Rapid chloride permeability test for durability studies on corrosion inhibiting self-compacting concrete

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ABSTRACT

The principally significant progress of concrete technology for the last two decades is that Self-compacting concrete (SCC). It was afforded to assure sufficient compaction through self-analogy and thereby facilitate placement of concrete in structures with congested reinforcement and also in impedimental areas. To avoid the total void content in concrete, a filler matter should be used. Flyash may be that material which can assist for that. As a result, it thus partakes in the strengthening of concrete. The most habitual environmental endanger is that the corrosion in reinforcement caused by the conjunction of chlorine which may lead to deterioration of concrete structures. In recent years, a widespread attention was incurred due to the frequent problem occur in durability associated with high repair cost. In this investigation the combined effect of replacement and addition of Flyash and Corrosion Inhibitor (CI) on corrosion inhibiting Self Compacting Concrete (SCC) has been carried out to study the durability. This investigation proceeds with the casted cylinders of size 100mm x 150mm with M25 design mix concrete along with the addition of corrosion inhibitors of varying percentage viz., 0.1%, 0.2%, 0.3%, 0.4%, 0.5%. The Rapid Chloride Permeability Test (RCPT) was conducted for the period of 7 and 28 days to find the durability. The results reveals that the addition of Corrosion Inhibitor mixes would have lesser permeable voids than the conventional concrete mixes of comparable strengths.

KEY WORDS: self-compaction concrete, Fly ash, Corrosion Inhibitor, rapid chloride permeability test, durability.

1. INTRODUCTION

Concrete is the material which was the most widely consumed one in the world, after water. Placing the fresh concrete needs a skilled operative to handling the dangerous mechanical vibrators to ensure sufficient compaction to obtain the required strength and durability of the concrete structure (Sumit Mahajon, 2013). Concrete is manufactured to flow under its own weight without any compaction. SCC should be designed to reduce or cease the segregation. SCC having a huge content of fine materials to provide the stability of mixes which results to cease the bleeding and segregation (Yun Wang Choi, 2004; Safiuddin, 2008). The fine materials like FA, Granulated blast furnace slag, Silica fume, or limestone filler in SCC contributes significantly towards its fresh and hardened properties as well as reading its cost. It results the scaling resistance of SCC depends on type of used admixture.

Very good results were obtained with slag and limestone (Liu, 2010; Lothia, 1996). SCC habitually contains super plasticizer to maintain the fluidity. It also has many advantages such as, effortless placement in complicated formwork and reinforcement, minimizes the construction time, noise pollution, high and more homogenous concrete quality through the whole concrete cross section and improved concrete surfaces and finishes. Corrosion of reinforcement in concrete is a complex phenomenon. There are different factors affecting the process of corrosion in concrete (Hope, 1969).

The increase in volume of steel after corrosion is one of the undesirable effects on the structure spaced out from the reduction in cross section area of reinforcement. Corrosion has been found one of the important reason causing weaknesses to concrete structures (Prabakar, 2009). Lot of research has been going on regarding the prevent process of corrosion in concrete structures all over the world (Justnes, 2001; Berke, 1989). The transmittance of concrete is observably relevant to the pore structure of the cement paste matrix. This will be affected by the water-cement ratio of the concrete, the inscription of additional cementing materials which serve to subdivide the pore structure and the extent of hydration of the concrete.

In early concrete may have the larger amount of hydration that was occurred and thus the pore structure will be highly developed. This is especially true for concrete containing slower reacting supplementary cementing materials such as Flyash require a longer time to hydrate. Radiance on the pore structure is the temperature that is proven at the time of casting. High-temperature curing quicken the curing process so that at fresh concrete ages, a high-temperature cured concrete will be more refine and thus have a better resistance to chloride ion transmittance than a normally-cured, otherwise identical, and concrete at the same at age (McGrath, 1996). However, at mature ages when the normally-cured concrete has a change to hydrate more fully, it will have a lower chloride ion scattering coefficient than the high-temperature-cured concrete (Feldman, 1994).

