min} (s)**	**T_{400mm} (s)**	**T_{600mm} (s)**	**T_L (s)**	**(h_2/h_1)**	**(h_1-h_2) (mm)**

SCC1	673.3	4.5	586.7	2.3	7.5	15	3.5	8.3	11.9	0.89	20
SCC2	690.0	3.0	580.0	6.7	4.5	5.1	1.4	2.4	3.5	0.95	10
SCC3	603.3	4.4	540.3	37.0	5.2	7.6	0.5	1.3	2.4	0.85	40
SCC4	673.3	3.0	626.7	3.0	6.1	9.5	1.2	2.2	4.0	0.95	5
SCC5	633.3	4.0	556.7	7.0	10.0	18.5	2.8	4.8	6.9	0.92	20

Halit Yazıcı (2008) replaced the cement with Class C Fly ash and silica fume in various proportions. Total powder content was 600 kg/m^3. Nine different concrete mixes were prepared including one control mix. In H series, cement was replaced as 30%, 40%, 50% and 60% by weight of fly ash. In HS series silica fume and fly ash both replacements are implemented. Silica fume replacements has been made at constant ratio (10%) while fly ash was replaced in the same manner such as 30%, 40%, 50% and 60%. Water/binder ratio was kept constant as 0.28.Apolycarboxylate based superplasticizer confirming the standard of ASTM C 494 Type F was used. It was observed that slump flow vary between 700 mm to 825 mm. In H series T50 time increases with increased content of fly ash. All concrete mixes confirm the fresh properties suggested by EFNARC except H50 and H60 mixtures. Various properties of fresh concrete were given as shown in Table 4 [10].

Table 4: Properties of Fresh Concrete [10]

Series	FA (%)	SF (%)	Flow (mm)	T50 (s)	V-box(s)	Air Temp. (°C)
C	0	0	710	3.5	20	30
H30	30	0	785	3.5	18	25
H40	40	0	750	4.5	23	27
H50	50	0	800	5	42	24
H60	60	0	780	7.5	35	18
HS30	30	10	825	3.5	12	30
HS40	40	10	765	4	18	29
HS50	50	10	775	3.5	19	26
HS60	60	10	780	4	16	30

4.2 Mechanical & Non-Destructive Properties

Suthar and Shah (2013) examined the strength development of high strength concrete containing Alccofine and fly ash as cement replacement. Class F fly ash in various proportions 0%, 20%, 25%, 30%, 35% and Alccofine as 0%, 4%, 6%, 8%, 10%, 12%, and 14% by weight of cement was replaced. Water binder ratio was fixed to 0.4 and a new generation polycarboxylic ether based super plasticizer was introduced. The total binder content was 425 kg/m^3.

Compressive strength was determined at 56 days. The ternary system such as cement-fly ash-Alccofine concrete was found to have more compressive strength at all ages when compared to concrete made with fly ash and Alccofine alone. The mix composition and results studied were as shown in Table 5, 6 and 7 [12].

Table 5: OPC +Alccofine (W/C=0.4, Water =170 Kg)

Mix No.	Materials				Strength (MPa)
	OPC (kg)		ALCCOFINE (kg)		
1	100%	425.0	0%	0.0	32.1
2	96%	408.0	4%	17.0	35.41
3	95%	387.6	5%	20.4	37.94
4	94%	364.3	6%	23.3	40.44
5	93%	338.8	7%	25.5	44.81
6	92%	311.7	8%	27.1	41.24
7	91%	283.7	9%	28.1	34.14
8	90%	255.3	10%	28.4	34.09
9	89%	227.2	11%	29.1	33.15

Table 6: OPC+Flyash (W/C=0.4, Water =170 kg)

Mix No.	Materials				Strength (MPa)
	OPC (kg)		FLYASH (kg)		
10	100%	425.0	0%	0.0	32.1
11	80%	340.0	20%	85.0	41.5
12	75%	255.0	25%	85.0	45.7
13	70%	178.5	30%	76.5	40.2
14	65%	116.0	35%	62.5	38.6

