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PERFORMANCE OF SUPERPLASTICISED FIBROUS CONCRETE BY RCPT TEST UNDER THERMOSHOCK

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ABSTRACT

This experimental investigation is about the chloride ion penetration of concrete by the effect of thermoshock on superplasticised fibrous concrete at 200 degree celsius. As reported in previous studies, concretes made with purely Ordinary Portland Cement (OPC) showed evidence of a steady decline in residual strength when subjected to thermoshock under elevated temperatures. Hence in the present study, tests were conducted to minimize the reduction of residual strength of OPC concrete by using chemical admixtures like superplasticiser and with different individual fibers and was examined by conducting compression and the chloride ion penetration test. This paper exposes the details of the test procedure, test results and were compared with earlier reports. The presented test results will help in assessing the residual strength of concrete after thermoshock. Also encouraged test results showed that the residual properties of concrete with its admixtures were not getting affected.

Keywords: concrete, chloride permeability, durability, corrosion, residual strength, polyester fiber.

1. INTRODUCTION

Chloride attack is one of the most important aspects for consideration in relation with durability of concrete. Possibly, chloride enters the concrete from cement, water, aggregate and sometimes from admixtures. Such an entry of chloride ions in concrete primarily affects the reinforcement by the action of corrosion. Statistics have indicated that over 40 percent of failure of concrete structures is due to corrosion of reinforcement. Apart from corrosion of reinforcement, concrete failures also occur when they are exposed to higher temperatures during fire. The fire induces high temperature gradients and as a result of it, the surface layers tend to separate and spall off from the interior cooler part of concrete. The structures like multi-storied buildings, hydraulic structures, and bridges are built near by seashore areas or chemical industries concrete may subject to higher temperature due to accidental fire in industries which influence the cracks or spalling of concrete in the buildings and secondly ingress of chloride ion may happen into the concrete and this causes the corrosion of embedded reinforcement in concrete or the ill-effect due to combination of the above. In such situation concrete needs higher residual properties in strengths as well as durability. Hertz(2005) in his classical paper reported that the continuous exposure of concrete to a higher temperature and sudden cooling causes the thermo shock which may regime significantly influence the dehydration of the hydrated calcium silicate and the thermal expansion of the aggregate increase the internal stresses in concrete which leads the micro cracks through the material. Hence there may be an increase in permeability of concrete. In another study reported by Khoury et al (2002), when concrete exposed to higher temperature, the chemical composition and physical structure of the concrete change considerably. The dehydration such as the release of chemically bound water from the calcium silicate hydrate (C-S-H) becomes significant above about 110°C. High temperatures, in general, cause deterioration in properties of concrete such as compressive strength, flexural strength, modulus of elasticity and bond with reinforcement. This may due to the thermal incompatibility between the aggregates and cement paste, and the pore pressure within the cement paste are the main detrimental factors due to the dehydration of the C-S-H phase under heating. Even though there are many recent researches available by mineral admixtures to the concrete there were no attempt made so for with fibers to arrest chloride penetration under thermoshock. Fibers are now found effective and easily available in the market for direct use in the concrete and it predominantly prevents the micro cracks developed at the inter facial transition zone making the structure inherently stronger and reduces permeability.

2. MATERIALS AND METHODS

2.1 Materials

The materials used for casting the test specimens consisted of Type I cement of 53 grade, locally available River sand and Hard blue granite of size 20 mm coarse aggregates. The aggregates were of the angular shape. The properties of ingredients are shown in Table-1.

Table-1. Properties of ingredients.

Items	Properties
Specific gravity of cement	3.1
Specific gravity of coarse aggregates	2.60
Specific gravity of fine aggregates	2.65
Grade of sand	zone II
Water absorption of coarse aggregates	1.1%
Water absorption of fine aggregates	2.51%

2.2 Chemical admixtures and fibres used

Specially selected organic based Superplasticiser. Type F conforms to IS: 9103-1989. The details of fibres used in this study are presented in Table-2.

Table-2. Properties of different types of fibres.

Properties	Corrugated steel fibre	AR glass fibre	Polyester fibre
Density (t/m^3)	7.86	2.6	1.334
Number of fibres/kg	22,820	212 Million	Millions
Cut length (mm)	36	12	12
Aspect ratio	80:1	857:1	267: 1

2.3 Mixture proportions

Indian Standard method is adopted to design the reference mix. As per the design, the mix ratio (RMX) is 1: 1.56: 2.9: 0.49 with the cement content of 383 kg/m^3 per m^3 of concrete. Perumal *et al*. conducted an experiment to make an economic concrete by reproportioning the reference mix by reducing the cement and water content simultaneously at the level of 5%, 10%, 15% and 20% and by adding 0.4%, 0.8% and 1.2% of superplasticiser by weight of cement at each level of reduction. It was found at the level of 15 % reduction of cement and water content and at the dosage level of 0.8 % of superplasticiser that concrete had attained high workability as well as high strength. Later the reference mix was fixed as 1: 1.83: 3.5:0.49 with 0.8% superplasticiser and at this stage cement content was 325.5 kg/m^3 per m^3 of concrete. Mix detailing is presented in Table-3. It was found that about 58 kg of cement was saved by the revised mix ratio.

