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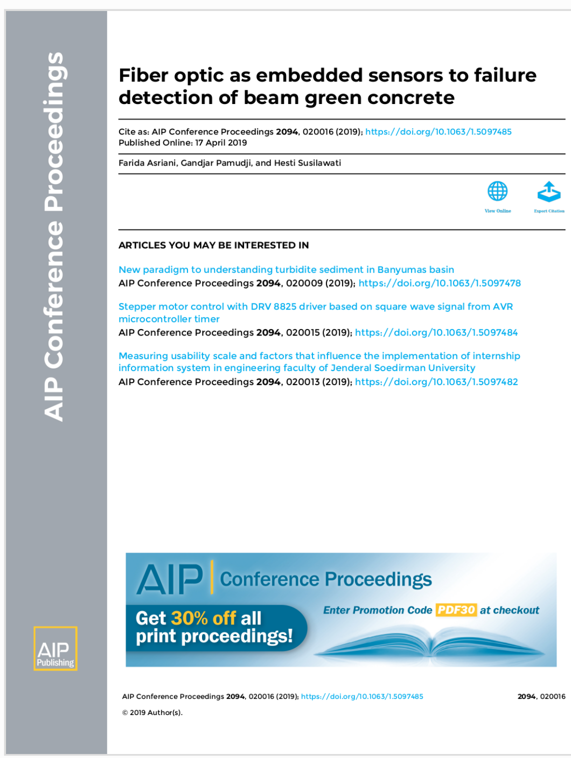

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16. Fiber optic as embedded sensors to failure detection of beam green concrete

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Farida Asriani, Gandjar Pamudji, and Hesti Susilawati

Fiber Optic as Embedded Sensors to Failure Detection of Beam Green Concrete

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Abstract . Concrete is one of the materials widely used in the construction field because of its strength and durability. But still this material will experience a decrease in quality even damage due to environmental influences such as pressure. It is very important to monitor the condition of the concrete and provide early warning to be able to know if there is damage to the concrete. This study aims to utilize singlemode fiber optic as an embedded beam failure sensor. Concrete failure detection systems are designed to read signals from fiber optics and define beam failure status. To achieve this goal, straight configuration of optical fiber is planted in reinforced beam concrete. In this study three reinforced beam concrete were made with aggregates from plastic waste. Design The concrete damage detection system consists of photodiode, Arduino and LCD. The beam press test is carried out with universal testing machine. From the results of data analysis, it was found that the value of the concrete beam began to fail when the defect reached 4.7 mmThis value is achieved when the output voltage of beam failure detection system is 2.6 volts. he system test results are when the output voltage is less than 2.6, the alarm status is off and when the output voltage is greater than 2.6 volts, the alarm status is on which indicates the beam has failed.

INTRODUCTION

Recently, concrete is still a major component in infrastructure development. The bridge is one of the most important infrastructure buildings because it can sustain economic growth in the region. Concrete on the bridge structure is generally applied to upper structural elements such as girders and bridge floors, as well as to lower structures, namely abutments and foundations. Components of concrete bridge structures must have long-term servicebility aspects and comfort aspects for bridge users. Long-term service resistance is limited by concrete cracks in bridge structure components. While the limitation of bridge service performance on the comfort aspects of bridge users is the amount of deformation of the bridge structure. Thus important to give an early warning system to anticipate structural failures that can be caused by overloading or declining performance of bridge services. This decrease in performance will be at high risk if it is not monitored every day and resolved as early as possible.

Continuous monitoring of concrete conditions throughout time is a new challenge, considering that currently the physical properties of concrete are measured only temporarily. Progress in the field of instrumentation supported by advances in information technology enables continuous physical monitoring of concrete. Optical fiber which is the result of material engineering, has been widely applied in telecommunications technology as a medium of transmission or propagation of light. Optical fiber sensors are now the main choice for sensing processes in concrete structures. Optical fiber sensors are embedded in concrete in order to measure the physical properties of concrete such as temperature, strain, concrete vibration [1], beam deflection[2], width of concrete cracks, and detect corrosion of reinforcement [3],[4]. Concrete used as a measurement medium is normal concrete.

In this study, lightweight concrete made from light coarse aggregates from polypropolyne plastic waste . Lightweight aggregates from plastic waste can produce lightweight concrete with a lower weight of 25% -35% of normal concrete [5][6][7]. Deformation monitoring in lightweight concrete applications needs to be done so that it can be known early on the strain changes in concrete, especially in the plastic interface zone and the mortar matrix. Cracks on the mortar matrix are caused by the mortar matrix which is not able to follow the elastic aggregate plastic deformation, where the plastic aggregate does not experience destruction like artificial lightweight aggregates generally.

