APPLICATION OF FIBER OPTIC POLARIZATION SENSOR

IN PAVEMENT INSTRUMENTATION

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Chapter 1

Introduction

1.1. Pavement Instrumentation

To understand pavement performance and its characteristics, the design of adequate instrumentation is proven to be of great benefit. Pavement performance can be examined by measuring its stress distribution when exposed to an external load, or by its transient response when struck by an impulse. Pavement instrumentation also provides an opportunity to validate analytical models as well as to calibrate model response variables.

Pavements continuously deteriorate under the combined action of loading and environmental effects. Prediction of pavement performance is essential for design of new and rehabilation of existing pavements. Important parameters in the structure of a pavement or pavement responses such as stress and strain at different levels of the pavement must be known. An indirect determination of the stress and strain may be obtained through different analytical methods but for precise measurement, implementation of a measurement device is necessary. This thesis will explain the procedural development of an instrumentation for pavement maintenance using optical fibers.

1.2. Fiber Optic Sensor

Optical fiber sensors have matured to the point where the impact of this new technology is now evident. They offer a number of advantages which leads to the development of a possible solution to the problem of pavement response measurements. Fiber optic properties such as geometrical versatility and sensitivity bring out a potential for application of these sensors in pavement instrumentation.

A fiber sensor may at first sound like a contradiction in terms; it is the insensitivity of optical fibers to outside influence, after all, that makes them valuable for communications. This can be possible by sensitizing fibers by exposure of the fibers to conditions unlike those normally encountered in communications. For example fibers are protected using an outer jacket to avoid the bending in the fiber while as for the sensor application the jacket can be removed and fiber could be exposed to pressure applied along its diameter and used as a pressure sensor.

For this application pure fiber sensors are to be used in which the fiber itself is the sensing element. A system of sensing is likely to include more than one sensor in which signals from different sensors at different locations are combined and multiplexed and transmitted over a common signal channel so that the overall performance of the pavement can be

controlled at the minimum cost. Figure 1.1 shows a block diagram of components common to some fiber optic sensors.

In Chapter 2 some optical fiber sensors are presented in which polarization properties are used to measure physical properties.

Chapter 3 discusses the theoretical background for polarization sensors by defining different parameters and deriving equations relating the fiber birefringence and applied mechanical forces.

The results of various tests performed on a plastic sample are discussed in Chapter 4.

Chapter 5 summarizes the overall performance of the sensor and provides some suggestions for a system of many sensors.

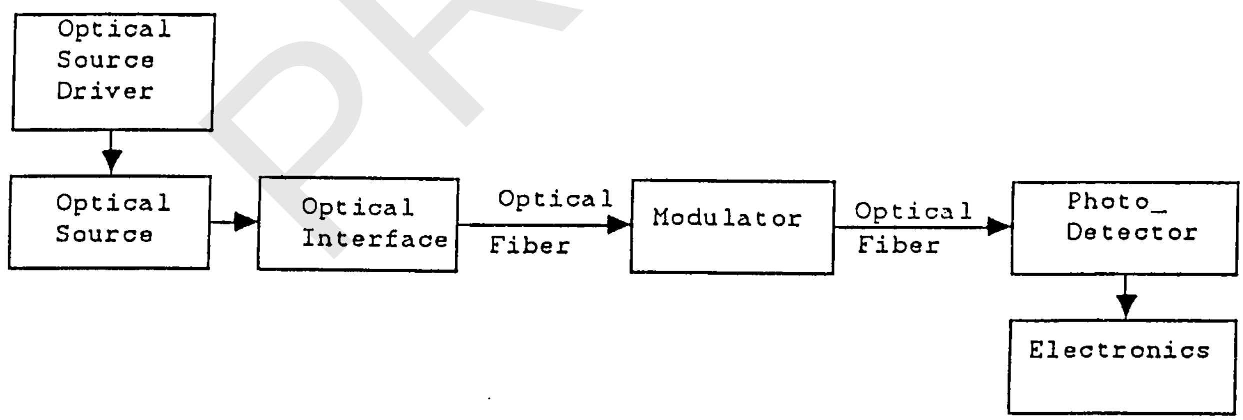

Figure 1.1. Components common to some fiber optic sensors

Chapter 2

Review of fiber optic sensors

Fiber optic sensors can be classified into two basic types:

1. Pure fiber sensor (intrinsic).
2. Remote optical sensor (extrinsic).

2.1. Intrinsic or Pure Fiber Sensors

Pure fiber optic sensors illustrated here depend on environmentally induced changes to light as light travels through a fiber.

2.1.1. Rotation

To sense rotation, laser light is split into two beams that travel in opposite directions in a single optical fiber wound around a cylinder. When the fiber ring rotates, the light beam going in the same direction as the rotation has to travel more than the one complete revolution to reach its starting point. Similarly the beam travelling counter to the ring's rotation reaches its starting point after going less than one complete rotation [10]. The difference in path length

appears as a phase shift, which can be detected by interfering the two beams with each other. Figure 2.1 shows a fiber optic gyroscope.

2.1.2. Temperature

Temperature induced change in refractive index turns fibers into sensitive thermometers. Because the core and cladding differ in composition, their refractive indexes change at different rates in response to a temperature change and more light escapes to the cladding causing light modulation with temperature.

An application of optical thermometer is Michelson temperature sensors in which light from a single frequency diode laser is coupled into a single mode optical fiber and is then amplitude divided by a single-mode directional coupler into the signal and reference arms of the fiber interferometer [9]. The signal and reference fibers are closely coupled together except at their mirrored ends and a path length imbalance for the interferometer is created.

2.1.3. Electric Current and Voltage

A fiber wound around an electrical conductor can serve as a current meter. Laser light is linearly polarized and then