CORROSION, THE CANCER TO CONCRETE: A STUDY TO MONITOR THROUGH SENSORS

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Abstract-This paper presents the Corrosion which is cancer to the concrete. The corrosion of steel embedded in concrete reduces the service life, functionality and durability of concrete structures. In the present age where construction industry is playing vital role in our economy. It is also important for its life prediction and functionality which is deteriorated by corrosion. The paper summarize the occurrence of corrosion, methods for its detection.The credibility of study is discussed and how the traditional methods failed and thus born sensor based monitoring, which are more reliable, durable and can be accounted for long term monitoring as the corrosion is long term process.Furthermore, it aims to asses deterioration through corrosion at early stage through monitoring and to consider system as integrated measure as whole maintenance program and life prediction of reinforced concrete structure.

Key words-Corrosion,Reinforced concrete, sensors, Durability

INTRODUCTION

In India 9% of country's GDP is contributed by construction industry, The industry contributes 55% share in the Steel industry. Hence maintenance and durability in construction Industry has to be emphasized, the Key issue which hinders the service life and application of reinforced concrete structures in corrosion. The corrosion of steel reinforcing bar in concrete can proceed out of sight and suddenly which results in failure of a section thus resulting in significant repair costs and endangering safety of public. For example, the suddencollapse because of corrosion fatigue of the Silver Bridge over the Ohio River at Point Pleasant, OH in 1967 resulted in the loss of 46 lives and cost millions of dollars[12] . In addition, corrosion being long-term process and not visible for embedded reinforcement. Structures exposed to marineenvironments are particularly at risk and as the steel reinforcement cannot be inspected visually, corrosion often remains undetected until extensive cracking or spalling has occurred which also disintegrates the concrete.

The word corrode is derived from the Latin corrodere, which signifies "to gnaw to pieces." The corrosion in general defines as wear away gradually. Corrosion in engineering terms can be defined as a chemical or electrochemical reaction between a metal and its environment that deteriorates material and its properties.

The corrosion of steel reinforcement can altogether undermine the structural integrity and reduce durability of concrete structures resulting in tremendous cost for maintenance, rehabilitation, and rebuild. Reinforcement corrosion is associated with concrete cracking, spalling, leading to loss of cross-sectional area and reduction of structural stiffness, which Consequently jeopardize the toughness and ductility of structures and hence structures will fail in a premature, brittle mode. Therefore, health monitoring and damage detection of concrete structures for early-stage steel corrosion are essential. Corrosion being the long term processtraditional wire based approach cannot be considered considering their durability and hence sensors which are durable, reliable and can work independently is the need for this field. In This paper we have reviewed and summarized the corrosion occurrence, various sensors and their working has been demonstrated to monitor corrosion and to reduce maintenance cost and to prevent sudden failure.

MECHANISM OF CORROSION

Corrosion is universal occurrence which takes place through diverse form, there is no particular place defined for occurrence of corrosion. Under ideal condition when concrete has a pH of approximately 12.5 – 13, and this provides a protective environment for the steel reinforcement as a thin film of passivating iron oxide forms on the surface of the steel, under this condition reinforcing steel will not corrode (Hausmann, 1965).

The two process that lead to a breakdown of the passivating film and initiation of corrosion are Chlorination and Carbonation.

CHLORIDE INDUCED CORROSION IN CONCRETE

The presences of chloride increases the severity of corrosion considerably and hence it is one of the most common causes for corrosion in reinforced concrete. Chloride can penetrate in concrete through de-icing salts and seawater intrusion. They breakdown the passive film that initially forms around reinforcing steel as a result of the alkaline nature of the pore solution in concrete. Some amounts of Chlorides may also be present in admixtures. The wetting- drying cycles makes this carrion attack more severe.

The chlorides, when diffused into concrete, reduce the alkalinity of the pore solution from pH . 13 to below 7 thus initiating corrosion. The initial destruction of passive layer takes place due to the adsorption of Cl- with simultaneous displacement of O2- from the passive layer from steel. Chloride having lower interfacial surface tension results in weakening of passive film which was protecting reinforcing bar from corroding and thus results in formation of cracks and flaws.

