STUDIES ON EFFECT OF MINERAL ADMIXTURES ON DURABILITY PROPERTIES OF HIGH STRENGTH SELF COMPACTING CONCRETE

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Abstract

To build high rise building by reducing column sizes and increasing available space, to built the super structure of long span bridges and to the durability of bridge decks a high strength is needed. High strength concrete was used in South Wacker in Chicago of 80 Mpa, Baynunah Tower in Abu Dhabi of 80 MPa and Frankfurt Trianon in Germany of 125 MPa. If high strength concrete is self-compacting, the production of densely reinforced building element from high strength concrete with high homogeneity would be an easy work. In the present investigation a rational mix design is established and self compactability testing methods have been carried out from the view point of making it a standard concrete by using mineral admixtures like micro silica and fly ash for imparting High Strength Self Compacting Concrete. The flow properties of resulting concrete is characterized in the fresh state by methods used for Self compacting concrete, such as Slump-flow, V-funnel and L- box tests respectively. Further the durability properties are examined for High Strength Self Compacting Concrete mix of grade M100. The durability factors are also studied .From these studies we observe that 15% Micro silica and 25% Fly ash will give optimum strength for M100 grade at water /powder ratio of 0.22. The effect of Na_2So_4 on these mixes is nil where as HCL and H_2So_4 had substantial impact.

***Keywords**: Self Compacting Concrete, Segregation Resistance, Filling ability, Passing Ability, Mineral Admixtures, durability properties.*

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1. INTRODUCTION

Concrete is an important versatile construction material, used in wide variety of situations. So it is very important to consider its durability as it has indirect effect on economy, serviceability and maintenance. Concrete is not fully resistance to acids. Most acid solutions will slowly or rapidly disintegrate Portland cement concrete depending upon the type and concentration of acid. Certain acids, such as oxalic acid and phosphoric acids are harmless. The most vulnerable part of the cement hydrate is Ca $(OH)_2$, but C-S-H gel can also be attacked. Siliceous aggregates are more resistance than calcareous aggregates. Concrete can be attacked by liquids with Concrete can attack by liquids with P^H value below 6.5, but the attacks are severe only at a P^H below 5.5, below 4.5 the attack is very severe. As the attack proceeds, all the cement compounds are evenly broken down and leached away, together with any carbonate aggregate material. With the sulphuric acid attack, calcium sulphate formed can be proceed to react with calcium aluminate phase in cement to form calcium sulphoaluminate, which on crystallization can cause expansion and disruption of concrete. If acids or salt solutions are able to reach the reinforcing steel through cracks or porosity of concrete, corrosion can occur which will cause cracking.

The sulphate attack denotes an increase in the volume of cement paste in concrete or mortar due to the chemical action between the products of hydration of cement and solution containing sulphates. When hardened concrete is exposed to soil or ground water containing sulphate compounds, the sulphates in solution are likely to react with hydrated Tricalcium Aluminate in the hardened cement paste to form a new chemical called Ettringite. This new compound causes expansion and disruption of the concrete. Therefore, it is necessary to limit the permeability of the concrete to reduce the penetration of sulphates in solution. Solid salts do not attack the concrete severely but when the chemicals are in solution, they find their entry into porous concrete and react with the hydrated cement products. Of all the sulphates, magnesium sulphate causes maximum damage to concrete. A characteristic whitish appearance is the indication of sulphate attack. The term sulphate attack denote an increase in the volume of cement paste in concrete or mortar due to the chemical action between the products of hydration of cement and solution containing sulphates. In the hardened concrete, calcium aluminate hydrate (C-A-H) can react with sulphate salt from outside. The product of reaction is calcium sulphoaluminate, forming within the framework of hydrated cement paste. Because of the increase in volume of the solid phase that can go up to 227 percent, gradual disintegration of concrete takes place. The deteriorating effect usually starts at the surface and corners and progressively enters into the concrete by causing scaling and spalling and finally reduces the concrete a friable mass.

2. RESEARCH SIGNIFICANCE

For a newly developing material like self compacting concrete, studies on durability are of paramount importance for instilling confidence among the engineers and builders. The literature indicate that while some studies are available on the durability of plain self compacting concrete and fibre reinforced self compacting concrete, a comprehensive study which involves durability parameters loss of weight and loss in compressive strength of specimens due to acid attack , sulphate attack are not available for high strength self compacting concrete (HSSCC). Hence, considering the gap in the existing literature, an attempt has been made to study the durability parameters of HSSCC i.e. Loss of weight and loss in compressive strength of specimens due to acid attack, sulphate attack as well as durability factors ..

