HEALTH MONITORING OF STRUCTURE USING CARBON FIBRE IN SELF SENSING CONCRETE UNDER STATIC LOAD

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Abstract

To create a simple way to keep an eye on the health of concrete structures. Small amounts of short (5mm length) carbon fibres added to mortar or concrete (0.2 to 0.5% by volume of cement) have been shown to induce self-sensing or intelligent behaviour. Due of this, electrical resistance increased under loading, resulting in crack propagation or fracture. The resistance change cannot be reversed once it reaches the inelastic stage for the purpose of monitoring the health of structures, an approach that can be utilised in place of fibre optic or strain gauge technology has been devised. When fibres are pulled out in the elastic range, resistance rises. A four-probe approach was used to measure the change in elastic resistance, and it was discovered that elastic deformation might reverse the change. Additionally, the specimen's irreversible resistance change can be used to detect the spread of cracks and fibre breakage. The graphs of load versus resistance were drawn. This phenomenon can be used to determine the weight of moving vehicles in real time as well as the stress levels within a loaded building, among other things.

Keywords— Carbon fiber, Four probe method, Crack propagation.

1. Introduction

Engineers frequently struggle with the dual tasks of determining appropriate methods for evaluating stresses in buildings and assessing those methods' economic viability. The requirement to have intelligent materials and sensors for non-destructive health monitoring is growing as it becomes increasingly important to monitor vital infrastructure like bridges, nuclear vessels, and chemical storage facilities in real time. The sensors must identify fractures in real time during static and dynamic loads in order to diagnose damage and develop a remediation strategy [1-6]. They must also be affordable in order to be used for the instrumentation of large constructions. The currently used sensors, include acoustic emission, piezoelectric, strain gauges, fibre optic gauges, and Bragg grating, are not only expensive, but they also have issues with erection, low durability, the need for qualified staff, and transportation. Additionally, they need pricey accessories like electronic and laser equipment [7-15]. However, in the current carbon fibre experiment, the carbon fibre itself functions as a sensor and doesn't need any other tools beyond a few straightforward instruments. The loaded specimen's voltage and current measurements were used to calculate the electrical resistance. The tools utilised were a regulated D.C power source, a voltmeter, and an ammeter, all of which are commonly available.

The present experimental procedure involved casting mortar cubes with 0.24% carbon fibre added to increase electrical resistance, methylcellulose added to improve fibre dispersion, and water reducing admixture naphthalene sulfuric acid added to improve workability [16-22]. The use of carbon fibre also reduced slump. This project intends to create self-sensing concrete without the use of any sensors by adding methyl cellulose to standard concrete and carbon fibre to a structure. to examine the electrical resistance of concrete blocks under various loads and to draw a breakdown graph for any concrete deformation.

2. Materials and Methods

Cement, Water and Aggregates

Cement is a binder, a chemical used in construction that binds things together by setting, hardening, and adhering to them. During the building process, it is utilised to make mortar and concrete. Contrarily, concrete is a building material created by combining aggregate (i.e., various types of sand and gravel), cement, tiny stones, and water. Throughout the project, ordinary Portland cement of grade 53 was employed. The fine aggregate is river sand that has been graded zone II-compliant IS sieved to a size of 4.75 mm. Table 1 displays the materials characteristics.

TABLE 1: Materials characteristics

Sl. No.	Parameter	OPC	Fine Aggregate	Coarse Aggregate
1.	Normal Consistency	29%	--	--
2.	Initial Setting Time (minutes)	45	--	--
3.	Final Setting Time(minutes)	240	--	--
4.	Specific Gravity	3.15	2.7	2.7
5.	Bulk density (kg/m^3)	--	1135	1169
6.	Fineness modulus	--	4.62	--
7.	Water Absorption	--	2.04%	--
8.	% of Voids	--	55.02	154.65

A. Carbon Fiber

Carbon atoms make up the majority of carbon fibers. High stiffness, high tensile strength, low weight, good chemical resistance, high temperature tolerance, and minimal thermal expansion are only a few benefits of carbon fibers. Carbon fibre is highly well-liked in the fields of civil engineering and aerospace because of these qualities. A substance that is electrically conductive permits current to flow through it. It was initially discovered as a matt, but was later sliced into short, irregular fibre that was between 5 and 6 millimeters long.