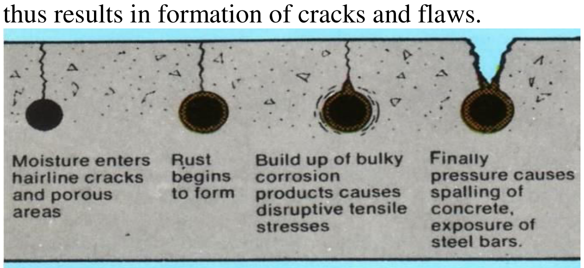

Figure1:Source: happho.com/corrosion-steel-sreinforcement-causes-effects-remedies/

CARBONATION INDUCED CORROSION IN CONCRETE

Due to climate change carbonation of concrete has recently gained attention. The carbonation induced corrosion in concrete is gaining importance due to two main factors:

1) due to ageing infrastructures and buildings.
2) Needs for reducing Carbon footprints.

Carbon dioxide gas in atmosphere interacts with alkaline hydroxide in the concrete and forms carbonic acid. This carbonic acid neutralizes the alkali's in pore water and forms calcium carbonates that fills pores. During formation of carbonic acid pH of concrete falls below 8, which is critical value where passive layer cannot protect the steel leading to corrosion. Whose volume is 5 times larger than steel and hence spalling and cracking of concrete occurs. Once corrosion occurs its repair is costly process as concrete has to be replaced. Hence its early detection is what is recommended.

EFFECTS OF CORROSION

Corrosion affects the mechanical and structural properties of reinforcing bar. Along with that it also impacts thefinancial market of country. According to a study by NACE loss due to corrosion in India is 5% of its GNP, which is 25,000 crore rupees per year.

Some key effects of corroded reinforcement bars on structure are:

- Loss of Strength
- Fatigue
- Reduced Bond Strength
- Limited Ductility
- Reduced Shear Capacity

LITERATURE REVIEW

Alcantara Jr[1] assessed thetheoretical and experimental study carried out for determining level of corrosion level in rebarsusing eddy current testing, and results were consistent showing higher results for higher corrosion.

Buyukozturk [3] presented the use of Radiography which is one of first non destructive techniques used for imaging reinforcement immersed in concrete. Because of their very small wavelengths, they propagate through the material along straight paths with no significant diffraction. X- and gamma-ray methods are capable of creating exact two-dimensional images of the concrete interior. However, due to their high initial costs, relatively low speed, heavy and expensive equipment, need for extensive safety precautions and highly skilled operators, and perhaps most important of all, the requirement of accessing both sides of the structure, their use in concrete testing is limited.

Cong Du [4]presented an article demonstrating his study on the sensor based on the photoacoustic mechanism of gold nanocomposites which converts light energy to mechanical waves to excite ultrasound waves, this active multipoint all-optical photoacoustic sensors evaluate the surface performance of steel bar, as corrosion increases due to pitting and rusting surface performance changes hence effects the propagation of ultrasound waves and which helps in detecting corrosion via frequency domain of ultrasound signals.

Dan Su [5] researched aimed at developing a self-powered smart sensor system with integrated prediction module for forecasting corrosion of rebars. For determining corrosion at unmonitored location spatial interpolation module was used to interpolated the data for corrosion monitor. For continuous data collection vibration-based energy harvester is used. The sensor was built for long term corrosion prediction and to provide appropriate actions for mitigation would be recommended.

Dean Neikirk [6] Discussed the corrosion as world wide problem and various methods for detecting corrosion and ambiguities in them, he has discussed about single point sensors to wired sensors but would not be usable for long term. The Electronic Article Surveillance (EAS) sticker which is low cost sensor, The circuit here is designed to be resonant, The sticker can be visualized as a bell that rings at a characteristic frequency, but is not excited by electromagnetic energy at other frequencies.

Figueira [10] considered destructive methods to be limited and cannot be represented for structure as whole. They have laid emphasis to consider corrosion monitoring system as integrated measure as whole maintenance program and life prediction of reinforced concrete structure.

Ms. Aparna Jagtap [8] described that traditional techniques for detecting corrosion are expensive and troublesome, hence with the help of strain calibration experiment, sensitivity measurement, corrosion mass loss rate and material composition used corrosion detecting sensors to detect corrosion in reinforcement of beam and suggested that with sensor system corrosion monitoring is done effectively and efficiently

Roqueta [11]studied twelve concrete samples with induced corrosion with the low-profile ultra-wide-band antennas , he further correlated electromagnetic signatures with the corrosion level of the steel reinforcing bars. To verify their consistency, The results were compared with numerical simulations.

