PERFORMANCE OF CONCRETE EXPOSED TO CORROSIVE ENVIRONMENT

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ABSTRACT

A comprehensive programme to investigate the behaviour of portland cement concrete exposed to corrosive environment was chalked out in this short duration study. The programme composed of compressive strength study, weight loss study, effect of carbonation, pH test study and study of ultrasonic pulse velocity test. Investigation to study the performance of portland cement concrete of M20 strength exposed to corrosive environment (5% H_2SO_4 Solution, 5% HC1 Solution, 10% (NH_4SO_4 Solution and 10% NaOH Solution) revealed that the concrete cube deteriorated more in acidic environment than alkaline environment. The strength of PCC exposed to aggressive medium reduced significantly after exposure of 28 days. This reduction in strength was mainly due to expansive salt formation. The formation of expansive salt also resulted in loss of cementitious properties and loss of weight. The concrete exposed to H_2SO_4 solution was found least durable. This study also shows that higher the ultrasonic pulse velocity lower is the corrosion. This paper presents an approach of investigation along with analysis of test results of PCC exposed to corrosive environment.

INTRODUCTION

Failure of concrete structure exposed to corrosive environment is a wide spread phenomenon and has been reported from different parts of world including gulf countries, the USA, the UK, India, France, Norway and Germany. Corrosive agents when present in significant concentration in plain cement concrete also form complex and expansive salts which results in reduction in strength. However, there is scanty data on the behaviour of PCC exposed to different corrosive environment of higher concentration right from the time ofdemoulding.

The formation of expansive salt and its quantum may vary depending on the stage ofhydrated cement paste. If the specimens are kept in aggressive environment right from the time of demoulding, aggressive salt may react with cement constituents more freely. However, if the concrete is old when exposed to corrosive environment the picture may be different.

It is normal practice to expose structure for curing 24 hour after casting. Therefore, in this study, specimens were exposed to corrosive environment right from the time ofdemoulding and studies were carried out after 28 days of exposure. In this paper the authors have made an attempt to assess the performance of concrete exposed to corrosive environment.

MATERIALS

The materials used in this investigation were ordinary portland cement (33 grade confirming to IS: 269 - 1976), fine aggregate and coarse aggregate. Fine aggregate and coarse aggregate confirmed to grading standard of IS: 383. Fine aggregate was washed river sand with fineness modulus 2.57. Its uniformity co-efficient was 1.9. The coarse aggregate was crushed stone aggregate of size 20mm and down having fineness modulus 6.24.MIX DESIGN

Mix design of M20 strength was prepared for all the tests. This mix design was based on IS code method and the mix proportion was 0.465:1:1.70:1.77 i.e. water: cement fine aggregate: coarse aggregate.

EXPERIMENTAL PROGRAMME

Fifteen cubes of 100 mm size of M20 grade concrete were cast. These cubes were cured in water for 28 days. After curing sets of 3 cubes of plain concrete were immersed in 5% H_2SO_4 Solution, 5% HC1 Solution, 10% $(NH_4)2SO_4$ and 10% NaOH Solution for 28 days.

To study the performance of concrete exposed to above mentioned corrosive environment following tests were carried out.

1. Weight loss test at the interval of 7 days
2. Compressive strength test
3. pHtest
4. Carbonation test
5. Ultrasonic pulse velocity test

TEST RESULTS AND DISCUSSION

Visual Examination

There was no change in colour of plain concrete cube except in HC1 Solution. The colour of concrete cube in HC1 Solution became brownish.

After 28 days it was observed that aggregates of plain concrete cubes in H_2SO_4, HC1 & $(NH_4)2SO_4$ solutions were visible. It was due to washingout of cement paste. But in NaOH solution aggregate of concrete cube was not visible because cement paste was not washed out due to alkaline environment.

Weight Loss Test

The weight of concrete cubes were taken before immersion into solution. The weight loss were found out at an interval of 7 days. The loss in weight of plain concrete cube is shown in Table-1.

