INVESTIGATING THE USE OF FIBER OPTIC SENSORS IN FERROCONCRETE STRUCTURES

Regular member ○ [1]Saber Rahimi

1. INTRODUCTION

The need for control safety maintenance and improvement of concrete structures is increasing every day and screening estimated safety and health of structures is of economic concern. Fiber optics have been used as the best sensors since 1970s because of their excellent light transmitting quality and other sensing advantages such as anti-electromagnetic and anticorrosion qualities. In addition to their possibility of early mixing with concrete, fiber optic sensors, due to their property to be embedded in the concrete, high detection strength and low expense can also be used to measure the internal strain of the structures. This paper presents the result of a research on recent and common approaches to control safety in concrete structures with strain and corrosion control by fiber optic sensors. Vulnerability of concrete to failure and crack is explained through its brittleness. Random and irregular short fiber reinforcements lead to tension and fixing cracks. According to conducted researches in the field, it was determined that using steel fiber in brittle matrixes reduces the stress density in the cracked zones. Implication of non-metal fibers in concrete saves huge amount of costs by preventing steel corrosion and concrete deterioration. This kind of fiber is a good alternative to thermal steel, and can favorably control the plastic and failure cracks caused by deformation and failure. It can also be widely used instead of thermal steel worldwide.

2. THE NECESSITY OF USING FIBER OPTIC SENSORS IN CONCRETE

Concrete is one of the most frequent construction materials. Yet its durability is of major concern in terms of infrastructures in developed countries. Damage in concrete structures may be started at the early ages. In huge structures such as dams, high temperature drops which occur during the initial hydration may cause cracks. Such thermal cracks can be measured by feedback control of strain alternation. In long- term loading, environmental impacts can also cause dramatic failure. Highway bridges bearing heavy traffic, and subjected to freeze-and-thaw cycles are of familiar instances. For proper maintenance of concrete structures in their service life, it is essential to create sensors to monitor the structural conditions.

The use of fiber-optic sensors in concrete was first suggested by Mendez et al. Since then, several research groups in the USA and Europe have reported on a variety of fiber-optic sensors embedded in or attached to reinforced concrete structures [4]. Many of these studies mainly emphasized on the measurement of strain vibration and temperature due to laboratory conditions. Optic fibers have been widely used in the field of data transmission due to their excellent anti-electromagnet sensing, little dimension and anti-corrosion qualities since 1970s [3]. Plastic optic fibers are instruments to transmit light in the visible wave length based on specific structures in which the index reflecting is greater than reflect coating index So that the light can be transmitted to the full reflection, since in optical fibers core and cavity size are larger than in silicon dioxide, they are capable of absorbing light at an angle greater than 60 degrees and provide a better light transmitting system, so optic fibers can show the advantages of flexibility and plasticity in extremely unfavorable weather conditions. Transmitting light through the fibers as electromagnetic wave and some specific physical parameters (such as temperature, pressure, stress, strain, electric field, and magnetic field, etc) will affect the performance of the waves [3].

Functions like amplitude phase, polarization state, frequency and physical state of output wave can be estimated by analyzing performance changes of the waves. Illuminated plastic optical fiber grids mixed with a certain proportion of cement namely transparent intelligent concrete provide novel clear view intelligent quality and long life structural material [3]. It should be noted that the production of light transmitting concrete under the name of "Lightracan" was also done and recorded in Iran for the first time in the country, and researchers were able to produce a high strength concrete with the capacity of transmitting synthetic and natural light through itself like the glass. Since the country is prone to earthquakes and the application of glass in facades can be very dangerous, the use of this type of concrete in buildings can be highly desirable, however, due to the lack of mass production of the industry, the application is only possible in some large buildings such as hotels, sport venues, aircraft, and hospitals, which can contribute to good light transmission absorbing heat energy and even as insulation in building in addition to its beauty.

3. SAFETY CONTROL BY CONTROLLING THE RATE OF CORROSION IN STRUCTURES

The main reason of damage to concrete structures is steel corrosion. Along with proper maintenance which can extend the life of structures, several practical methods are being developed for detecting corrosion of steel in concrete which need to progress. In an alkaline environment, steel corrosion rate is less than when carbon dioxide and chloride on the structure coat penetrate to reach in steel. In this case the influence can clearly affect the corrosion rate significantly. One way to detect the steel corrosion is by measuring the depth of the curve chloride or carbon in the structure. The easiest way is doing the

[1] - Department of Civil, Pars Abad Branch, Islamic Azad University, Pars Abad, Iran, s.rahimi@iaupmogan.ac.ir
Keywords: fiber optic, sensors, ferroconcrete, corrosion, strain control

conventional chemical analysis of the structure core, although the PH of variation range is not still equal with the lowest PH in which steel corrosion occurs. Thus a reasonable judgment is necessary to interpret the results. In fact, the chloride concentration is not directly related to the steel corrosion in concrete structures [2].

