AN OVERVIEW ON THE APPLICATION OF EMBEDDED OPTICAL FIBER SENSORS FOR CONCRETE STRUCTURES

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Abstract -Structural health monitoring and contol have received a great attention in construction. Nowadays Structural heatlh minitoring is certainly one of the most powerful management tool and is therefore gaining importance the civil engineering community, therefore it is necessary to minitor the structure very properly under applied loads .It helps in the investigation of cracks and damage under applied loads, corrosion due to steel, failure of bonds, excessive strains in concrete and reinforcement steel bars, critical deflection etc. Monitoring, both in the long term and short term, helps to increase the knowledge of the real behaviour of the structure and the planning of maintainance thereoff . In the long term, static monitoring requires an accurate and very stable system, able to relate deformation measurements over years. On the other side, dynamics analysis of structure , or short term monitoring, require of a sysytem capable of measuring deformations occuring over relatively short period of time.

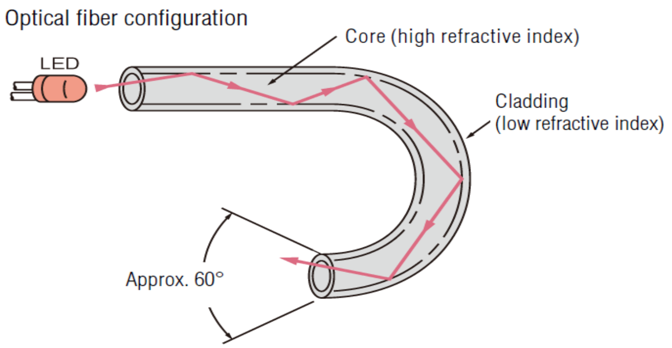
Because of the increase awareness and efforts of aging, damage and other natural disaster it has become necessary to introduced the advanced and latest method of monitoring system and should develop new tools for indentifying thecracks and damages in the structure. Today, these tasks are done by visual inspection and very traditional methods such as the tap test. There is a check of cracks in the structure in one to two year with the help of labour for the bridges and there is a need to keep a check on building and infrastrcuture as well. The monitoring of the structure has been used from the last three decades and when the damage is sustainable it has some success and when there is insufficient damage it is not successful.Therefore there is a need to improve the technique of monitoring.

Keywords
Optical fibre, Optical sensor, Health Monitoring, Poisson's Ratio, Crack Detection Tool, Applications, damage, detection infrastrcuture.

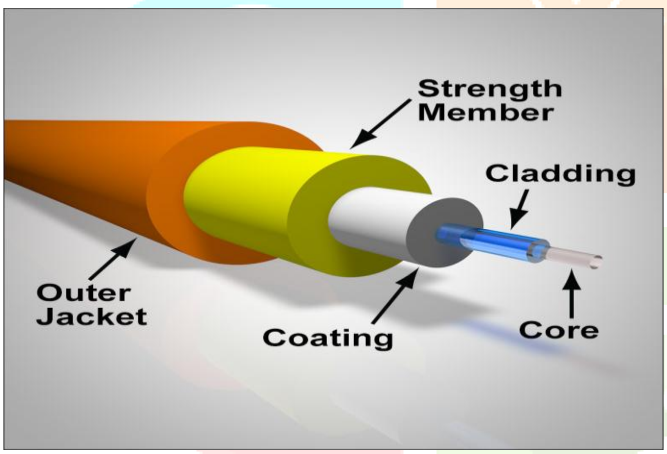
Introduction

Nowadays, the monitoring and control of civil infrastructure have received increasing attention. Structural heatlhs minitoring is certainly one of the most powerful management tool and is therefore gaining importance the civil engineering community. The important structure required a monitoring system, throughout its working life to ensure its performance under applied loads. This usually involves investigation of cracking and damage due to applied loads, corrosion to steel, failure of bonds, excessive strains in concrete and reinforcement bars, critical deflection etc. A typical health monitoring system is composed of a network of sensor that measure the parameters relevant to the state of the structure and its envionment. Monitoring, both in the long term and short term, helps to increase the knowledge of the real behaviour of the structure and the planning of maintainance thereoff . In the long term, static monitoring requires an accurate and very stable system, able to relate deformation measurements over years. On the other side, dynamics analysis of structure , or short term monitoring, require of a sysytem capable of measuring deformations occuring over relatively short period of time.Conventional sensors based on mechanical and/or electrical transducers are able to measure most of these parameters, but these transducers have their own limitations. For example, it may not be functional and effective sensor throughout the life of structure , involving high maintainance cost. There is therefore a real need for a tool allowing an automatic and permanent monitoring from within a stucture itself and with high precision and good spatial resolution.

