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

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Abstract

This paper outlines laboratory study on chloride resistance of waste plastic fibre reinforced self compacting concrete. Self compacting concrete mixes with varying percentages of waste plastic fibers like 0.0%,0.25%,0.5%,0.75% ,1.00%,1.1%,1.2%,1.3% and 1.4% were developed for M40 grade of concrete. The mix proportion was done by NANSU method. The result of fresh property test satisfies the limits specified by EFNARC. The cubes and cylinders were immersed in 5% magnesium chloride solution for a period of 30 days, 60days and 90 days. The degree of chloride attack is determined by evaluating the reduction in compressive strength split tensile strength and percentage loss of weight of specimen. From the test results it is observed that maximum compressive strength and split tensile strength were achieved for 1% of plastic fibre. The chloride content is determined by Argentometric titration method. Percentage loss of weight, loss in compressive strength and chloride penetration have decreased as the percentage of fibre increased.

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Keywords: Self-compacting concrete, waste plastic fibres, Durability, chloride penetration,Weight loss, Compressive strength, Split tensile strength, Argentometric titration method.

1.Introduction

SCC is a concrete, whereby concrete can be placed in forms containing dense rebars without the need for any vibration. The concrete flows to fill all the voids in the form, completely surrounding and flowing through the rebars without leaving air pockets or voids. No segregation or bleeding occurs with the concrete during placement or during the time it remains in the plastic state. The concrete is made flowable by altering the mix proportions and through the use of additional admixtures that prevent segregation. Self-Compacting Concrete was developed in Japan in the late 1980s to reduce the labour required to properly place concrete.

The use of pozzolanic materials, such as fly ash, GGBS, and limestone powder helps the SCC to flow better. Due to high fluidity and resisting power of segregation of SCC, it can be pumped to longer distances. The use of SCC not only shortens the construction period also ensures quality and durability. The new concept and technology reveal that the engineering advantages of putting fibre in concrete may improve the fracture toughness, fatigue resistance, impact resistance, flexural strength, compressive strength, thermal crack resistance, rebound loss, and so on. 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. The disposal of such waste plastics is a major challenge to the municipalities especially in the metropolitan cities and such waste plastics can be used in the form of fibres to impart some additional desirable qualities to the concrete.

Chloride attack is one of the most important aspects for consideration when we deal with the durability of concrete. Chloride attack is particularly important because it primarily causes corrosion of reinforcement. Statistics have indicated that over 40 per cent of failure of structures is due to corrosion of reinforcement. Due to high alkalinity of concrete a protective oxide film is present on the surface of steel reinforcement. The protective passivity layer can be lost due to carbonation. This protective layer also can be lost due to the presence of chloride in the presence of water and oxygen. In reality the action of chloride in inducing corrosion of reinforcement is more serious than any other reasons. One may understand that Sulfates attack the concrete, whereas the chloride attacks steel reinforcements. Chloride enters the concrete from cement, water, and aggregate and sometimes from admixtures. The present day admixtures are generally containing negligible quantity of chloride or what they call chloride free. Chloride can enter the concrete by diffusion from environment.

The Bureau of Indian Standard earlier specified the maximum chloride content in cement as 0.05 percent. But it is now increased the allowable chloride content in cement to 0.1 per cent. . In this study the behavior of SCC with GGBS and waste plastic fibres and its resistance to chloride is investigated. 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%.

2.Literature review

Self compacting concrete mixes have been achieved by various methods since the beginning. Ozawa [1] showed that the flowing ability and segregation resistance improved remarkably when Portland cement was replaced with flyash and GGBS. Muthupriya[2] showed that in SCC compressive strength, split tensile strength and flexure strength is more when silicafume admixture is used. Gencel[3]studied SCC with flyash and polypropylene fibres and showed that the polypropylene fibres can be used at much lower content than steel fibres. Kandaswamy[4] has compared fibre reinforced concrete and self compacting concrete with fibres cut from domestic waste polythene bags. He concluded that tensile strength and flexural strength of SCC with fibers is higher compared to fibre reinforced concrete.Mostafa jalal[5] used titanium dioxide nano powder to determine the chloride ion penetration for high strength SCC. The results showed increase in durability.Amr.S. EL-Diab[6] studied the effect of steel fibres on ultra high strength SCC and conducted RCPT tests and concluded that ther is not much change in bulk chloride diffusion values due to inclusion of steel fibres.Antonious Kanellopoulos[7] studied durability of SCC with respect to sorpivity porosity and chloride ion permeability and compared with conventional concrete. The results showed SCC made with silica fume showed substantial reduction in chloride ion permeability. N R Gaywala [8] studied hardened properties of SCC with fly ash and durability was studied by immersing cubes in sodium chloride solution of 3.5% concentration. The resistance to concrete to chloride action can be increased by making the concrete less permeable by using materials like GGBS, Flyash, and Silica fume. Many investigations have been made using the above materials for normal concrete and SCC with steel fibres but very less data is available for durability study of SCC with waste plastic fibres.