B. Carboxyl Methylcellulose

Carboxyl methylcellulose is a dispersion agent that distributes the chopped carbon fiber for a better electric conductivity around the concrete.

C. Defoamer

There are different types of defoamer like petrol, kerosene that eliminate the stickiness of methylcellulose while mixing it with the carbon fiber and it is an anti-foaming agent.

3. Experimental Procedure

It is the process of choosing appropriate concrete materials and figuring out their relative proportions with the goal of making concrete that is as strong and long-lasting as feasible. The major goal of the experiment is to evaluate the qualities of hardened concrete using carbon fibre and the four-probe method, which uses a regulated power source of current to detect voltage and current as well as an ammeter to measure current. Under UTM400, a variety of loads were tested. The concrete mix design was suggested using control concrete made in accordance with Indian Standard IS 10262:2009. It received an M25. Table 2 displays the materials proportion.

TABLE 2: Materials proportion

Material	For 1 m^3	For cube	For cylinder (dia=100mm, Height=200mm)	Total
Ordinary Portland Cement	383.96 g	0.39 kg	0.6 kg	1 kg
Coarse Aggregate	1232.77 g	1.232 kg	1.94 kg	3.17 kg
Fine Aggregate	607.19 g	0.60kg	1 kg	1.5 kg
Water	191.98 g	0.192 kg	0.3 kg	0.492 kg
Carbon Fiber	-	2 g	3 g	5 g

Methyl Cellulose	-	1.6 g	2.4 g	4 g

4. Results & Discussions

We had made the concrete cube and cylinder using carbon fiber in it and we had tested each type weekly i.e. 7th day, 14th day and 28th day under UTM400.We take down reading of at various load and represented in graph under the tabulation.

4.1 **Results after 7 Days**

The test specimen i.e. cube and cylinder, after 7days of curing were tested using four-probe method that contains a Regulated power supply of current Voltmeter and Ammeter for detection of voltage and current. The tests were carried out for various loads under UTM400.

4.1.1 Result after 7 Days for Cube

The specimen i.e. cube after 7 days of curing, was tested for various loads under UTM400 whose reading are shown in Table 4.1.

Table 4.1: Result after 7 days for cube

S. No.	Load (kN)	Ammeter (mA)	Resistance X10^3	Change in resistance ratio $\Delta R = (Ri - Ro)/Ro$
1	0	2.39	4.18	0
2	10	2.35	4.25	0.0148
3	16	2.39	4.34	0.0167
4	28	2.30	3.48	0.038
5	40	2.87	3.54	0.167
6	46	2.94	4.23	0.153
7	50	2.96	3.1	0.174
8	56	2.36	4.13	0.0127

Fig 4.1 shows graphical representation of our result from which we came to know about health condition of block at various load.

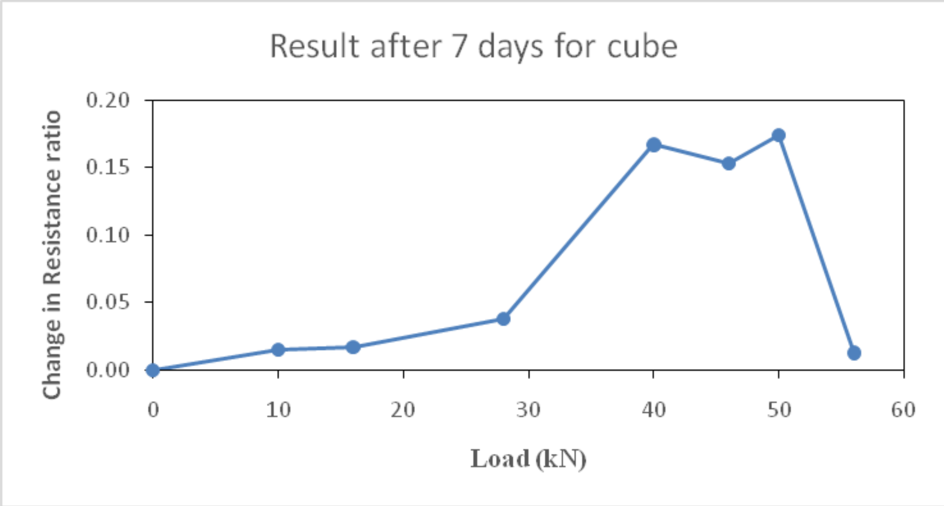

Fig 4.1: Result of cube after 7 days

The relationship between load and the change in resistance ratio was depicted in the graph above. In cases when load is applied on block resistance ratio shows increment there slope value but at time crack there values will shows negative slope values. Hence, from graph we can able to know that we are getting 1st crack generated between 40-45 kN and 2nd and major crack generated between after 50kN.