2. METHODS & MATERIALS

Experimental Investigations

Objectives of the study: In the current research work to investigate the durability properties of M25 grade of SCC with different optimum percentages of addition of inorganic corrosion inhibitors CN4% and SN3% at 7 & 28 days compare with 0% at 7 and 28 days.

Research Significance: Corrosion inhibitors provide a principle system for achieving the durability requirements of new constructions. This research study investigated the distinctive of inorganic corrosion inhibitors with different optimum percentages of addition to M25 grade of concrete.

Materials Used

Cement: Ordinary Portland cement was offered in local marketplace is used in the research work. The Cement used has been tested for different proportions as per IS: 4031 and found to be confirming to different specifications of I.S-8112- 1989. The specific gravity was 3.15 and fineness was 5.0% and standard consistency 29 %.

Fine Aggregate: In this study, the use of fine aggregate was instrumented about the whole work comprising natural river sand of maximum size 4.75mm. By IS 383-1970, it is ratified to grading zone-II against specific gravity of 2.60 and fineness modulus of 2.25 was applied in this investigation.

Coarse Aggregate: Coarse aggregate obtained from nearby granite quarry has been used for this research. It consisted of machine crushed stone angular in shape and the highest size of aggregate is 12.5 mm with specific gravity 2.80, and fineness modulus 6.23 was used.

Fly Ash: Class F fly ash from Mettur Thermal Power Station, Tamil Nadu was used as cement replacement material. The properties fly ash are confirming to I.S. 3812 – 2003 of IS Specification for Fly Ash for use as cementitious material and Admixture. The specific gravity was 2.15.

Mixing water: For casting the concrete specimens used for clean water. Also the water has been had a water-soluble Chloride content of 140 mg/lit. The allowable limit for chloride is 500 mg/lit as per IS 456 – 2000. Therefore the amount of chloride present is very less than the allowable limit.

Admixture: Sulphonated Naphthalene Polymers (Conplast SP430) based super plasticizer which is brown colour and free flowing and having relative density 1.20 super plasticizer confirming to IS: 9103-1999. To present more water reduction upto 25% without loss of workability or to make high quality of concrete that reduces permeability it is formulated Conplast SP430.

Corrosion Inhibitor

Calcium nitrite: is an inorganic admixture that exposes to use in reinforced concrete. The molecular formula Ca $(NO_2)_2$. The calcium nitrite protects steel reinforcement bars from chloride induced corrosion. **Sodium nitrite** is the inorganic compound with the chemical formula $NaNO_2$. It is an efficient corrosion inhibitor moreover is used as an chemical addition in industrial greases.

Mix Proportions: The concrete mix design was proposed by using IS 10262:2009 (EFNARC, 2009). The grade of concrete used was M-25 with water to cement ratio of 0.40. Proportion of concrete should be selected to construct the for the most part of cost-effective utilize of accessible materials to produce concrete of required quality. The reference concrete mix proportions were custom-made as per EFNARC specifications and different trial mixture proportions. Varying percentage inorganic corrosion inhibitor (calcium nitrite and sodium nitrite) from 0% to 5% i.e., 0%, 1%, 0.1%, 2%, 3%, 4% and 5% to the total volume of cement content. The details of mix proportions are given in Table 1 for $1m^3$ of concrete.

Table.1. Materials required per $1m^3$ of SCC

Mix	Grade of Concrete	Cement	Fly ash	FA	CA	Water	SP
SCC	M25	330.72	220.48	907.68	713.18	220.48	2.76

Tests on fresh concrete: SCC has a number of criteria that contain to be satisfied. Those criterions are related with passing and flowing ability of self-compacting concrete. Fig. 1(a, b, c & d) show the various tests conducted while the test results and their acceptance criteria as per EFNARC are listed in Table 2.

(a).Slump flow & T50 Test

(b). J- Ring Test

(c). V -Funnel Test (d). L- Box Test

Figure.1. Workability Tests on SCC

Table.2. Fresh SCC properties of reference mix

Test Method	Unit	Typical range of values as per EFNARC		Results of Tests
		Min	Max	Mix M25
Slump flow	mm	650	800	700
V - funnel	Sec	6	12	7
L - Box	(H2/H1)	0	1.0	0.89
J-Ring	mm	0	30	8

Preparation of specimen: The program consists of samples were left for curing under water with their moulds after 24 hours of casting. After 28 days of curing, permeability test was conducted.

