ISSN No:-2456-2165

Assessment of the Efficiency Restriction of Amine based Inhibitor for Constructional Steel in a Saline Sand Concrete

Dr. Bui Quoc Binh[1,*], Dr. Pham Quoc Hoan[2]
Faculty of Civil Engineering, Vietnam Maritime University

Abstract:- This paper presents an overview of research results and applying of Dimethl ethanolamine inhibitor (DMAE) to limit the corrosion of constructional steel in saline sand concrete for sustainable building material purpose. In this study,06 series of concrete samples were prepared with sanline sandof Dau resort, Hai Phong, Vietnam was used as fine aggegate. A CB300-V D10 bars (TCVN 1651-2:2018) was used for electrodes for corrosion testing. Electrochemical analyzes by corrosion potential of the samples were carried out in a 3% NaCl solution with a sample immersion time of 60, 90, 140 and 300days. Experimental results show that the corrosion ability of the samples were significantly reduced when using that inhibitors.

Keywords:- *Corrosion of steel, Corrosion potential,organic inhibitor, Saline sand, Sustainable building material.*

I. INTRODUCTION

A large number of reinforced concrete structures such as harbors, docks, bridge decks, piers, floating offshore platforms and marine facilities are generally subjected to chloride ions and other chemical matters those come from seawater, salt spray in atmosphere. Reinforced concrete structures exposed to marine environments are subjected to the actions of a number of physical, chemical and electrochemical deterioration processes. In those conditions, the durability performance of concrete structures has been causing great concern among researchers and designers all over the world. Among several degradation processes of reinforced concrete, the corrosion of steel reinforcements is of much greater importance. Embedded steel in concrete gets corroded through two reactions which are environmentally related, such as carbonation of concrete and chloride diffusion in concrete. In the other way, attack on concrete due to any one of these causes tends to increase the permeability; not only would this make the material progressively more susceptible to further action by the same destructive agent but also to other types of attack. Thus mazes of interwoven chemical as well as physical causes of deterioration are found at work when a concrete structure exposed to seawater is in an advanced stage of degradation. The basic approaches that have so far been taken to prevent corrosion of reinforced concrete are as follows:

- Improving the quality of concrete and increasing its cover thickness,
- Providing a protective coating on the surface of concrete,
- Using corrosion inhibitors,
- Implementing cathode protection of the surface and,
- Protecting the steel reinforcement in concrete [1].

The use of inhibitors in concrete is an alternative option for preventing the corrosion of steel in concrete in the presence of chloride ions [2,3]. Corrosion inhibitors can be divided into three types: anodic, cathodic and mixed depending on whether they interfere with the corrosion preferentially at the anodic or cathodic sites or whether both are involved [4]. The use of corrosion inhibitors in concrete has been reviewed by Tread away and Russel [5], Craig and Wood [6],Griffin [7],Slater [8] and most recently by Berke [9].

In this study, 06 series of concrete samples were prepared with sanline sand of Dau resort, Hai Phong, Vietnam was used as fine aggegate.Dimethlethanolamine inhibitor (DMAE) was used. A CB300-V D10 bars (TCVN 1651-2:2018) was used for electrodes for corrosion testing. Electrochemical analyzes by corrosion potential of the samples were carried out in a 3% NaCl solution with a sample immersion time of varied days. Corrosion behavior of 06 series of samples with and without DMAE inhibitor was investigated.

II. EXPERIMENTAL

A. Material

The experiment in this study used rebar CB300-V D10 according to TCVN 1651-2:2018 as reinforced concrete. Sample concrete is normal concrete grade 300 (strength level B22.5) - coarse aggregate is crushed stone 0.5x1 - slump 2-4cm according to norm 1784/BXD-VP dated August 16, 2007 of the Ministry of Construction. The ratio of W/C is 195 litre /390kg, sand: 0.44m^3, stone: 0.83m^3 for 1m^3 of concrete, thus ratio W/C ~0.5, cement PCB40. Corrosion solution is 3% v/v salt water as used. Saline sand is taken from sand to create beach in Dau island tourist area. Single core copper wire with a cross section of 1.3mm^2 is used as a reciprocating electrode, the wire ends are tinned to prevent corrosion.

