STRUCTURAL HEALTH MONITORING OF GLASS FIBRE REINFORCED CONCRETE BEAM

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Abstract – *Glass fibre reinforced concrete is those structures in which the steel reinforcement is replaced by glass fibre mesh. In this study, casting of the prism specimen is done by placing the glass fibre mesh in box type. The sensor that is used is thermocouple which is used for measuring the internal concrete temperature. With the help of thermocouple sensor embedded at the middle and one-third distance of the prism, along the transverse direction, the temperature of the glass fibre reinforced concrete prism during loading is measured. With the help of the data obtained, a relation between the internal concrete temperature and load is derived. In addition to this the temperature at which the glass fibre reinforced concrete fails is also measured. With all the information collected, the temperature range can be fixed in the sensor for continuous monitoring of the structure and the system can be programmed to ring an alarm when the temperature exceeds the specified limit.*

Key word: Glass fibre reinforcement, Structural health monitoring, Thermocouple sensor, Temperature

1. INTRODUCTION

Structural health monitoring refers to the process of implementing a damage detection and characterization strategy for the structures. Damage is defined as the changes in the material or geometric behaviour of the structure including changes in the boundary condition and system connectivity which affects the system's performance. The SHM process involves the observation of a system over time using periodically sampled dynamic response measurements from an array of sensors. The extraction of damage-sensitive features from these measurements, and the statistical analysis of these features are used to determine the current state of system health. For long term SHM, the output of this process is periodically updated information regarding the ability of the structure to perform its intended function in light of the inevitable aging and degradation resulting from operational environment. The SHM includes sensing technology, data acquisition, transmission and management and health diagnosis.

1.1 Health Assessment of Engineered Structure

Commonly known as Structural Health Assessment (SHA) or SHM, this concept is widely applied to various forms of infrastructure, as countries all over the world enter into greater period of construction of various infrastructures ranging from bridges to skyscrapers. Especially when damages to structures are concerned, it is important to note that there are stages of increasing difficulty that require the knowledge of previous stages and they are.

a) Detecting the existence of the damage on the structure
b) Location of the damage
c) Identifying the types of damage
d) Qualify the severity of the damage

1.2 Textile reinforcement

Textile reinforced concrete is a combination of plain concrete and textile reinforcement. Steel reinforcement is replaced by textile reinforcement in textile reinforced concrete. The textile material has high tensile strength and negligible elongation properties when reinforced with woven and non-woven material fabrics. The different types of textile reinforcement fabric materials are,

a) Alkali-resistant glass
b) Basalt
c) Aramid
d) Carbon

In this study glass fibre reinforcement is used. AR glass fibre mesh has high strength and is corrosion resistant.

2. MATERIAL PROPERTIES

In this study, the following materials are used and testing of materials such as cement, M-Sand and coarse aggregate are done to determine the properties such as fineness of cement, consistency of cement initial & final setting time of cement, specific gravity, fineness modulus of fine aggregate and coarse aggregate.

2.1 Concrete material

2.1.1 Cement

Ordinary Portland cements (OPC) is the basic Portland cement and is best suited for use in general concrete construction. In this study 53 grade of cement is used.

Table I Physical Properties of 53 Grade Ordinary Portland cement

Properties of cement	Values
Fineness of cement	9.2%
Specific Gravity	3.66
Consistency	33%
Initial Setting Time	25 minutes

2.1.2 Fine aggregate

According to IS 383:1970 fine aggregate is being classified into four different zones they are, zone-I, zone-II, zone-III and zone-IV. Manufactured sand is artificially produced sand. It is the crushed aggregates produced from hard rock stone while quarrying which is cubically shaped with grounded edges, washed and graded with consistency to be used as a substitute of river sand. The material tests conducted on fine aggregate were specific gravity, fineness modulus and water absorption.

Table II Physical properties of manufactured sand

Properties of fine aggregate	values
Specific gravity	2.75
Fineness modulus	2.82
Grading zone	II

2.1.3 Coarse aggregate

Ordinary blue granite crushed stone aggregate was used as a coarse aggregate. The optimum size of the coarse aggregate used for AR glass fibre mesh with 5mm grid size was found to be 10mm and hence it was adopted. The specific gravity test, fineness modulus test and water absorption test were conducted on coarse aggregate.

Table III Physical properties of coarse aggregate

Properties of coarse aggregate	values
Specific gravity	2.55
Fineness modulus	6.58
Water absorption	1.45%

2.1.4   AR Glass Fibre Mesh

To improve the tensile reinforcement high strength fabrics made of textile reinforcement can be used. The multi-filament yarn made of AR (alkali-resistant) glass fibre was used in this study. AR Glass fibre mesh was used as reinforcement and the other material properties are listed below.