General discussion of optical fiber- As the laser light was invented in the year 1960, and after the invention of the laser the researcher shown their interest in findind the application of optical fiber and their use in the communication. After the research it was known that optical fiber sensing system tranfers the gigabyte of data in a very lesser time. This type of fiber optic communication is used to transmit data, over a long distance communication or computer networks or LANs. In the sensing technique the data is transferred with the help of light wave over a fiber by changing the electronics signals into light. It has some characteristic featureslike smaller diameter,low attenuation,long distance signal transmission etc. It is a very thin fibril of plastic or glass that is used for transmission of light from one end to another.



Significantly, the fiber optic technology has changed the advancement of telecommunication. Most of the components associated with these devices are often developed for the fiber-optic-sensor uses. The fiber optic sensors has increased the use in the place of traditional sensor. An optical fiber is a very thin fabril of plastic tube in which messages are tranferred via light signals. These fabrils are bundled together in a protective cover and the whole assembly is known as fiber optic cable.



Think of two people standing at opposite ends of a long dark hallway and signaling each other with flashlights. In the case of optical fiber, the strand (the hallway in the example) can be about as thin as a human hair, and the material it is made of (glass or plastic) is very pure. So the messages transmitted via light can travel a very long way, across oceans.But, you ask, don't fiber optic cables bend? How does a signal of light, which travels in a straight line (remember the flashlight beam), go around a curve? The answer is in the way a fiber optic cable is built. Wrapped around each strand of optical fiber is cladding, an outer optical material that reflects the light back into the core strand. Think of using a mirror to reflect a beam of light around a corner. Cladding acts as a mirror all along the cable, continuously reflecting light along the cable down the intended path.The transmitters at either end of an optical fiber cable typically use light-emitting diodes (LEDs) or laser diodes to generate the light. Think of our flashlight example, where the flashlight is the light source. Optical receivers take the light signal fromthe cable and convert it into an electrical signal. The data moves at a very high rate of speed; think of milliseconds for a message to go across the Atlantic! Why? Light travels faster than an electrical signal through a copper cable.

Literature Review

K.Bremer et al. (2016) : In this study use of different fibre optic sensors for the structural health monitoring of civil engineering structures are reported. In this study a fibre optic crack sensor anddifferent fibre optic moisture sensors have been used to detect the moisture present in concrete building structures. After applying the fibre optic sensors health monitoring of the structures is noticed.

Mahmudah Salwa Gianti et al. (2016) : In the study vibration based fiber optic sensors were used for recording the vibration that wass occuring in the mathematical pendulum as a model suspension bridge durability sensors. The intensity of the light in optical fiber was reduced due to the bending of optical fiber with critical radius. The signals that were obtained were processed using computer so that the history of vibration can be recorded. The detected result may be recorded and analyse to obtain precise information of the structure.

Chin Chang and Rahul Mehta (2009) : In this study fiber optic sensors are used for the transportation infrastructure health monitoring. This technology offer advantages like minimized downtime, avoidance of catastrophic failure, and reduction in maintenance labour. With the help of fiber optic technology a light source is used as a single source to detect parametric changes at different locations of the structure.

Frank Basedau et al. (2015) : In this study a concept ofself-diaganostic fiber optic sensor is introduced.This sensor is used to resolve the problems of embedded fiber optic sensors in complex structures and to enable the validation under operational conditions. For this purpose, different magnetostrictive coated fiber optic sensors were developed and various experiments were performed to verify their mode of operation and to determine the respective reproducibility. The measuring principle is illustrated by obtained experimental results, which showed a change in wavelength from 1 pm at a magnetic field strength change of 0.25 mT.

Juho Siivola et al. (2017) : In this studythedimpling in the face sheets of honeycomb sandwich structures due to the change in the thermal expansion coefficient of the consituents material on its monitoring was studied by using fiber optic sensor. Strain distributions in the face sheet of the sandwich structures were monitored during manufacturing of the structure. The strain data was interpreted by the help of finite element analysis.