3.Experimental investigations

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

3.1.*Materials*

Ordinary Portland cement 53 grade confirming to the requirements of IS: 12269-1987 specifications was used. GGBS having specific gravity of 2.62 obtained from Bellary steel plant was used. The characteristics of cement and GGBS are presented in Table 1 and Table 2 respectively. Manufactured sand with specific gravity of 2.6 and bulk density of 1550 kg/m^3 was used as fine aggregate. The sand was confirmed to grading zone II as per IS: 383-1970 specification.12.5 mm down size aggregate tested as per IS: 383-1970 and 2386-1963 specifications were used as coarse aggregate. Glenium B_{233} polycarboxylic ether was used as a superplastizer. 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.

3.2.*Mix Design, casting and curing*

In the present study nine different mixes of waste plastic fibre reinforced self compacting concrete were designed with varying percentage of fibres. The methodology of mix design was explained in detail elsewhere. The mix proportion (Cement: GGBS: Fine aggregate: Course aggregate 1: 0.705: 3.34: 2.62) for M 40 grade of concrete was obtained. The super plastizers dosage was varied 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. The details of mixes are shown in Table 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 IV. After the workability tests concrete mix was poured in the moulds to prepare the specimens for strength tests.

4. Test Program

4.1. Compressive strength and tensile strength studies

The compressive strength and tensile strength tests were carried out on compression testing machine as per IS: 516-1959 and IS: 5816-1999 respectively. The compressive test specimens were of dimensions 150x150x150mm. The cylinders for split tensile strength were of 150mm diameter and 300mm length.

4.2. Acid attack

Acid attack studies by immersing the cubes and cylinders in acid solution, the chemical resistance of concrete was studied. After 28 days of curing in water, specimens were immersed in 5% magnesium chloride solution for 30, 60 and 90days. Before immersion they were weighed accurately. After immersion the specimens were removed from chloride media, washed in running water, weighed accurately and tested for their respective strengths. The percentage loss of compressive strength and percentage weight loss in cube specimen after immersing in magnesium chloride solution are shown in Fig 3 and Fig 5 respectively. The percentage loss in split tensile strength and percentage weight loss in cylinder specimens after immersing in the solution are shown in Fig. 4.

4.3. Chloride penetration test.

To determine the chloride ion penetration after the specimens were taken out from solution and surface of cubes were brushed to remove loose scales with the help of nylon brush. The cubes are thoroughly dried. The powered samples were prepared by drilling the specimens to a depth of 10mm and concrete powder samples were extracted as per ASTMC1218. Argentometric titration of chloride with silver nitrate method was used to determine the total chloride content from powdered samples. The result of chloride penetration test is tabulated in Table 5.

Table 1. Physical properties 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	160	Should not be less than 30 Min
b. Final	350	Should not be more than 600 Min
Specific gravity	3.14	-
Compressive strength of mortar cubes for		
a. 3days.	33.0 N/mm^2	Should not be less than 27 N/mm^2
b. 7days.	45.5 N/mm^2	Should not be less than 37 N/mm^2
c. 28 days	62.5 N/mm^2	Should not be less than 53 N/mm^2

Table 2. 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

5. Experimental Results

Table 3. 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 4. Test results of SCC for various percentage additions of waste plastic fibers in fresh state.