Table 1

Chemicals	Average Loss of Weight (%) after			
	7 days	14 days	21 days	28 days
1. 5% H_2SO_4 Solution	6.1	10.5	14.5	18.98
2. 5% HCl Solution	5.4	10.2	13.1	15.4
3. 10%$(NH_4)2SO_4$ Solution	1.9	3.2	4.7	6.3
4. 10%NaOH Solution	0.7	1.5	1.7	1.87

It can be seen from Table -1 that the loss of weight for PCC is maximum in H_2SO_4 medium while it is minimum in NaOH medium. The loss of weight of concrete cubes in H_2SO_4 medium is due to ettringite formation. Sulphuric acid attacks on Ca(OH)s and form $CaSO_4$ which is leached out of concrete easily. The calcium silicate hydrate reacts with H_2SO_4 to form fragile silica gel which is easily destroyed by external physical forces. The calcium sulphate formed by initial reaction can proceed to react with calcium aluminate phase in cement to form voluminous calcium sulphoaluminate (ettringite) which can cause expansion, cracking, loss of weight & strength and disintegration of concrete. The chemical reaction involved in H_2SO_4 attack on cement concrete can be represented as follows.

$$Ca(OH)2 + H_2SO_4 = CaSO_4 . 2H_2O$$

$$3\ CaO_2\ SiO_2 . 3H_2O + H_2SO_4 = CaSO_4 . 2H_2O + Si(OH)_4$$

$$3\ CaSO_4 + 3CaO.\ Al_2O_3 . 6H_2O + 25H20$$

$$= \qquad 3CaO . Al_2O3 . 3CaSO_4 + 31\ H_2O$$

Loss in wt. of plain concrete in HC1 medium is upto 15.4%. This is likely due to formation of calcium chloro aluminate. Similarly weight loss in $(NH_4)\ 2SO_4$ medium is upto 6.3% which is due to calcium sulpho aluminate formation. But in NaOH medium the weight loss was only 1.87% which is very less. It is due to strong bond, non leaching of lime and alkaline environment which don't promote deterioration of concrete. Hence the concrete in NaOH medium is most durable.

Compressive strength test

After 28 days of exposure the compressive strength of concrete cubes were determined as per IS : 516-1959 at a loading rate of 140 kg/ cm^2 /min on 200 ton compression testing machine. The test results are tabulated in Table 2

Table-2

Type of solution	Average compressive strength ofPCC after 28 days (N/mm^2)	Depth of Carbonation (mm)	pH of concrete Cube after 28 days of exposure	Ultrasonic pulse Velocity (Km/Sec)
5% H_2SO_4	10.5	7.3	2.0	0.95
5% HCl	15.5	5.2	4.0	2.0
10% $(NH_4)2SO_4$	21.25	3.1	8.5	2.5
10%NaOH	34.30	–	11.0	4.10

It is observed from table 2 that cube compressive strength has decreased from 34.97 N/mm^2 to 10.5 N/mm^2 in 5% H_2SO_4 medium, 15.5 N/mm^2 in 5% HC1 medium, and 21.25 N/mm^2 in $(NH_4)2804$ medium. But in NaOH medium no such decrease in strength was observed. The decrease in strength can be attributed to expansive salt formation, leaching of lime and weakening of bonds. No decrease in strength in PCC exposed to NaOH medium was found due to high pH value and strong bond.

Carbonation & pH test

The calcium hydroxide in concrete reacts with CO_2 and form calcium conbonate. This phenomenon is called Carbonation. This can be detected by adding phenolphthalien on different depth of concrete and observing the colour profile. If Carbonation has occurred no colour will be observed while pink colour will be observed if Carbonation has not occurred. The depth of Carbonation for plain concrete is reported in table - 2. It can be observed that depth of Carbonation is more in H_2SO_4 medium and in NaOH medium no Carbonation has occurred. The depth of Carbonation in different medium is also shown in figure 2.

pH value of PCC is reported in table - 2. It is obvious from table 2 and figure 3 that pH of PCC in H_2SO_4 is minimum and maximum for concrete exposed to NaOH medium. This reveals that deterioration of concrete in acidic medium is severe while in basic medium durability of concrete is more.

Ultrasonic Pulse velocity test

This is a well recognised non destructive test method to assess the homogeneity and integrity of concrete exposed to corrosive environment. This method basically involves the measurement of velocity of electronic pulse passing through concrete from a transmitting transducer to a receiving transducer. The test was performed with the help of digital ultrasonic concrete tester. Time was recorded in micro seconds. The thickness of concrete specimen divided by time gives pulse velocity. The UPV value is reported in table 2 and graphical representation is shown in figure -4.

