Effect of Corrosion Inhibitor on the Durability Properties of Hardened Self Compacting Concrete

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***Abstract*— This paper presents the results of an experimental study on the durability properties of self compacting concrete (SCC) mixes. Self compacting concrete mixes with a higher cement replacement at 40% of cement with fly ash, are designed and their performance is compared with conventional concrete mixes (CC) of equivalent M25 strength grade. The durability properties are evaluated in terms of chloride-ion permeability as measured by RCPT tests. The results indicate that the SCC mixes would have lesser permeable voids than the conventional concrete mixes of comparable strengths. The experimental results also show that improvements against chloride penetration can be realized with self compacting concrete mixes additionally inhibitors with Hexamine and Diethanolamine.**

Keywords*— *Self compacting concrete; fly ash; chloride permeability; corrosion inhibitor; Durability.

I. INTRODUCTION

The development of a special form of concrete specifically self compacted concrete provides an opportunity to the contractors and changed the options open to the construction industry. The wide ranching interest in the development of self compacting concrete highlights the significance of this new type of concrete to modern day construction. The advances in admixture technology are refusal doubt helping the concrete producers towards achieve their target with ease. Apart from increasing the quality of concrete structures, the make use of self compacting concrete reduces the construction cost, all the way through minimizing the compaction effort and reducing the construction time.

The self compacting concrete differs as of conventional concrete in the following three characteristic features, that is to say, appropriate flow ability, non segregation, and no blocking tendency. An increase in the flow ability of concrete is well known to increase the risk of segregation. Therefore it is essential to have proper mix design.

Durability of concrete possibly will be defined as the ability of concrete to resist weathering action, chemical attack and abrasion while maintaining its looked-for engineering properties. Corrosion of reinforcing steel is a major problem facing the concrete infrastructures. Many structures in adverse environments have experienced unacceptable loss in serviceability of safety earlier than predictable due to the corrosion of reinforcing steel and thus need replacement, rehabilitation or strengthening.

Corrosion can be prohibited by chemical technique by using certain corrosion inhibiting chemical and coating to reinforcement. According to National Association of Corrosion Engineers (NACE) inhibitors are substances which when added to an environment, decrease the rate of attack on a metal. Corrosion inhibitors function by forming a passive layer around the reinforcing steel an prevent outside agents and reduce the corrosion current. Corrosion inhibitors are becoming an accepted method of getting your strength back durability of reinforced concrete in chloride laden environments.

II. EXPERIMENTAL DETAILS

A. Objective

The objectives of the current research work to study the durability properties of M25 grade of self compacting concrete with different optimum percentages of addition of organic corrosion inhibitors H2% and DA3% at 7 and 28 days compare with 0% at 7 and 28 days.

B. Materials used

Cement

Ordinary Portland cement of available in local market is used in the investigation. The Cement used has been tested for various proportions as per IS: 4031 and found to be confirming to various 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 study. it consisted of machine crushed stone angular in shape and the maximum size of aggregate is 12.5 mm with specific gravity 2.80, and fineness modulus 6.23 was used.

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

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 Indian Standard Specification for Fly Ash for use as Pozzolanic and Admixture. The specific gravity was 2.15.

Mixing water

For casting the concrete specimen potable water has been used. Also the water has been had a water-soluble Chloride content of 140 mg/lit. The permissible limit for chloride is 500 mg/lit as per IS 456 – 2000. Therefore the amount of chloride present is very less than the permissible 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 give high water reduction up to 25% without loss of workability or to produce high quality of concrete that reduces permeability it is formulated Conplast SP430.

Corrosion inhibitor

Hexamine is Hexamethylenetetramine which is a heterocyclic organic compound with the molecular formula $(CH2)_6N4$.

Diethanolamine (DEA) is an organic compound with chemical formula $C_4H_11NO_2$. DEA is used as a surfactant and a corrosion inhibitor.

Mix proportions

The concrete mix design was proposed by using IS 10262:2009. The grade of concrete used was M-25 with water to cement ratio of 0.40. Proportion of concrete should be selected to make the most economical use of available materials to produce concrete of required quality. The standard concrete mix proportions were modified as per EFNARC specifications and different trial mixture proportions. Varying percentage inorganic corrosion inhibitor (Hexamine and Diethanolamine) 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 1m3 of concrete.

III. PREPARATION OF SPECIMEN

The program consists of specimens were cured under water along with moulds after 24 hours of casting. After 28 days of curing, permeability test were conducted.

A. Rapid chloride permeability test

Corrosion is mainly caused by the ingress of chloride ions into concrete annulling the original passivity present. Standardized testing procedures are in ASTM C 1202. The RCPT is performed by monitoring the amount of electrical current that passes through a sample 50 mm thick by 100 mm in diameter in 6 hours using the apparatus and the cell arrangement is shown in Fig - 1 and Fig - 3 shows the experimental set up for RCPT and Fig - 2 concrete discs. Readings are taken every 30 minutes. This sample is typically cut as a slice of a core or cylinder. A voltage of 60V DC is maintained across the ends of the sample throughout the test. One lead is immersed in a 3% sodium chloride (NaCl) solution and the other in a 0.3M sodium hydroxide (NaOH) solution. At the end of 6 hours the sample is removed from the cell and the amount of coulombs passed through the specimens is calculated.

