Experimental Study on Concrete Using Calcium Nitrite and Sodium Nitrite as Corrosion Inhibitor

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Abstract— Reinforced concrete has been widely used in the last century; however, due to carbonic gas and chloride ions, it suffers premature deterioration. The concrete protects steel from corrosion, and the alkalinity of concrete leads to the formation of a passive layer around the reinforcement, which increases protection against corrosive processes. However, concrete is a porous material and has cracks that allow the entrance of aggressive agents, destabilizing the passive layer and corroding steel. The corrosion is the major cause of deterioration of concrete structures and several methods of protection and repair have been developed to increase the durability of such structures. Corrosion inhibitors, chemical substances that reduce the corrosion rate, have been widely used, both for prevention and correction. Inhibitors are classified according to their method of application, their mechanism of protection and chemical composition. Due the advantages that they offer, corrosion inhibitors have been receiving more attention in recent years. The use of inhibitors is a promising method to increase the durability of concrete structures exposed to chloride ions and carbonation.In this research work, calcium nitrite and sodium nitrite are used as a corrosion inhibitors. Different percentages of inhibitors are added in the concrete for experimental work. Rebound hammer test, UPV test, half cell potentiometer test are performed on concrete cubes.

Index Terms—Inhibitor, concrete, calcium nitrite, sodium nitrite.

I. INTRODUCTION

Reinforced concrete is having good durability. But, corrosion is the main problem of reinforced concrete structure, which affects the service life of structure. Corrosion of reinforcement in concrete structure is an electrochemical process in which flow of electrical current and chemical reactions occur. Attack of chloride is the main reason for the corrosion of steel in reinforced concrete structure. Chloride penetrates through pores of concrete and reaches the reinforcing steel, which forms oxide film over bars. Due to this passivity of steel is broken. The water present in the pores of concrete acts as electrolyte and steel surface act as a cathode. Some of the common corrosion control measures are selection of good quality materials, providing extra thick cover to reinforcement bars, reducing w/c ratio, adding super plasticizer, use of corrosion inhibitors, coating of bars with epoxy, use of stainless steel as reinforcement etc. Using corrosion inhibitors in concrete is one of the effective method to control corrosion of reinforcement bars. Corrosion inhibitors when added to concrete forms a layer on steel surface and prevent it from corrosion. Inhibitors can be used in two ways: by adding in concrete or by applying at surface. But, addition of inhibitor in concrete is more efficient. Generally the mechanisms of the inhibitor are:

- the inhibitor is chemically adsorbed (chemisorption) on the surface of the metal and forms a protective thin film with inhibitor effect or by combination between inhibitor ions and metallic surface;
- the inhibitor leads a formation of a film by oxide protection of the base metal;
- the inhibitor reacts with a potential corrosive component present in aqueous media and the product is a complex

Inhibitors are classified as anodic, cathodic and mixed type.Anodic inhibitors forms protective oxide film over the surface of reinforcement bars and prevent the area from corrosion. They are known as passivators. Cathodic inhibitors forms a precipitate over the cathodic region of reinforcement bars. But, they are less effective than anodic inhibitors. While mixed inhibitors have combination of anodic and cathodic process.

Another classification of corrosion inhibitors is organic inhibitors and inorganic inhibitors. Organic inhibitors act as both anodic and cathodic inhibitor. They do not have any adverse effect on concrete structure. Some examples of organic inhibitors are amines, aldehydes, nitrogen compounds, caffeine, extracts of natural substances, etc. Inorganic inhibitors are also known as passivating inhibitors. Examples of this are nitrites, hydroxides, silicates, zinc compounds, etc.

II. MATERIAL AND METHODS

(i) Material:

In this research, calcium nitrite and sodium nitrite are used as corrosion inhibitors. They are used by replacing cement in 2%, 5% and 10% respectively. Ordinary Portland cement (43 grade) is used for experiment. Crushed sand is used as fine aggregate confirming to zone I as per IS 383-1970. It is having specific gravity 2.72 and bulk density 1460 kg/m^3. Mix design for M25 concrete is done as per IS 10262-2009. Water cement ratio of 0.5 is used. Reinforcement bars of 8mm size are used.