From table and graph it can be seen that the UPV of plain concrete in H_2SO_4 is 0.95 km/sec which is least while in NaOH medium it is 4.10 km/sec which is maximum. Lower velocity indicates more transit time thereby more chemical attack and integrity of concrete has disturbed more. It may be due to expansive salt formation, presence of voids and weakening of bonds. UPV value reveals the fact that PCC in H_2SO_4 medium has deteriorated more than any other medium.

CONCLUSION

(1) PCC in acidic medium shows more deterioration than basic medium.

(2) There was severe deterioration of concrete exposed to H_2SO_4 medium.

(3) Loss of cementitious property of concrete in H_2SO_4 medium was maximum and it was minimum in NaOH medium.

(4) The loss in strength was due to expansive salt formation and weakening of bonds.

(5) Lower ultrasonic pulse velocity indicates higher deterioration.

(6) UPV test is a quick and scientific method to assess the performance of concrete exposed to corrosive environment.

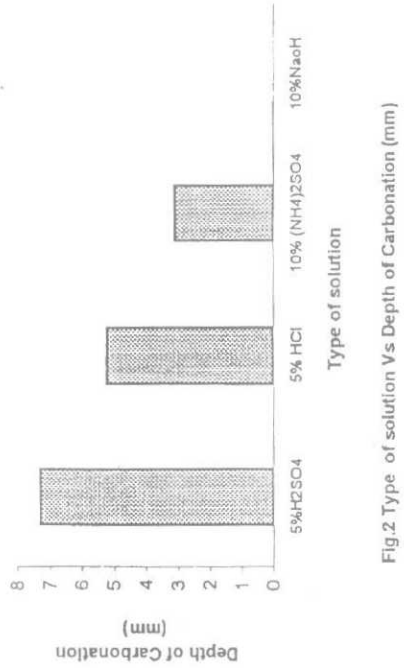

Fig.2 Type of solution Vs Depth of Carbonation (mm)

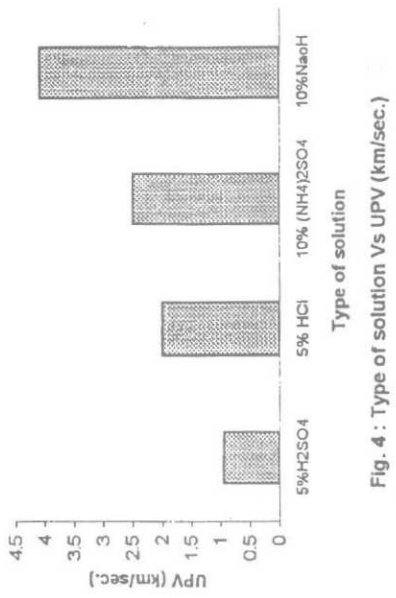

Fig. 4 : Type of solution Vs UPV (km/sec.)

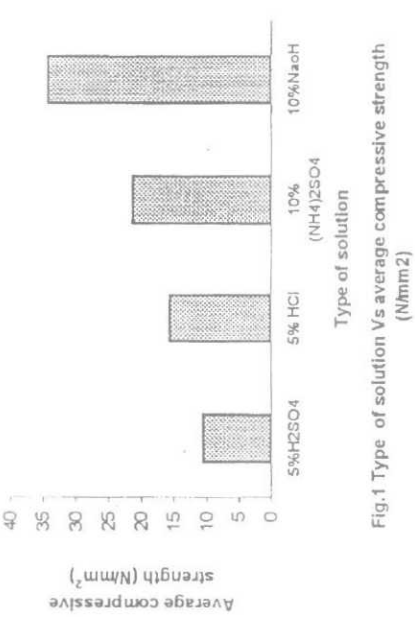

Fig.1 Type of solution Vs average compressive strength (N/mm2)

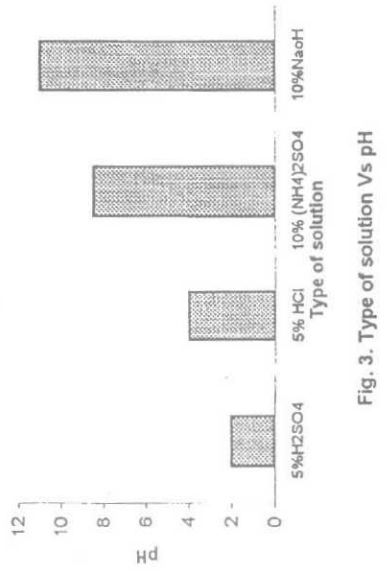

Fig. 3. Type of solution Vs pH

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