Corrosion prevention in concrete and strength characteristics in admixture concrete

Sathanandham.T*, Vijayan.V, Sathes Kumar.K, Karthi.P, Balachandar.B
Jay Shriram Group of Institution, Avinashipalayam, Tirupur, Tamil Nadu
***Corresponding author: E-Mail: sathanadhamcivil@gmail.com**

ABSTRACT

Corrosion of reinforcement in concrete is one of the main causes of structural deterioration, The aim of our work was to develop corrosion preventions systems for reinforced concrete structures by using admixtures .This study indicates the applicability of those compounds for steel corrosion preventions in reinforced concrete structures. Various techniques for including accelerated corrosion of steel in concrete are used by the researchers. In this paper, an experimental studies dealing with a strength characteristics in admixture concrete using super plasticizers (SP), viscosity modifying agents (VMA) at the dosage of 2%, 4% and 6% by weight of water. Corrosion of steel in concrete is a slow process due to the protective nature of concrete. It takes a reasonably long time for this process of rebar corrosion in a limited duration available for performing tests studies are, The effect of mineral admixture in reducing reinforcement corrosion, Test behavior of for compressive strength, split tensile strength, flexural strength of self-compacting concrete. The effectiveness of the applied current in inducing reinforcement corrosion and some of the alternative techniques for inducing accelerated corrosion of the steel in concrete are also described in the paper.

KEY WORDS: Concrete, Super plasticizers, Viscosity modifying agents, Rebar, Chloride induced corrosion, Half-cell potential measurement, Voltmeter and Ammeter.

1. INTRODUCTION

Reinforced concrete is one of the most widely used construction materials in the world. It is a Versatile and economical material that generally performs its intended use well over its service life. The most important and costly deterioration mechanism affecting the reinforced concrete Structures is the corrosion of steel reinforcement. Different corrosion protection methods include increased cover depths, lower permeability concrete (lower water-cement ratio and mineral admixtures) and Viscosity modifying agents (VMA) to produce thyrotrophic mixes and then to obtain cohesive fresh concrete even when they are very fluid. The term self-compacting concrete (SCC) refers to a special type of concrete mixture, characterized by high resistance to segregation that can be cast without compactions or vibration with the advent of super plasticizers, flowing concrete with slump level up to 25mm were manufactured with no or negligible bleeding, provided that an adequate cement factor was used, the most important basic principle for following and un segregable concretes including SCC is use of the super plasticizer, VMA combined with a relatively high content of powder materials in terms of Portland cement, mineral admixtures and very fine sand.

In the recent revision of IS: 456-2000, one of the major points discussed is the durability aspects of concrete. So the use of concrete is unavoidable. The rust volume will be two to four times greater than the volume of the parent steel, resulting in large stresses that ultimately crack and spall the concrete cover. The initiation time of corrosion depends on quality and thickness of the concrete cover and the permeability of concrete. It is important to know the initial Chloride content since they are present in the concrete mix ingredients from cement, aggregates, and water. They can also diffuse from outside of the structure. Corrosion inhibitors can be added during mixing the fresh concrete or can be applied on the surface of hardened concrete structures. Several advantages for using corrosion inhibiting admixtures are: All steel bars in structure are equally protected since the admixture is distributed uniformly throughout the concrete and there is no need for specialized skill because the task consists only adding the correct amount of admixture.

In addition to existing standard test methods, such as ASTM G 109 (Standard Test Method for Determining Effects of Chemical Admixtures on Corrosion of Embedded Steel Reinforcement in Concrete Exposed to Chloride Environments)

2. MATERIAL AND METHODS

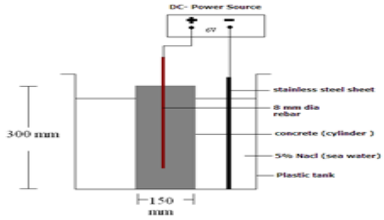
2.1. Electrical Potential: Once chloride has reached the reinforcing steel in concentrations above the threshold limit (typically 0.6 to 1.2 kilograms of chloride ion per cubic meter of concrete for uninhibited systems), the deterioration of the passive layer initiates, and the corrosion process begins. Research has shown that the arrival of sufficient chloride to initiate sustained corrosion is marked shortly thereafter by a sharp increase in the magnitude of electrical potential of the reinforcing steel, as measured against a standard reference probe, such as a copper-copper sulfate electrode (CSE).

Although the magnitude of the electrical potential does not directly relate the rate of corrosion, it may provide a reasonable indication of the probability that corrosion is occurring. A summary of the ASTM C 876-91 interpretation guidelines for electrical potential readings versus CSE is presented in Table 1.