Table-3. Mix designation.

RMX	**1: 1.55: 2.89: 0.49**
OSP	1: 1.83: 3.51: 0.49 +0.8% SP
OS1	OSP+0.2%SF
OS2	OSP+0.4%SF
OS3	OSP+0.6%SF
OS4	OSP+0.8%SF
OS5	OSP+1%SF
OG1	OSP+0.2% ARGF
OG2	OSP+0.4%ARGF
OG3	OSP+0.6% ARGF
OG4	OSP+0.8% ARGF
OG5	OSP+1%ARGF
OP1	OSP+0.2% PF
OP2	OSP+0.4% PF
OP3	OSP+0.6% PF
OP4	OSP+0.8% PF
OP5	OSP+1% PF

Note: SF- Steel fiber; ARGF- Alkali resistant glass fibre; PF- Polyester fibre.

3. EXPERIMENTAL PROGRAMME

The following tests were carried out on the specimens to evaluate the behavior of fiber added superplasticised concrete.

Phase 1

It was decided to conduct the experiments for strength as well as durability tests. Compression test for strength and Chloride ion penetration tests for durability were conducted on the reference mix before and after thermo shock.

Phase 2

Separate mixes were prepared with Steel fibers, Alkali Resistant Glass Fiber, Polyester fiber. To the reference mix, Steel fibers, Alkali Resistant Glass Fiber, Polyester fiber were added independently at 0.2%, 0.4%, 0.6%, 0.8 % and 1.0% by weight of cement as per the Table-3. At each volume of fibres, compression strength and RCPT tests were conducted before and after thermoshock.

3.1 Thermoshock test

All the specimen for compression strength and chloride permeability are placed inside the hot air oven and are heated to a temperature of 200^o C and the temperature is constantly maintained for two hours. After two hour, the specimens are taken out and are immediately quenched in water for 30 minutes to simulate the thermo shock effect. The specimen cured for 28 days were tested against thermo shock test. The specimens are then tested for its residual strength. The percentage variation in reduction of strength is calculated by comparing the strength of specimens before and after thermo shock. The residual strength is the strength of heated and subsequently cooled concrete specimen expressed as a percentage of strength of unheated specimen. The residual strength of concrete after thermoshock is generally less than its original strength.

3.2 Compressive strength test

The Steel mould of size 150 x 150 x 150 mm size is well tighten and oiled thoroughly. They were allowed for curing in a curing tank for 28 days and they were tested in a 200-tonne electro hydraulic closed loop machine. The test procedures were used as per IS: 516-1979. The load was applied at the rate of 140 kg/cm^2/minute till the cube breaks and recorded the failure load.

3.3 Rapid chloride penetration test (RCPT)

In this present study, the rapid chloride penetration test was performed as per ASTM C 1202-97 to determine the electrical conductance of the fibrous concrete at the age of 28 days curing. The test method consists of monitoring the amount of electrical current passed through 51 mm thick slices of 102 mm nominal diameter of cylindrical specimens for duration of six hours. The RCPT apparatus consists of two reservoirs. The specimen was fixed between two reservoirs using an epoxy bonding agent to make the test setup leak proof. One reservoir (connected to the positive terminal of the DC source) was filled with 0.3N NaoH solution and the other reservoir (connected to the negative terminal of the DC source) with 3 % NaCl Sodium Chloride solution. A DC of 60V was applied across the specimen using two copper electrodes and the current across the specimen was recorded at 30 minutes interval for duration six hours. The total charge passed during this period was calculated in terms of coulombs using the trapezoidal rule as given in the ASTM C 1202-97. Table-4 shows Chloride ion penetrability based on charge passed by ASTM C 1202-97.

$$Q = 900\,(I_0 + 2\,I_{30} + 2\,I_{60} + \ldots\ldots + 2\,I_{300} + 2\,I_{330} + 2\,I_{360})$$

Where,

Q = charge passed (coulombs)
I_0 = current (amperes) immediately after voltage is applied
I_t = current a (amperes) at t' minutes after voltage is applied

The total charge passed, in coulombs, has been found and this relates to the resistance of specimen to chloride ion penetration.

Table-4. Chloride ion penetrability based on charge passed.