Rapid chloride permeability test: Corrosion is mainly caused by the intrusion of chloride ions into concrete annulling the original passivity present. Standardized testing procedures are in ASTM C 1202. The RCPT is performed by formalities the quantity of electric supply that passes through a sample 50 mm thick by 100 mm in dia in 6 hours using the apparatus and the cell arrangement is shown in Fig - 2 and Fig - 4 shows the experimental setup for RCPT and Fig - 3 concrete discs. Readings are taken every half an hour. This specimen is typically cut into a slice of a cylinder. A 60V DC is constantly maintained across the ends of the sample right through the test. One lead is engrossed in a 3% sodium chloride (NaCl) solution and the other in a 0.3M sodium hydroxide (NaOH) solution. The sample is removed from the cell after the end of the 6 hours and the amount of coulombs passed through the specimens is calculated.

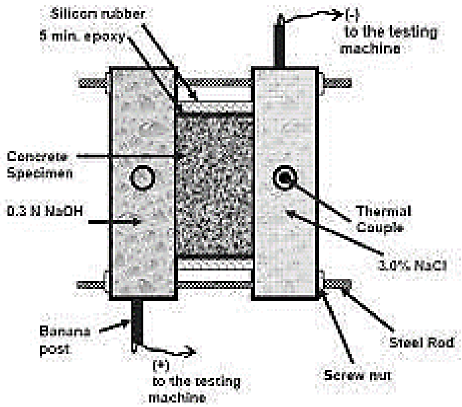

Figure.2.Schematic diagram of RCPT (ASTM C1202-94)

Testing of specimens: The specimens were fits within the chamber along the brass as well as rubber oaring. The record time is set as 30 minutes and also the log time as 6 hours and 30 minutes and the current of 60 V is passed continuously. The data were recorded in the record logger and the reading of corresponding cells at the even interval record time from the initial readings. At the end of the experiment system stops after taking the final reading.

Table.3.Chloride permeability base on charge passed

Charge Passed (Coulombs)	Chloride Permeability
> 4,000	High
2,000 - 4,000	Moderate
1,000 - 2,000	Low
100 - 1,000	Very Low
< 100	Negligible

Average electric current flowing through one cell is calculated by,

$$Q = 900 \times (I_0 + +2I_{30} + 2I_{60} + 2I_{90} + 2I_{60} + 2I_{120} + 2I_{150} + 2I_{180} + 2I_{210} + 2I_{240} + 2I_{270} + 2I_{300} + 2I_{330} + 2I_{360})$$

Q	Current flowing through one cell (Coulombs)
I_0	Initial current reading in mA
I_{30}	Current reading at 30 minutes in mA
I_{60}	Current reading at 60 minutes in mA
I_{90}	Current reading at 90 minutes in mA
I_{120}	Current reading at 120 minutes in mA
I_{150}	Current reading at 150 minutes in mA
I_{180}	Current reading at 180 minutes in mA
I_{210}	Current reading at 210 minutes in mA
I_{240}	Current reading at 240 minutes in mA
I_{270}	Current reading at 270 minutes in mA
I_{300}	Current reading at 300 minutes in mA
I_{330}	Current reading at 330 minutes in mA
I_{360}	Current reading at 360 minutes in mA

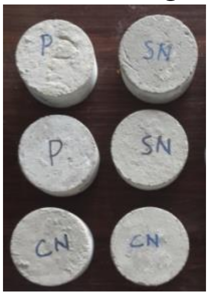

Figure.3. Typical M25 grade SCC concrete disc with different optimum % of corrosion inhibitors

