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State of art – Study on HVFA SCC Durability Point of View

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ABSTRACT

Infrastructural growth has witnessed many forms of concrete like High Strength Concrete (HSC), High Performance Concrete (HPC), Self Compacting Concrete (SSC), High Volume Fly Ash Concrete (HVFC) and the latest in the series is High Volume Fly Ash Self Compacting Concrete. The construction techniques have been modernized with keeping focus on high strength, dense and uniform surface texture, more reliable quality, improved durability and faster construction. Study found the addition of fly ash by replacing cement helps to reduce cement consumption, environmental pollution as well as less heat of hydration. But HVFC has limitations of ductility, expansion and contraction properties, flexural property where as it increases the workability. So detail literature study has done on the High volume fly ash self compacting concrete as a durability point of view.

KEYWORDS :

Introduction

Many current structures are characterized by the complexity of their architecture and a high concentration of reinforcements, which often makes it difficult to use concrete with conventional plasticity. Researches had been conducted in order to adapt concrete to these structures [7]. Due to this difficulty in concreting, Professor Ozowa of Japan introduced SCC in 1989. Since then, it has been used in Europe and it is said to replace vibrated concrete (VC) in many applications in the long term. This concrete had other advantages too like reduction of harmful effects of noise in an urban environment; possibility of pouring in strongly reinforced places or places with complex geometry; and decrease of the industrial processes costs. But main problem with SCC is large amount of cement being used in preparing it. Cement which is the main component of concrete is cost and energy intensive. It is responsible for 7% of world's carbon dioxide emissions. So in 1985, CANMET was requested to make a concrete having characteristics like sufficient early age strength and high later age strength, high modulus of elasticity, low heat of hydration. Outcome of this was a concrete having low quantity of ASTM Type II cement and high volume of ASTM class F Fly ash. Fly ash is the byproduct of the combustion of pulverized coal and is collected by electrostatic and mechanical separators where coal is used as a fuel [5]. The disposal of fly ash is also one of the major issues so the utilization of fly ash as supplementary material to cement could solve the environmental problems and its disposal issue. The concrete made with fly ash replacement has properties like low w/c ratio and similar workability, reduced bleeding, and lower evolution of heat. Due to these properties it has been used in mass concrete applications and large volume placement to control expansion due to heat of hydration and also helps in reducing cracking at early ages. This type of mass concrete works normally contains more than 50% fly ash by mass of total cementitious materials.

Now by using fly ash which is a partial replacement to cement in SCC. As SCC needs large amount of cement and by replacing it by fly ash what would be the durability properties of concrete made with these are found out. Many researches have been done with high volumes of Class C and Class F fly ashes in concrete.

Durability properties of the concretes investigated

No	Name	30 Min.Abs. (%)	Final Abs.(96 h)(%)	Permeable voids (%)	Weight loss in acid attack (90 days)	Chloride permeability results		
						Initial current (mA)	Resistivity at 60 V (Ω m)	Total charge (coulombs)
1	NC20	0.86	4.92	12.7	−25.73	121.2	77.76	3413
2	SCC558	2.51	8.84	16.7	−4.31	43.5	216.67	1424
3	NC30	1.23	4.93	13.3	−15.19	102.4	91.89	2983
4	SCC557	0.83	4.91	17.1	−1.37	16.5	569.91	352
5	SCC757	1.49	4.12	15.8	−11.09	20.5	458.44	500
6	NC60	0.86	2.98	11.1	−23.12	71.7	130.31	1688
7	SCC555	1.30	4.61	15.5	−23.26	29.4	320.28	659
8	SCC655	1.19	4.06	15.8	−38.90	28.5	329.70	740
9	NC90	0.55	1.68	8.5	−24.16	42.5	221.37	1008
10	SCC553	1.21	4.69	12.6	−37.86	20.8	452.16	737
11	SCC530	0.78	4.33	12.8	−57.29	27.7	339.12	629
12	NC120	0.69	2.15	7.6	−23.35	52.1	180.55	1115

