INVESTIGATION ON CORROSION BEHAVIOUR OF REINFORCED CONCRETE WITH DIFFERENT ADDITIVES

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Abstract - *Reinforced concrete may be flexible and low-cost construction material that generally performs its intended use effectively over its service life. But severest and costly deterioration mechanism affecting the reinforced concrete structures is the corrosion of steel reinforcement. This paper summarises chloride-induced corrosion performance of concrete with different additives and coatings based on different experimental results. Different additives such as supplementary cementitious materials, fibres, inhibitors, etc. can significantly reduce the corrosion risk along with improved mechanical properties. These practices make the system more sustainable and economically feasible.*

***Key Words*:** Reinforced concrete, Chloride-induced corrosion, Supplementary cementitious materials, Fibres, Corrosion inhibitors.

1.INTRODUCTION

Reinforced concrete is one of the popularly used building materials in the world. The demand for concrete and steel is increasing day by day for its ease of preparing and fabricating in all sorts of convenient shapes. When reinforced concrete is exposed to an aggressive environment, it will suffer some durability issues and fails in safety and serviceability requirements. Corrosion is one of the severest durability issues that we face today. It is an electrochemical process during which refined metal is transformed into more chemically consistent forms like oxides, hydroxides, or sulphide. Chloride-induced corrosion of steel bar causes urgent issues to marine structures thereby it seeks more attention in recent years. As a result of these, decrease concrete-reinforcement bonds and delaminate the concrete cover. Hence, it leads to reducing the durability, degradation of member bearing capacity, or even devastation of the marine structure [5][7]. The effect of corrosion shows in the form of premature deterioration or failure necessitates maintenance, repairs, and replacement of damaged parts. It can be a minimum of 3.5% of the nation's GDP.

1.1 Chloride Induced Corrosion

The impact of chloride-induced corrosion is more critical than CO_2-induced one in reinforced concrete structures. This may result in local disruption of the passive layer. Corrosion due to chloride ion, which is usually taking place in marine environments or consequence of using contaminated ingredients, de-icing salts or chemical admixtures, etc. The consequences of chloride-induced corrosion in structures are often studied in two stages. During the initiation stage, chloride particles proliferating through the cover layer and arriving at a critical concentration close to steel. Subsequently, collapse the passive layer around the bars which is generally steady in a highly alkaline climate. This is followed by the propagation phase. During the propagation stage, corrosion starts, and the by-products of rust gathering around the bars can prompt such structural harm as concrete spalling, delamination, loss of flexibility of the bars, and so on. [3] The propagation period is defined as the time taken for corrosion to result in sufficient deterioration such that remedial action is required [10]. Reinforced concrete sections can even withstand the applied loads during the initial stages of the propagation phase. [3]

Absorption, permeation, and diffusion are the three major mechanisms that cause the entrance of chlorides into the structure. To define the durability of concretes, it is essential to measure the coefficients of these transport mechanisms. The volume of permeable voids plays an important role in chloride diffusivity, a more porous microstructure of concrete lead to a longer zig-zag path for the diffusion of chloride ion. [8] The natural process of diffusion of chlorides in concrete is slow, so we adopt different techniques such as impressed voltage, wet/dry cycles, and saltwater immersion (3.5% NaCl).

Due to corrosion, the initial cracks developed will act as a path for chloride ions to reach the reinforcement and extended corrosion causes the structure to lose its reliability. In the accelerated corrosion technique, chloride ions easily cross the cover and making the steel bar more susceptible to corrosion. The critical crack width influencing the invasion of harmful ions would be wider in marine corrosion than that under accelerated corrosion. [5] [10]

2. CORROSION PROTECTION METHODS IN CONCRETE

Three principle corrosion protection techniques presently being utilized in the construction industry consist of the addition of corrosion inhibitors (chemical admixtures) into the concrete, the utilization of alternative corrosion safe fortification types, and decreasing the penetrability of concrete. The aforementioned techniques can be used separately or together for improved corrosion performance and longer service lives. Cathodic protection can likewise be utilized to ensure metals against corrosion. This technique secures metals by making them cathodes in an electrochemical cell. This is accomplished either by associating the metal to a sacrificial anode or an anode associated with a power source. In contrast to the three prior strategies, cathodic protection requires continuous checking and maintenance. Reinforcing steel embedded in NP/slag-based alkali-activated concrete boasts a higher corrosion resistance compared to steel bars embedded in Portland cement (OPC)-based concrete. Also, alkali-activated concretes are being considered as an alternative environmentally friendly construction material. [2]

