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Effect of Addition of Combination of Admixtures on the Properties of Self Compacting Concrete Subjected to Cholride Attack

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ABSTRACT

This paper presents an experimental investigation on the effect of acid attack on the properties of SCC produced by the combination of admixtures such as (Superplasticizer + Viscosity modifying admixture +Air entraining agent + Accelerator), (Superplasticizer + Viscosity modifying admixture +Air entraining agent +Retarder), (Superplasticizer + Viscosity modifying admixture +Air entraining agent + Water proofing compound) and (Superlasticizer + Viscosity modifying admixture +Air entraining agent + Shrinkage reducing admixture). The concrete testing specimens was prepared by a mix proportion 1:2.7:6.1:5.1 with cement: fly ash: sand: coarse aggregate with a water/binder ratio of 0.38. Specimens after 28 days of curing were immersed in magnesium chloride solution of 5% and 10% concentrations for 90 days. Before immersion, they were weighed accurately. After 90 days of immersion, the specimens were removed from chloride media, washed in running water, weighed accurately and tested for their respective strengths. Before testing, the specimens were drilled to a depth of 30mm. The powder collected in this manner was titrated against $AgNO_3$ solution to find chloride content in the concrete. SCC produced with above combination of admixtures show better resistance to chloride attack as compared to SCC produced with combination of admixtures (SP+VMA) only.

Keywords: Self compacting concrete, Chloride attack, Superplasticizer, Viscosity modifying admixture, Air entraining agent, Accelerator, Retarder, Water proofing compound, Shrinkage reducing admixture.

1.0 INTRODUCTION

The concrete technology has made tremendous strides in the past decade. The development of new technology in the material science is progressing rapidly. In recent two or three decades, lot of research was carried out throughout the globe on improving the performance of concrete in terms of strength and durability qualities. Today we can prepare any type of concrete to suit the site conditions. Now the concrete is no longer a material consisting of cement, sand, aggregates and admixtures, but it is an engineered material with several constituents. To obtain good concrete all good practice of operations of concrete have to be taken care. Meticulous care has to be exercised during proportioning, mixing, placing, compacting and curing. Negligence in any one operation may damage the concrete severely. One of the most important operations of concrete is consolidation or compaction. But is very difficult to achieve 100% compaction economically. Thus it was the dream of concrete technologists to invent a concrete, which does not need compaction and fills every cavity by its flow characteristics. This dream of concrete technologists came true when Okamara invented self compacting concrete in 1988 in Japan. The studies on self compacting concrete were further reinforced by Ozawa and Meekawa of Japan.Self compacting concrete is a mix that can be compacted into every corner of formwork, by means of its own weight and without the need for vibrating compaction. Inspite of its high flowability, the coarse aggregate is not segregated. The alternate wetting and drying affects the durability of concrete. There is an in built assurance of uniform placement and fully consolidation concrete when self compacting concrete is used at site this ensures high durability since air voids and other flaws are likely to be absent in self compacting concrete. The development and uses of self compacting concrete has increased in these years. Given its highly flowable nature self compacting concrete can flow readily under its own weight, fills restricted sections and congested formwork without segregation. EFNARC has published specifications and guidelines for self compacting concrete (EFNARC 2002).

2.0 EXPERIMENTAL PROGRAMME

The main objective of this experimentation is to study the effect of aggressive environments on the properties of SCC produced by the combination of admixtures such as (Superplasticizer + Viscosity modifying admixture + Air entraining agent + Accelerator), (Superplasticizer + Viscosity modifying admixture + Air entraining agent + Retarder), (Superplasticizer + Viscosity modifying admixture + Air entraining agent + Water proofing compound) and (Superlasticizer +Viscosity modifying admixture + Air entraining agent + Shrinkage reducing admixture). The aggressive environment considered in the study was chloride attack of different concentrations.

3.0 MATERIALS USED

Cement:

43 grade ordinary Portland cement (OPC) with specific gravity of 3.15, complying with IS: 8112-1989.

Fine aggregate:

Locally available sand with specific gravity of 2.63 falling under zone II, complying with IS: 383-1970.
Coarse aggregate: Locally available coarse aggregate with specific gravity of 2.88 complying with IS: 383-1970.