2. Literature Review

P.Dinakar, K.G Babu, ManuSanthanam[3] made study by making eight different fly ash self-compacting concrete mixes with varying dosage (10-85%) of fly ash and five different normally vibrated concrete (NVC) ranging from 20MPa-100MPa for both and durability tests were conducted. It was reported that fly ash replacement in SCC upto 70-85% is possible with low strength grades (20-30MPa) for grades of higher strength (60-90MPa) only 30-50% replacement is possible. Permeability Test showed permeability from higher to lower grades was in the range of 16.7%-12.8% for High volume Fly Ash SCC while for NVC it was from 12.7%-7.6%.This showed permeability was higher for Fly ash SSC than NVC and permeability decreased as grade increases for both type of concrete. Fly ash SCC should these characteristics mainly because of high fly ash replacement, high water content and high super plasticizer dosage. Acid resistivity was also found for this concrete by immersing specimens in 3% solution for 90 days. It was found that weight loss due to acid attack increased up to a cement content of 400kg/, after which there was a marginal decrease. It was also found that both SSC and NVC followed same trend but High Volume Fly ash SSC performed better than NVC. Weight loss was minimum (-1.37) for SSC with 70% fly ash replacement and w/p ratio of 0.34. This showed that low strength concrete with low amount of cement showed better resistance against acid attack and weight loss significantly decreased with increasing fly ash replacement in SCC. Chloride Permeability Test was also done and it was found that diffusion values obtained for SCC of grades 20, 30 and 60MPa, which had high volumes of fly ash (85, 70 and 50%), were about 2 to 8 times less than corresponding NVC whereas Higher Grades 90 and 100MPa which had fly ash replacements at 30and 10% performed almost similar to NVC. This should high volume fly ash self compacting concrete performed better than NVC. Values related to all the above test are listed below:

P. Dinakar , M. Kartik Reddy, Mudit Sharma[4] made study on fresh and hardened properties of SCC Fly Ash concrete by replacing Fly Ash in percentage of 10%,30%,50% and 70% respectively . Water absorption was found for the specimens and it showed that water absorption was highest (12.12%) for 70MPa while lowest (0.89%) for 10MPa. This showed that as fly ash in concrete increases the water absorption for concrete specimens also increases but it can be seen from table below that this absorption were smaller than limit specified for "good" concrete. Water penetration test was also conducted to find permeability of concrete. It showed the same pattern as that of Absorption test, penetration depths increases as fly ash increases not very significantly up to 50% replacement whereas significant increase was noticed for 70% replacement. This can be seen from fig 1 and tale below. It was also seen that absorption and penetration decreases from 28 to 56 days. Lastly Chloride Penetration Test was also conducted it was found that 70% Fly ash replaced concrete had highest Coulomb charge of 3520 C while lowest it was 923 C for 30% replaced fly ash as seen it table below and fig 2. These low durability properties of concrete with 70% fly ash replacement were due to more amount of super plasticizer and VMA dosage in M70 concrete. It was also found from all these test that as w/c ratio decreases durability increases.

Durability properties of the concretes investigated.

Concrete name	Absorption (28 day) (%)		Absorption (56 day) (%)		Water penetration (mm)		Chloride permeability (Coulombs)	
	Initial (30 min)	Final (72 h)	Initial (30 min)	Final (72 h)	28 day	56 day	28 day	56 day
SCC10	0.89	3.54	0.84	3.14	5	4	1812	1188
SCC30	1.00	4.53	0.95	3.74	5	3	923	692
SCC50	1.29	5.55	1.18	4.95	11	9	1312	823
SCC70	1.49	12.12	1.32	10.52	35	24	3520	1876

K. M. A. Hossain, Ph.D., P.E., M.ASCE; and M. Lachemi, Ph.D., P.E.[1] made study by replacing volcanic ash (VA) from 20% to 50%. It was found that Drying shrinkage (DS) generally increased with age and mixtures with lower w/b and high VA exhibit lower DS. DS strain for VA-SCC mixes ranged between 484 and 572 microstrain at age of 224 days while for 0% VA SCC it was ranged between 536 and 585 microstrain. It was also found that DS increased with increase in w/b from 0.35 to 0.45 and decreases with increase in total aggregate to binder (TA/B) ratio from 4.1 to 4.2. Rapid Chloride Permeability (RAP) of VA-SSC mixtures showed low in range of 900 and 1,540 C while for 0% VA SCC range between 1,100 and 1,405 C. In VA-SSC it was interesting to know that RCP decreased with the increase in percentage of VA up to w/b of 0.4 but for w/b of more than 0.4 the RCP was found to increase again with the increase in percentage of VA as shown in fig 3. From this it was seen that chloride ion resistance of VA-SSCs increased with the increase in VA. VA addition improves the chloride ion diffusivity and hence can lead to higher long term corrosion of VA-SSCs. From this it can be said that SCC with 20–50% VA replacement is found durable.