Table IV The following are the properties of glass fibre mesh

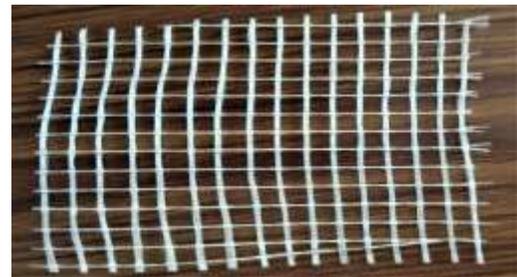| Name	AR Glass fibre mesh
Tensile strength	1276 N/mm^2
Elongation of fibre	1.78%
Modulus of elasticity	7200N/mm^2
Diameter of fibre	1 mm
Size of the grid	5mm x 5mm

Fig 1 Glass Fibre mesh

2.2 Thermocouple Sensor

In health monitoring many types of sensors are used. In order to detect the temperature changes within the concrete, thermocouple sensor was used. A thermocouple sensor is an electrical device consisting of two similar electrical conductors forming electrical junctions at differing temperatures.
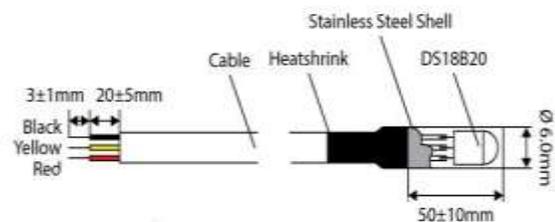

Fig 2 Thermo Couple Sensor

2.3 Concrete

Table V shows mix proportioning of concrete for compressive strength of 25MPa.

Table V Mix proportioning of concrete

Components	Quantity
Water	220.48 litres
Cement	400.87 kg/m^3
M Sand	782.62kg/m^3
Coarse aggregate	951.75kg/m^3

3. EXPERIMENTAL INVESTIGATION

3.1 Test specimen

Three specimens of size 500mm x 100mm x 100mm were casted with thermocouple sensor embedded at the middle and one-third distance of the prism, along the transverse direction. AR Glass fibre mesh was placed in box shape having a cover of 15mm on all the sides.
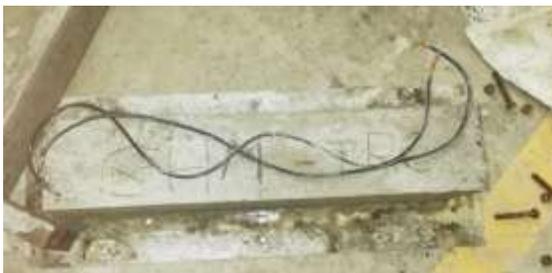

Fig 3 Test Specimen

3.2 Experimental setup and Loading

All the 3 prisms were tested to failure in a two-point loading system with a clear span of 500mm and an effective span of 400mm. The load was applied using Universal Testing Machine. Two dial gauges were used to measure the deflection of the specimen. The testing of prism was carried out in Universal Testing Machine of 1000 kN load capacity. Two-point load was applied in the specimen and the corresponding change in temperature was noted.
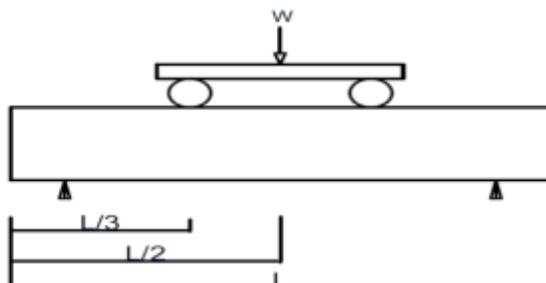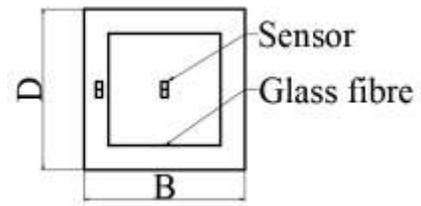

Fig 4 Experimental Setup

Fig 5 Position of sensor

Fig 6 Specimen Testing Setup

Fig 7 Monitoring Setup

3.3 Result and Discussion

For the applied load the corresponding change in temperature was noted. The load change for the glass fibre reinforced concrete at one-third and mid-distance was obtained as 0.2°C. For every change in load, the corresponding change in temperature has been noted. From the value arrived, The relation between the internal concrete temperature and applied load for the specimens has been arrived as below.

Relation arrived

$$y = -31.818x^2 + 1804.1x - 25555$$

x – Temperature (°C)

y – Load (KN)

4. CONCLUSION

From the testing it can be inferred that with increase in loading, the internal temperature of the concrete also increases which can be used as a means of warning. Further studies and experiments have to be made on different specimens and at different sizes to arrive a global relation between the temperature and load and thereby make the health monitoring system more economical with the thermocouple sensors.

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