The Behaviour of Self Compacting Concrete with Waste Plastic Fibers When Subjected To Acid Attack.

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Abstract - **Self compacting concrete (SCC) has been developed in order to achieve durable concrete structures. Long term durability studies of self compacting concrete become necessary as it is different from normal concrete. Due to high powder content and cementitious paste in self compacting concrete it is vulnerable to chemical attack. This study aims at investigating the resistance of SCC with addition of waste plastic fibres to acid attack. The strength based mix proportion of SCC was arrived based on NANSU method of mix design for M40 grade plastic fibre reinforced self compacting concrete. It was developed by varying percentages of fibres from 0.0%, 0.25%, 0.5%, 0.75%, 1.00%, 1.1%, 1.2%, 1.3% and 1.4%. The result of fresh property tests satisfy the limit specified by EFNARC. The specimens were cured in water for 28days and then immersed in sulphuric acid solution with P^H2.0. The percentage loss in compressive and split tensile strength and loss in weight of specimens for different percentages of fibers were evaluated. The addition of waste plastic fibres improved the compressive, tensile and durability characteristics. At 1.0%of plastic fibre content by weight of cement, maximum compressive and split tensile strength have been achieved. From the test results as the percentage of fibre increased, percentage weight loss and loss in compressive strength decreased when immersed in sulphuric acid with controlled P^H of 2.0 for 30, 60 and 90 days.**

Keyword - Self-Compacting Concrete, Waste Plastic Fibres, Durability, Acid Attack, Compressive Strength, Split Tensile Strength.

I. INTRODUCTION

For several years beginning in 1983, the problem of the durability of concrete structures was a major topic of interest. The creation of durable concrete structures requires adequate compaction by skilled workers. As the designs of modern reinforced concrete structures become more advanced, the designed shapes of structures are becoming increasingly complicated and heavy reinforcing is no longer unusual. Furthermore, the gradual reduction in the number of skilled workers in construction industry has led to a similar reduction in the quality of construction work. One solution for the achievement of durable concrete structure independent of the quality of construction work is the employment of self compacting concrete, which can be compacted into every corner of a form work, purely by means of its own weight and without the need for vibrating compaction.

The prototype of SCC was first completed in 1988 using materials already on the market. The proto type performed satisfactorily with regard to drying and hardening shrinkage, heat of hydration, denseness after hardening, and other properties.

In Europe it was probably first used in civil works for transportation networks in Sweden, in the middle of 1990's.SCC was first developed so that durability of concrete structures can be improved. Since then, various investigations have been carried out and the concrete has been used in practical structures in Japan and Europe, mainly by large construction companies. Investigations for establishing a rational mix design method and self-compactability testing methods have been carried out from the viewpoint of making it a standard concrete. Recommendations and manuals for self-compacting concrete were also written.

SCC was developed in order to achieve durable concrete structures. Due to inadequate compaction in normal concrete there will be durability defects, where as in SCC the removal of need for compaction reduced the potential for durability defects. SCC has large amount of powder content with low water to powder ratio. Hence its strength and durability properties may be different for similar grades of concrete and needs through investigation.

The waste water treatment facilities and sewer pipes get degraded by sulfuric acid attack which results in economic loss. Sulphate reducing bacteria, the microorganisms present in the sewer pipes initiates the degradation of concrete by sulphuric acid. The sulfuric acid present in the sewer pipes reacts with hydration products to form gypsum and ettringite, which has greater volume. Due to the increased volume, the internal pressure is increased which results in formation of cracks leading to aggregate loss which causes thinning of wall of sewer pipes. Other structural elements like foundation which is susceptible for acid attack due to presence of ground water containing sulphuric acid, super structures are also susceptible for acid attack. Role of supplementary cementitious material used in SCC in chemical attack is ambiguous.

Plastic which is a non-biodegradable material neither decays nor degenerates completely in water or in soil. Plastic when burnt releases many toxic gases which is not only dangerous to health of living beings but also results in environmental pollution. In recent time significant research is underway to study the possibility of disposal of these wastes in concrete in the form of fibres to impart some additional desirable qualities to the concrete. In this study the behavior of SCC with GGBS and waste plastic fibres and its resistance to sulfuric acid with a controlled P^H 2.0 is studied. The percentage of fibre by weight of cement is varied like 0.0%, 0.25%, 0.5%, 0.75%, 1.00%, 1.1%, 1.2%, 1.3% and 1.4%.

