A Study on Protection of Marine Structures from Effects of Salinity

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ABSTRACT

Seawater contains a wide variety of dissolved inorganic material of which the dissolved salts in particular significantly influences the corrosion of marine structures. Marine structures are exposed to severe aggressive environment, because of which these types of structures deteriorate through a combination of chemical, biological and physical actions. In the atmospheric exposure zone, air-borne chlorides are major factors responsible for the corrosion of concrete structures. In the splash zone, chlorides, waves and tides make a major impact on the degree of corrosion by the action of both chemical reaction and erosion due to ocean waves. Also, in the splash zone, bio-organisms play an important role to accelerate the corrosion. In view of the above complex effects on the marine structures, proper protection is required to be taken to safeguard the integrity of the structures and their components which are exposed to such extreme environments.

INTRODUCTION

Salinity is a measure of the amount of salt present in water. Salinity in water is:

- Important in some chemical processes.
- An important determinant of mixing method.
- An important ecological parameter in its own right.

Marine structures are susceptible to degradation due to salinity. Marine structures are man-made and are alien to nature. The natural environment tends to work against them. The decay invariably starts from the surface exposed to the atmosphere and proceeds inwards to cause damage to the structure which can be substantial and can lead to the collapse of the structure. Protection of exposed surfaces of structures against actions resulting from salinity is of vital importance and constitutes the most significant items in the engineering maintenance of marine structures. Atmospheric corrosion is the most extended type of corrosion. It is well known that very high atmospheric corrosion exists in coastal atmospheres all over the world, but the effect is particularly severe in tropical and sub-tropical conditions. Atmospheric corrosion may significantly change depending on exposure conditions in coastal zones because the deposition of airborne salinity may change and the washing effect of precipitation plays an important role depending on the metal.

Aqueous corrosion, that is, corrosion involving water or moisture, accounts for the major part of corrosion losses encountered at ambient temperatures with the water becoming an electrolyte. When a metal corrodes, anodic and cathodic areas can be formed on a single surface in contact with the aggressive aqueous environment. As a result, corrosion can occur at a large number of sites over the surface of a metal.

PREVENTIVE MEASURES

A correct understanding of the mechanism of corrosion and the local environment is necessary in order to take adequate preventive steps in each of the following stages in the life-span of a marine structure.

The factors that are needed to be considered at the design stage are given below:

i. Geometrical shape and structural detail.
ii. Selection of construction material.

iii. Consideration of the operational environment.
iv. Selection of protective coatings/methods.
v. Formulation of proper guidelines for use and maintenance through Life-Cycle-Costing (LCC).

The factors that are needed to be considered at the construction stage are given below:

i. Correct reproduction of design and details.
ii. Use of specified materials.
iii. Implementation of workmanship as specified.
iv. Adoption of appropriate quality assurance system.
v. Use of specified materials and methods for repair and maintenance.
vi. Monitoring the environment.
vii. Monitoring of the structural behaviour.
viii. Monitoring the protective coatings/methods.
ix. Reduction of abuse of structures.

In many a case, during the service life of a structure, it may be possible to introduce systematic preventive maintenance with respect to various components of the structure. Adequate information needs to be collected from the suppliers/manufacturers of different items and a thorough understanding of environmental conditions prevailing at site is also required. Based on all this information, the necessary maintenance schedule can be prepared leading to substantial saving on expenditure as compared to the expenditure that would have been incurred were haphazard maintenance and repair to be done. Theoretically, corrosion can be stopped by cutting-off/inhibiting any of the four essential constituents of the basic corrosion cell, that is, anode, cathode, electrolyte and the electrical connection in the system. Though there are several methods to prevent corrosion, some measures which have been found to be most suitable for protection of marine structures are highlighted in this paper.

PROTECTIVE COATINGS

These coatings provide for a barrier with the objective of preventing any contact of the protected metal with the corrosive environment so as to prevent any adverse chemical and electrochemical action on the metal. Coatings are of two types. They are:

i. Metallic Coatings.
ii. Non Metallic Coatings.

Metallic Coatings

There are different methods of application of protective metallic coatings. In all of these, a coating of less corrodible metal is provided on a corrodible metal. The coating can be provided by means of any of the following methods:

i. Electroplating.
ii. Dipping in molten metal.
iii. Cladding.
iv. Metal spraying.
v. Cementation process.
vi. Vapour deposition.

Tinning, galvanising and aluminium-coating are widely used to protect marine structures, particularly mooring items like Chain, Eye hook, D-Shackles, etc.

Non-Metallic Coatings

Non-metallic materials like organic or inorganic materials are used for non-metallic coatings which, however, have relatively lower life as compared to metallic coatings. The types of non-metallic coatings which are commonly available are given below:

i. Painting and lacquering.
ii. Plastic coating.
iii. Vitreous enamelling.
iv. Slush compounds coating.
v. Anodising and other oxide films.
vi. Chemical dip coating.