DMAE inhibitor was used as a liquid that is mixed by mass in concrete mixing water. Concrete samples with/without inhibitors, using normal construction sand and saline sand are specified in table 1.

Table 1: Sample denote and composition

Sample denote	PC	BC	IO1	IO2	IO3	IO5
DMAE ratio by mass of water	0	0	0.1%	0.2%	0.3%	0.5%
Sand	Normal construction sand	Saline sand	Saline sand	Saline sand	Saline sand	Saline sand

B. Samples preparation

➢ *Electrodes preparation*

Firstly, the CB300-V rebar (figure 1) is cut into 7cm long bars (figure 2), the cutting surface submerged in concrete is ground flat with sandpaper number 180, 240 and 400 respectively. Finally, rinse the electrodes with tap water and blow dry with a de-oiled air compressor nozzle. The sample surface preparation ensures conditions equivalent to those of the reinforcement surface preparation in the field such as when cleaning the reinforcement surface by sandblasting (ceramic grit, alloy balls), rinsing with tap water and blow dry with compressed air.

➢ *Concrete samples preparation*

Figure 3 is the sample electrode rod and the counter electrode positioned before insertion into the formwork. Figure 4 shows the structural principle of the concrete sample used in this test. The sample electrode is positioned on the Alumex sheet to a set of 70.7mm square 3-cell formwork. The surface of the formwork is coated with a layer of non-stick vegetable oil. Mixed concrete according to the specified grade according to the norm of 1784/BXD-VP with the inhibitor added to the concrete mixing water, the content shown in table by manual mixing method. A concrete mixing was spread 2cm thick layer into the cell and compacted thoroughly with a 10mm diameter stainless steel bar, using a rubber hammer to lightly tap the outer surface of the formwork to smooth the surface of the concrete sample. All samples were stored in a room with a temperature of 25±2^{0}C, relative humidity RH=50±5%. The formwork was removed after 12 hours and completely immersed in 3% NaCl solution to simulate the working state of cast-in-place concrete members in the marine environment with flooded areas but accelerate the corrosion process. The sample bath was shaken once a day to increase dissolved oxygen, the electrodes played the role of reinforcement, the concrete block acts as a protective layer of concrete with a thickness of 25mm, the counter electrode was used to measure the corrosion potential.

