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Correlation of strength and loss in strength of VMA type Self-consolidating Concrete in sulphuric acid

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Abstract - The viscosity modifying agent (VMA) type of Self-consolidating Concrete (SCC) can be an option to powder type SCC where use of mineral admixtures is not economic. The performance of VMA type SCC of different strength in sulphuric acid environment has been studied in this investigation. Four strength categories M25, M35, M45 and M55 were immersed in 3% H_2SO_4 for period of 30, 60, 90 and 180 days. The loss of mass and strength was determined and it was observed that the higher strength SCCs performed better than lower strength SCCs. Good correlation was obtained between the strength of SCC and loss of strength in sulphuric acid.

Key Words: SCC, acid attack, super plasticiser, VMA

I.INTRODUCTION

The most preferred type of high performance concrete in advanced countries had been the SCC, the use of which has gradually increased throughout the world since the 1980s, gaining particular momentum in the late 1990s. Proportioning methods for SCC have traditionally been classified into three general categories depending on the predominate change in mixture proportions. These categories include use of high powder content and low water-powder ratio (powder-type SCC);use of low powder content, high water-powder ratio and VMA (VMA-type SCC); and use of moderate powder content, moderate water-powder ratio, and moderate VMA (combination-typeSCC). When pozzolanic fillers are not available or it becomes uneconomical to use them then the choice remains between inert powder type SCC and VMA type SCC. However only very limited data occur in the available literature on these types of SCC. This paper attempts to investigate performance of VMA type SCC when it is immersed in sulphuric acid.

The objectives of the work described in this paper were to compare the relative performance of VMA type SCC with different strengths in acidic environment. In four categories of strength i.e. M25, M35, M45 and M55 the performance in 3% H_2SO_4 was investigated through loss of mass and strength at different intervals of immersion period such as 30, 60, 90 and 180 days. Fresh properties like flowing ability, passing ability, filling ability and segregation resistance were tested as per reference [1].

In the absence of codal provisions for mixture proportioning of any type of SCC, methods suggested in the literature were studied and found that these methods deal mainly with powder type of SCC [2], [3], [4]. The method suggested in reference [2] does not take into consideration the target strength of the concrete. Method suggested in reference [3] which takes into consideration the target strength of the SCC. In reference [4] it has been shown that method suggested in reference [3] resulted in less amount of cement for grades less than M50.

Resistance to acid attack is one of the important parameters of durability of the concrete. As reported in reference [5] the sulphuric acid is very deteriorative due to the fact that the sulphate ions tend to initiate the sulphate attack, in addition to the dissolution process caused by the hydrogen ions. The degradation of concrete by sulphuric acid consists of two stages. In the first stage, the sulphuric acid chemically reacts with hydration products such as calcium hydroxide (CH) and calcium silicate hydrates (C-S-H) to form gypsum ($CaSO_4.2H_2O$). In the second stage, gypsum reacts with hydrated tricalcium aluminates (C_3A) to form ettringite ($C_6AS_3H_{32}$) and its analogs. The process is described by the following equations:

$Ca(OH)_2 + H_2SO_4 \rightarrow CaSO_4 . 2H_2O$

$CaO \cdot SiO_2 \cdot 2H_2O + H_2SO_4 \rightarrow CaSO_4 + Si(OH)_4 + H_2O$

$3CaO \cdot Al_2O_3 \cdot 12H_2O + 3(CaSO_4 \cdot 2H2O) + 14H_2O \rightarrow 3CaO \cdot Al_2O_3 \cdot 3CaSO_4 \cdot 32H_2O$

Both gypsum and ettringite have very low structural stability in comparison to the reactants they replace. They are also believed to cause expansion, which initiates cracks in concrete.

II. EXPERIMENTAL PROGRAMME

2.1 Materials

Ordinary Portland cement of 53 grade conforming to the IS 8112:1989 with specific gravity 3.12 was used for all the mixes. The river sand conforming to zone II of IS 383:1970 having a specific gravity 2.52 was used as fine aggregate (F A). The coarse aggregate (C A) had a maximum size of 16 mm. While 10 percent of it was passing through 10 mm IS sieve and retaining on 4.75 mm IS sieve, 60 percent of it was passing through 12.5 mm IS sieve and retaining on 10 mm IS sieve and 30 percent of it was passing through 16 mm IS sieve and retaining on 12.5 mm IS sieve. The specific gravity of the coarse aggregate was 2.67. Use of super plasticiser is unavoidable in manufacture of any type of SCC. The super plasticiser used in this study was Glenium B233 procured from BASF. It is based on modified polycarboxylic ether. It complies with ASTM C494 Types F and IS 9103:1999. The Viscosity Modifying Agent used to manufacture VMA type of SCC was Glenium Stream 2 procured from BASF. Clean potable water available in the laboratory was used for mixing the concrete. The properties of all the materials are shown in Tables 1-3.