II. Literature Review

For achieving SCC mixes various methods have been used. Okamura [1] fixed coarse aggregate and fine aggregate content and achieved SCC by adjusting water cement ratio and super plasticizer dosage. M Ouchi [2] proposed an index which is the ratio of funnel speed to flow area and is useful in evaluating the amount of super plasticizer and viscosity of mortor. Nansu [3] used material properties to determine the amount of aggregates, binders, mixing water and super plasticizer dosage. The workability of SCC gets affected due to addition of fibres. Different types of fibers have been used to improve the hardened properties. Salmet widodo [4] used polypropylene fibres upto 0.15% of volume and strength was high at 0.1% fibres .Buquen Miao[5] used steel fibres upto 1.5% , and fiber content of 1% has high workability and strength retention.Kishore[6]used steel fibres of aspect ratio 50,80 and more strength was achieved for 50 aspect ratio . B Krishna rao [7].used steel fibres with flyash for an aspect ratio of 15, 25 and 35. 1% with 25 aspect ratio showed better performance. Different innovative materials are added to improve the service life of concrete structures when exposed to sulphuric acid. Monteny [8] reported that silica fume addition has negative effect when immersed in 0.5% sulphuric acid where as 60% GGBS concrete offered highest resistance 0.5% sulphuric acid. Z. Chang [9] investigated that mixture made with GGBS has poor performance than 100% ordinary port land cement in 1% sulphuric acid. Swetha [10] used 15 sulphuric acid, 1% hydrochloric acid and 1% nitric acid and found that mass loss was higher in hydrochloric and nitric acid. Joong Kyujeon [11] investigated that decrease in PH and increase in duration of immersion higher was the weight loss and lower was the compressive strength, the mixture with60% GGBS was most resistant to acid. Data on waste plastic fibres in SCC and its durability for acid exposure is very limited.

III. Experimental Work

In this experimental investigation an attempt has been made to study the effect of sulphuric acid attack on self compacting concrete containing various percentages of waste plastic fibers into it.

A. Materials Used

1) *Cement:* Ordinary Portland Cement-53 grade was used having a specific gravity of 3.15 and it satisfies the requirements of IS: IS: 12269-1987 specifications. The physical and mechanical properties of cement are given in Table I.
2) *Ground granulated blast furnace slag:* GGBS obtained from Bellary steel plant was used. The GGBS used was having Specific gravity of 2.62. The properties of GGBS are given in Table II.
3) *Fine aggregates*: Manufactured sand was used as fine aggregate. The sand used was having a specific gravity of 2.6 and bulk density of 1550kg/m^3 and confirmed to grading zone-II as per IS: 383-1970 specification.
4) *Coarse aggregates*: The coarse aggregates used in the experimentation were 12.5 mm and down size aggregate and tested as per IS: 383-1970 and 2386-1963 (I, II and III) specifications. The aggregates used were having specific gravity of 2.72 and bulk density as 1430kg/m^3
5) *Water*: Ordinary potable water free from organic content, turbidity and salts was used for mixing and for curing throughout the investigation.
6) *Superplastizers*: Glenium B_{233} an admixture of new generation based on modified polycarboxylic ether was used.
7) *Fibres*: The waste plastic fibres were obtained by cutting waste plastic pots, buckets, cans, drums and utensils.

   The waste plastic fibres obtained were all recycled plastics. The fibres were cut from steel wire cutter and it is labour oriented. The thickness of waste plastic fibres was 1mm and its breadth was kept 2.5mm and these fibres were straight. The different volume fraction of fibres and suitable aspect ratio of 50 were selected and used in this investigation.

8) *Sulfuric acid*: Liquid form of sulfuric acid which was almost colourless oily liquid of grade Excelar was used. In the present study sulfuric acid was diluted with water and p^H of 2 was maintained.