2.1 Mineral Additives

To produce environmentally friendly concrete, it is inevitable for an alternative material to the expensive resource-consuming Portland cement. The incorporation of mineral additions originated from industrial waste materials such as silica fume, metakaolin, and fly ash, can reduce the problem. It has been promoted since it reduces pollutant waste and beneficial in construction works toward sustainable development. In special, these supplementary cementing materials can change the physical characteristics of the cement matrix as its total porosity and the pore size distribution. In this manner inhibiting the transport properties, for example, capillary absorption, permeability, and ion diffusion hinders the entrance of aggressive substances, (for example, chlorides) and changes electrical resistivity parameters. [9]

2.2 Fibres

Fibre-reinforced concrete (FRC) is a widely used construction material within the civil infrastructure. FRC is favoured for its beneficial mechanical properties and ability to restrain cracks. The improvement in concrete properties due to fibre addition depends on many factors, including fibre type, content, aspect ratio, and tensile strength of the fibre itself. Several types of fibres are commercially available such as steel, polypropylene, nylon, and glass fibre. Among these types, steel fibre is the most commonly used since it is characterized by high tensile strength. However, steel is a conductive material. Thus, concrete electric resistivity will decrease, increasing the reinforcement corrosion risk. Nonconductive fibre presents a better option than steel fibre to provide adequate mechanical strengths while reducing the risk of corrosion. [4]

2.3 Corrosion Inhibitors

An ideal corrosion inhibitor is a chemical substance that can forestall corrosion of installed steel when added in a sufficient quantity. It has no adverse effect on the fresh and hardened properties of concrete. Mainly anodic, cathodic, and mixed types of corrosion inhibitors are available. The type is determined depending on whether they meddle with the corrosion reaction especially at the anodic or cathodic destinations or the two sites. Of the available corrosion inhibiting materials, the most widely used one is calcium nitrite. [1] Corrosion inhibitors can influence many elements of the corrosion process. They include the amount of chloride entrance, chloride threshold of the system, the degree to which chlorides are chemically bound in the concrete cover, the electrical resistance of concrete, and the chemical combination of the electrolyte. It will densify the concrete pore spaces and effectively develop the formation of the passive film on the surface of the steel bar. [1]. Ginger and kelp are two botanic corrosion inhibitors used to improve the chloride-induced corrosion resistance of reinforcing steel in simulated concrete pore solutions. The green inhibitor is obtained from ultrasound-assisted alkali extraction and is sustainable in terms of inexpensive, non-toxic readily available one. [6]

2.4 Reinforcement Coatings

Using appropriate coatings can reduce the corrosion rate of reinforcement. Coating to reinforcement bar intends to provide a durable barrier to aggressive materials, such as chlorides. Various types of primer and coating including alkyd-based primer, hot-dip galvanized coatings, alkyd top coating, zinc-rich epoxy primer, etc. were applied on steel reinforcement to determine the effect of coating type on the corrosion resistance. Among different coatings, Polyurethane was the best coating due to the highest strength, lowest corrosion rate, and highest adhesion to substrate. [1]

3. CORROSION MONITORING TECHNIQUES

Monitoring the structures with a certain interval may be helpful to identify future problems to facilitate scheduled, cost-effective maintenance. Improved techniques have been created to screen corrosion rates along with chloride entrance into the concrete cover. Chloride transport parameters such as diffusion coefficient indicate the ease of chloride penetration into the cementitious matrix. Various electrochemical tests such as half-cell potential, Linear polarisation resistance, Electrical resistivity, rapid chloride permeability (RCPT), etc can also be used to evaluate the corrosion performance of structures. Determination of gravimetric mass loss predicts how much quantity of base metal is lost during the corrosion, which indirectly measures the rate of corrosion. [7][9]

4. CONCLUSIONS

Corrosion in reinforced concrete structures may be considered as the severest and most urgent issue in the construction industry. Major problems are caused by chloride ion contamination. Monitoring may be used to assess existing deterioration mechanisms and predict future performance. An improved interpretation of the deterioration measures has prompted new advancements in repair techniques. The use of different additives and coatings enhance the protection against corrosion and improves the life of reinforced concrete structures. The use of supplementary cementitious material will reduce the consumption of natural resources and leads to a sustainable and cost-effective system.

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