Flyash:

Obtained from Thermal Power Station, Shaktinagar, Raichur.

Viscosity modifying admixture:

A viscosity modifying admixture called Structuro 485 was used to induce the flow without segregation. It was used at the rate of 0.30% weight of binder (cement + flyash)

Superplasticizer:

A high performance concrete superplasticizer Structuro 100 based on modified polycarboxylic ether was used. It was used at the rate of 0.40% by weight of binder (cement + flyash).

Air entraining admixture:

Air-entraining admixture used in the experimentation was Conplast PA21(S). It was used at the rate of 0.30 % by weight of cement.

Retarder:

The retarder used in the experimentation was Conplast RP264. It was used at the rate of 0.4% (by weight of cement).

Accelerator:

The accelerator used in the experimentation was Conplast NC. It was used at the rate of 2% by weight of cement.

Water proofing compound:

The water proofing compound used in the experimentation was Conplast X421 IC. It was used of at the rate of 0.30% by weight of cement.

Shrinkage reducing admixture:

The shrinkage reducing admixture used in the experimentation was Cebex 100. It was used of at the rate of 0.45% by weight of cement.

4.0 EXPERIMENTAL PROCEDURE

The concrete was prepared by a mix proportion 1:2.7:6.1:5.1 with cement: fly ash: sand: coarse aggregate with a water/binder ratio of 0.38. Now the admixtures taken in order were added in the required quantities and thoroughly mixed. At this stage concrete was in a flowable state. Concrete mix was poured in the moulds to prepare the specimens for strength tests.

The specimens after 28 days of curing were immersed in magnesium chloride solution of 5% and 10% concentrations for 90 days. Before immersion, they were weighed accurately. After 90 days of immersion, the specimens were removed from chloride media, washed in running water, weighed accurately and tested for their respective strengths. Before testing, the specimens were drilled to a depth of 30mm. The powder collected in this manner was titrated against $AgNO_3$ solution to find chloride content in the concrete.

Compressive strength specimens were of dimensions 150 x 150 x 150mm and were tested as per IS 516:1959. Tensile strength specimens were of 150mm diameter and 300mm length. Split tensile strength was conducted on these specimens as per IS5816:1999. Flexural strength test specimens were of dimensions 100mm x 100mm x 500mm. Two point loading was adopted on an effective span of 400mm while conducting the flexural strength test as per IS 516:1959. Impact strength test was conducted on specimens of dimension 150mm diameter and 60mm height. Schruders impact testing machine was used for this purpose.

5.0 EXPERIMENTAL RESULTS

The following tables give the details of the experimental results of self compacting concrete subjected to chloride attack.

5.1 *Compressive strength test results when subjected to chloride attack*

The following Table 5.1.1 gives the compressive strength test results of SCC with different combination of admixtures subjected to chloride attack.

Table 5.1.1: Compressive strength test results of SCC when subjected to chloride attack

Description of SCC	Compre-ssive strength without subjecting to chloride attack (ref.mix) (MPa)	Chloride attack of 5% concentration				Chloride attack of 10% concentration			
		Percen-tage weight loss	Chloride content (mg/lit)	Compr-essive Strength (MPa)	Percentage decrease of compressive strength as compared to ref.mix	Percent ae weight loss	Chloride content (mg/lit)	Compre-ssive strength (MPa)	Percentage decrease of compre-ssive strength as compared to ref.mix
SCC with (SP+VMA+ AEA+ACC)	24.00	8.32	98.10	18.80	22	8.87	108.25	18.40	23
SCC with (SP+VMA+ AEA+RET)	23.33	8.77	112.33	18.49	21	9.09	125.80	18.22	22
SCC with (SP+VMA+ AEA+WPC)	24.44	8.61	74.90	19.37	21	10.39	84.50	18.84	23
SCC with (SP+VMA+ AEA+SRA)	22.89	6.20	125.30	18.22	20	6.82	136.25	17.78	22
SCC with (SP+VMA)	22.15	10.31	132.40	17.21	22	11.50	149.20	16.83	24

5.2 *Tensile strength test results when subjected to chloride attack*

The following Table 5.2.1 gives the tensile strength test results of SCC with different combination of admixtures subjected to chloride attack.