3. LITERATURE REVIEW

Anne-Mieke et.al[1] studied the deformations in more detail, the applicability of traditional creep and shrinkage models test series as described, the following conclusions can be formulated with increasing c/p ratio, and consequently increasing cement content and decreasing w/c ratio, a decrease of the creep deformations is found. The fineness of the tested fillers has almost no influence on the deformations.

Audenaert K [2] made an extended experimental programme on chloride penetration of 16 self compacting concrete mixtures and 4 traditional concrete mixtures were determined. Based on these tests, the conclusion is that the penetration depth in real conditions is strongly influenced by water/cement and water/(cement +filler) ratios. Decreasing one of these ratios or both is leading to as decreasing penetration depth. Another important conclusion is that the chloride penetration depth in SCC by cyclic immersion is lower than the penetration depth in TC.

Ganesan N et.al [3] studied the effect of steel fibres on the durability parameters of self-compacting concrete (SCC) such as permeability, water absorption , abrasion resistance , resistance to marine as well as sulphate attack and concluded that addition of steel fibres improved the durability aspects of self compacting concrete.

C. Selvamony et.al [4] involved evaluating the Effectiveness of various percentages of mineral admixtures in producing SCC. Okamura's method, based on EFNARC specifications, was adopted for mixed design.

Dr.R.Sri ravidrarajah et.al [5] investigated into the development of self-compacting concrete with reduced segregation potential. The fine particle content is increased by replacing partially the fine and coarse aggregates by low-calcium fly ash.

S. Venkateshwara Rao et.al [6] aims at developing standard and high strength Self Compacting Concrete with different sizes of aggregate based on Nansu’s mix design procedure. Also, fly ash optimization is done in study with the graded course aggregate.

Seshadri Sekhar.T [7] et.al studied on the effect of glass fibers on the durability properties of glass fibre self compacting concrete for different grades of concretes M 30 to M65 and also discussed about durability factors also. **Seshadri Sekhar.T [8]** et.al developed the high strength self compacting concrete using mineral admixtures.

4. OBJECTIVES OF STUDY

- To study the durability properties like loss of weight and loss in compressive strength of specimens due to acid attack, sulphate attack , durability factors of high strength self compacting concrete using mineral admixtures

5. MATERIALS

Cement

Ordinary Portland cement of 53 grade having specific gravity was 3.02 and fineness was 3200cm^2/gm was used in the investigation. The Cement used has been tested for various proportions as per IS 4031-1988 and found to be confirming to various specifications of are 12269-1987.

Coarse Aggregate

Crushed angular granite metal of 10 mm size having the specific gravity of 2.65 and fineness modulus 6.05 was used in the investigation.

Fine Aggregate

River sand having the specific gravity of 2.55 and fineness modulus 2.77 was used in the investigation.

Viscosity Modifying Agent

A Viscosity modified admixture for Rheodynamic Concrete which is colourless free flowing liquid and having Specific of gravity 1.01$\pm$0.01 @ 25^{0}C and pH value as 8$\pm$1 and Chloride Content nil was used as Viscosity Modifying Agent.

Admixture

The Modified Polycarboxylated Ether based superplasticizer which is pale yellow colour and free flowing liquid and having

Relative density 1.10±0.01 at 25°C, pH >6 and Chloride Ion content <0.2% was used as superplasticizer.

Fly Ash

Type-II fly ash confirming to I.S. 3812 – 1981of Indian Standard Specification was used as Pozzolana Admixture.

Micro Silica

The Micro silica having the specific gravity 2.2 was used in the present investigation

6. TEST PROCEEDURE

Test on sulphate resistance of high strength self compacting concrete using mineral admixtures

Sulphate resistance of concrete is determined by immersing test specimens of size 100 X100 X 100 mm cubes in 10% sodium sulphate. The deterioration of specimens are presented in the form of percentage reduction in weight and percentage reduction in compressive strength concrete of specimens at 28, 56, 90 and 180 days.