Painting is a convenient and economical non-metallic coating used to protect marine structures. However, use of plastic coating is also on the increase. There are two main factors which govern the performance of a protective paint system, namely, the nature of the coating of paint and the degree of cleanliness of the surface to which the paint is applied. Preparation of the surface is one of the most important criteria for effective performance of a painting system. Any method of preparation of the surface can be adopted from the methods mentioned below:

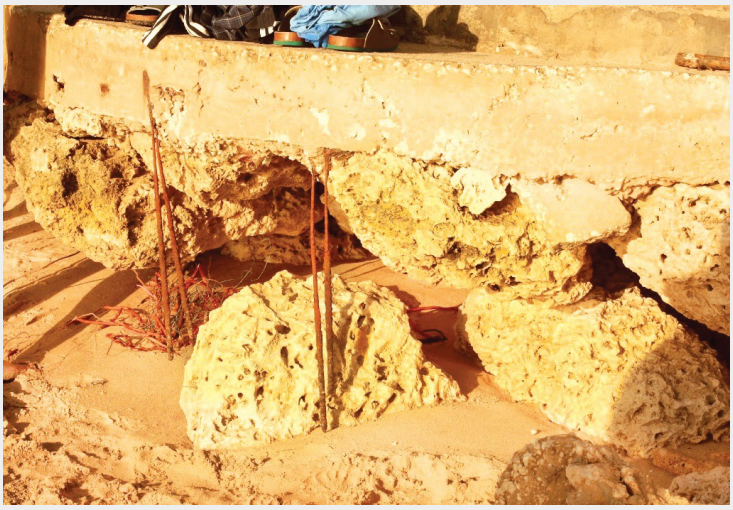
i. Hand-tool cleaning.
ii. Power-tool cleaning.
iii. Acid pickling.
iv. Abrasive blast cleaning.

For a better performance, hand-tool / power-tool cleaning should be preceded by removal of contaminants like oil, grease, mill-scale, corrosion products and soluble salts by applying a degreasing solvent. In the case of painting with the objective of maintenance of an existing structure, hand-tool cleaning and power-tool cleaning are found to be convenient and economical. For new structures, abrasive blast cleaning is found to be the most economical for protection of the structure in the long run. There are a wide range of paints of different compositions and natures which have different uses depending on the required environment to be dealt with. The types of coatings are given below:

i. Primer: Epoxy, Chlorinated Rubber, etc.
ii. Intermediate coating: Epoxy.
iii. Final coating: Epoxy, Polyurethane, etc.

REPAIRS

Conventional repair techniques at the existing corrosion sites do not provide a long-term solution because of the presence of significant levels of chloride ions and/or carbonation of cover-concrete. Conventional repair by replacement of all the contaminated concrete at the reinforcement is neither cost-effective nor environment-friendly. The most acceptable alternative to the conventional replacement of a large volume of concrete is to use an electrochemical technique like cathode protection.



Since corrosion takes place only at the anode, the technique of cathode protection is based on the premise that corrosion will cease when the reaction at the anode is completely suppressed. Cathode protection can involve two methods to achieve this. They are:

i. Impressed current system.
ii. Sacrificial anode system.

The impressed current system which relies on external power source is conventionally used to protect reinforced concrete structures suffering from reinforcement corrosion. If the surface of steel or other metal requiring protection is made into a cathode, it will be subjected to a reducing and not to an oxidising effect. The material for the impressed current anode is selected from metals/alloys, for example, iron, steel, cast iron, lead-platinum, lead–silver, etc., depending upon the nature of the environment. Consumption of the material forming the anode is almost negligible. This technique is extensively used in marine vessels, off-shore platforms, etc.

The alternative to the impressed current system is the sacrificial anode system which does not require an external power source and can be used to provide protection to buried, immersed and steel-reinforced concrete structures exposed to the atmosphere suffering from corrosion of reinforcement. Steel structures in marine environments are protected against corrosion by connecting them to other metals which are more reactive than iron in the electro-chemical series, for example, Magnesium, Zinc or Aluminium. These metals act as the sacrificial anode. The proportions and quantity of the sacrificial anode are decided through careful calculation. Although the sacrificial anode system may be limited in its application due to the limited driving voltage and in its electrochemical capacity, it has some advantages over impressed current systems. They are listed below:

i. The most crucial advantage is the independence from an external power supply.
ii. Monitoring requirements are minimal since the current is self-regulating.
iii. The sacrificial anode system is potentially less expensive to install and operate.

CONCLUSION

The corrosion rate varies depending on the level of exposure to the aggressive coastal environment. Care should be taken while selecting a method to protect marine structures from salinity. Electrochemical method of protection is cost-effective and cathode protection is an established method to control corrosion. A combination of cathode protection and protective coating is the most economical means of protecting a steel structure.