Table 5.2.1: Tensile strength test results of SCC when subjected to chloride attack

Description of SCC	Tensile strength without subjecting to chloride attack (ref.mix) (MPa)	Chloride attack of 5% concentration			Chloride attack of 10% concentration		
		Percentage weight loss	Tensile strength (MPa)	Percentage decrease of tensile strength as compared to ref.mix	Percentage weight loss	Tensile strength (MPa)	Percentage decrease of tensile strength as compared to ref.mix
SCC with (SP+VMA+ AEA+ACC)	2.29	7.13	2.02	12	8.74	1.87	18

SCC with (SP+VMA+ AEA+RET)	2.24	6.52	1.90	15	7.97	1.81	19
SCC with (SP+VMA+ AEA+WPC)	2.38	6.25	2.00	16	9.97	1.92	19
SCC with (SP+VMA+ AEA+SRA)	2.21	5.87	1.88	15	8.68	1.76	20
SCC with (SP+VMA)	2.13	7.92	1.75	18	10.77	1.69	21

5.3 *Flexural strength test results when subjected to chloride attack*

The following Table 5.3.1 gives the flexural strength test results of SCC with different combination of admixtures subjected to chloride attack

Table 5.3.1: Flexural strength test results of SCC when subjected to chloride attack

Description of SCC	Flexural strength without subjecting to chloride attack (ref.mix) (MPa)	Chloride attack of 5% concentration			Chloride attack of 10% concentration		
		Percentage weight loss	Flexural strength (MPa)	Percentage decrease of flexural strength as compared to ref.mix	Percentage weight loss	Flexural strength (MPa)	Percentage decrease of flexural strength as compared to ref.mix
SCC with (SP+VMA+ AEA+ACC)	1.82	8.46	1.73	5	9.60	1.62	11
SCC with (SP+VMA+ AEA+RET)	1.80	9.54	1.71	5	10.83	1.60	11
SCC with (SP+VMA+ AEA+WPC)	1.92	8.23	1.82	5	11.39	1.67	13
SCC with (SP+VMA+ AEA+SRA)	1.77	9.88	1.63	8	11.14	1.56	12
SCC with (SP+VMA)	1.72	10.76	1.59	8	12.26	1.50	13

5.4 Impact strength test results when subjected to chloride attack

The following Table 5.4.1 gives the impact strength test results of SCC with different combination of admixtures subjected to chloride attack.

Table 5.4.1 Impact strength test results of SCC when subjected to chloride attack

Description of SCC.	Impact strength without subjecting to chloride attack (ref.mix) (N-m)		Chloride attack of 5% concentration					Chloride attack of 10% concentration				
			Perce -ntage weight loss	Impact strength (N-m)		Percentage decrease of impact strength as compared to ref.mix		Perce -ntage weight loss	Impact strength (N-m)		Percentage decrease of impact strength as compared to ref.mix	
	first crack	final failure		first crack	final failure	first crack	final failure		first crack	final failure	first crack	final failure

SCC with (SP+VMA+ AEA+ACC)	373.46	456.45	7.92	331.96	352.71	11	23	7.90	248.97	297.36	33	35
SCC with (SP+VMA+ AEA+RET)	373.46	414.96	6.72	290.47	311.12	22	25	7.13	228.22	276.64	39	33
SCC with (SP+VMA+ AEA+WPC)	414.96	477.20	8.62	352..71	380.38	15	20	15.25	331.96	373.46	20	22
SCC with (SP+VMA+ AEA+SRA)	331.96	394.21	5.99	262.81	290.47	21	26	8.19	214.39	242.06	35	39
SCC with (SP+VMA)	325.05	366.55	12.07	248.97	276.64	23	25	17.71	207.48	228.22	36	38

6.0 OBSERVATIONS AND DISCUSSIONS

1. It is observed that the compressive strength of SCC produced with the combination of admixtures such as (SP+VMA+AEA+ACC), (SP+VMA+AEA+RET), (SP+VMA+AEA+WPC) and (SP+VMA+AEA+ SRA) when subjected to chloride attack ($MgCl_2$) of 10% concentration decreases as compared to the reference mix (without subjecting to chloride attack).The percentage decrease of compressive strength is found to be 23%,22%,23% and 22% respectively as compared to the reference mix. Similar observations are made when SCC with above combination of admixtures are subjected to chloride attack of 5% concentration. The percentage decrease of compressive strength w. r. t. reference mix are found to be 22%, 21%, 21% and 20% respectively. Thus, on an average percentage decrease of compressive strength is 21%.

