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Guest Editorial

FIBER OPTIC SENSORS — AN EMERGING DIAGNOSTIC TOOL FOR CONCRETE

Today's highly developed infrastructure is the encompassing framework of our daily lives. It is a pervasive and complex fabric made up of many kinds of facilities and services including highways, bridges, tunnels, dams and seaports. The bulk of this infrastructure is constructed completely or in part by using concrete. However, concrete has not always performed well as a construction material. Concrete's most persistent problem is cracking. Cracking adversely influences the structural design and service life of concrete elements. Retrofit actions can only be effective if the authorities are properly warned in advance of impending degradation. While research is needed to enhance the attributes of concrete, there is also an urgency for methodologies that could accurately identify the presence of cracks, estimate the extent of degradation, and locate the damaged zone for repair. At this point in time there is no one method that can provide this information in a pragmatic manner. Other fields of engineering and science are very effectively utilizing optical fibers for their sensing and measurement applications. Most notably the aeronautics and defense industry utilize these sensors in a wide spectrum of operations which include in-flight sensing of structural vibrations, determination of aircraft skin temperature fluctuations, detection of cracks, and for control and stabilization operations, i.e. in fiber gyros. It is this widespread utilization of sensors in other disciplines that has brought about the recent surge in fiber optic research within the civil engineering community.

Optical fibers provide unique self diagnosis capabilities for concrete structures as they are able to maintain constant vigilance over the structural integrity. Due to their small size and geometric adaptability, optical fibers are easily integrated throughout a structural system. A structurally integrated fiber optic sensing system could monitor the state of a structure throughout its working life. The articles in this issue of the journal discuss the capability of fiber optic sensors in detecting a variety of disturbances including strains, deformations, pressures, temperature variations, and other structural phenomena. It is possible to design the embedded optical fiber sensor in a way capable of serving a dual purpose by providing in-place quality control of concrete at early ages during construction, and condition monitoring for cracks and other structural anomalies thereafter. In this respect, one very promising application is embedment of a network of optical fibers in structures during pouring and placement operations. At early ages, these sensors provide a real-time map indicating distribution of temperature within various segments of the structure. Excessive temperature variations are detected instantaneously, and concrete maturity data can be employed for nondestructive estimation of in-place strength. This same network of optical fibers will subsequently remain in the hardened concrete for sensing the initiation and progression of cracks during the structure's service life.

Unique characteristics intrinsic to optical fibers provide for many sensing and measurement applications in concrete. For this reason, optical fibers have been employed for sensing a wide spectrum of physical and environmental phenomena. In essence, it is possible for engineers to conceive of many innovative applications in order to develop a variety of diagnostic tools pertinent to concrete elements and structures. Physical or environmentally induced disturbances give rise to shifts in the phase, intensity, or the wavelength of light waves propagating through optical fibers. These changes in one or more properties of light are related to the parameter being sensed. Physical parameters need not necessarily represent mechanical strains or deformations. Extensive research has been done in regards to chemical and environmental fiber optic sensors. For instance, a variety of optical fiber sensors have been developed for the determination of pH levels in fresh concrete. Others detect the presence and amount of entrained air bubbles in fresh concrete. Yet another emerging class of optical fiber sensors are being developed for detection of moisture ingress in hardened concrete.

Geometric versatility allows for optical fibers to be configured to arbitrary shapes. However, their most attractive feature is their inherent ability to serve as both the sensing element and the signal transmission medium. This characteristic provides great flexibility in terms of applications, ease of usage, and capability for remote condition monitoring of concrete structures. Conventional transducers such as electric and piezoelectric sensors are susceptible to electric and electromagnetic interference. Optical fibers are immune to these interferences and due to this attri bute fiber optic sensors have found widespread usage in sensing applications involving structures for power industry, military and aeronautics.

It is envisioned that optical fiber sensor technology will reach the point where it can provide a true distributed sensing capability for concrete structures. In addition to the real-time crack and damage detection a distributed sensing system could provide data pertaining to structural and material behavior. Such information will assist structural engineers with new design concepts and construction of better structures. There are still some technological barriers inhibiting full integration of a fully distributed fiber optic sensory system within large concrete structures. Power deficiency of laser diodes, insertion loss of fiber connectors and optical switches exemplify some of the obstacles in multi-sensor and distributed sensing applications. However, most of these impediments are also issues of main concern to the telecommunications industry, and therefore it is foreseen that they will be resolved before the end of the century.

It is apparent that as in many disciplines revitalization of the science of concrete engineering requires advancement through innovation in emerging technologies. Sole applications of traditional civil engineering methodologies are not sufficient to address the majority of today's concrete design and construction related issues. The highly specialized nature of the fiber optic sensor technology calls for an interdisciplinary forum of scientists and engineers to work on various sensor design and application projects. It is therefore advantageous to develop a mechanism for coordinated research which is specifically geared towards application of these technologies to concrete. Research projects summarized in the present issue of the journal address some of these interdisciplinary team work concepts. There is no doubt that full implementation of fiber optic sensor technology to concrete structures will require even more interdisciplinary research and development activity.

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