Table 7: OPC+ Alccofine + Flyash (W/C=0.4, Water =170 kg)

Mix No.	Materials						Strength (MPa)
	OPC (kg)		ALCCOFINE (kg)		FLYASH (kg)		
15	100%	425.0	0%	0	0%	0.0	32.1
16	70%	297.5	6%	25.5	20%	85.00	41.60
17	65%	276.25	6%	25.5	25%	106.25	42.49
18	78%	331.5	6%	25.5	30%	127.50	40.06
19	76%	323.0	7%	29.75	20%	85.00	43.84
20	73%	310.25	7%	29.75	25%	106.25	50.74
21	71%	301.75	7%	29.75	30%	127.50	42.39
22	70%	297.50	8%	34.00	20%	85.00	37.78
23	65%	276.25	8%	34.00	25%	106.25	40.19
24	78%	331.5	8%	34.00	30%	127.50	36.42

Gritsada and Makul (2013) investigated the properties of SCC comprising Portland cement (OPC), untreated rice husk ash (RHA) and pulverized fuel ash (FA) as ternary combinations. RHA and FA were used as a replacement of 20% or 40% by weight of cement. Total powder content was 550 kg/m^{3}. It was observed that ultrasonic pulse velocity decreased with increase of RHA and FA content. Mix proportions of SCC and results for UPV test were as shown in Table 8 which is also depicted by the graph in Figure 5 [11].

Table 8: Mix proportions of SCC and results for UPV test

Mix	**Materials (kg/m^3)**						**HRWR (%)**
	Cementitious				**Aggregate**		
	Total powder	**Cement**	**Rice husk ash**	**Pulverized fuel ash**	**Fine**	**Coarse**	
Control	550	550	0	0	813	708	2.0
RHA20	550	440	110	0	813	708	2.0
RHA40	550	330	220	0	813	708	2.0
FA20	550	440	0	110	813	708	2.0
FA40	550	330	0	220	813	708	2.0
RHA10FA10	550	440	55	55	813	708	2.0
RHA20FA20	550	330	110	110	813	708	2.0

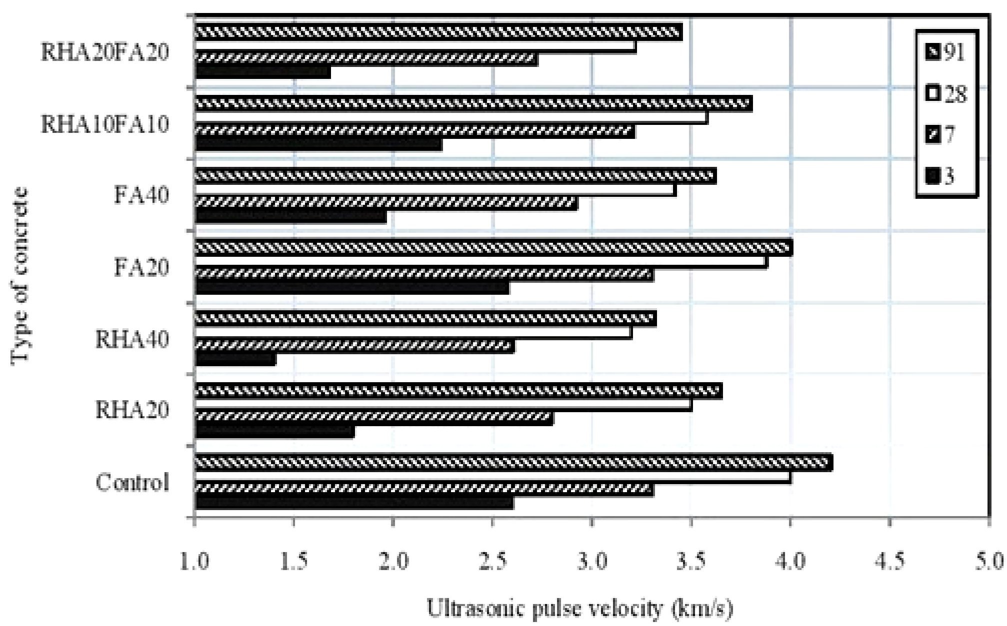

Fig.5: Relation of different types of concrete with the Ultrasonic Pulse velocity (km/s)

