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RELIABILITY STUDY OF HIGH PERFORMANCE CONCRETE UNDER CARBONATION ATTACK: A REVIEW

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Abstract- Even though the concrete can be a very strong material, it is also subjected to deterioration. The durability of a concrete structure is affected when it is prone to chemical actions (carbonation, chloride attack, sulphate attack etc). This chemical action may cause cracking of concrete, volume change and deterioration of structure. The penetration of chemical ions and carbon dioxide into the concrete leads to dissolution of thin oxide protective layer surrounding the reinforcing steel, thus affecting the durability of structure and leading to premature failure. Different measures are used to prevent the steel bars from these chemical attacks. Coating steel bars with layers of zinc is one such economical method to protect reinforcing steel concrete structures. In this experiment, the steel bars will be coated with zinc powder and neem powder, the beam specimen will be casted and subjected to saline curing and the corrosion potential of the reinforcement will be measured by using half-cell potentiometer.

Keywords— Corrosion of steel in concrete, High performance concrete, Chemical attack, Chloride, Zinc, Azadirachta Indica (Neem), Potentiometer.

I. INTRODUCTION

The deterioration of reinforcement in concrete can be caused by chloride attack, sulphate or any other acid attack. Concrete under normal exposure conditions protects reinforcing steel against corrosion. This protective behaviour of concrete is attributed to its high pH (12-13) and the formation of a protective film on the surface of the embedded steel. Steel has poor corrosion resistance and concrete has good anti-corrosion properties. The hydration process of concrete leads to the formation of hydroxides which raises the pH level of the cement to around 12.5 and provides a stable oxide layer on the steel surface, which prevents the anodic dissolution of the steel. This passive layer is broken down by the chemical attacks leading to corrosion of steel. Once the passive layer is broken, the reinforcing steel is exposed to the effects of air and water. The steel then begins to rust and expand putting pressure on the concrete and causing cracks, thus increasing the chances of failure in the reinforced concrete member dramatically.

Many methods can be used to reduce the corrosion of concrete such as coating the steel reinforcement, Galvanized reinforcement, improving metallurgy by adding chromium and copper, using corrosion inhibitors. These inhibitors can be either added to the concrete during mixing or applied on the metal bars. Since use of some of the inhibitors, such as chromates has been banned because of toxicity and the environmental hazards they create. Therefore, there is a need to make use of environmental friendly, non- toxic, corrosion inhibitors such as Neem powder (Azadirachta Indica), which is made from the naturally occurring plant extracts also known as green corrosion inhibitors.

The reinforced bar must be descaled and cleaned ready for an anti-corrosion coat to be applied. This coat isolates the bar and protects it from water and chemicals that could cause corrosion. Corrosion inhibitors present an alternate method for preventing or delaying corrosion of reinforcement in concrete. An ideal corrosion inhibitor has been defined as “a chemical compound, which, when added in adequate amounts to concrete, can prevent corrosion of embedded steel and has no adverse effect on the properties of concrete.

II. LITERATURE REVIEW

Compressive strength

George et al (2017) studied corrosion resistance of reinforced concrete with the green corrosion inhibitors extracted from Neem. OPC of grade 53 and M25 grade concrete was used. Three specimens are casted for conventional concrete, three specimen for concrete with neem powder. Water cement ratio is taken as 0.5. Neem powder of 2% by wt. of cement is directly added to concrete while mixing. Cube specimens of size 150x150x150mm were casted for determining compressive strength at 28 days. Cylindrical specimens of diameter 150mm and height 300mm were casted for finding the split tensile strength of the concrete at 28 days.

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It was observed that the compressive strength of concrete with corrosion inhibitor was less than the strength of conventional concrete, but the strength was within the permissible values. However, the split tensile strength of concrete with neem powder was increased by 5.18% than conventional concrete.