4.1.2 Result after 7 Days for Cylinder

Here, we had tested our specimen i.e. cylinder after 7 days curing test was carried out under various loads under UTM400 whose reading are shown in Table 4.2.

Table 4.2: Result after 7 days for cylinder

S. No.	Load (kN)	Ammeter (mA)	Resistance X10^3	Change in resistance ratio $\Delta R = (Ri - Ro)/Ro$
1	0	4.09	2.44	0
2	6	3.75	2.55	0.0431
3	12	3.65	2.74	0.074
4	20	3.50	2.86	0.1215
5	30	3.37	2.96	0.16
6	40	3.14	3.18	0.24
7	46	3.02	3.54	0.39
8	50	2.43	4.11	0.61
9	57	2.89	3.46	0.35

Fig 4.2 shows graphical representation of our result from which we came to know about health condition of block at various load.

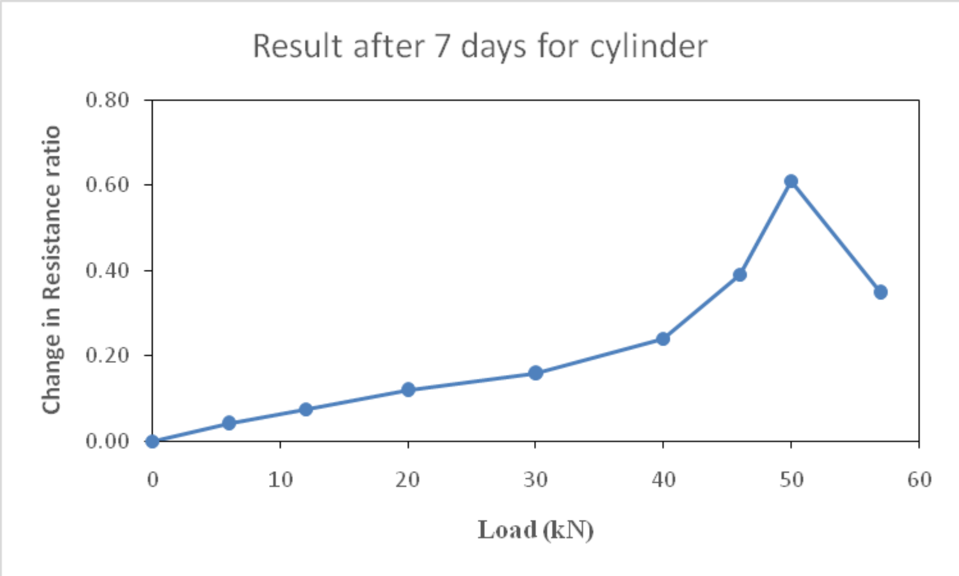

Fig 4.2: Result after 7 days for cylinder

In above graph that we had plotted between load and change in resistance ratio. In cases when load is applied on block resistance ratio shows increment there slope value but at time crack there values will shows negative slope values. Hence from graph we can able to know that we are getting one major crack generated after 50 kN needs repair**.**

4.2 Results after 14 Days

Here, we had tested our specimen i.e. cube and cylinder after 14 days curing using four-probe method that contains a Regulated power supply of current Voltmeter and Ammeter for detection on voltage and current. The test carried out under various loads under UTM400.

4.2.1 Result after 14 Days for Cube

Here, we had tested our specimen i.e. cube after 14 days curing test was carried out under various loads under UTM400 whose reading are shown in Table 4.3.