K. Kesavanet al. (2009) : In this study embedded fiber optic sensors are used for quantitative non-destructive long-term monitoring of concrete structures. Fiber optic sensors can be embedded in different types of structures, such as, buildings, roads, bridges, dams, etc. for monitoring different physical parameters like strain, temperature, deformation, etc. Bare fiber optic sensors are not suitable for directly embedding in concrete. Hence, some form of protective mechanism needs to be provided to the fragile fiber optic sensor for reliable performance. Suitable protective encapsulation to the bare sensor should ensure that there is no relative slip at the interface of the matrix concrete and the encapsulation. Investigations carried out to develop techniqueof embedding fiber optic sensor in concrete and performance evaluation of the developed embedment techniques are presented.

Hong-Nan Liet al. (2004) : In this study there is an overview of current research and development in the field of structural health monitoring with civil engineering applications. This paper gives the details of the structural health monitoring in civil engineering and structures like buildings, bridges, tunnels, dams. The use of fiber optic sensor is discussed briefly.

Dong Luo et al. (2016) : In this study, a tapered polymer fiber sensor (TPFS) is employed to detect the crack of Concrete Beam (CB). The sensing principle for crack detection is simply described based on V-number theory. The experiments are carried out by cement mixture mixed with high reactive powder to form the CB, in which the TPFSs are embe dded and surface glued. Thermocouples and strain gauges are also embedded to calibrate anddetermine the ambient temperature and applied strain, meanwhile, the Linear Variable Differential Transformer (LVDT) sensors are used to measure the deflection of the CBs. Four points loading test is applied for several samples to evaluate the sensors' ability for monitoring the beam deflection and crack. Experimental results also indicate that the TPFSs can be used for post-crack detection.

Gorriz Bet al. (2016) : In this study monitoring temperatures in structures during fires provides valuable information to the firemen engaged in extinguishing it, those who assess its security, and the organizations who have to find on its possible repair, renovation or demolition. Fiber optic sensors are able to measure extremely high temperatures in actual blaze conditions and is therefore a fundamental requirement. In this research a new fiber optic sensor based on Regenerated Fiber Bragg Gratings specially designed to be embedded in concrete structures to monitor temperatures during fire events. The temperatures recorded by the new sensors were compared with those obtained from electrical sensors (thermocouples) and a numerical model, with which they showed a good fit, except in those places in which concrete spalling caused distortions in the results and/or failure of the sensors. This research thus provide the viability of optical technologies in monitoring reinforced concrete during fires and analyzes sensor behavior to point out areas in which additional research is required.

J.Waeytenset al. (2016) : In this study it deals with the aims at detecting and quantifying early structural damages using deterministic and probabilistic model updating techniques. To achieve this purpose, local information in a form of optical strain measurement is employed. It consists in updating the parameters like damage, modulus of elasticity. In order to minimise the gap between numerical strains obtain from finite element solves sensor output. As it is inverse problem and it requires regulation. The results show that all the methods are properly localize the damaged area and give similar estimation of the damage level.

Chen Yang S Olutunde Oyadiji (2016) : In this the study of fibre optic bundle displacement sensor with multiple layers of transmitters are carried out. By arranging the transmitter of two-layers in certain ratio, an enhancement of the linear range as well as sensitivity can be achieved compared to conventional bifurcation arrangement. A theoretical model using the Gaussian beam assumption has been developed to characterise the response curve of the various two-layer configurations. The designed two-layer multiple transmitter of fibre optic sensor is fabricated to give the results. The predicted displacement response shows an enhancement of the linear range and sensitivity of four and two times, respectively, better than the corresponding ranges for the conventional bifurcation configuration and is validated by experimental static calibration. Harmonic excitation test is employed to deduce its dynamic displacement response behaviour. Results show constant sensitivity of about 0.363 mV/μm (absolute deviation less than 5%) over a bandwidth up to 2.2 kHz with minimum measurable displacement amplitude of about 50 nm at 2.2 kHz and signal-tonoise ratio of around 26 dB. The minimum measurable displacement is found to be 18 nm at 3.4 kHz with a signal-to-noise ratio of around 6 dB. Finally, application of the proposed sensor in structural health monitoring is demonstrated experimentally with comparison of conventional contact and non-contact sensors.