Prasanth (2017) studied influence of calcium nitrate on properties of concrete. Grade of concrete was M25. Three samples of conventional concrete (C1, C2, C3) and three samples of concrete with 4%, 5%, 6% of calcium nitrate were casted. The compressive strength of these samples was determined by using cube specimen of size 150x150x150mm at the period of 7^{th}, 28^{th}, & 56^{th} days of curing. Similarly, for determination of the split tensile strength of concrete, cylindrical specimens of diameter 150mm and 300mm long were casted. The split 0tensile strength was calculated for 28^{th} and 56^{th} days.
The test results of conventional concrete and inhibitor concrete specimens were compared. At the end of 28 days, it was observed that the compressive strength of inhibitor concrete was increased by 5.4%, and split tensile strength was increased by 1.4%. The best inhibition was seen in the sample with 6% of calcium nitrate.

Daniel Dobias et al. (2016) studied the influence of corrosion of zinc powder on concrete by using pure Portland cement. In this experiment, cube specimens with 0%, 0.5%, 5% of zinc powder were casted to determine the compressive strength of specimens. After the evaluation of compression cubic test, static modulus of elasticity in compression was calculated with samples of size 100x100x400mm. Cyclic loading of 0.5 MPa to 1/3 of measured compressive strength and the all the properties were measured in longitudinal axis.
After 28 days of curing, the compressive cubic strength is slightly reduced with the addition of 0.5 wt. % Zn. And with the addition of 5.0 wt % Zinc the compressive strength is reduced to a factor of 10. Similarly, with 0.5% addition of zinc, there was no change in value of elastic modulus but with 5.0% zinc, the elastic modulus of concrete was reduced to 25%.

Effect on chemical attack

Vagelis.G et al (2017) studied effect of supplementary cementing materials on concrete resistance against carbonation ingress. Silica fume, low-calcium fly ash, high-calcium fly ash were used as the supplementary cementing material. Portland cement was used for this experiment and water cement ratio was 0.5. Three different amounts were selected for the aggregate replacement for each SCM type. Silica fume specimens after 5, 10 and 15% addition to cement mass –SF1, SF2, SF3. Low-Ca fly ash specimens after 10, 20, and 30% addition to cement mass –FL1, FL2, FL3. And high-Ca fly ash specimens after 10, 20, and 30% addition to cement mass-FH1, FH2, & FH3.
Similarly, in the case of cement replacement by SCM, the same amounts were also selected: silica fume—5, 10, and 15% replacement of the control cement mass (specimens SFC1, SFC2, and SFC3, respectively); low-Ca fly ash—10, 20, and 30% replacement of the control cement mass (specimens FLC1, FLC2, and FLC3, respectively); and high-Ca fly ash—10, 20, and 30% replacement of the control cement mass (specimens FHC1, FHC2, and FHC3, respectively). Cylindrical specimens of diameter 100mm and 200mm height were casted and specimens were placed under water [saturated in Ca(OH)2] for 1 year.
It was observed, the carbonation depth decreases as aggregate replacement by SCM increases and carbonation depth increases as cement replacement by SCM increases

George et al (2017) studied corrosion resistance of reinforced concrete with the green corrosion inhibitors extracted from Aloe-Vera and Neem. OPC of grade 53 and M25 grade concrete was used. Three specimens are casted for conventional concrete, three specimen for concrete with neem powder. Water cement ratio is taken as 0.5. Neem powder of 2% by wt. of cement is directly added to concrete while mixing. Cylindrical specimen of size 75mm diameter and 150mm height were cast to assess the initiation time of corrosion. HYSD steel bar of 16mm diameter was embedded centrally into the cylinder. After 28 days of curing, the specimens were dried for 24 hours and immersed in saline water with 3.5% sodium chloride solution. The steel bar is connected with the anode (positive terminal) and the stainless steel plate is connected to the cathode (negative terminal) of the power source. Specimens were subjected to constant voltage of 6V from the D.C power source. The current response is monitored with respect to time. The result showed that the concrete with green organic inhibitors have high corrosion initiation time when compared to the conventional concrete.