Table 4.3: Result after 14 days for cube

S. No.	Load (kN)	Ammeter (mA)	Resistance X10^3	Change in resistance ratio $\Delta R = (Ri - Ro)/Ro$
1	0	4.81	2.079	0
2	20	4.57	2.108	0.052
3	30	2.90	2.564	0.533
4	40	3.04	3.289	0.582
5	50	3.07	3.257	0.566
6	60	3.09	3.23	0.554
7	70	2.64	3.78	0.810

8	80	2.90	3.44	0.654
9	90	2.94	3.40	0.035

Fig 4.3 shows graphical representation of our result from which we came to about know health condition of block at various load.

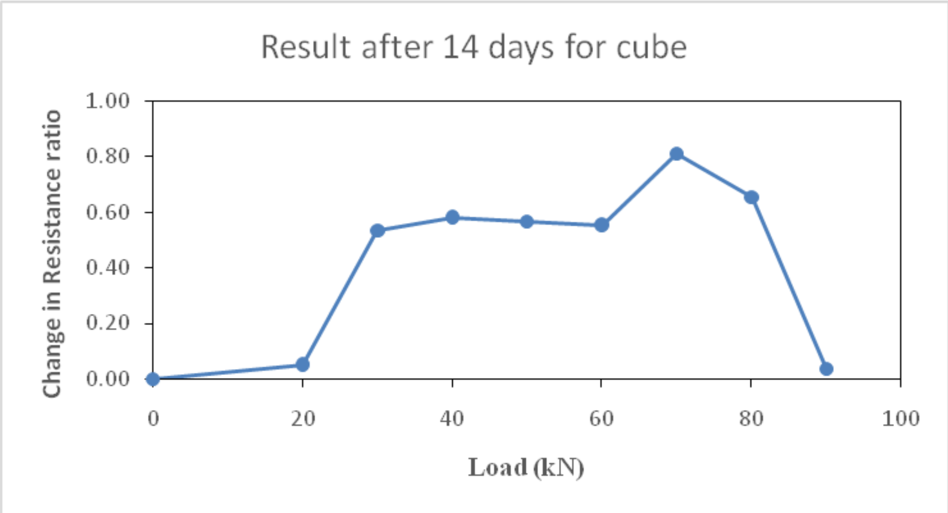

Fig 4.3: 14 days of cube

In above graph that we had plotted between load and change in resistance ratio. In cases when load is applied on block resistance ratio shows increment there slope value but at time crack there values will shows negative slope values. Hence from graph we can able to know that we are getting 1st minor crack generated at 40 kN and 2nd major crack generated at 70 kN get enlarged at 80kN needs repair.

4.2.1. Result after 14 Days for cylinder

Here, we had tested our specimen i.e. cylinder after 7 days curing test was carried out under various loads under UTM400 whose reading are shown in Table 4.4.

Table 4.4: Result after 14 days for cylinder

S. No.	Load (kN)	Ammeter (mA)	Resistance X10^3	Change in resistance ratio $\Delta R = (Ri - Ro)/Ro$
1	0	13	0.770	0
2	20	12.2	0.820	0.050
3	30	11.3	0.885	0.143
4	40	10.9	0.917	0.191
5	50	10.2	0.971	0.261
6	60	09.6	1.034	0.344
7	70	09.3	1.070	0.389
8	80	09.4	1.060	0.376
9	90	09.6	1.040	0.350

Fig 4.4 shows graphical representation of our result from which we came to about health condition of block at various load.