Critical chloride concentration is also affected by the PH of the structures from the side from which the steel is not effectible, and this exact relationship is unknown. Of course different researchers have noted various relations between critical chloride concentration and PH [6]. Another method of controlling the amount of steel corrosion within concrete is developing the fiber-optic sensor for the detection in reinforced concrete structures on simple physical principles. In this method the flat end of optic fiber is covered by a thin layer of iron using ion cathode projection technology and then light is sent into the fiber embedded in concrete, and the reflected signal is observed. Initially, most of the light is reflected by the iron layer and when corrosion occurs it is removed, a noticeable amount of the light intensity is reduced which is in turn the reason for steel and concrete tank destruction. This leads to safety detection [5].

Researches showed that the sensor can detect the presence of chloride ions, and the change in sensor output depends on the chloride concentration and the conditions of the environment. The starting time of steel corrosion can be determined by observing the drop-down of sensor reflecting and its compatibility with the obtained standard large cell [6].

4. SAFETY CONTROL OF CONCRETE STRUCTURES BY STRAIN CONTROL

As noted, the need to recognize safety, repairing, maintenance and improvement of structures and screening their safety is economically necessary and essential, especially for the structures which have already been repaired or improved. Although various detecting techniques with high accuracy have been developed, unfortunately most of the optic fibers sensing capacity serves the control of steel corrosion and subsequently structure local failure which is limited to a minor proportion of the whole structure. Fiber optic sensors have been recently built in large-scale concrete structures such as dams and bridges to show the strain in the structure. It seems that fiber-optic sensors are ideal for the structures carrying high-voltage power lines such as underground bridges with high-voltage power lines inside. Their high detection power for less than micro-epsilon with interferometer techniques) changed them into ideal sensors for controlling applications and direct measurement of internal strain. For a fiber- optic strain sensor, the relationship between average fiber strain and receiving area and strain in concrete matrix surrounding area is an index, for sensor calibration factor which is different in various sensor configurations [2]. Capability of fiber-optic sensors in displaying the strain distribution in steel and other materials depends on its connections between optic fiber and the material. The transferred strain from structure to the fiber optic sensors causes changes to the characteristic of light signal transmitted by glass fiber core, and the transmission of this signal provides a device for measuring strain in the structure. Sensor calibration factor is also discussed for different configurations in sensors and differs in conditions. For a fiber-optic strain sensor, the relationship between average fiber strain and receiving area and strain in surrounding concrete matrix reveals the sensor calibration factor [5].

In fiber-optic strain sensors for concrete structures, the calibration factor in sensor depends on the strain distribution along the optic fiber. When a fiber embedded in the concrete is exposed to strain, deflection may occur and cause strain distribution leading to calibration changes. Regarding that the surface specifications leading to deflection are sensitive to environmental conditions, when they are exposed to environments, calibration factors can also be changed, therefore there is a theoretical framework for determining the effects of environmental conditions on the calibration changes [5].

CONCLUSION

According to the necessity of concrete structures safety, repairing, maintenance, improving and also preserving its performance, the use of fiber-optic sensors as a new method is crucial, but their sensing capacity is limited to the control of steel corrosion and structures safety in a small part of the structure. However safety control of reinforced concrete by direct measuring of internal strain using optic-fiber sensor and screening strain distribution as a nondestructive instrument to investigate the whole structure safety in order to increase their life is a necessary economical issue.

REFERENCES

1-Rahimi, S,: The Implementation of Plastic Optical Fiber Sensor in Concrete for detecting of Bar Corrosion , Research project, Pars Abad Azad University, 2011

2- Christopher K. Y. Leung, Member, ASCE, Xinyang, Wang, and Noah Olson.: Debonding And Calibration Shift Of Optical Fiber Sensors in Concrete, Journal of Engineering Mechanics, March 2000

3. Zhi Zhou, Ge Ou, Ying Hang:" Research and Development of Plastic Optical Fiber Based Smart Transparent Concrete", 6th International Conference on Vibration Engineering, June 2008

4- K.-T. Lau (2003)"Fibre-optic sensors and smart composites for concrete applications" Magazine of Concrete Research, 2003, 55, No. 1, February, pp19–34

5- Ansari, F, Libo, y.: Mechanics of bond and interface shear transfer in optical fiber sensors" journal of engineering mechanics, 1998 pp 385-394

6- Christopher K.Y. Leung, Kai Tai Wan, Liquan Chen.: A Novel Optical Fiber Sensor for Steel Corrosion in Concrete, Structures, Sensors 2008, 8, ISSN 1424-8220 , pp 1960-1976