The Mix Proportion:

Cement	W/C	Water	Sand	20mm	10mm

350	0.5	175	736	394	900
1		0.50	2.1	1.12	2.57

Units – Kg/ M^3

Cement : Sand: Coarse Aggregates = 1 : 2.1:3.69

(ii) Method:

Concrete cubes were casted having size 150x150x150 mm. Cement is replaced by 2%,5% and 10% respectively. Two cubes were casted for each percentage respectively. Two cubes of normal concrete also casted. For each combination, one cube is inserted by 8mm size reinforcement bar. Cubes without reinforcement bar are kept in normal water for curing for a period of 28 days. While, setup is made for corrosion acceleration in reinforced concrete cubes. Impressed current technique is used to accelerate corrosion. Constant 12V DC power supply is given to bars. 5% NaCl solution is used for immersion of cubes. Setup is as shown in figure,

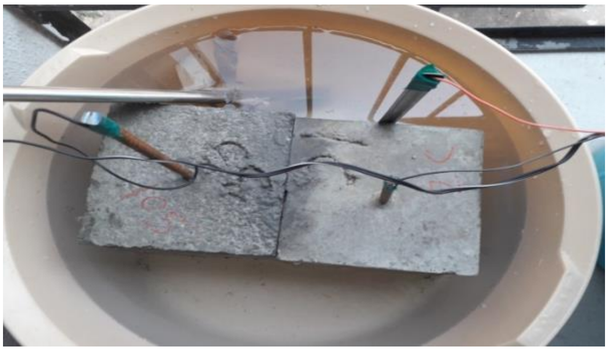


Fig. 1: setup for impressed current technique

NaCl solution is replaced periodically. Positive terminal of supply is connected to steel bar in cube and negative terminal is connected to stainless steel rod immersed in solution. After some time of supplying current to the bars, deposition of rust is observed on the surface of stainless steel bars.

Fig. 2: Deposition of rust on stainless steel bars

Rebound hammer test and ultrasonic pulse velocity test is taken on unreinforced concrete cubes. Half cell potentiometer test is taken on reinforced concrete cubes.

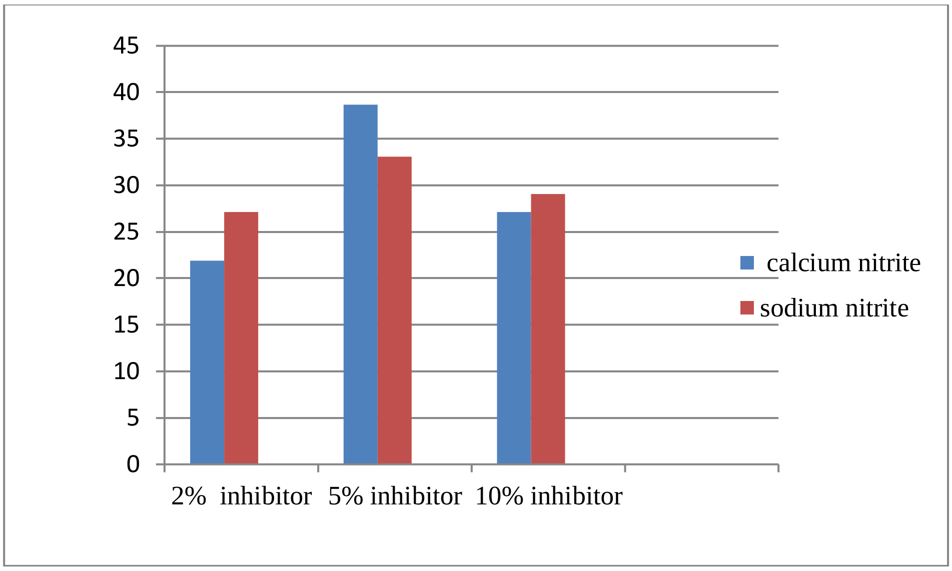
II. RESULT

(i) Test result of rebound hammer test:

Rebound Hammer test is a Non-destructive testing method of concrete which provide a convenient and rapid indication of the compressive strength of the concrete. When the plunger of rebound hammer is pressed against the surface of concrete, a spring controlled mass with a constant energy is made to hit concrete surface to rebound back. The extent of rebound, which is a measure of surface hardness, is measured on a graduated scale. This measured value is designated as Rebound Number (rebound index).