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

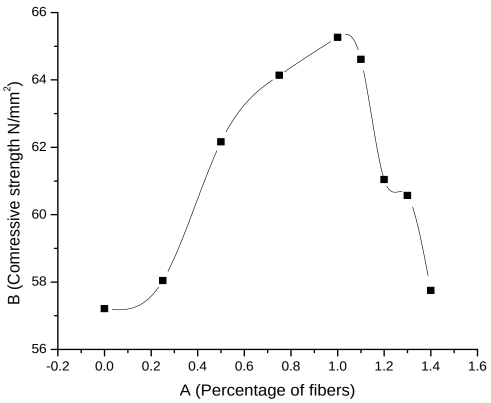

Fig 1. Average compressive strength after 28 day water curing

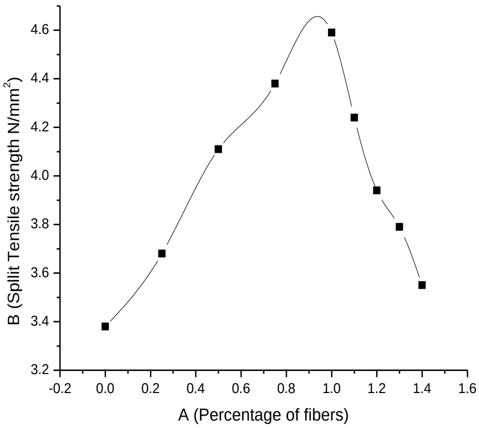

Fig. 2. Average split tensile strength after 28 days water curing

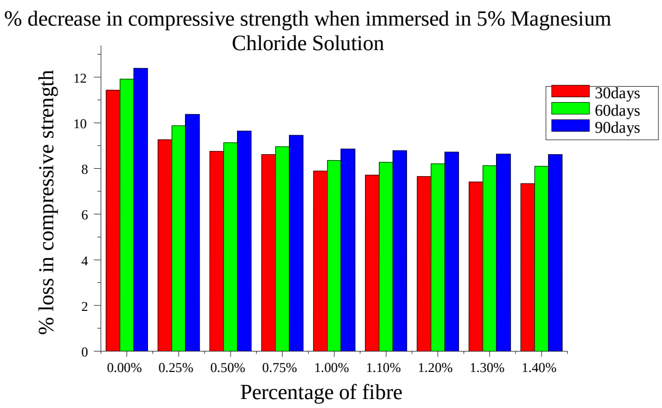

Fig. 3. Percentage decrease in compressive strength when subjected to chloride exposure.

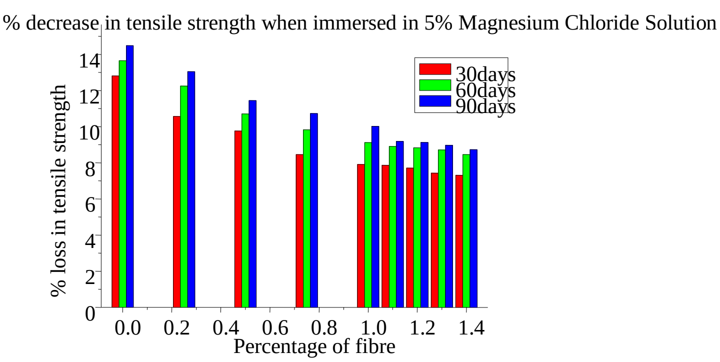

Fig. 4. Percentage decrease in tensile strength when subjected to chloride exposure

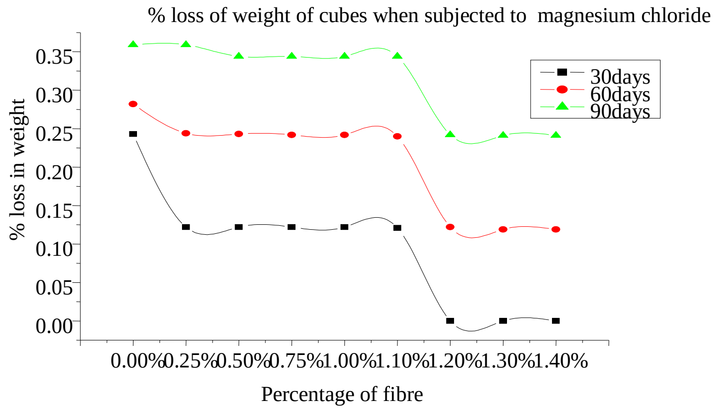

Fig. 5. Percentage decrease in weight loss of cube specimens

Table 5. Comparison of test results of 30, 60 and 90 day's chloride content

% of fibres	Average chloride content in % for 30days	Average chloride content in % for 30days	Average chloride content in % for 30days
0.0	3.59	15.14	26.70
0.25	2.54	10.53	18.57
0.50	2.53	10.10	17.81
0.75	2.50	9.75	17.19
1.0	2.50	9.56	16.86
1.1	2.48	9.36	16.43
1.2	2.40	9.09	16.03
1.3	2.44	8.52	15.55
1.4	2.39	8.48	14.95