Rafat Siddique[6] made SCC with replacement to cement with fly ash in percentage of 15%, 20%, 25%, 30% and 35%. Carbonation depth was found for this specimens and it was found that carbonation depth increases with increase in age i.e. from 90 days to 365 days. For 90 days it was between 0.83mm and 1.67mm while for 365 days it was between 1.33mm and 1.78mm. SCC with 15% replacement had showed less depth as compared to 20%. At 25% it showed less as compared to 20% and after that up to 35% replacement it remains constant as shown in fig 4. Lesser depth was with 15% fly ash replacement and w/c ratio of 0.48. Chloride ion penetration test was done and it was found that chloride penetration resistance was less for 25% replaced fly ash concrete and w/c ratio of 0.56 having very low 594 C as shown in table below and fig 5. Coulomb charge for 35% fly ash replacement was also nearly less of 610 C while for 15%, 20% and 30% coulomb charged values were high between 662-634 C. Charge passed through the specimen was of less ranged between 381-310 C at 365 days as compared to 694-610 C at 90 days. From the result it shows that the use of fly ash reduced the rapid chloride ion penetration to a very low range of 400 and 700 Coulomb at the age of 90 and 365 days respectively.

Charge passed and rating for SCC mixes.

Mix	90 Day		365 Day	
	Charge passed in Coulomb C	Chloride ion penetrability	Charge passed in Coulomb C	Chloride ion penetrability
SCC1	662	Very low	381	Very low
SCC2	649	Very low	373	Very low
SCC3	594	Very low	303	Very low
SCC4	634	Very low	350	Very low
SCC5	610	Very low	310	Very low

Neelam Pathak, Rafat Siddique[2] made their study by using fly ash and foundry sand as replacements in concrete and cured the specimens at different temperature ranging from 100 to 300˚C. Rapid Chloride Penetration(RCP) Test was conducted at 28, 91 and 365 days it was found that SCC mixes containing fly ash and foundry sand reduced the rapid chloride ion permeability to low range of 1000-2000 coulomb after 28 days this reduced lesser to <1000 coulomb at 91 and 365 days as compared with control mix. This values are shown in fig 6,7 and 8. It was also found that concretes became insignificantly more permeable with increase in temperature. The graph below shows different results of temperature on RCP of concrete. Porosity test was also conducted and it was found that porosity was stable up to 100˚C it increased after increasing the temperature up to 300˚C. When percentage of fly ash increases porosity increased. This increase in porosity is attributed to change SCC from impermeable to permeable material. This porosity increase in expansion of pores and it leads to increase in permeability.