Charge passed (Coulombs)	**Chloride ion penetrability**
> 4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very low
< 100	Negligible

4. TEST RESULTS

4.1 Compression test

From the experiential results with the increase of volume of fibre the compressive strength fibrous concrete was also increased from 0.2% to 1%. Similar results were reported by saluja *et al* (1992). Comparing test results, before thermoshock, from Table-5 it was observed that mixes containing steel fibers offer maximum increase in strength as 23.78%. Mixes with AR Glass fibers offers maximum increase in strength 18.9% at 1% volume of fibers. It was found that mixes with polyester fiber offer maximum strength as 17%.

After thermoshock test at 200 degree celsius strength of concrete was decreased to nearly 10 percent to 15 percent of unheated specimen at each mixes. Similar results were reported by Bhal *et al* (1999) and pointed out Malhotra expression for residual strength factor as 0.97 times unheated specimen at 200 degree Celsius. Under thermoshock test, it was found that residual compressive strength started increasing from 0.6%, maximum percentage increase in residual strength was 10.6 % over reference mix 37.78 MPa at duration of exposure of heat 2 hr for thermoshock at 1% volume of fibers. It was found that percentage increase in compressive residual strength was improved at 0.6% volume of fibres for AR glass fibre as 9.95% over reference mix 37.78 MPa at 2hr exposure of heat under thermoshock. But polyester fibre had values lower than reference mix and not having better values as other fibres. It may be due to softening of polyester fibres at 200 degree celsius.

4.2 Rapid chloride penetration test

Experimental results are presented in Table-6. It shows that the penetration of chloride ion into the concrete was resisted by the inclusion of fibers in tests before and after thermoshock. Polyester fibers and AR Glass fibers offer more resistant to chloride ion penetration with the increase of volume of fibers under the tests before thermoshock. Polyester fibers show better performance in chloride ion penetration even after thermoshock. From the test results chloride permeability of concrete was decreased on increasing the volume of fibers. It was decreased to 17% for steel fibers, 28% for AR Glass fibers and 25% for Polyester fibers at 1% volume of fibers under the tests without thermoshock.

After thermoshock effect, mixes with steel fibers were found that they were affected by chloride permeability to the highest degree. But on the contrary mixes AR Glass fibers and Polyester fibers offers resistant chloride permeability and found that mixes resist as 20% and 21%, respectively.

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Table-5. Compressive strength test.

MIX	BTS	ATS
	Compressive stress	**Residual strength**
RMX	37.78	34.25
OSP	40.44	36.20
OS1	40.65	36.54
OS2	40.89	36.90
OS3	42.16	37.89
OS4	44.78	41.10
OS5	46.67	41.78
OG1	38.75	35.41
OG2	40.37	36.42
OG3	42.41	38.45
OG4	42.52	39.45
OG5	44.85	41.54
OP1	38.82	35.89
OP2	40.89	37.21
OP3	41.67	37.54
OP4	42.23	35.69
OP5	44.14	35.58

Note: BTS- Before thermo shock; ATS- After thermo shock.

Table-6. Rapid chloride ion penetration test results.

MIX	Charges passed in coulombs in RCPT results			
	BTS	**ATS**	**% Improvement**	
	Charges passed	**Charges passed**	**Charges passed-BTS**	**Charges passed-ATS**
RMX	1350	1647	100.00	122.00
OSP	1521	1611	112.67	119.33
OS1	1449	1494	107.33	110.67
OS2	1323	1575	98.00	116.67
OS3	1287	1683	95.33	124.67
OS4	1233	1629	91.33	120.67
OS5	1125	1521	83.33	112.67
OG1	1323	1521	98.00	112.67
OG2	1179	1323	87.33	98.00
OG3	1152	1269	85.33	94.00
OG4	1098	1197	81.33	88.67
OG5	972	1080	72.00	80.00
OP1	1233	1350	91.33	100.00
OP2	1125	1215	83.33	90.00
OP3	1080	1125	80.00	83.33
OP4	1053	1125	78.00	83.33
OP5	1017	1071	75.33	79.33

5. CONCLUSIONS

Based on the limited experimental investigations of plain and superplasticised fibrous concretes the following conclusions were arrived.

a) By using revised mix ratio, OSP, about 58 kg of cement was saved;
b) It was found that concrete properties getting affected at 200° celsius when was subjected to thermoshock .
c) On increasing volume of fibres compressive strength is also increased. Steel and AR glass fibres help to resist thermoshock effect on concrete;
d) Polyester fibres are found effective and can be used in the structures nearby chemical industries as well as in substructures;
e) Polyester fibres offer more resistant to chloride permeability under thermoshock; and
f) Mixes with steel fibers are suffered from chloride ion penetration. Steel fibres should never be used for the construction of hydraulic structures as it is susceptible for rusting and corrosion effect to concrete structures.

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