6. Results and discussions

- The slump flow values are tabulated in Table 4. For the final control mix and eight other mixes. It can be observed that flow spread decreases with increase in fibre content up to 1.0% up to which the fines quantity was kept at 477kg/m^3 and w/p ratio was kept at 0.35.as shown in Table 3. Thereafter to get the required flow, fines content was changed to 500kg/m^3 and w/p ratio to 0.34 and super plasticizer dosage was increased to 0.81% therefore the slump flow values also increased but were within the EFNARC limits. . The fibres are needle like structures which increases the resistance to flow. But the plastic fibres are flexible compared to stiff steel fibres, so the flow properties are better for plastic fibres. All the slump flow values are in the range of 760 -850 which is the limit specified by EFNARC 2005 for SF3 class of SCC.
- The resistance to segregation is measured by T_{50cm} time. The T_{50cm} time values are tabulated in Table 4. Lower time is an indication of greater flowability. As the dosage of the fibre content has increased T_{50cm} time has also increased. The value of T_{50cm} time for all mixes are greater than or equal to 2. According to EFNARC 2005 requirements all the mixes satisfy VS2 class of SCC.
- In V-funnel test the SCC is made to change its path and pass through constrict area to evaluate its fluidity. High flow time indicates low deformability which may be due to more paste viscosity and more fibre content. High paste content and high fibre content will cause high inter particle friction or blockage of flow which can be observed. From V-funnel test results, tabulated in Table 4. It can be observed that V-funnel time increases with the increase in percentage of fibres. The value for V-funnel is slightly higher for higher percentages of fibres is due to blockage of openings of V-funnel by fibres. The value of V funnel time for most of mixes are between 9 to 25. According to EFNARC 2005 requirements all the mixes satisfy VF2 class of SCC.
- L –Box is used to measure the passing and filling ability. According to EFNARC specification the blocking ratio is greater than 0.8 the passing ability is good. When the ratio is below 0.8 there is risk of blockage of concrete. From L-Box test results, tabulated in Table 4, all the mixes satisfy the requirements of PA2 class

SCC.

- The J –ring test results indicate the passing ability of the developed WPFRSCC and the control mix. The values are shown in Table 4. There is increase in the values with the increase in percentage of fibre content. The values are within the specified limits suggested by EFNARC 2005 up to 1.0% of fibre content. Lower the value higher is the workability. After 1.0% the values are slightly greater than the specified limits.
- As seen from Fig 1, it is observed that the average compressive strength is increasing with increase in percentage of fibres upto 1.0 %. In this work the percentage of fibres by weight of cement was increased from 0.0% to 1.4%. But after 1.1% of fibre addition the compressive strength of concrete specimen tends to decrease. In this investigation a maximum of 65.26 N/mm^2 compressive strength was achieved for M40 grade of waste plastic reinforced self compacting concrete.
- As seen from Fig. 2, it is observed that the average split tensile strength is increasing with increase in percentage of fibres upto 1.0 %. In this work the percentage of fibres by weight of cement was increased from 0.0% to 1.4%.But after 1.1% of fibre addition the split strength of concrete specimen tends to decrease. In this investigation a maximum of 4.59N/mm^2 split tensile strength was achieved for M40 grade of waste plastic reinforced self compacting concrete.
- When the cube specimens were immersed in 5% magnesium chloride 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 11.43% to 7.34%, 11.91% to 8.10% and 12.39% to 8.61% for 30 days, 60 days and 90 days as shown in Fig. 3.
- When the cylinder specimens were immersed in 5% magnesium chloride 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 12.81% to 7.31%, 13.65% to 8.45% and 14.49% to 8.73% for 30 days, 60 days and 90 days as shown in Fig. 4.
- The weight of the cube specimens were measured before and after immersing in the magnesium chloride 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 decreases as the percentage fibre content increases as shown in Fig. 5.
- The results of chloride ion concentration test are tabulated in Table 5, it can be observed that the chloride penetration is reduced with the increase in percentage of fibre.

7.Conclusions

Based on the experimental results the following conclusions can be drawn,

- 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 content 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.
- 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.
- The compressive and split tensile strength tests after immersing the specimens in magnesium chloride solution for 30, 60 and 90days it was observed that there is decrease in compressive and split tensile strengths. It is found that the decrease in compressive strength reduces as the percentage of fibres increases.
- It can be concluded that addition of waste plastic fibre into SCC will improve durability characteristics and mechanical characteristics

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