Boukendakdji et al. (2012) studied compressive strength of self-compacting concrete replacing Portland cement with blast furnace slag. They prepared five mix proportions, of which one is control, and four were prepared by replacing cement with 10%, 15%, 20% and 25% of blast furnace slag. Polycarboxylate based superplasticizer and naphthalene sulphonate based super plasticizers were used. It was observed that out of these polycarboxylate based superplasticizer concrete mix gave higher compressive strength at all ages. Compressive strength decreases with increase of slag content at early ages when compared to vibrated concrete but it become less important at later ages (56 and 90 days). Variation of compressive strength was shown as below in figure 6 [13].

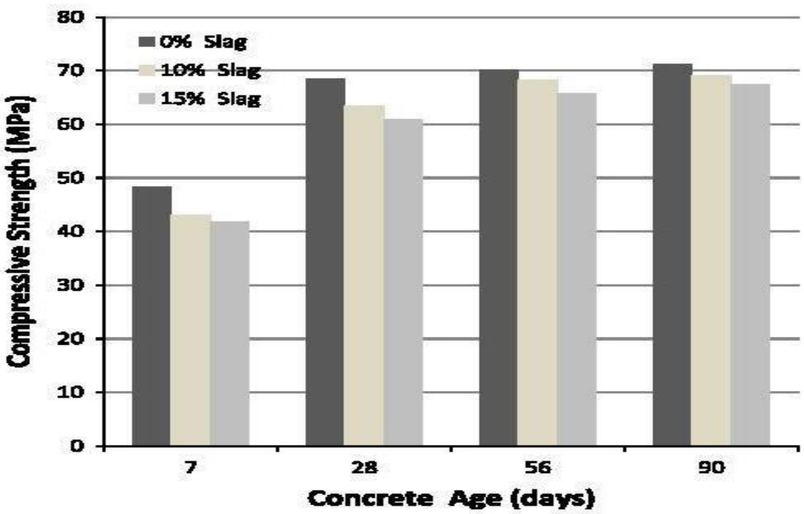

Fig.6: Variation of compressive strength (MPa) with concrete age (days)

Siddique et al. (2012) studied the influence of water/powder ratio on strength properties of self compacting concrete containing coal fly ash and bottom ash. Fine aggregates were replaced by coal bottom ash while cement was replaced with fly ash. Twenty concrete mixes were prepared with varying percentage of bottom ash as 0%, 10%, 20% and 30% and fly ash as cement replacement from15% to 35%. Total powder content was 550 kg/m^3. Mix compositions of concrete were summarized as shown below in Table 9and 10 while the Figures 7, 8 and 9 respectively gives the strength variations versus the water/powder ratio with different bottom ash contents at ages of 28, 90 and 365 days [14].

Table 9: Mix composition for 0% and 10% bottom ash mixes

Mix	0% Bottom ash					10% Bottom ash				
	M01	M02	M03	M04	M05	M101	M102	M103	M104	M105
Cement (kg/m^3)	465	440	415	385	355	465	440	415	385	355
Fly ash (kg/m^3)	85	110	135	165	195	85	110	135	165	195
Fly ash (%)	15	20	25	30	35	15	20	25	30	35
C.A. (kg/m^3)	590	590	590	590	590	590	590	590	590	590
F.A. (kg/m^3)	910	910	910	910	910	819	819	819	819	819
B.A. (kg/m^3)	-	-	-	-	-	91	91	91	91	91
S.P. (%)	1.95	2.00	1.80	1.80	1.80	1.85	1.80	1.50	1.60	1.70
w/p	0.41	0.41	0.42	0.43	0.44	0.472.	0.48	0.48	0.49	0.50
Slump flow										
Dia. (mm)	675	690	605	675	635	675	605	625	605	645
T_{50cm} s	4.5	3.0	4.5	3.0	4.0	3.5	2.5	2.2	3.5	3.8
L-box (H2/H1)	0.9	0.9	0.6	0.95	0.92	0.8	0.82	0.8	0.7	0.9
U-box (H1-H2) (mm)	20	10	50	15	20	25	20	65	50	30
V-funnel										
T_{10s} s	7.5	4.5	7	5	10	6.6	7.5	5.2	8.9	9
T_{5min} s	15	5	8.5	9.5	18	12.5	12.5	6.8	16	18
Room temp.	31	32	32	33	32	29	32	33	30	32
Conc temp.	30	29	28	29	28	27	29	29.5	28	28.5