Test on acid attack of high strength self compacting concrete using mineral admixtures

Acid attack is determined by immersing test specimens of size 100 X100 X 100 mm cubes in 10% H_2So_4 solution and 10% HCl solution respectively. The deterioration of specimens are presented in the form of percentage reduction in weight and percentage reduction in compressive strength concrete of specimens at 28, 56, 90 and 180 days.

Durability factors of high strength self compacting concrete using mineral admixtures

After casting, the specimens are immersed in water for 28 days. Then they are immersed in 10% H_2So_4, 10% HCl and 10% Na_2So_4 solution continuously. Then six specimens are removed from each group, brushed with a soft nylon brush and rinsed in tap water. This process removes loose surface material from the specimen. The specimens are tested at 28 days, 56 days, 90 days and 180 days for the compressive strength.

The durability factor is calculated as follows.
Durability Factor (D F) = (Sr. N) / M
Sr = Relative strength at N days %
N= Number of days at which durability factor is needed
M= Number of days at which the exposure is to be terminated. The acid attack test is terminated at 180 days. So M is 180 in this case.

7. DISCUSSION OF RESULTS

Quantities of materials required per 1 cum of high strength self compacting concrete mixes

Table 1 gives the quantities of material required for M100 grade of high strength self compacting concrete using mineral admixtures.. To build high rise building by reducing column sizes and increasing available space, to built the super structure of long span bridges and to the durability a high strength is needed. So we have attempted for M100 grade mixes as very limited work is available using mineral admixtures.

Fresh State properties of high strength self compacting concrete mixes

Table 2 provides a summary of the fresh state properties of high strength self compacting concrete mixes for mix 100. As it is evident, the basic requirements of high flow ability and segregation resistance as specified by guidelines by EFNARC are satisfied.

Percentage Loss of weight of specimens after immersing in 10 % HCL Solution

From table 3 the percentage loss of weight is observed to be 1.68 % for 28 days, 3.74 % for 56 days, 4.25 % for 90 days and 5.92 % for 180 days respectively. The percentage weight loss is observed to be increasing in correspondence with time. The behavior is given in fig 1.

Percentage Loss of weight of specimens after immersing in 10%Na2So4 Solution

From table 3 the percentage loss of weight is observed to be Nil. This shows that high strength self compacting concrete mixes have the resistance against Na_2So_4 solution. The behavior is given in fig 2.

Percentage Loss of weight of specimens after immersing in 10 % H2So4 Solution

From table 3 the percentage loss of weight is observed to be 8.12 % for 28 days, 14.78 % for 56 days, 23.38 % for 90 days and 27.98 % for 180 days respectively. The percentage weight loss is observed to be increasing in correspondence with time. The behavior is given in fig 3.

Percentage Loss of compressive strength of specimens after immersing in 10 % HCL solution

From table 4 the percentage loss of compressive strength is observed to be 4.74 % for 28 days, 6.28 % for 56 days, 9.38 % for 90 days and 12.78 % for 180 days respectively.

The percentage loss is observed to be increasing in correspondence with time. As the attack proceeds, all the cement compounds are evenly broken down and leached away, together with carbonate aggregate material.

Percentage Loss of compressive strength of specimens after immersing in 10 % Na2So4 solution

From table 4 the percentage loss of compressive strength is observed to be Nil. Incorporation of pozzalona material reduces the sulphate attack. Admixing of pozzolona converts the leachable calcium hydroxide into insoluble non leachable cementitious product. This pozzolona action is responsible for impermeability of concrete. This shows that Na_2So_4 solution indirectly helping in curing the specimens.

Percentage Loss of compressive strength of specimens after immersing in 10 % H2So4 solution

From table 4 the percentage loss of compressive strength is observed to be 22.21 % for 28 days, 29.42 % for 56 days, 38.40 % for 90 days and 48.45 % for 180 days respectively.
With the sulphuric acid attack, calcium sulphate formed can be proceed to react with calcium alumininate phase in cement to form calcium sulphoaluminate, which on crystallization can cause expansion and disruption of concrete.

Durability factors of specimens after immersing in 10 % HCL solution

From table 5 the durability factors are observed to be 14.81% for 28 days, 29.15 % for 56 days, 45.31 % for 90 days and 87.22 % for 180 days respectively.

Durability factors of specimens after immersing in 10 % Na2So4 solution

From table 5 the durability factors are observed to be 15.11% for 28 days, 31.11 % for 56 days, 50.00 % for 90 days and 100.00 % for 180 days respectively.