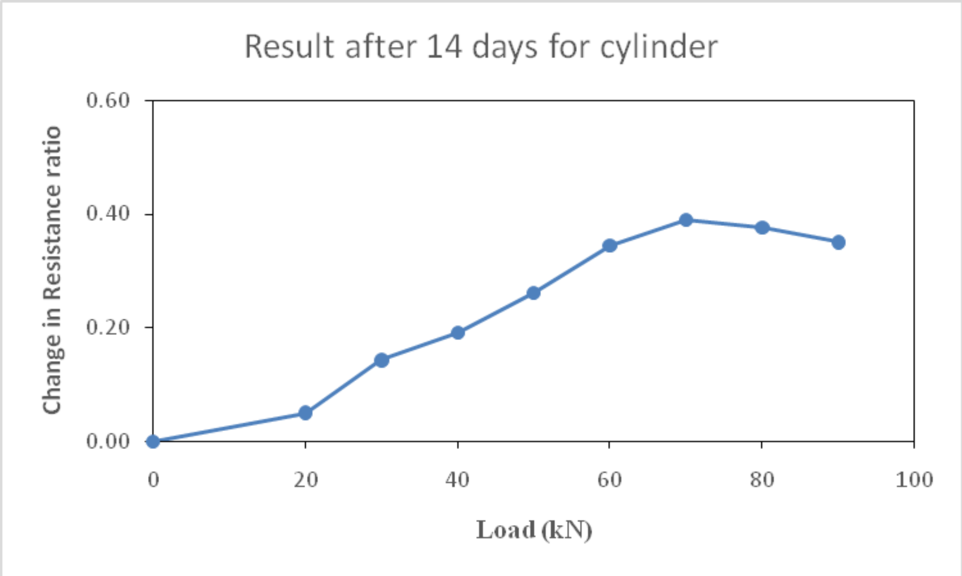

Fig 4.4: 14 days of cylinder

In above graph that we had plotted between load and change in resistance ratio. In cases when load is applied on block resistance ratio shows increment there slope value but at time crack there values will shows negative slope values. Hence, from graphwecanabletoknowthatwearegettingonlyoneminorcrackgeneratedat70kN may need repair in future.

4.3 **Results after 28 Days**

Here, we had tested the specimen i.e. cube and cylinder after 28 days curing using four-probe method that contains a Regulated power supply of current Voltmeter and Ammeter for detection on voltage and current. The test carried out under various loads under UTM400.

4.3.1. Result after 28 Days for Cube

Here, we had tested our specimen i.e. cube after 28days curing test was carried out under various loads under UTM400 whose reading are shown in Table 4.5.

Table 4.5: Result after 28 days for cube

S. No.	Load (kN)	Ammeter (mA)	Resistance $X10^3$	Change in resistance ratio $\Delta R= (Ri – Ro)/Ro$

1	0	7.89	1.267	0
2	20	7.53	1.328	0.048
3	40	7.11	1.406	0.1098
4	50	6.88	1.453	0.146
5	60	6.31	1.584	0.250
6	80	6.21	1.610	0.271
7	100	6.08	1.644	0.297
8	120	5.98	1.672	0.319
9	140	6.02	1.6	0.311
10	160	6.16	1.623	0.281
11	180	6.19	1.615	0.274

Fig 4.5 shows graphical representation of our result from which we came to about health condition of block at various load.

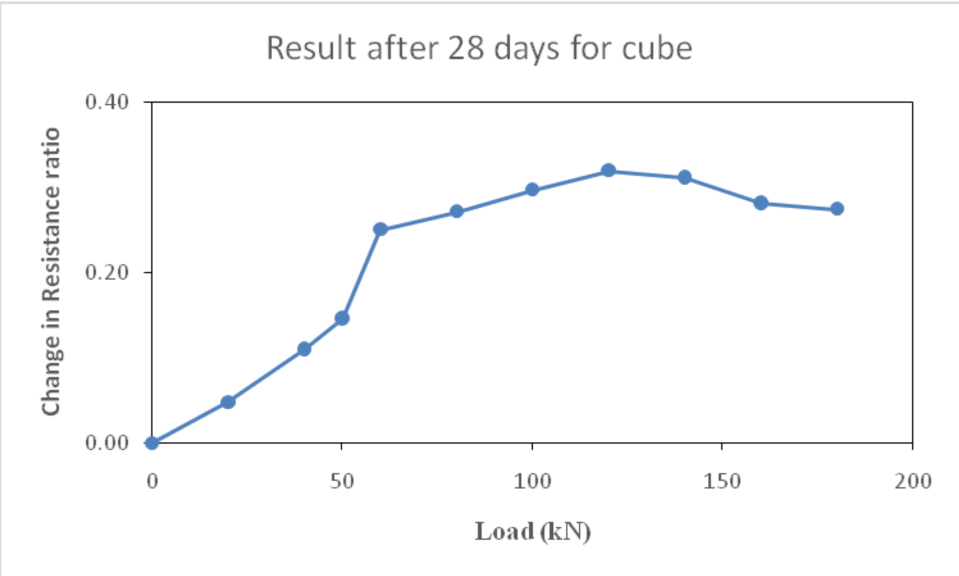

Fig 4.5: 28 days of cube

In above graph that we had plotted between load and change in resistance ratio. In cases when load is applied on block resistance ratio shows increment there slope value but at time crack there values will shows negative slope values. Hence from graph we can able to know that we are getting a Minor crack will generated after 120kN but not create problem