Table 10: Mix Composition for 20% and 30% bottom ash mixes

Mix	20% Bottom ash					30% Bottom ash				
	M201	M202	M203	M204	M205	M301	M302	M303	M304	M305
Cement (kg/m^3)	465	440	415	385	355	465	440	415	385	355
Fly ash (kg/m^3)	85	110	135	165	195	85	110	135	165	195
Fly ash (%)	15	20	25	30	35	15	20	25	30	35
C.A. (kg/m^3)	590	590	590	590	590	590	590	590	590	590
F.A. (kg/m^3)	728	728	728	728	728	640	640	640	640	640
B.A. (kg/m^3)	182	182	182	182	182	270	270	270	270	270
S.P. (%)	1.9	1.3	1.4	1.4	1.6	1.8	1.2	2.0	1.3	1.3
w/p	0.51	0.52	0.54	0.56	0.58	0.55	0.55	0.56	0.61	0.62
Slump flow										
Dia. (mm)	590	645	600	600	590	625	600	590	610	590
T_{50cm} s	6.0	3.0	1.5	2.5	2.7	2.5	3.0	2.0	1.8	4
L-box (H2/H1)	0.95	0.95	0.6	0.9	0.8	0.82	0.7	0.6	0.87	0.86
U-box(H1-H2) mm	30	30	45	30	50	30	55	30	20	40
V-funnel										
T_{10s} s	6.5	4.5	7	6.5	8	4	4.8	4.2	5.4	6.1
T_{5min} s	8.8	7.0	7.9	12.7	16	6.5	5.8	9.7	9.5	10.5
Room temp.	32	30	32	31	32	34	30	33	32	32
Conc temp.	28	27	28	28	28	28	27	30	29	28

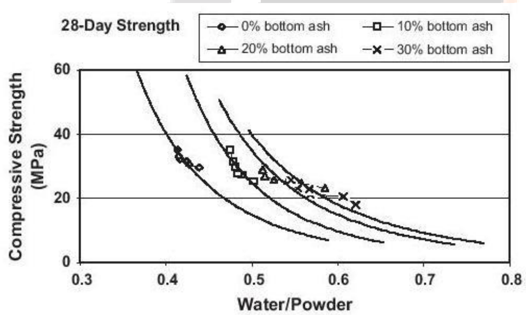

Fig: 7

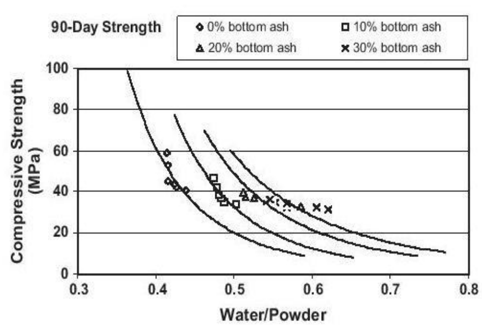

Fig. 8

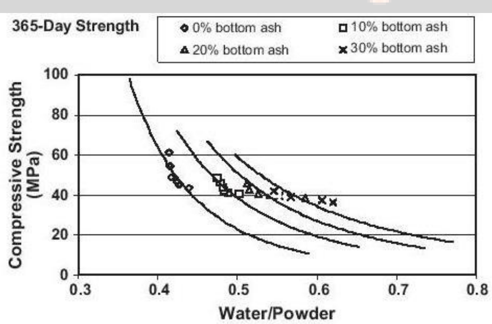

Fig: 9

Fig. 7-9: Strength variations versus the water/powder ratio with different bottom ash contents at ages of 28, 90 and 365 days respectively.