Kenichi Sogaet al. (2016) : In this study the driving trend toward increased implementation of structural monitoring systems are the need for structural health monitoring of existing and ageing structures and the desire for a better understanding of increasingly complex designs through performance monitoring of new structures. This drive is sustained by rapid progress in research and technology development on sensors and communications.

This chapter presents three case studies focusing on the monitoring of tunnels using distributed fiber-optic sensing. The first case study presents the results of strain development in the sprayed concrete lining (SCL) of a new Crossrail station tunnel during excavation of a cross-passage. The second case study focuses on the short term monitoring of a century old cast iron tunnel during the proximity construction of a large platform tunnel for the Crossrail project. The final case study describes the early stage implementation of a long-term structural health monitoring program to assess the integrity of tunnels at CERN. For all these projects Brillouin-based time domain techniques were used. A brief description of the basic principles of the method and the fiber-optic systems used is presented before the case studies.The variety of optical fibers available today combined with the number of fibre devices, with improved characteristics, recently developed provides a countless potential sensor configurations for environmental monitoring. In this chapter, a background of the use of fiber optic sensor networks in environmental applications are discussed focus in the optical detection for gas leakage sensing, water contamination sensing, soil contamination sensing and mapping with distributed fiber-optic sensors for environment

Enrico Köppe et al. (2016) : In this study fiber optic sensors have gained increasing importance in recent years and are well established in many areas of industrial applications. In this paper, we introduce a concept of a self-diagnostic fiber optic sensor. The presented sensor is to resolve the problems of embedded fiber optic sensors in complex structures and to enable the validation under operational conditions. For this purpose, different magnetostrictive coated fiber optic sensors were developed and various experiments were performed to verify their mode of operation and to determine the respective reproducibility. The measuring principle is illustrated by obtained experimental results, which showed a change in wavelength from 1 pm at a magnetic field strength change of 0.25 mT. In addition, the temperature characteristics of the implemented magnetostrictive sensor were analyzed and an experimental factor of 1.5 compared to a reference fiber optic sensor was determined.

L.Wonget al. (2016) : (2017) : In this study corrosion induced failures are common in cast iron (CI) pipes used in water supply networks. Over times, cracks may initiate from the corroded pits and grow when subjected to fatigue internal loading. When the particular region of the pipe loses its structural capacity, it will eventually lead to leakage or even pipe burst. Thus, it is important to use non-destructive techniques to perform permanent and real-time integrity monitoring on these pipelines. Distributed optical fibre sensors (DOFS) have been used to monitor the structural health of water pipelines from the last decades. Most of the studies shows that DOFS is effective in monitoring the condition of a pipeline and to identify the damage. This research tells us optical fibre sensor can be used to monitor the crack growth along the CI pipeline. The fatigue test was carried out using a large scale cyclic internal pressure loading facility. The optical fibre sensorwas implemented on the pipeline to monitor the circumstances of the load is implemented and the internal pressure loading experienced in the field. The response measured will show the application of distributed optical fiber sensor as the crack detection, as well as monitoring the crack growth along the pipe. This results confirmed that DistributedOptical FibreSensors(DOFS) is able to enhance the detection of cracks along the monitored pipe.

JinleiZhao (2015) : In this study optical fibers have been widely used in structural health monitoring. Traditional silica fibers can easily break due to its brittleness.In this study silica fibers are replaced by plastic optical fiber in the monitoring of cracks . However, considering the uncertainty of crack formation direction in composite materials, the influence of the angles between fibers and cracks on the monitoring of plastic optical fibers is studied. An Optical Fiber sensing device was developed and the relationship between light intensity loss and crack width under different crack angles was first measured through the device. Afterthat, three-point bend tests were done on concrete beams. Plastic optical fiber were pasted at the bottom surfaces of the beams and the light intensity loss with crack width were measured. The results which came showed that the intensity of the light decreases as the crack width increases. Due to this, application of plastic optical fibers in crack monitoring can be used. However, the results shows that the sensitivity of the POF crack sensor decreases with the increase in angles between fibers and cracks.

Conclusion

Optical fiber sensos can be used for measuring strains, deformation of crack, temperature , humidity, vibration etc. Therefore it can be concluded that more simplified methods need to be developed for monitoring of structures using optical fiber sensors.

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