B. Mix Proportioning, casting and curing

The mix proportion (Cement: GGBS: Fine aggregate: Course aggregate 1: 0.705: 3.34: 2.62) for M_{40} grade of concrete was done by using Nan Su method. The super plastizers dosage was varied to adjust flowability for different percentage of fibres. The materials are taken in order and added in the required quantities and thoroughly mixed. At this stage concrete was in a flowable state. In this work one control mix and eight different mixes were prepared and the details of mixes are shown in Table No 3. The workability tests like slump flow, $T_{50cm,}$ j –ring, V funnel and L-boxes tests were conducted and the test results are presented in Table No 4. After the workability tests concrete mix was poured in the moulds to prepare the specimens for strength tests. For acid attack test, the specimens after 28 days of curing in water were immersed in sulphuric acid solution with a controlled p^H of 2.0 for 30, 60 and 90days.Before immersion they were weighed accurately. After the exposure period,the specimens were removed from acid media, washed in running water, weighed accurately and tested for their respective strengths. Compressive strength specimens were of dimensions 150 x150 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 IS 5816:1999

TABLE I. Physical properties of Ordinary Portland Cement-53 grade (IS: 12269-1987)

Properties	**Results**	**Permissible limit as per IS: 12269-1987**
Fineness	28.4 m^2/N	Should not be less than 22.5m^2/N
Normal consistency	26%	-
Setting Time a. Initial b. Final	 160 350	 Should not be less than 30 Min Should not be more than 600 Min
Specific gravity	3.14	-
Compressive strength of mortar cubes for a. 3days. b. 7days. c. 28 days	33.0 N/mm^2 45.5 N/mm^2 62.5 N/mm^2	Should not be less than 27 N/mm^2 Should not be less than 37 N/mm^2 Should not be less than 53 N/mm^2

Table II. Physical properties of GGBS

Properties	**Results**
Specific Gravity	2.86
Fineness % (by wet sieve on 45µ sieve)	10.2
Specific surface (m2/Kg)	314
Glass content %	93.26

IV. EXPERIMENTAL RESULTS

The workability (Slump flow, T_{50cm}, J-ring, V-funnel and L-box tests) test results of Self-compacting concrete with various percentage additions of waste plastic fibres are given in Table IV. The average compressive strength and tensile strength with varying percentage of fibres after 28 days of water curing is shown in Fig. 1 and Fig. 2. The percentage loss of compressive strength and percentage weight loss in cube specimen after immersing in sulfuric acid solution is shown in Fig. 3 and Fig. 4 and the percentage loss in split tensile strength is shown in Fig. 5.

Table III. Mix proportions of SCC for various percentage additions of waste plastic fibers

Mix	% of Fibre	W/P ratio by mass	Cement (kg/m^3)	GGBS (kg/m^3)	Fine Agg. (kg/m^3)	Coarse Agg. (kg/m^3)	Total Powder (kg/m^3)	SP %
$SCC_{0.00}$	0.00	0.35	280	197.5	936	734	477.5	0.60
$SCC_{0.25}$	0.25	0.35	280	197.5	936	734	477.5	0.62
$SCC_{0.5}$	0.50	0.35	280	197.5	936	734	477.5	0.65
$SCC_{0.75}$	0.75	0.35	280	197.5	936	734	477.5	0.72
$SCC_{1.00}$	1.00	0.35	280	197.5	936	734	477.5	0.80
$SCC_{1.10}$	1.10	0.34	280	220	936	734	500	0.81
$SCC_{1.20}$	1.20	0.34	280	220	936	734	500	0.82
$SCC_{1.30}$	1.30	0.34	280	220	936	734	500	0.84
$SCC_{1.40}$	1.40	0.34	280	220	936	734	500	0.86

Table IV. Test results of SCC for various percentage additions of waste plastic fibres.

Mix	% of fibre	Slump flow (760-850) (for class SF3)	T_{50cm} (≤2forVS1) (> 2 forVS2)	V-funnel (≤8 forVF1) (9 to25 for VF2)	V-funnel T_{5min} (+3 sec)	J –Ring (0-10mm)	L-box- (>0.75)
$SCC_{0.00}$	0.00	800	2	8	12	3	0.80
$SCC_{0.25}$	0.25	795	2.5	8.36	11.5	5	0.85
$SCC_{0.5}$	0.50	780	3	9.5	13	8	0.93
$SCC_{0.75}$	0.75	750	4	12	15	10	1.00
$SCC_{1.00}$	1.00	735	8.5	18	21	10	1.80
$SCC_{1.10}$	1.10	780	9.0	19.5	22	12	1.93
$SCC_{1.20}$	1.20	780	9.2	21	24	12	1.93
$SCC_{1.30}$	1.30	770	10	23	27	11	1.93
$SCC_{1.40}$	1.40	764	10.4	24	28	12	1.85