They concluded that there was increase in strength on decrease of w/p ratio from 0.439 to 0.414 for 0% bottom ash, 0.5 to 0.47 for 10% bottom ash, 0.58 to 0.51 for 20% bottom ash and 0.620 to 0.546 for 30% bottom ash. We have found the fly ash dose 25% to 30% and bottom ash up to 20% as an optimum dose.

4.3 Chloride attack and Sulphate attack

Kannan and Ganesan (2014) studied the chloride and chemical resistance of SCC containing rice husk ash (RHA) and Metakaolin (MK). The durability properties of seventeen various mixes were studied. Specimens were exposed to 5% hydrochloric acid and 5% sulfuric acid solutions. In acidic environment cement blended with RHA and a combination of MK and RHA showed improved properties over unblended SCC while SCC blended with metakaolin showed unsatisfactory performance. For both sulfuric and hydrochloric acid, the minimum weight loss was obtained in SCC blended with MK, RHA + MK and RHA at replacement levels of 5% for MK, 40% for RHA + MK and 25% for RHA [15].

Siad et al. (2013) studied the effect of sodium sulfate environment on the behavior of SCCs with different types of mineral additions. The Limestone filler, fly ash and natural pozzolana were the three mineral admixtures which were investigated and the results were compared with vibrated concrete. Specimens were immersed in 5% Na_2SO_4 solution for 720 days. The penetration depth was determined using SEM–EDS. It was concluded that low strength vibrated concrete or SCC mixtures with limestone filler, could not be recommended in a rich sodium sulfate environment. Also the incorporation of natural pozzolana and fly ash as in SCC seem to be beneficial [16].

Dinakar et al. (2008) studied the durability properties of SCC with high volume replacements of fly ash. Five mixes of normally vibrated concrete and eight mixes of fly ash self compacting concrete of equivalent strength with fly ash percentage as 0%, 10%, 30%, 50%, 70%, and 85% were prepared. Crust granite with maximum grain size of 12mm was used as coarse aggregates and commercially available sulphonated naphthalene formaldehyde was used as a water reducer. To assess the chloride permeability, a test was conducted as per ASTM C 1202. A potential difference of 60 V DC was maintained across the specimen. The total charge passed for 6 hour was measured which indicate the degree of resistance to chloride ion penetration. It was observed that high volume of fly ash leads to increase the amounts of tri-calcium aluminates. Chloride ions react with C_3A and thus consequently less free chloride has left to initiate the corrosion process. As alumina content increases the total charge decreases. Various figures 10 (a) , (b) and (c) indicate the variation of total charge passed versus resistivity, initial current, and alumina content respectively [17].

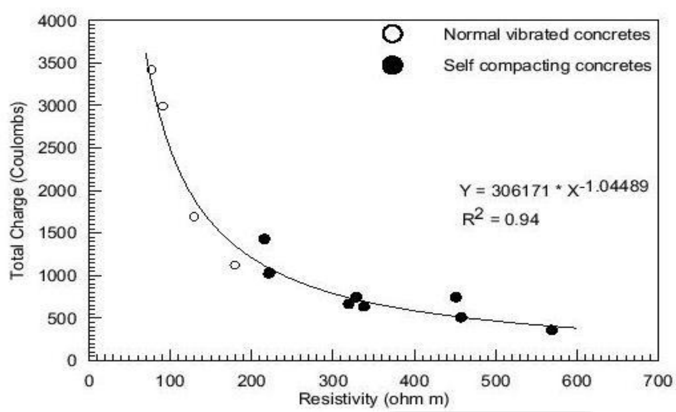

Fig. 10(a)