Graphs

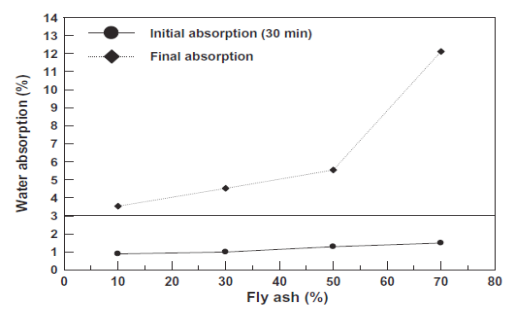


Fig1. Relation between water absorption and fly ash replacement

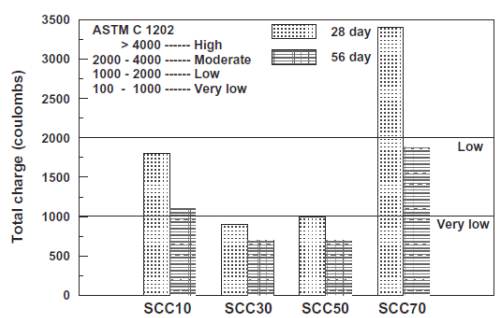


Fig2. Chloride Permeability values of the concrete

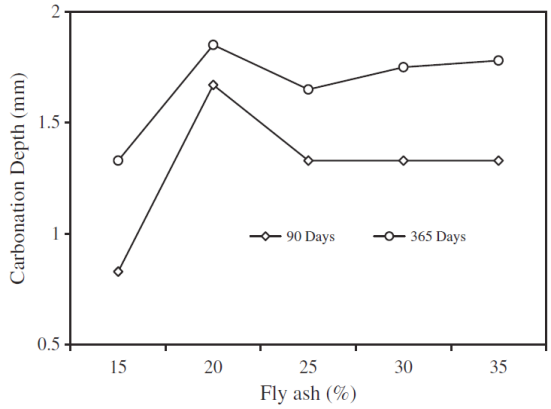


Fig3. RCP of VA-SSC mixtures

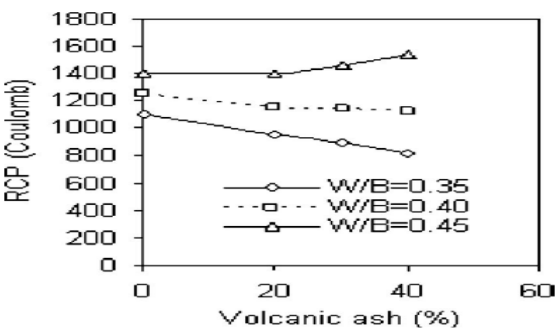


Fig4. Carbonation depth for SCC mixes at various fly ash content

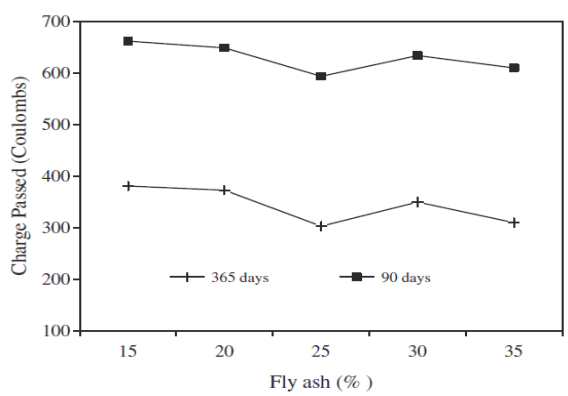


Fig5. Chloride penetration for SSC mixes at various fly ash content

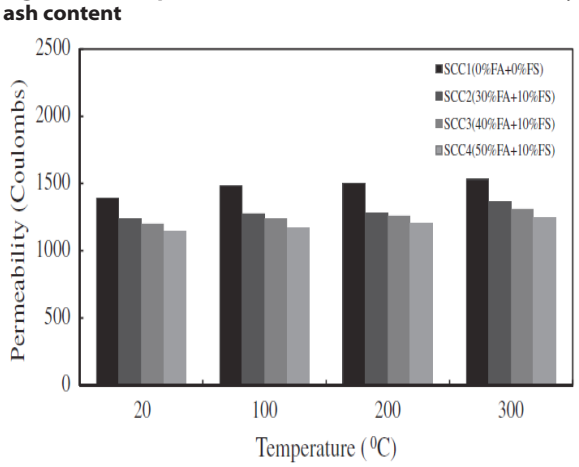


Fig6. Rapid Chloride permeability of fly ash concrete (28 days)

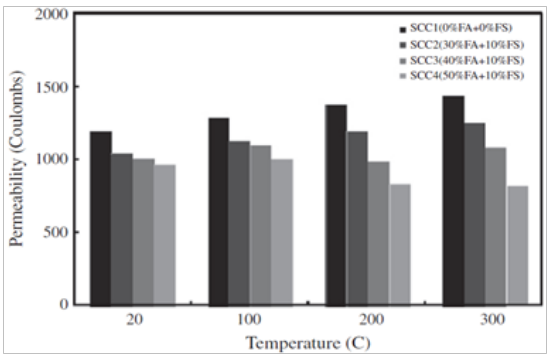


Fig7. Rapid Chloride Permeability of fly ash concrete (91 days)

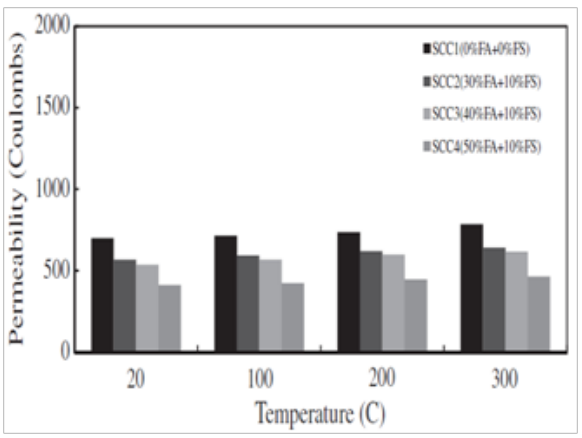


Fig8. Rapid Chloride Permeability of fly ash concrete (365 days)

3. Conclusion

Different Durability test were done on SSC in which some had fly ash replacement. Different Ratios and materials showed different properties of SSC. These properties are listed below:

a) High amount of fly ash replacement is possible for lower grades of concrete.
b) Permeability increases with increase in fly ash content and it also increases as temperature is increased.
c) RCP decrease with increasing fly ash replacement in concrete but these values increases again with increase in temperature. RCP values decreases with increase in W/C of 0.4 after 0.4 its values increases.
d) Carbonation Depth increases with age. With 25% replacement with fly ash showed minimum depth.

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