Table 1: Properties of Cement

Physical Property	Result
Normal Consistency	29%
Vicat initial setting time (minutes)	75 min.
Vicat final setting time (minutes)	482 min.
Specific gravity	3.12
Compressive strength at 7-days	37.33 Mpa
Compressive strength at 28-days	53.64 Mpa

Table 2: Sieve analysis of fine aggregate

IS sieve size, (mm)	Percentage passing
4.75	98.9
2.36	92
1.18	86.4
0.60	35.3
0.30	5.4
0.15	1.1

Table 3: Properties of Super plasticiser and VMA

	Glenium B233	Glenium Stream 2
Aspect	Light Brown Liquid	Colourless free flowing liquid
Specific Gravity	1.01± 0.01 at 25^0C	1.01± 0.01 at 25^0C
pH	> 6	> 6
Chloride ion content	< 0.2%	< 0.2%

2.2 Mix proportioning of self-consolidating concrete

The mix proportioning method proposed in reference [3] was used to arrive at trial mixes and modifications were made to arrive at final mix proportions which satisfied the fresh as well as strength properties. The final mix proportions are shown in Table 4.

Table 4: Mix proportions per cubic metre SCC in kg.

SCC mix Type	Specimen	Grade of SCC	Cement	F A	C A	Water	SP	VMA
VMA type SCC	CV1	M25	305	960	813	137	6.1	0.183
	CV2	M35	348	960	813	139	8.0	0.209
	CV3	M45	393	960	813	138	10.21	0.235
	CV4	M55	443	960	813	133	10.45	0.266

2.3 Specimen preparation

A pan type of concrete mixer of capacity 100kg was used for mixing of all SCC mixes. Mixing of ingredients in dry condition was carried out for one minute. Then 70% of calculated amount of water was added to the dry mix and mixed thoroughly for two minutes, out of remaining 30% water, 20% was mixed with super-plasticiser and poured in the mixer and mixed for four minutes. Finally VMA was added in the last 10% of water and then poured in the mixer and mixed for one minute [6].

Then every mix was checked for self-consolidating ability by slump flow test, v-funnel test, L-box test and GTM Screen stability test. The results of fresh concrete properties of all the mixes satisfying the self-consolidating ability have been shown in Table 5. These mixes exhibited horizontal slump flow without signs of bleeding even at the outer boundary. This visual inspection and result of GTM screen stability test confirmed the segregation resistance of the SCC mixes. After checking the self-consolidating ability of the mix it was poured into the cube moulds of specific sizes. The moulds were covered with wet gunny bags for 24 hours after casting and the specimens were then immersed in water for curing after demoulding. Cube moulds of 150×150×150mm conforming to IS 10086: 1982 were used to cast for test of compressive strength. The tests for acid resistance were performed on 100×100×100mm cube specimens.

2.4 Test procedure

2.4.1 Compressive strength

Cube specimens were tested for compressive strength at 3 days, 7 days and 28 days according to IS 516. The test results shown in Table 5 are average strength of three specimens for every mix.

2.4.2 Acid attack

The % loss in mass and compressive strength was determined for the test in following manner. The cube specimens after curing in water for 28 days were taken out of curing tank. The specimens were then place in solution of 3% H_2SO_4. The pH of the solution was regularly monitored and adjusted to keep it constant. The consumed solution was replaced with freshly prepared solution every week. The cubes were immersed in acid for 90 days and the assessment was made of performance in acid attack from

- Mass loss
- % loss in compressive strength.

The results of performance of all SCC mixes in acid attack have been shown in Table 6.

III RESULTS AND DISCUSSIONS:

3.1 Fresh Properties and Compressive Strength: The results of fresh properties and compressive strength of all types of SCC are shown in Table 5. It can be observed that these mixes have passed all the tests deployed to assess the self-consolidating ability and the requirement of strength.