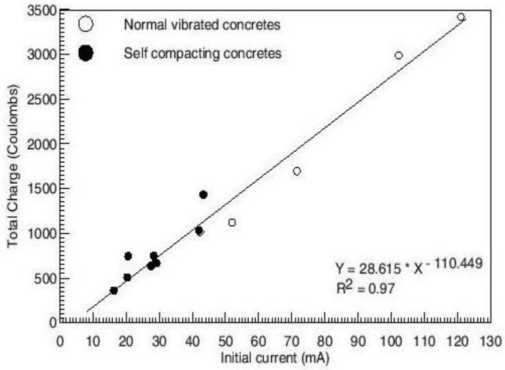

Fig.10 (b)

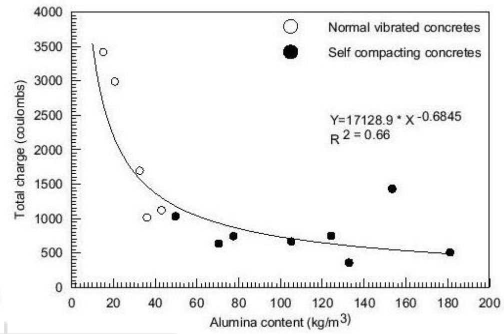

Fig. 10 (c)

Fig.10 (a), (b) and (c): Variation of total charge passed versus resistivity, initial current, and alumina content, respectively.

5. DISCUSSIONS AND CONCLUSIONS

With the study of the various researches carried out on the SCC, the following points were concluded:

- Polycarboxylate based super plasticizer gave more workability and acceptable values of all fresh properties as suggested by EFNARC [6] at all ages as compared to naphthalene sulphonate based super plasticizer.
- The optimum content of blast furnace slag was found to be 15% [7].
- It was observed that out of these polycarboxylate based superplasticizer concrete mix gave higher compressive strength at all ages [7,13].
- It was concluded that the flowability decreases with the use of crushed aggregates and increasing the maximum size of coarse aggregate with the same dose of superplasticizer and water-powder ratio. A partial replacement of cement by 10% metakaolin leads to a decrease in flowability and an increase in viscosity [8].
- The ternary system such as cement-fly ash-Alccofine concrete was found to have more compressive strength at all ages when compared to concrete made with fly ash and Alccofine alone [12].
- Strength with 7% alccofine was optimized which was 44.81 MPa as compared to other percentages of alccofine added and also much higher than the control mix (32.1 MPa) [12].
- Compressive strength with 25% replacement with fly ash was found to be optimized as compared to the control mix (21.1 MPa) and other percentage of replacement with OPC [12].
- Compressive strength decreased with increase of slag content at early ages when compared to vibrated concrete but it became less important at later ages (56 and 90 days) [13].
- With the various experiments conducted, it was concluded that there was increase in strength on decrease of w/p ratio from 0.439 to 0.414 for 0% bottom ash, 0.5 to 0.47 for 10% bottom ash, 0.58 to 0.51 for 20% bottom ash and 0.620 to 0.546 for 30% bottom ash. We have found the fly ash dose 25% to 30% and bottom ash up to 20% as an optimum dose [14].
- It was concluded that low strength vibrated concrete or SCC mixtures with limestone filler, could not be recommended in a rich sodium sulfate environment. Also the incorporation of natural pozzolana and fly ash as in SCC seem to be beneficial [16].
- It was observed that high volume of fly ash leads to increase the amounts of tri-calcium aluminates. As alumina content increases the total charge decreases [17].

Also, various advantages and disadvantages were seen which can be summarized as below:

A. Advantages

(a) No vibrations are needed during placement of concrete.
(b) Concreting time is reduced.
(c) Noise level is reduced.
(d) Fewer workers are required.
(e) High quality can be achieved, regardless the skill of the workers.

(f) Good quality concrete finish can be achieved.
(g) Placement of concrete is easier.

B. Disadvantages

(a) There is no established mix design procedure as yet.
(b) Mix must be specially designed based on material availability and required specifications.

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