Test specimen	Direction of impact	Estimated compressive strength(N/mm^2)
Normal concrete	Horizontal	26.6
2% calcium nitrite	Horizontal	21.9
5% calcium nitrite	Horizontal	38.7
10% calcium nitrite	Horizontal	31.8
2% sodium nitrite	Horizontal	27.1
5% sodium nitrite	Horizontal	33.1
10% sodium nitrite	Horizontal	29.1

Table no. 1: compressive strength result by rebound hammer test



Graph of compressive strength obtained by rebound hammer test

(ii) Test result of ultrasonic pulse velocity test:

Ultrasonic testing of concrete or ultrasonic pulse velocity test on concrete is a non-destructive test to assess the homogeneity and integrity of concrete. With this ultrasonic test on concrete, following can be assessed:

- Qualitative assessment of strength of concrete, its gradation in different locations of structural members and plotting the same.
- Any discontinuity in cross section like cracks, cover concrete delamination etc.
- Depth of surface cracks.

Test specimen	**location**	**Distance(mm)**	**Time(microsec.)**	**Velocity (km/sec)**	**Concrete quality grading**
Normal concrete	Center	150	37	4.05	Good
2% calcium nitrite	Center	150	38	3.95	Good
5% calcium nitrite	Center	150	37	4.05	Good
10% calcium nitrite	Center	150	35	4.05	Good
2% sodium nitrite	Center	150	36	4.29	Good
5% sodium nitrite	Center	150	37	4.17	Good
10% sodium nitrite	Center	150	37	4.05	Good

Table no. 2: Concrete quality by UPV test

According to IS 13311.1.1992, if pulse velocity is in between 3.5 to 4.5, then, concrete quality grading is good.

(iii) Cost effectiveness of concrete having different percentage of inhibitor compared with normal concrete for $1m^3$.

Normal concrete	Rs. 4150/-
Concrete with 2% calcium nitrite	Rs. 4875/-
Concrete with 5% calcium nitrite	Rs. 5960/-
Concrete with 10% calcium nitrite	Rs. 7770/-
Concrete with 2% sodium nitrite	Rs. 4560/-
Concrete with 5% sodium nitrite	Rs. 5160/-
Concrete with 10% sodium nitrite	Rs. 6185/-

Table no. 3: costing of $1m^3$ of concrete

(iv) Half cell potentiometer test

The instrument measures the potential and the electrical resistance between the reinforcement and the surface to evaluate the corrosion activity as well as the actual condition of the cover layer during testing. The electrical activity of the steel reinforcement and the concrete leads them to be considered as one half of weak battery cell with the steel acting as one electrode and the concrete as the electrolyte. The name half-cell surveying derives from the fact that the one half of the battery cell is considered to be the steel reinforcing bar and the surrounding concrete. The electrical potential of a point on the surface of steel reinforcing bar can be measured comparing its potential with that of copper – copper sulphate reference electrode on the surface. Practically this achieved by connecting a wire from one terminal of a voltmeter to the reinforcement and another wire to the copper sulphate reference electrode.

Sr. no.	Name of chemical used	% of chemical used	Half cell potential reading(-mV)
1	-	-	-379
2	Calcium nitrite	2%	-212

3	Calcium nitrite	5%	-282
4	Calcium nitrite	10%	-309
5	Sodium nitrite	2%	-277
6	Sodium nitrite	5%	-309
7	Sodium nitrite	10%	-339

Table no.4 –Half cell potential readings

According to ASTM C876,for reading less than 350, there is moderate risk of corrosion and above 350, there is high risk of corrosion.

III. Conclusion

The research studied different types of inhibitors and focused on the use of calcium nitrite and sodium nitrite as a inhibitors in concrete. The corrosion inhibitors are effective in preventing reinforcement from corrosion within concrete structures. The corrosion inhibitor forms a protective passive film around the steel bars. From the results, it can be stated that, upto 5% addition of inhibitors, concrete strength increases. After that, strength goes on decreasing. Also, cost is also not much increases by adding 5% inhibitors for both the cases. So, addition of 5% of calcium or sodium inhibitor is sufficient for strength gain. Also, in comparison with normal concrete, corrosion protection is also achieved by inhibitors.

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