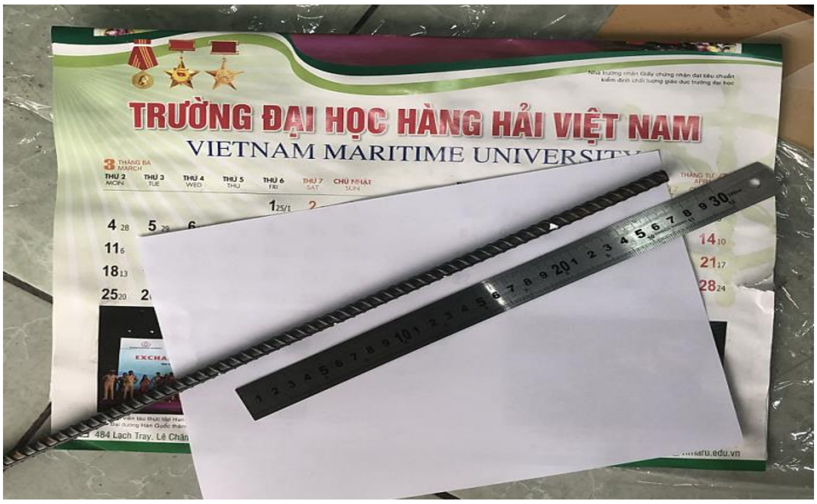

Fig. 1: CB300-V rebar

Fig. 2: CB300-V rebar cut as the sample electrode

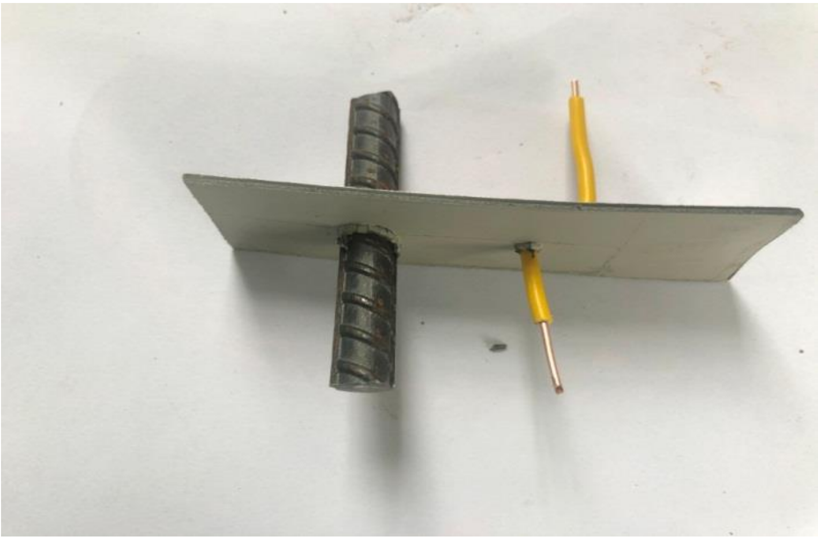

Fig. 3: Electrodes and wire as reciprocal electrode mounted on Alumex plate for positioning