Durability factors of specimens after immersing in 10 % H2So4 solution

From table 5 the durability factors are observed to be 12.80% for 28 days, 21.96 % for 56 days, 19.20 % for 90 days and 51.55 % for 180 days respectively.

CONCLUSIONS

- High strength self compacting concrete mixes with addition of 15% Micro silica and 25% Fly ash will give optimum strength for M100 grade.
- Water powder ratio of 0.22 is used to in developing High Strength self compacting concrete.
- The percentage weight loss of high strength self compacting concrete mixes after immersing in 10 % HCL solution increases corresponding to the time.
- The percentage weight loss of high strength self compacting concrete mixes after immersing in 10 % Na_2So_4 is observed to be nil for any period of time. This shows that high strength self compacting concrete mixes have the resistance against Na_2So_4 solution.
- The percentage weight loss of high strength self compacting concrete mixes after immersing in 10 % H_2So_4 solution increases corresponding to the time.
- The percentage loss of compressive strength of high strength self compacting concrete mixes after immersing in 10% HCL solution increases corresponding to the time.
- The percentage loss in compressive strength of high strength self compacting concrete mixes after immersing in 10 % Na_2So_4 solution is nil . This shows that Na_2So_4 solution indirectly helping in curing the specimens.
- The percentage loss of compressive strength of high strength self compacting concrete mixes after immersing in 10 % H_2So_4 solution increases corresponding to the time.
- Higher the Durability factor higher will be the resistance to the acid and sulphate attacks.

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Table 1 Quantities of Materials for 1m^3 of High Strength Self Compacting Concrete mixes

Mix	Cement (Kg/m^3)	Fly ash (Kg/m^3)	Micro Silica (Kg/m^3)	Water (Kg/m^3)	Coarse Aggregate (kg/m^3)	Fine Aggregate (Kg/m^3)	SP (kg/m^3)	V.M.A (Kg/m^3)	Water/ Powder Ratio
Mix 100	500	125	75	154	774.985	766.195	11.2	0.35	0.22

Table 2 Fresh Concrete properties of High Strength Self Compacting Concrete Mix M 100

		Mix 10	Permissible limits as per Efnarc Guidelines	
			Min	**Max**
V-Funnel		12 sec	6 sec	12 sec
Abrams slump flow		665 mm	650mm	800mm
T $_{50cm}$ slump flow		4.5 sec	2 sec	5 sec
L-Box	**H_2/H_1**	0.90	0 .82	1.0
	T $_{20}$	1sec	1sec	2 sec
	T_{40}	2 sec	2sec	3sec
V-Funnel at T $_{5 min}$		14 sec	11 sec	15 sec

Table 3 Percentage Loss of Weight of High Strength Self Compacting mixes

Grade of Concrete	10% HCl Solution				10% Na_2So_4 Solution				10% H_2So_4 Solution			
	28 days	56 days	90 days	180 days	28 days	56 days	90 days	180 days	28 days	56 days	90 days	180 days
M 100	1.68	3.74	4.25	5.92	0	0	0	0	8.12	14.78	23.38	27.98

Table 4 Percentage Loss of Compressive Strength of High Strength Self Compacting mixes

Grade of Concrete	10% HCl Solution				10% Na_2So_4 Solution				10% H_2So_4 Solution			
	28 days	56 days	90 days	180 days	28 days	56 days	90 days	180 days	28 days	56 days	90 days	180 days
M 100	4.74	6.28	9.38	12.78	0	0	0	0	22.21	29.42	38.40	48.45

Table 5 Durability Factors of High Strength Self Compacting Mixes

Grade of Concrete		10% HCl solution		10% Na_2So_4 solution		10% H_2So_4 solution	
		Relative strength	Durability Factor	Relative strength	Durability Factor	Relative strength	Durability Factor
M 100	28	95.26	14.81	100.00	15.55	77.79	12.10
	56	93.72	29.15	100.00	31.11	70.60	21.96
	90	90.62	45.31	100.00	50.00	61.60	19.20
	180	87.22	87.22	100.00	100.00	51.55	51.55

Fig 1 Test Specimens of High Strength SCC mix of M100 grade immersed in HCL solution

Fig 2 Test Specimens of High Strength SCC mix of M100 grade immersed in Na_2SO_4 solution

Fig 3 Test Specimens of High Strength SCC mix of M100 grade immersed in H_2SO_4 solution

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