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The addition of an fiber optic sensor to the concrete needs to be done to determine the crack propagation that cuts the mortar matrix. The measurement of deformation on press test the cylinder lightweight concrete from plastic waste has been carried out. A significant decrease in fiber optic output power occurs when the concrete is damaged because the load increases [8].

In addition, it was also developed the collapse detection of reinforced concrete beams based on deflected beams due to the centered load in the middle of the span. The multimode fiber optic sensor is implanted in a concrete beam measuring 150 mm x 150 mm x 600 mm using 3 different configuration variations in order to determine the effectiveness of the output power reduction in the optical fiber sensor [9].

In this research developed a failure detection system for reinforced concrete beams using light coarse aggregates of plastic waste. The purpose of this research is to find the signal threshold that is passed on a fiber optic sensor that can inform that the beam is at its capacity threshold.

EXPERIMENTAL PROGRAM

The research method applied is an experimental method in the laboratory with research steps shown in the flow chart of Figure 1.

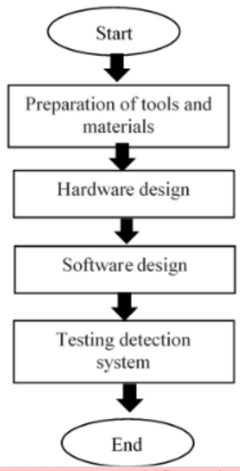

FIGURE 1. Research flow chart.

Preparation phase

The most important thing is to prepare equipment related to sensors, namely optical fiber, invisible laser, photodiode sensor, Arduino Uno and 16x2 character LCD. In addition, other supporting tools are also prepared such as fiber optic cable cutters, connectors, handtools and other supporting devices. The concrete material that is made consists of sand, plastic aggregate, cement, water and superplasticizer.

Hardware Design

The hardware design consist of fiber optik configuration, circuit of beam failure detection and the creation of beams with embedded fiber optic.

1. Design of Fiber Optic configuration

   The jacket layer fiber optic is peeled on the part to be planted in concrete. the peeled part is affixed to the horizontal reinforcement. Optical fiber configuration in concrete is shown in Figure 2

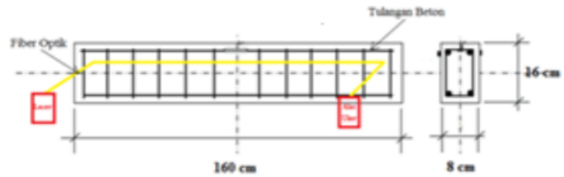

FIGURE 2. fiber optic configuration in concrete

1. Designing a beam failure detection circuit

This circuit will read a laser signal that passes through the fiber optics embedded in the beam concrete and detects the condition of the beam whether it is still good or has failed due to loading. The laser signal that passes through the fiber optic will be captured by the photodiode. The photodiode output voltage is inserted into Arduino. Arduino is programmed to be able to define a beam with embedded fiber optics that is given a load test whether or not it fails. Information about the condition of this beam is displayed in the LCD. The block failure detection system is shown in Figure 3.

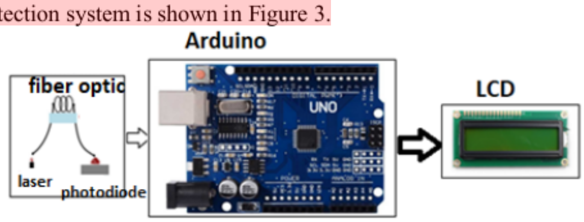

FIGURE 3. Block diagram failure detection system

2. Making beam samples

3 samples beams with embedded sensors are made with a size of 160cm x 8cm x 12cm. The composition of the concrete as shown in Table 1.

TABLE 1. Concrete mixture composition

Code	Cement (kg)	Sand (kg)	Plastic Coarse Aggr. (kg)	Water (kg)	Supplasticizer (kg)
M1	500	845	432	150	12

Software design

The software design phase is done to program Arduino so that it can read the voltage data from the photodiode, display the voltage to the LCD. Beam failure is informed by the alarm condition displayed on the LCD.