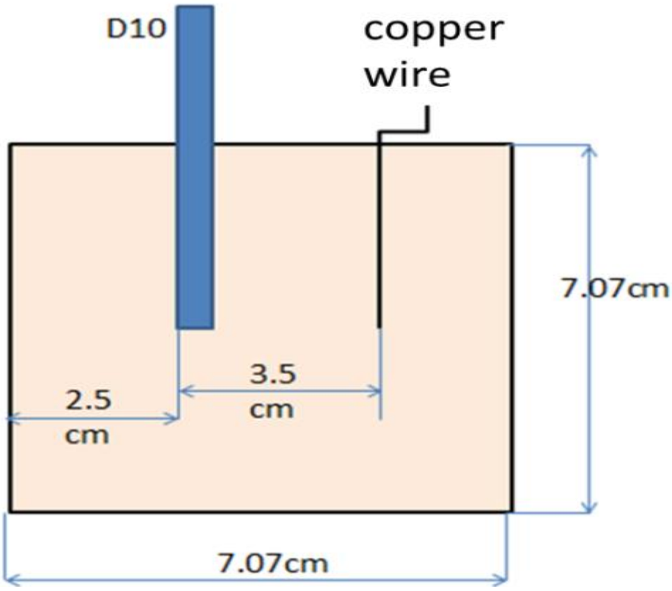

Fig. 4: Schematic diagram of the concrete sample

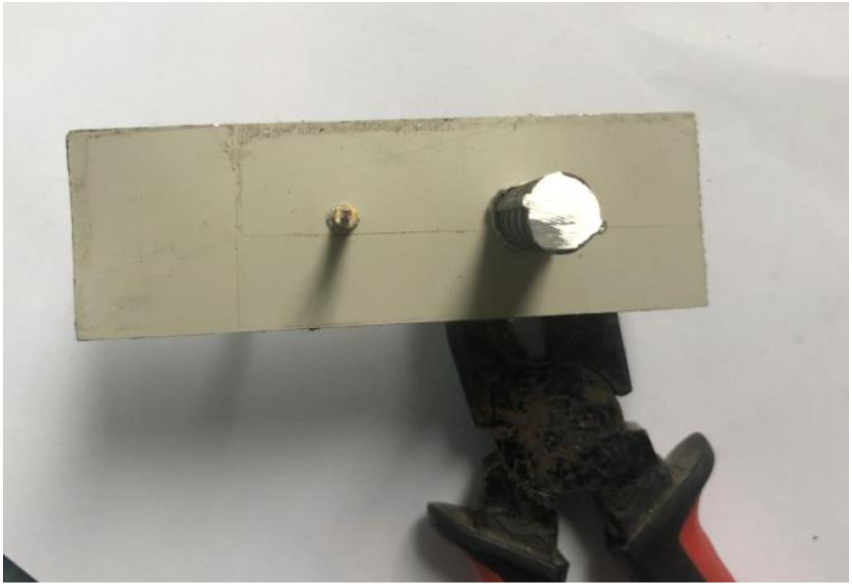

Fig. 5: The cutting surface of the electrode rod

Fig. 6: Samples molded in 70.7mm cell formwork

C. Experiment method

Electrochemical analysis: to evaluate the corrosion behavior of CB300-V steel samples in normal/saline sand concrete with/without inhibitors, the concrete samples were soaked in 3% NaCl solution, after turn 60,90, 140 and 300 (days). Measure the voltage between the sample electrode and the copper wire using a DT9208A multimeter. The samples were fabricated and tested under the same conditions. The experimental results were compared with the results of the analysis of samples without inhibitors, without using saline sand as aggregate.

Fig. 7: Measuring the corrosion potention

III. RESULTS AND DISCUSSION

The results of measuring the corrosion potention between the CB300-V construction steel electrode bar and the reciprocal copper electrode bar using a multimeter are presented in Table 2.

After 300 days of immersion, the samples were removed from the NaCl solution, dried and broken to observe the electrode surface (figure 8).

Table 2: Corrosion potention measurement results between 2 electrodes (mV)

Immersion time (days)	PC	BC	IO1	IO2	IO3	IO5
60	-480	-770	-670	-380	-290	-30
90	-570	-890	-710	-420	-330	-110
140	-910	-900	-850	-570	-350	-310
300	-950	-900	-800	-650	-370	-350

The corrosion potention between the two electrodes was measured. The result shows that at the early stage of the concrete hardening process, the thin film created by the chemical components of the cement paste creates a protective film on the surface of the reinforcement. Thus, the PC sample has a more positive voltage potential than the BC sample. Cl^- ions in saline sand always affect the steel surface of the BC sample, and the corrosion process always occurs on the surface of the base steel. Despite inhibitors that slow down the diffusion of dissolved oxygen and Cl^- ions, the inhibitor effected in IO1 samples is not high due to their low content. In the first period of sample immersion, the higher the inhibitory content, the higher the anti-corrosion effect.