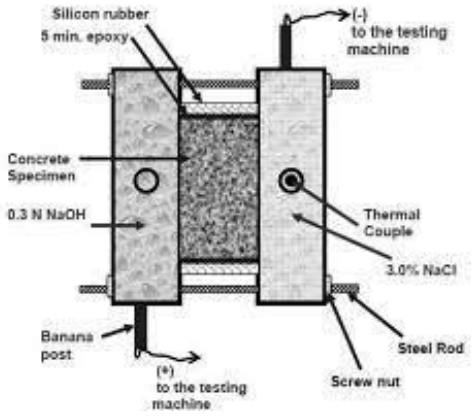

Fig. 1. Schematic diagram of RCPT (ASTM C1202-94)

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

Table 2. Chloride permeability base on charge passed

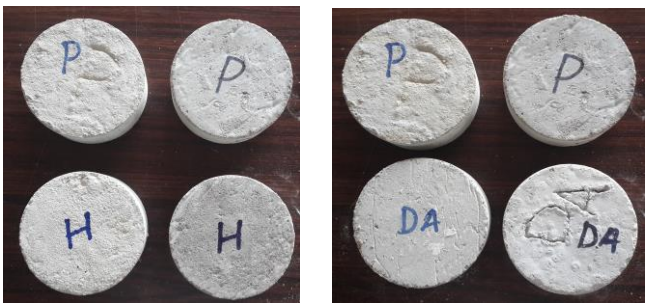

Fig.2. Typical M25 grade SCC concrete disc with different optimum % of organic corrosion inhibitors

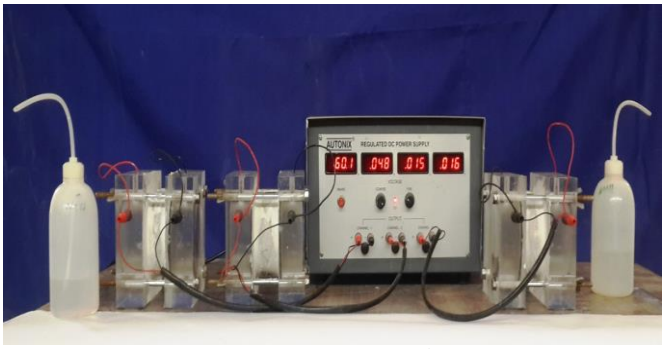

Fig. 3. Experimental set up of RCPT

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
	H 2%	567.45	448.65	Very Low	Very Low
	DA 3%	1161	1559.70	Low	Low

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

IV. TESTING OF SPECIMENS

The specimens were fit in the chamber with the required 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 logger records the reading of corresponding cells at the every record time with its initial readings. At the end of log time the system halts after taking the final reading.
Average current flowing through one cell is calculated by,

$$Q=900\times(I0+2I_{30}+2I_{60}+2I_{90}+2I_{120}+2I_{150}+2I_{180}+2I_{210}+2I_{240}+2I_{270}+2I_{300}+2I_{330}+I_{360})$$

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

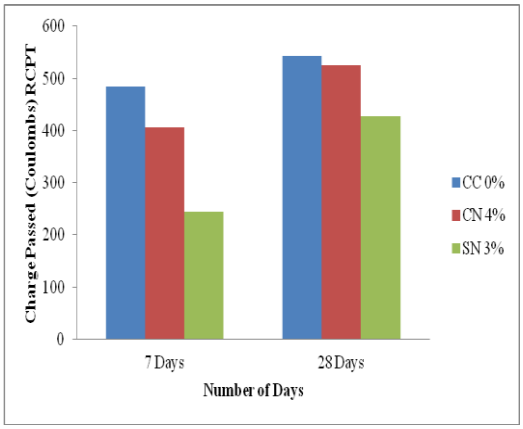

Fig. 4. Average values of rapid chloride permeability test

IV. CONCLUSION

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

- Rapid Chloride permeability of Self Compacting concrete shows less permeability of chlorides into concrete resulting into reduction the cracks causing interconnecting voids to be minimum.
- The high volume fly ash SCC mixes showed significantly lower chloride ion permeability than conventional concrete mixes.
- Considering strength as well as durability criteria, the optimum percentage of Hexamine and Diethanolamine to be added in self compacting concrete containing fly ash as cementitious material is 40% for delaying corrosion and to increase the strength and other durability characteristics.
- Addition of the organic corrosion inhibitors to fly ash replaced self compacting concrete, offered very good resistance against chemical attack and increases corrosion resistance by forming thin oxide layer to prevent outside agents and protecting the anodic sites.

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