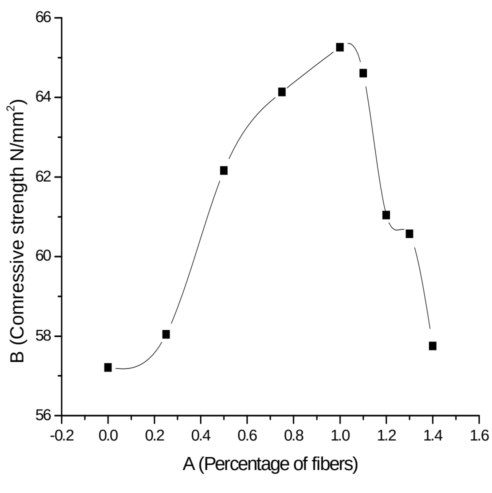

Fig. 1 Average compressive strength after 28 day water curing
curing

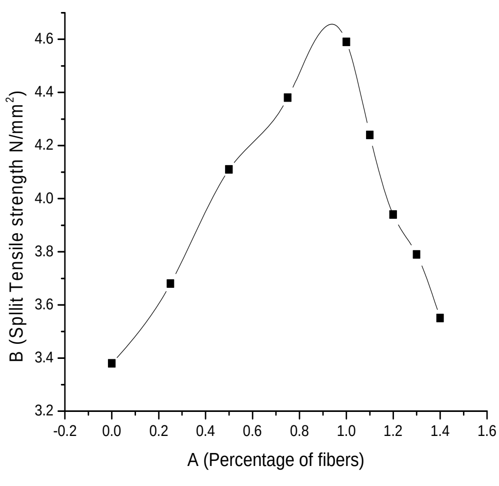

Fig. 2 Average split tensile strength after 28 days water

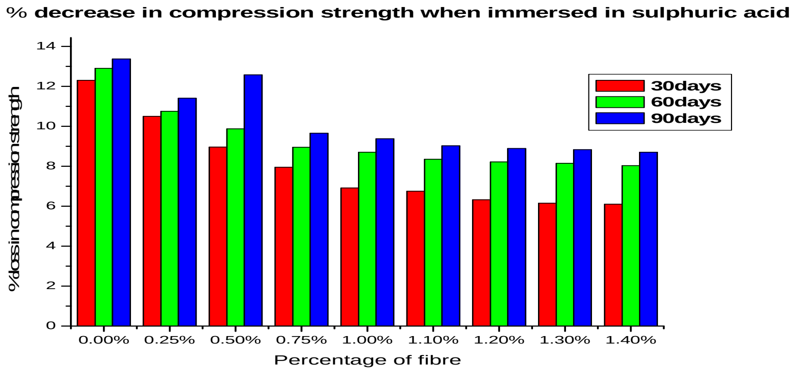

Fig. 3 Percentage decrease in compressive strength when subjected to acid exposure.