Table 5: Fresh Properties of all SCC mixes and Compressive Strength

Specimen	Grade of SCC	Slump Flow (mm)	T_{50} flow time (Sec)	V-Funnel (sec)	V-Funnel at $T_{5min.}$	L-Box h1/h2	GTM Screen %	28 Days Compressive Strength (MPa)
CV1	M25	674	3.88	10.65	13.34	0.83	12.8	29.38
CV2	M35	665	3.29	11.2	14.1	0.81	13.9	38.84
CV3	M45	682	4.45	10	12.6	0.85	10.64	47.32
CV4	M55	735	2.56	9.1	11.14	0.94	14.5	57.34

3.2 Acid attack:

The results of acid attack on SCC specimens when immersed in 3% H_2SO_4 for 30 days, 60 days, 90 days and 180 days have been reported in Table 6. The deterioration of all grades of SCCs took place at faster rate after 90 days. The rate of mass loss went up at faster rate with the increase in immersion time. At 30 days immersion period M25 and M35 grade SCCs lost the mass but M45 and M55 grade SCCs gained the mass. This was shown by –ve sign in the Table 6. The mass gain must be due to hydration of the unhydrated cement paste present in higher grades due to excess amount of cement in these SCCs.

As the grade of the SCC increased the deterioration decreased. This can be attributed to more impermeable surface of SCCs with higher cement content and lesser W/C ratio in the same. The % loss in mass was 8.84 for M25 grade of SCC which was highest and it was 5.77 for M55 grade which was lowest. The loss of strength was much more and significant as compared to loss of mass. Higher % loss in mass shows higher penetration of acid hence damage and deterioration to higher depths which leads to much higher % loss in strength.

Table 6: % Loss in Mass and strength in 3% H_2SO_4

Grade of SCC	% Loss in Mass in 3% H_2SO_4 (No. of days)				% loss in strength in 3% H_2SO_4 (No. of Days)			
	30	60	90	180	30	60	90	180
M25	0.32	0.98	2.81	8.84	2.05	6.73	17.13	43.54
M35	0.28	0.87	2.59	7.86	1.71	5.18	14.71	35.83
M45	-0.12	0.79	2.21	6.95	0.17	3.63	12.46	29.58
M55	-0.19	0.71	1.73	5.77	-0.21	2.12	9.35	24.39

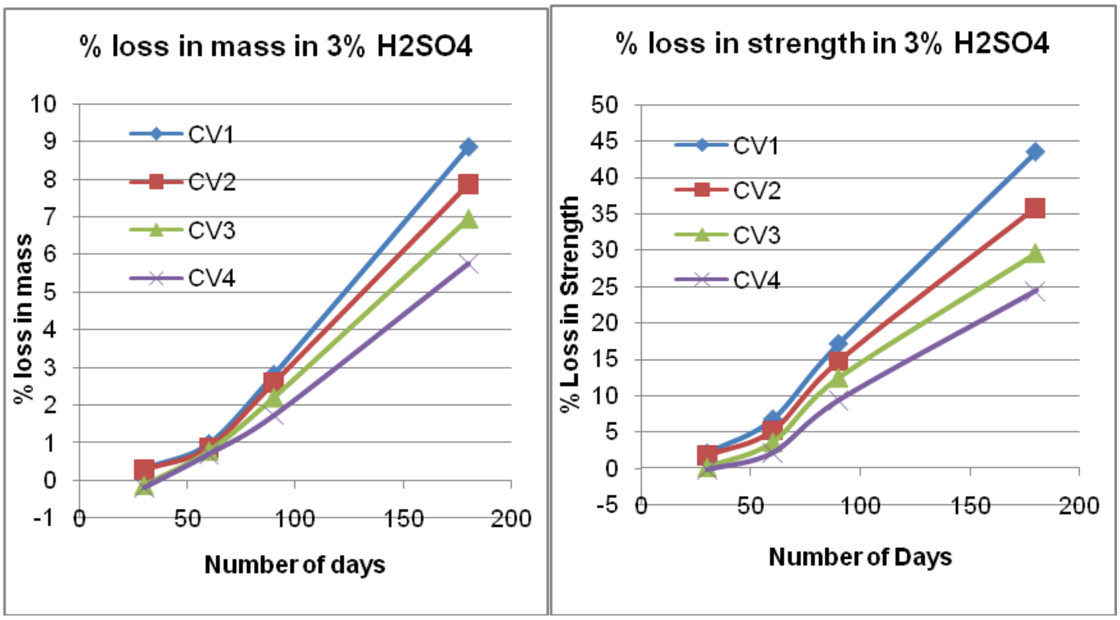

Figure 1 **Figure 2**

Figure 1 and 2 shows the variation of % loss of mass and strength respectively with number of days of immersion in sulphuric acid. The trend appears same for both the damage parameters. The correlation between the strength of SCC and % loss in strength after immersion in sulphuric acid is shown in figure 3. All the trend lines are second degree polynomials. The equation of each trend line and corresponding value of R^2 are shown in table 7. It can be observed that good correlation exist between the strength and % loss in strength for different immersion periods. The values of R^2 are very near to one as can be seen.