MONITORING OF CORROSION

A few techniques for corrosion checking of reinforced structures have been proposed in the last few decades. The destructive methods are restricted to sampling. Therefore, sampling may not be representative of the entire structure, which is critical in reinforced structures with large heterogeneities both in terms of materials used and in terms of the environmental exposure. Furthermore, it may not be advisable to use destructive methods in situations where the evolution of the corrosion over time is assessed For instance, for repair procedures it would not be appropriate to remove a large quantity of samples required for assessment. Non-destructive methods have been widely developed within this context, which are planned to provide quick data about the whole structure. But also there is need of system which is durable and reliable which is a self-powered ie battery-less and automated so that human errors are eliminated. Because of sensors system lots of difficult work can be done effectively and easily than other non destructive tests. For proper corrosion monitoring of structure it is difficult to monitor embedded corrosion of steel rebar accurately, but due to sensor system this work automatically converted into efficient and effective monitoring system.And hence sensors based detection is the most promising technique in the present scenario.

The desirable properties for any sensor to monitor the durability of reinforced structure to be embedded in concrete are

1. robustness
2. good design and location
3. high reproducibility and sensitivity;
4. low cost,
5. environmentally friendly and
6. easy to store data
7. Multifunctional

TRADITIONAL METHODS VS SENSORS

Traditional techniques for figuring out the proof and charge of corrosion are pricey and posses ambiguity to find out. The traditional negative trying out can be carried out best on components of shape and hence its consequences cannot be accounted for structure as entire.

Although there are numerous ways to locate corrosion and predict the corrosion price, there are a few essential troubles in enterprise that preclude the utility of these techniques. These vital troubles are as follows:
(1) Local to spatial: even though all of the researchers are centered on detection of corrosion at a couple of factor but failed to provide solution on interpolation un a spatial scale.
(2) Integration of detection and prediction: the crucial hyperlink between corrosion detection and prediction is lacking as a result traditional practices of detection lacks in it.
(3) Data series: the conventional practices lacks in module of information series and transmission. Hence there is want for wi-fi and battery-less sensor community.
(4) Static versus dynamic self-updating: the present day corrosion forecasting strategies are static methods which dose now not recollect the variant of environmental conditions and structural conditions over the years.

VARIOUS SENSORS AVAILABLE

Following are the various form of sensors substantially implemented in systems as: i) Ultrasonic sensors ii) Pressure sensor iii) Piezoelectric sensor iv) Magnetostrictive sensor v) Fiber optical sensor

i) Ultrasonic sensors emit quick, high-frequency sound pulses at ordinary intervals. If they strike an object, then they're pondered again as echo signals to the sensor, which itself computes the space to the purpose supported the time-span among emitting the signal and receiving the echo.

Ii) The pressure implemented will deflect the diaphragm in the stress transducer. The deflection of the interior diaphragm is measured and transformed into an electrical output. Most Pressure transducers are designed to supply linear output with implemented strain.

Iii) A sensor that utilizes thepiezoelectricity , to degree modifications in acceleration, strain, pressure, and pressure through changing them into electric charge is called as a piezoelectric sensor. This generated piezoelectricity is proportional to the strain carried out to the strong crystal materials.

Iv) Magnetostrictive Level Sensor Operating Principle. Inside the probe tube there's a inflexible cord made from magnetostrictive material. The sensor circuitry emits pulses of modern thru the cord, producing a spherical magnetic flux . The quantity transmitter can be a magnet, that's included into the go with the flow.

V) Fiber optic sensors paintings supported the principle that slight from a laser or any superluminescent source is transmitted thru an optical fiber , reviews adjustments in its parameters either within the glass fiber or fiber Bragg gratings and reaches a detector which measures those modifications.

CONCLUSION

Failure of concrete structures due to corrosion of embedded reinforcement is a major problem causing significant loss of money and affecting durability of structure. Therefore the need to understand the root cause of failure to function as desire arises for effective remediation. In most of cases deterioration of concrete is caused due to corrosion. Therefore it is the most fundamental approach to monitor the corrosion of concrete structure from early-stage and hence effective remedies may be provided which shall be considered as fundamental requirement for planning maintenance, repairing, and removal for reinforced concrete structures.

From the above study it may be concluded that traditional techniques of destructive testing which aims for only partly result cannot be accounted for whole structure. The traditional techniques in which the testing has to be done on embedded reinforcement is not feasible for built-up structures and Hence there is an need for sensor based monitoring which can sense the corrosion from concrete surface only and which is reliable, durable, self-powered, and have wireless sensor network for long-term corrosion monitoring emerged and are used in modern age.

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