Table.1.Interpretation of ASTM C 876-91 Corrosion Potential Readings

Potential Reading (mV CSE)	Probability of Corrosion
X ≥ -200	<12 %
200 > x > -350	Indeterminate
X ≤ -350	>99 %

Figure.1.Experimental Test set-up



2.2. Material and mix proportion

Table.2.Properties of materials used

Material	Properties	Remarks
Cement	Specific Gravity- 3.14	43 grade-O.P.C.
Fine aggregate	Specific Gravity- 2.66 Fineness modulus- 2.4	Cauvery river sand, Tamil Nadu, India
Coarse aggregate	Specific Gravity- 2.78 Fineness modulus- 7.1 Bulk density- 1523 kg/m^3	Local Quarry, Tirupur, Tamil Nadu, India
Water	Potable- as per IS 456-2000	Cauvery river water, Tamil Nadu, India
Super plasticizers	Brown colour liquid Chloride content- Nil	Obtained from a chemical supplying company, Bangalore, India.
Viscosity modifying admixtures	Colour less , water liquid	Obtained from a chemical supplying company, Bangalore, India.
Reinforcement MS,TMT rod	8mm Dia,300mm long, Mild Steel, Thermo mechanically treated, Cold twisted deformed Rebars- Fe 415	Obtained from a steel producing company, Salem, Tamil Nadu, India.

2.3. Concrete mix design: As per ACI 211-1-91, M20 concrete mix was designed with the water cement ratio of 0.5. The proportion of ingredients by weight of cement is 1: 1.46: 2.57: 0.5. After 28 days of curing, the actual strength of M20 grade concrete obtained was 20.27 N/mm^2 for this mix proportion. The mixes were compacted using vibrating table. The slump of the fresh concrete was determined to ensure that it would be within the design value and to study the effect of admixture on the workability of concrete. The specimens were demoulded after 28 days, cured in water and then tested at room temperature at the required age.

3. RESULTS AND DISCUSSION

3.1. Compressive Strength of Cubes: Cube moulds of size 150x150x150 mm were used. The cube moulds were cleaned thoroughly using a waste cloth and then properly crude oil along its faces. Concrete was then filled in mould and then compacted using a standard tamping rod or vibrators of 60 cm length having a cross sectional area of 25mm$^{2.}$ Concrete cubes of size 150 mm×150mm×150mm were cast with and without admixture. The maximum load at failure reading was taken and the average compressive strength is calculated using the equation.

$$compressive\ strength\ (N/mm^2) = \frac{Ultimate\ load\ in\ N}{Area\ of\ cross\ section\ (mm^2)}$$

3.2. Split Tensile Strength of Cylinder: Cylinder moulds of diameter 150mm and height 300mm were used. The crude oil was applied along the inner surfaces of the mould for easy removal of cylinder from the mould. Concrete was poured throughout its length and compacted well. Concrete cylinders of were cast using 1:1.67:3.76 mix with a W/C ratio of 0.45 with and without copper slag. The maximum load at failure reading was taken and the average split tensile strength is calculated using the equation.

$$Split\ tensile\ strength\ (N/mm^2) = \frac{2P}{\pi LD}$$

Where, P=Ultimate load at failure (N), L=Length of specimen (mm), D=Diameter of cylindrical specimen (mm).

3.3. Flexural strength of Beam: Beam moulds of size 500x100x100 mm were used. The crude oil was applied along the inner surfaces of the mould for easy removal of cylinder from the mould. Concrete was poured throughout its length and compacted well.

$$Flexural\ strength\ (N/mm^2) = \frac{3FL}{2bd^2}$$

Where, F= the load at the fracture point, L= Length of the support span (mm), b= Width (mm), d= Thickness (mm).

3.4. Half Cell Potential Measurement (ASTM C 876): It is a non-destructive electro-chemical method applied to find out the corrosion tendency of rebar in concrete. The technique directly measures the potential of rebar using a high-impedance voltmeter as in Figure 2. The meter has 2 terminals, one of which goes straight to the rebar in concrete, while the other is connected to a copper/copper sulfate reference cell with a porous sponge end. During the measurement process, the sponge is guided to slide over the surface of the concrete, and readings from the voltmeter are registered.