System Testinig

Concrete with an embedded fiber optic is connected to a failure detection system at one end of the fiber optic. The other end is connected to a laser source with a wavelength of 1310nM.. Pengujian dilakukan dengan memberikan pembebanan pada beton dengan UTM. ests are carried out by loading the concrete with UTM. As a result of loading on concrete will affect the change in laser power .. Changes in the power laser are read as changes in voltage in the detection system. Data observations carried out include changes in load and changes in fiber optic output voltage and beam deflection. Deflection changes due to loading were analyzed to get the maximum load limit value that can be received by the beam where the beam starts to fail. The system output voltage threshold for beam failure detection is determined by the load value at which the beam begins to fail.

RESULT AND DISCUSION

Hardware design

1. Fiber Optic Configuration and Making Beams

   The configuration of fiber optics embedded in concrete is in a straight configuration as shown in Figure 4. The fiber optic jacket planted in the concrete was peeled and then attached to reinforcement . fiber which is used 3 meters long. There are two optical fibers in each concrete sample.

FIGURE 4 Fiber optic with straight configuration

Reinforced beams with embedded sensors are made with the planned composition, and the results are shown in Figure 5.

FIGURE 5. Reinforced beam with embedded fiber optic

The beam is still inside the mold. The yellow cable is an optical fiber that will be connected to a laser source and a beam failure detection device. In this study 3 pieces of the same beam were used.

Software Design

The software design in question is for Arduino programming so that fiber optic output data can be displayed on the LCD. The flowchart of Arduino programming is shown in Figure 6.

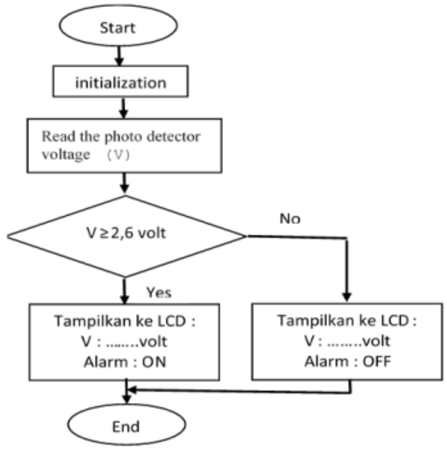

FIGURE 6. Arduino programming flowchart

Based on the results of data analysis, 2.6 volts is a voltage threshold where the beam starts to fail. Arduino programming is made according to the flowchart of Figure 6.

Data collection and analysis

Data retrieval is done by loading on concrete. The length of the concrete support is 1,175 meters. Load deflection data is shown in graphs Figure 7, Figure 8 and Figure 9.

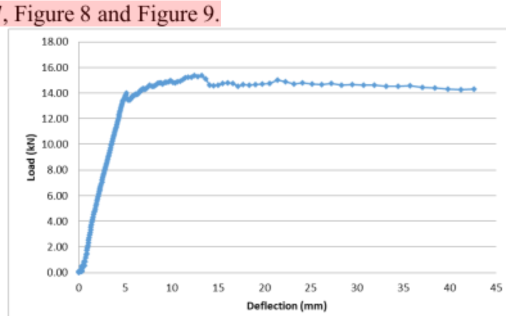

FIGURE 7. Relationship between deflection and load for beam 1

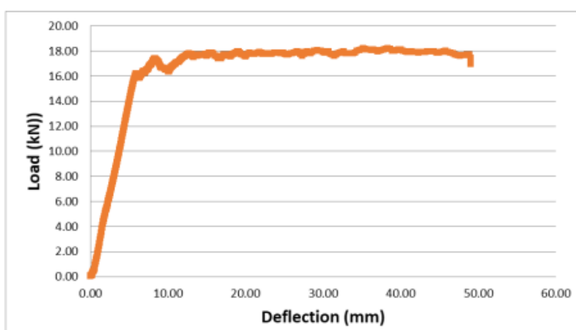

FIGURE 8. Relationship between deflection and load for beam 2

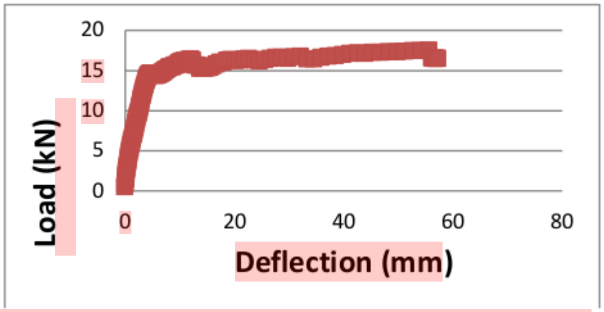

FIGURE 9. Relationship between deflection and load for beam 3.