Table 7. Correlation of strength and % loss in strength

Number of days of immersion	Equation of trend line, y=% loss in strength, x= 28 days strength	R^2
30	$y = 9E\text{-}05x^2 - 0.0969x + 4.9452$	$R^2 = 0.9107$
60	$y = 0.0004x^2 - 0.1998x + 12.29$	$R^2 = 0.9991$
90	$y = -0.0015x^2 - 0.1459x + 22.709$	$R^2 = 0.9999$
180	$y = 0.0082x^2 - 1.4016x + 77.684$	$R^2 = 0.9996$

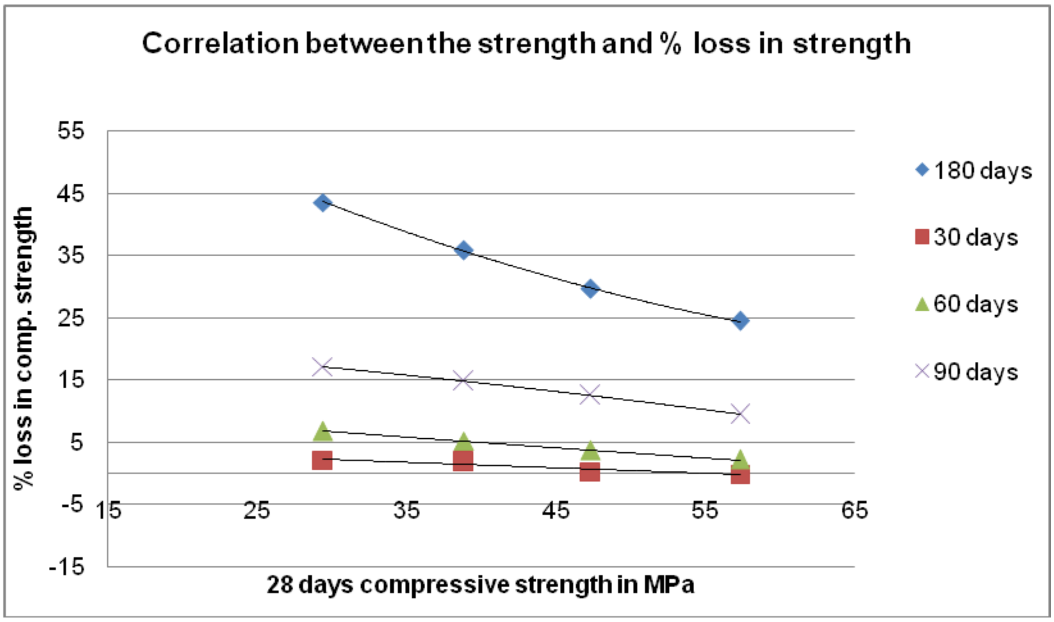

Figure 3 Correlation between the compressive strength and % loss in strength

IV. CONCLUSIONS

From the study undertaken it can be concluded that

- VMA type of SCC can produce good strength.
- The durability of the VMA type SCC increases with the strength of it as its resistance to acid attack.
- The higher cement content and lower w/c ratio in SCC produces better resistance to acid attack.
- High strength VMA type SCC can be used where the structure is exposed to aggressive acid environments.
- The strength of VMA type SCC can be correlated to resistance to acid.

REFERENCES:

[1] EFNARC (2002) (European Federation of national trade associations representing producers and applicators of specialist building products), Specification and Guidelines for self-compacting concrete, Hampshire, U.K.

[2] Okamura, H., and Ozawa, K., (1995) Mix Design Method for Self-compacting concrete. Concrete Library of JSCE, No. 25, pp. 107-120

[3] Nan Su, Kung-Chung Hsu and His-Wen Chai, (2001) A simple mix design method for self compacting concrete, Cement and Concrete Research, 31, pp. 1799-1807.

[4] Karjinni, Vilas and Anadinni, Shrishail, (2009) Mixture proportion procedure for SCC, The Indian Concrete Journal, pp 35-41.

[5] E. Hewayde, M. Nehdi, E. Allouchi, and G. Nakhla. Effect of mixture Design Parameters and Wetting-Drying Cycles on Resistance of Concrete to Sulfuric Acid Attack. J. Mater. in Civ. Eng.19 (2) (2007) 155-163

[6] Ganesan, N., Indra, P. V. and Santosh Kumar. (2006) Durability aspects of steel fibre-reinforced SCC. The Indian Concrete Journal, pp. 31-37.