4.2.1 Result after 28 Days for cylinder

Here, we had tested our specimen i.e. cylinder after 28 days curing test was carried out under various loads under UTM400 whose reading are shown in Table 4.6.

Table 4.6: Result after 28 days for cylinder

S. No.	Load (kN)	Ammeter (mA)	Resistance X10^3	Change in resistance ratio ΔR= (Ri – Ro)/Ro
1	0	11.76	0.850	0
2	20	11.52	0.868	0.021
3	40	11.17	0.895	0.053
4	50	10.81	0.925	0.088
5	60	10.43	0.958	0.127
6	70	10.28	0.972	0.143
7	90	10.05	0.995	0.170
8	110	09.96	1.004	0.181
9	130	09.84	1.016	0.195
10	140	09.89	1.011	0.189
11	160	09.97	1.003	0.180
12	170	10.03	0.997	0.173

Fig 4.6 shows graphical representation of our result from which we came to about health condition of block at various load

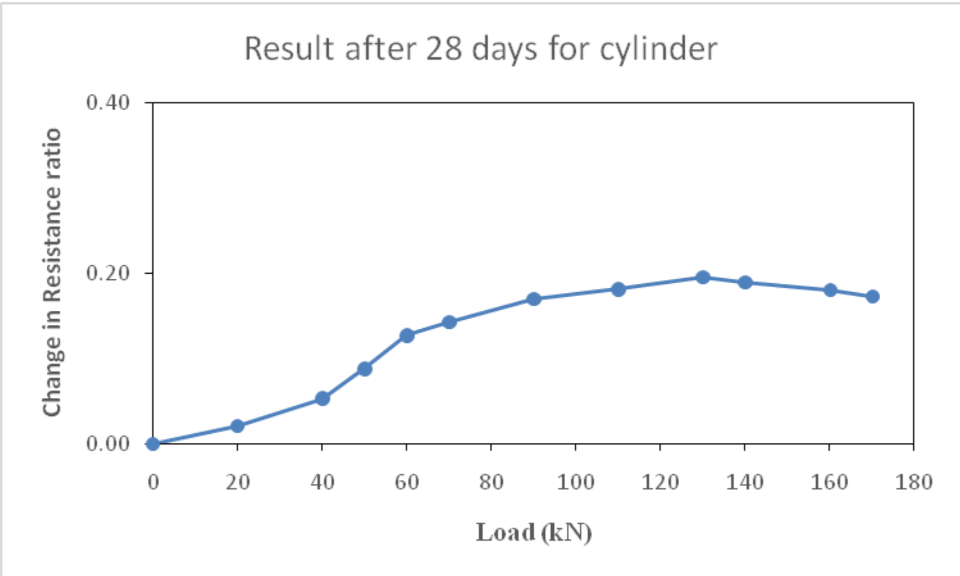

Fig 4.6: 28 days of cylinder

In above graph that we had plotted between load and change in resistance ratio. In cases when load is applied on block resistance ratio, shows increment slope value but at the time when crack appears the values will show negative slope values. Hence, from graph we are able to know that we are getting a minor crack which is generated after 130kN of load may need repair work in future.

5. CONCLUSION

We concluded that by adding only carbon fiber to our conventional concrete, this will save our structure from performing destructive test. We can identify the difference between minor and major crack, can also tell that which crack need urgent repair and which need repair in future. This may increase life span of structures like bridges, bridge collapse can be avoid which are not caused by natural disaster.

SCOPE

This concrete can be used in a frame structure in beams and columns for detecting the minor and major cracks without using any sensors. It will minimize the time required for evaluating the cracks in a structure and detect the area where urgent repair is needed to done to avoid any disaster in future. It may also will minimize the inspection cost we can observe each part of by sitting at a place.

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