ASTM C 876 has provided guidelines on the relationship between half-cell potential and tendency of rebar corrosion as follows.

a) If potentials over an area are more positive than -250 mV, there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area at the time of measurement.

b) If potentials over an area are in the range of -250 mV to -350 mV, corrosion activity of the reinforcing steel in that area is uncertain.

c) If potentials over an area are more negative than -350 mV, there is a greater than 90% probability that reinforcing steel corrosion is occurring in that area at the time of measurement.

3.5. Experimental Procedures

a. Evaluate properties of the 4 concretes.

a.1 Tests for Slump according to ASTM C 143.

a.2 Tests for Compressive Strength according to BS 1881: Part 4.

b. Appraise corrosion severity of rebar in the concretes due to chloride.

b.1 Prepare black and galvanized deformed bars; grade SD 40 according to TIS 24, with 8 mm diameter.

b.2. Prepare sample cylinder of dimensions 150 * 300 mm. The deformed bars are placed in the cylinder having concrete cover thickness of 7.5 cm. Four concrete mixes are used.

b.3. Place the cubes in NaCl solution at 6% w/w concentration for 120 days to accelerate rebar corrosion. After a period of 8 hours , the cylinder are taken out from the solution which is now renewed, and the cylinder are let to settle for 15 mis before the half cell potential measurement is carried out. All results are recorded.

b.4 When 120 days have elapsed and the corresponding work has all been completed, the cylinder is crushed to expose the rebar. Severity of corrosion as well as the chloride content on the surface of rebar are examined and measured respectively. The chloride contents are examined according to ASTM C 1218 Standard Test Method for Water-Soluble Chloride in Concrete.

3.6. Corrosion detection analysis and results: The compressive, split tensile, and flexural strength results after 28 days curing are given. figures 1to 9. When comparing the results of control concrete [CC] and self-compacting concrete [SCC], it is obvious that add to admixtures concrete specimens have shown improvement in the above strength properties. There was 8.75% increase in compressive strength, 2.5% increase in split tensile strength and 1.68% increase in flexural strength. From the impressed voltage test results it is evident that, the corrosion resistance performance of self compacting concrete was 10.62% greater than the control concrete in group. The rapid chloride permeability test results clearly indicate that, the corrosion resistance performance of self-compacting concrete is 8.84% greater than control concrete.

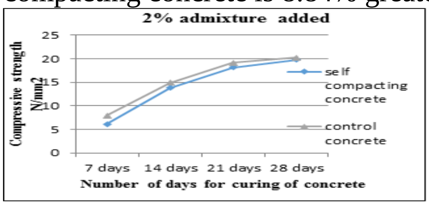


Figure.2.Compressive strength (N/mm^2) of control concrete vs. self compacting concrete 2% admixture

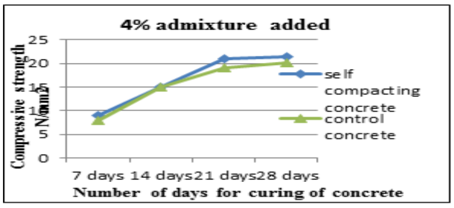


Figure.3.Compressive strength (N/mm^2) of control concrete vs. self compacting concrete 4% admixtures

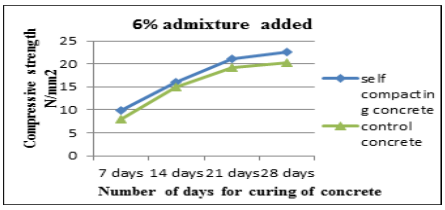


Figure.4.Compressive strength (N/mm^2) of control concrete vs. self compacting concrete 6% admixtures

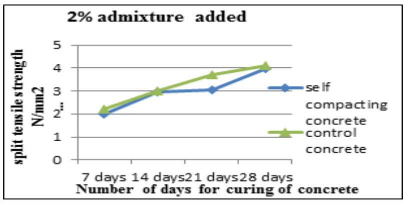


Figure.5.Split tensile strength (N/mm ^{2}) of control concrete vs. self compacting concrete 2%

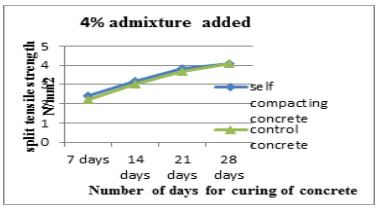


Figure.6.Split tensile strength (N/mm^2) of control concrete vs. self compacting concrete 4%