George Batis et al (2014) studied protection systems for reinforced concrete with corrosion inhibitors. Corrosion inhibitors were used as admixture into concrete and were sprayed on the external surface of mortar specimens. Specimens were divided into 3 groups, each group consisted of 6 samples. Reinforced bars of diameter 10mm and 10cm long were used. Size of sample was 100x100x100mm. 4 bars were inserted in the cube at equal distance from centre. The bars were embedded 80mm into the mortar. Samples were immersed in 3.5% NaCl solution to induce corrosion. In group A, the samples were not inhibited by corrosion inhibitor. In group B, corrosion inhibitor was sprayed on the external surface. In group C, corrosion inhibitor was used as an admixture. Methods used to measure corrosion potential were Half cell potential measurement, mass loss of steel bars.

It was observed Group C has fewer tendencies to corrode since it has less half cell potential compared with Groups A and B. From the above results, it is obvious that the corrosion inhibitor has the tendency to protect the rebars from the corrosion.

Ackmez Mudhoo et al (2010) studied the corrosion efficiency of azadirachta indica leaf extract as corrosion inhibitor for mild steel in nitric acid. The experiment was conducted at 30°C and 60°C. 4 extract concentrations were used for evaluating the inhibition efficiency of inhibitor. Nitric acid concentration used was 0.5, 1, and 2N solutions. Neem extract was prepared by boiling 602 gms of dried neem leaves in deionized water. Size of specimen used was 50mmx25mmx0.45mm thick. The results revealed that Azadirachta indica posses corrosion inhibition properties and that the efficiency varies with inhibitor concentration and temperature. The best results were obtained at inhibitor concentration of 28.57 mg/l at 30°C and 60°C.

Concentration of AZI extract (mg/L)	Corrosion rate (mmpy)					
	0.5 N HNO_3		1.0 N HNO_3		2.0 N HNO_3	
	303 K	333 K	303 K	333 K	303 K	333 K
Uninhibited	0.335	0.424	0.552	1.554	2.985	3.304
9.09	0.209	0.304	0.387	0.519	0.842	2.294
16.64	0.192	0.236	0.377	0.359	0.820	2.444
23.06	0.208	0.217	0.341	0.346	0.715	1.113
28.57	0.134	0.151	0.146	0.289	0.595	0.636

Effect on thermal properties

Rama Debbarma and Ratul Das studied effect of corrosion inhibitor on properties of concrete and mortar with silica fume as admixture. Ordinary cement was used for the experiment. Sodium nitrite was used as the corrosion inhibitor. Tests were performed on fresh concrete, the workability, setting time was evaluated. The initial and final setting time was delayed after the addition of 5% of corrosion inhibitor. By the addition of silica fume the initial setting time was reduced. When sodium nitrite is added to the super plasticizer admixed concrete the setting time is delayed.

III. CONCLUSION

1) The concrete with green corrosion inhibitors have high corrosion initiation time and low corrosion rate compared to the conventional concrete. Azadirachta Indica (Neem) has superior corrosion inhibition efficiency.
2) Lower amount of zinc in concrete (0.5 wt. %) has no significant effect on hydration and hence no effect on mechanical properties evolution. Higher amount of zinc (5 wt.%) reduces the compressive strength and elastic modulus of concrete.
3) Addition of sodium nitrite (5% of cement) as Corrosion inhibitor delays initial and final setting time for both type of samples made with OPC and slag cement.
4) The carbonation depth decreases as aggregate replacement by supplementary cementing materials (SCM) increases, and increases as cement replacement by SCM increases. The lowest carbonation depth is observed for high-Ca fly ash, then for low-Ca fly ash, and the highest for silica fume.
5) The use of SCM as an addition to concrete mix by replacing aggregates increases the chloride-induced and carbonation-induced corrosion initiation stage.
6) Specimens with corrosion inhibitors have tendency to protect the rebars from corrosion than the specimens with no corrosion inhibitors.
7) The specimens in which corrosion inhibitor was used as an admixture have better behaviour than the specimens in which corrosion inhibitor was sprayed on the external surface of mortar specimens.
8) Calcium nitrate as an inhibitor has proved more effective in the strength aspect as compared to sodium nitrate.

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