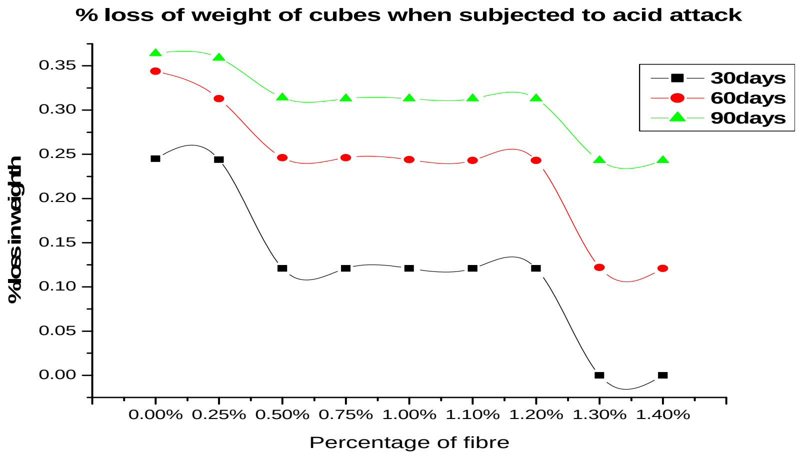

Fig. 4 Percentage decrease in weight loss of cube specimens

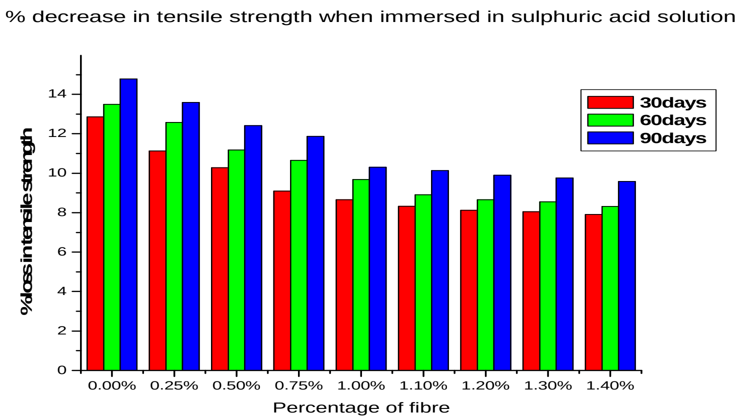

Fig. 5 Percentage decrease in tensile strength when subjected to acid exposure.

V. DISCUSSIONS OF RESULTS

Based on the experimental results and observations, the following discussions were made

1. It can be observed from the values presented in Table No. 4.0 that all mixes from 0% fibre to 1.4% fibre, satisfy flowability measured by slump flow, viscosity assessed by T_{50} and passing ability assessed by L-Box and segregation resistance by V funnel out of four key characteristics as per EFNARC 2005 guide lines and hence be considered as SCC mixes.
2. It has been observed that from the experimental results, the addition of waste plastic fibres from 0.25% to 1.0% by weight of cement has shown increase in strength characteristics (compressive strength, split tensile strength,) of SCC compared to SCC without plastic fibers and then starts decreasing after 1.0% addition of waste plastic fibers into it as shown in Fig 1 and Fig 2 This is because higher volume of fibers interfere

with cohesiveness of concrete mix. Improper mixing of fibers with matrix takes place due to balling effect of fibers which increases the air voids in the mix and in turn reduces the strength.

3. When the cube specimens were immersed in 5% sulphuric acid solution for 30, 60 and 90 days there is percentage decrease in compressive strength. It is found that the decrease in compressive strength reduces as the percentage of fibres increases. For 0.0% to 1.4% fiber content there is a decrease from 12.3% to 6.10%, 12.9% to 8.03% and 13.37% to 8.71% for 30 days, 60 days and 90 days. as shown in Fig 3.
4. When the cylinder specimens were immersed in 5% sulphuric acid solution for 30, 60 and 90 days there is percentage decrease in split tensile strength. It is found that the decrease in split tensile strength reduces as the percentage of fibres increases. For 0.0% to 1.4% fibre content there is a decrease from 12.86% to 7.91%, 13.50% to 8.31% and 14.79% to 9.58% for 30 days, 60 days and 90 days as shown in Fig No. 5

   The weight of the cube specimens were measured before and after immersing in the sulphuric acid solution for 30, 60 and 90 days. It is observed that there is weight loss in the cube specimens. From the weight loss observations we can see that the percentage reduction in loss of weight.

VI. Conclusions

Based on the experimental results the following conclusion can be drawn

1. In the present investigation waste plastic fibre reinforced self compacting concrete were developed without adding viscosity modifying agent. In the fresh state, when the addition of waste plastic fibres were increased it caused lower flowability, passing ability and segregation resistance. So the super plasticizer dosage was increased from 0.6% to 0.86% as the fibre decreases as the percentage fibre content increases as shown in Fig No.4content increased from 0.0% to 1.4%. The super plasticizer dosage for fibre content greater than 1.4%was more than 0.86 which caused bleeding and segregation. So it can be concluded that beyond 1.4% fibre content for an aspect ratio of 50 it is difficult to achieve waste plastic fibre reinforced self compacting concrete.
2. From the hardened properties test results it can be concluded that maximum compressive strength, split tensile strength and flexural strength can be achieved at 1.0% addition of waste plastic fibres with respect to an aspect ratio of 50.Hence 1.0% of waste plastic fibre can be considered as optimum from strength considerations for waste plastic reinforced self compacting concrete.
3. There was small amount of spalling at the edges of specimens when exposed to sulphuric acid solution for 60 days and 90 days. After conducting the compressive and split tensile strength tests it was observed that there is decrease in compressive and split tensile strengths after immersing the specimens in sulphuric acid for 30, 60 and 90days. It is found that the decrease in compressive strength reduces as the percentage of fibres increases.
4. It can be concluded that addition of waste plastic fibre into SCC will improve durability characteristics and mechanical characteristics.

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