Based on the RSNI-T-12-2004 concerning the planning of concrete structures for bridges, it is stated that the deflection requirements for the components of highway bridge structures do not exceed 1/250 spans [10]. In this study the distance of the beam span during the test was 1,175 meters. So that the deflection limit of the beam called failure is 4.7 mm. This deflection value occurs when the loading values are 15.44 kN for beams 1, 12.94 kN for beams 2 and 14.57 for beams 3. The average load for the three beams begins to fail is 14.317 kN. Furthermore, the value will be a benchmark in determining the system output voltage threshold failure detection beam.

The relationship between the test load and the output voltage detection system is presented in the graph in Figure 10, Figure 11, and Figure 12. The system output voltage of the failure detection beam is 3.55 volts for testing beam 1, 2.67 volts for testing beam 2, and 2.66 volts for beam testing 3. Of the three values, a voltage of 2.6 volts is set as the value of the system output voltage which indicates the beam starts to fail.

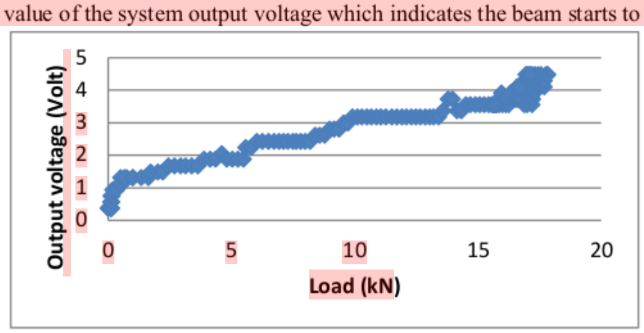

FIGURE 10. Relationship between test load and output voltage failure detection system for Beam 1

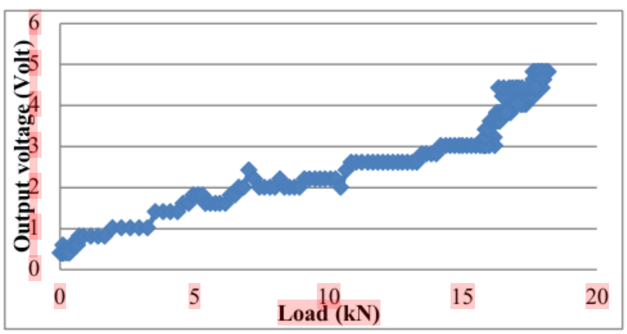

FIGURE 11. F Relationship between test load and output voltage failure detection system for Beam 2

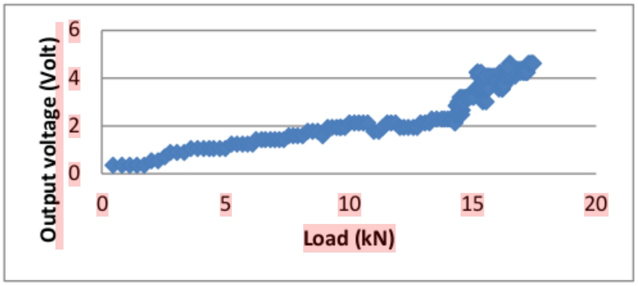

FIGURE 12. Relationship between test load and output voltage failure detection system for Beam 3

Failure detection system testing

This test was conducted to determine the performance of the beam failure detection system. Testing using a compressive test and the results observed are data on the relationship between the deflection and photodiode output voltage and the alarm status of the failure detection system. The results of the observations are presented in the graph Figure 13.

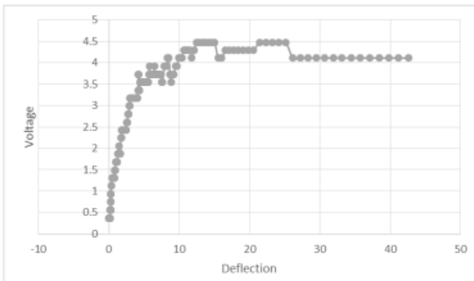

FIGURE 13. Relation between beam deflection and output voltage of detection system

Alarm off if the detection system output voltage is less than 2.66 volts. So that it can be concluded that the beam failure detection system using optical fiber and photodiode has good performance.

CONCLUTION

Based on the results and discussion, the following matters can be concluded singlemode optical fiber with a straight configuration can be used as a beam failure detection sensor. The deflection value that becomes the beam failure threshold is 4.7mm. The threshold value of the photodiode output when beam failed is 2.66 volts. The beam failure detection system designed in this study can function properly

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