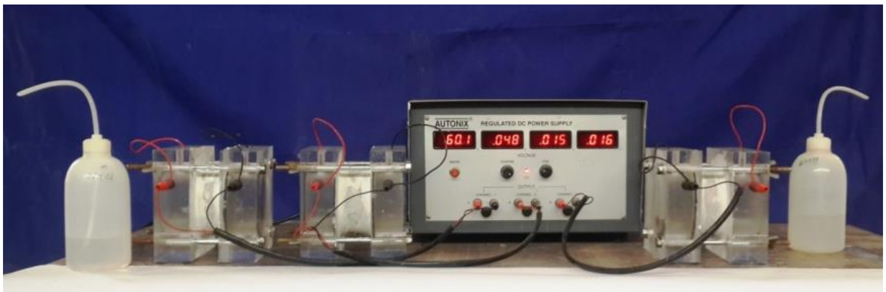

Figure.4. Experimental set up of RCPT

3. RESULTS AND DISCUSSION

Quantities of materials required per 1 cum of SCC mixes: From table 1 gives the quantities of material required M25 grade SCC using mineral admixtures and inorganic corrosion inhibitors. To build high rise structures by decreasing column cross-section and also increasing floor area space, to build the super structure of long span bridges and to the durability a superior strength is needed.

Fresh state of Self Compacting Concrete mixes properties: From table 2 provides a summary of the fresh properties of SCC mixes for a grade of M25 concrete. As it is obvious, the essential requirements of more flowability and segregation resistance as specified by guiding principle by EFNARC are satisfied.

Chloride permeability base on charge passed: From table 3 is important to know that these ranges were established on laboratory concrete by the test method. The range have to be used barely for comparison purpose.

Rapid Chloride Permeability Test: The object of the test was to evaluate the performance of CC, CN and SN mixes and compared with each other. Chloride ion permeability test were conduct on cylinder samples for every concrete mixture at 7 and 28 days for design mix of SCC. The results of chloride permeability in coulombs for different corrosion inhibitors with age are given in Table 4.

Table.4. Rapid chloride permeability test for SCC with and without corrosion inhibitors

Grade of concrete	Optimum % of Corrosion Inhibitor	Charge passed (Coulombs)		Chloride permeability as per ASTM C1202	
		7	28	7	28
M 25	CC 0%	484.65	543.60	Very Low	Very Low
	CN 4%	405.45	525.60	Very Low	Very Low
	SN 3%	244.35	427.05	Very Low	Very Low

Figure 5 depicts the average values of rapid chloride penetration in the CN and SN specimens exposed to the conventional condition at 7 and 28 days respectively.

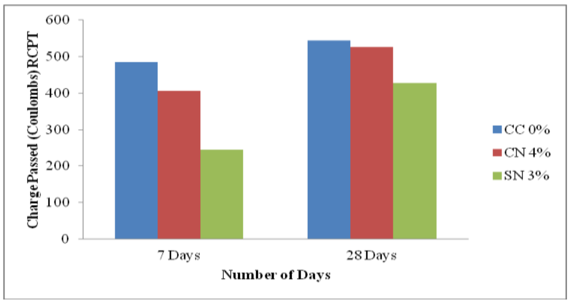

Figure.5. Average values of rapid chloride permeability test

4. CONCLUSIONS

Rapid Chloride ion Penetration Test (RCPT) is essentially a measure of concrete's electrical conductivity which depends upon the both pore structure characteristics and also the pore solution chemistry Chloride diffusion is also the major reasons for causing corrosion to reinforcement inside concrete. Therefore it is essential to study concrete for its chloride ion permeability.

- Rapid Chloride permeability of SCC shows less permeability of chlorides into concrete resulting into reduction the cracks causing interconnecting voids to be minimum.
- Denser microstructure of SCC contribute for a lower plastic settlement, higher bond between steel and concrete matrix, lower permeability to oxygen and lower chloride diffusion factor and higher tensile strength
- As the mineral admixture increase in SCC the RCPT charges decreases. Thus we can say that RCPT of SCC is having 'Low' chloride ion penetrability for more admixture of concrete.
- The Invention of 7 days allowed high change to pass in concrete specimen.
- The maximum and minimum charges passes for 28 days was 427.05, 525.60 and 543.60 coulombs for SN, CN and CC respectively.

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