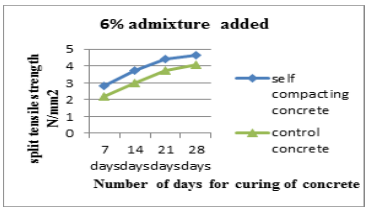


Figure.7.Split tensile strength (N/mm ^{2}) of control concrete vs. self compacting concrete 6%

admixtures **admixtures** **admixtures**

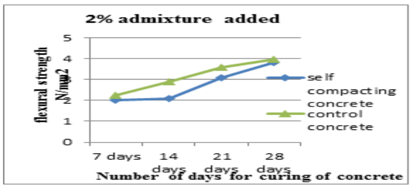


Figure.8.Flexural strength (N/mm^2) of control concrete v_s self compacting concrete 2% admixtures

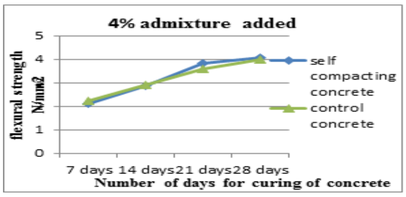


Figure.9.Flexural strength (N/mm^2) of control concrete v_s self-compacting concrete 4% admixtures

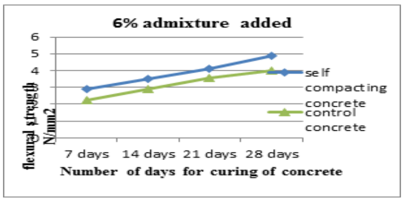


Figure.10.Flexural strength (N/mm^2) of control concrete v_s self compacting concrete 6% admixtures

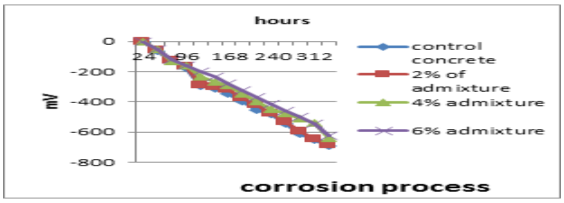


Figure.11.Control concrete v_s self-compacting concrete is added to 2%,4%, 6% of admixtures by corrosion process

4. CONCLUSION

From the experimental studies the following conclusions were drawn

Concrete containing self-compacting concrete as with appropriate dosage of super plasticizer, Viscosity modifying agents gives slightly higher strength when compared with control concrete.

Among all the percentages of super plasticizer, Viscosity modifying admixture added, 2%, 4%, 6% addition of self-compacting concrete maximum improvement in the compressive strength, split tensile strength, and flexural strength when compared to the control specimen.

The results of corrosion tests indicate that, corrosion initiation time of steel rod embedded self-compacting concrete is delayed due to the addition of inhibitor and also there was a reduction in corrosion rate. Among all the percentages of inhibitors 6% was found to be the optimum percentage for getting maximum corrosion resistance

Considering strength as well as durability criteria of self-compacting concrete along with 6% dosage of super plasticizer, Viscosity modifying admixture can be effectively used in reinforced concrete structures for delaying corrosion and to increase other strength and durability characteristics.

REFERENCES

ASTM C876-09, Standard Test Method for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete, 2000.

Austin S.A, Lyons R, and Ing M.J, Electrochemical Behavior of Steel-Reinforced Concrete During Accelerated Corrosion Testing, Corrosion, 60(2), 2004, 203–212.

Concrete and Materials Committee, Standards for construction materials and concrete structures, Engineering Institute of Thailand, 4, 1997, 22-24.

Dr. Faiza E Gharib, Ahmed Abdulhaq and Ali Abd, Experimental Study Of Reinforcing Steel Bars Behaviour Under Corrosive Conditions, Australian Journal of Basic and Applied Sciences, 6(9), 2012, 371-377.

Gu P & Beaudoin J.J, Obtaining Effective Half-cell Potential Measurements in Reinforced Concrete Structure, Construction Technology Updates, 18, 1998, 1-4.

Mayilvaganam P, How chemical admixtures produce their effects in concrete, The Indian Concrete Journal, 2001, 23-25.

Michael C Brown, Richard E Weyers, and Michael M Sprinkel, Effect of Corrosion – Inhibiting Admixtures ON Material Properties of Concrete, Aci Material Journal, 98(3), 2001.

Schutterg Luol.D, Effect Of Corrosion Inhibiting Admixtures On Concrete Properties, Construction And Building Materials, 2004, 483-489.

Yuan Y, Ji Y, and Shah S.P, Comparison of two Accelerated Corrosion Techniques for Concrete Structures, ACI Structural Journal, 104(3), 2007, 344–347.

Yuttana Srimahajariyaphong and Satian Niltawach, Corrosion prevention of rebar in concrete due to chloride, Journal of metals, materials and minerals, 21(1), 2001.