Similar observations are made w. r. t. tensile strength, flexural strength and impact strength. The percentage decrease of flexural strength is found to be less as compared to compressive strength, tensile strength and impact strength.

2. It is also observed that compressive strength, tensile strength, flexural strength and impact strength of SCC produced with the combination of admixtures such as (SP+VMA+AEA+ACC), (SP+VMA+AEA+RET), (SP+VMA+AEA+WPC) and (SP+VMA+AEA+ SRA) when subjected to chloride attack is more as compared to SCC produced with the combination of admixtures (SP+VMA). This may be due to the fact that addition of accelerator or retarder or water proofing compound or shrinkage reducing agent in above combination of admixtures have made the concrete more denser leaving less chance for the chloride ions to penetrate inside.

3. Among all the combination of admixtures tried, it is found that the performance of SCC containing the combination of admixtures (SP+VMA+AEA+WPA) is more satisfactory w. r. t. chloride attack. The residual strengths of SCC produced with the combination of admixture (SP+VMA+AEA+WPA) is more promising in chloride media as compared to other combination of admixtures. This may be due to the fact that the WPC added may form a layer which can resist the entry of chloride media into the concrete mass thus limiting the damage.

4. Also it is observed that the strength properties of SCC containing combination of admixtures such as (SP+VMA+AEA+ACC), (SP+VMA+AEA+RET), (SP+VMA+AEA+WPC) and (SP+VMA+AEA+ SRA) are less when subjected to chloride attack of 10% concentration as compared to chloride attack of 5% concentration. This is due to the fact that higher concentration of $MgCl_2$ solution will give rise to more free chloride ions.

5. However, in general, it is observed that the resistance of SCC containing the combination of admixtures such as (SP+VMA+AEA+ACC), (SP+VMA+AEA+RET), (SP+VMA+AEA+WPC) and (SP+VMA+AEA+ SRA) is found to be satisfactory for chloride attack. This may be due to the fact the added combination of admixtures might have resulted in improved microstructure of concrete thereby reducing porosity of concrete Chloride content in concrete at a depth of 30mm is observed to be less.

7.0 CONCLUSIONS

1. SCC produced with combination of admixtures such as (SP+VMA+AEA+ACC), (SP+VMA+AEA+RET),

(SP+VMA+AEA+WPC) and (SP+VMA+AEA+ SRA) show better resistance to chloride attack as compared to SCC produced with (SP+VMA) only.

2. The combination of admixtures (SP+VMA+AEA+ACC) can be used in SCC where SCC is used in the rapid repairs of rigid pavements where there is a suspect of chloride attack.

3. The combination of admixtures (SP+VMA+AEA+RET) can be used in SCC when SCC is used in ready mix concrete which is likely to be subjected to chloride attack.

4. The combination of admixtures (SP+VMA+AEA+WPC) can be used in SCC when SCC is used in construction of sewage treatment plants which are likely to be subjected to chloride attack.

5. The combination of admixtures (SP+VMA+AEA+SRA) can be used in SCC to reduce the shrinkage of concrete structure subjected to chloride attack.

6. SCC produced with combination of admixtures such as (SP+VMA+AEA+ACC), (SP+VMA+AEA+RET), (SP+VMA+AEA+WPC) and (SP+VMA+AEA+ SRA) show lesser residual strength characteristics when it is subjected to chloride attack of 10% concentration as compared to 5% concentration.

7.The resistance of SCC containing the combination of admixture (SP+VMA+AEA+WPC) is found to be superior for chloride attack as compared to SCC containing the other combination of admixtures.

8. SCC produced with combination of admixtures such as (SP+VMA+AEA+ACC), (SP+VMA+AEA+RET), (SP+VMA+AEA+WPC) and (SP+VMA+AEA+ SRA) show more chloride penetration when it is subjected to chloride attack of 10% concentration as compared to 5% concentration.

9. The chloride penetration of SCC containing the combination of admixture (SP+VMA+AEA+WPC) is found to be less as compared to SCC containing the other combination of admixtures.

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