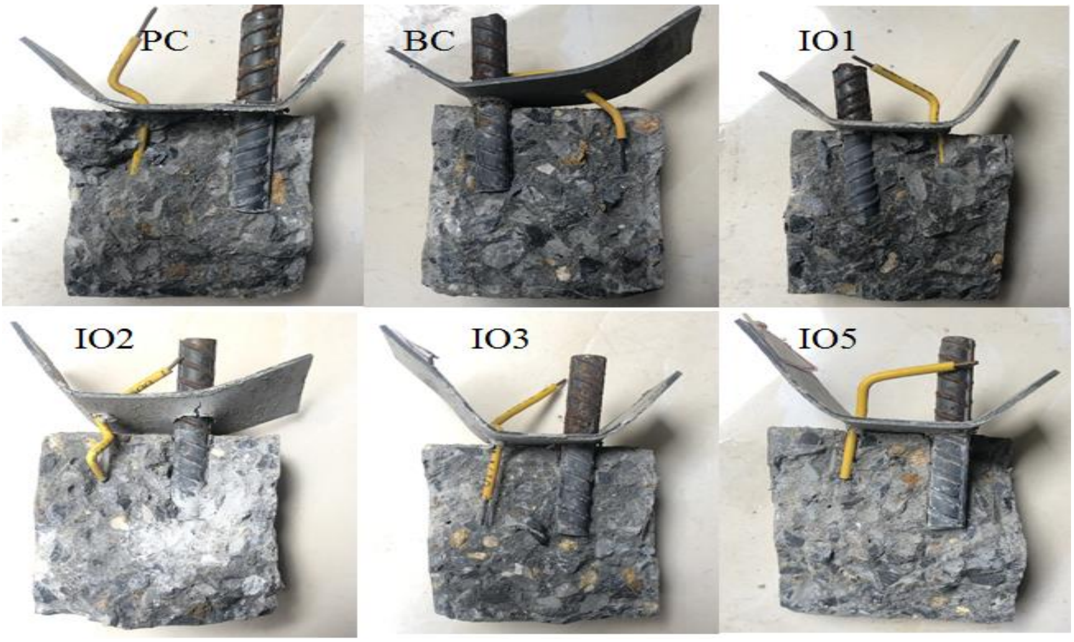

Fig. 8: Surface of electrodes after 300 days of immersion in 3% v/v NaCl solution

In the next period, the strong penetration of Cl^- ions and dissolved oxygen into the concrete block directly affects the electrode surface. Thus, the passive film of the PC sample was gradually broken. Then, the corrosion process gets stronger and stronger. In the case of sample BC, from 3rd period, as corrosion products have formed on the electrode surface, the corrosion process is similar to that of the PC sample. Therefore, if the same corrosive conditions after a certain time, concrete using saline sand and normal concrete have the same corrosion process.

For the samples with DMAE inhibitor, the corrosion process was significantly slowed down but only really effective with concentrations of 0.3%-0.5% water weight. At such inhibitor content, the process of diffusion of oxygen, Cl^- ions, and moisture into the new concrete is slowed down, and the degradation and chemical metabolism of the inhibitor takes place over time to be sufficiently limited the corrosion process. As was shawn in figure 8, after 300 days, the PC sample appeared a small rust spot, the BC sample had a rusty patch, indicating that saline sand had strongly affected the surface of the reinforcement. The samples with DMAE did not have any effect, indicating that the inhibitor was effective in reducing reinforcement corrosion.

DMAE not only has the ability to protect reinforcement but also has the advantage of being less toxic than nitrite-based inhibitors. In addition, it also reduces the rate of chloride ion permeability and slows down the corrosion process that has already occurred. However, its effect on the setting time of the concrete mortar mixture as well as the strength of the concrete needs further research.

IV. CONCLUSION

Currently, Vietnam is entering the boom period of economic development, with tens of thousands of large and small projects such as: North-South Expressway; Long Thanh international airport; hundreds of buildings; thousands of bridges… have been and will be built. Therefore, the demand for sand is extremely large. However, the sand supply is increasingly depleted, due to climate change, less and less rainfall, deforestation or conversion of forests to other trees; Countries compete to build hydroelectric dams on large rivers such as the Mekong and the Red River, which are blocking the flow of floods and are also a source of natural sand [10].A saline sand is used to replace traditional sand can be considered as a solution, therefore, studies for using saline sand effectively are urgently needed.

By experiment method and using corrosion inhibitor, the authors have evaluated the advantages/disadvantages of an environmentally friendly organic inhibitor in slow down the corrosion of reinforcement in concrete with exposure time up to 300 days. Research results can be used as reference for practical applications.Focusing on comprehensive research over a long period of time and continuously in the field of inhibitors in particular and corrosion in general is necessary work that research results help maintain life and improve work quality of construction in coastal estuaries and throughout Vietnam.

ACKNOWLEDGMENTS

This research in funded by Vietnam Maritime University under grant number DT19-20.81.

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