Experimental Investigation on Self SensingConcrete Using Carbon Fiber

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Abstract: To find an easy method to health monitor structures. Self-sensing concrete (SSC) refers to a structural material that can monitor itself without the need of any embedded, attached or remote sensors. Self-sensing concrete has the capability to sense the conditions itself such as cracks, damage, strain, deformation etc. Self-sensing or smart behavior has been observed in concrete with the addition of small amount (0.5-5% by weight of cement) of short carbon fibers (5mm length). This method is developed which can be used in place of, often used strain gauge technique or fiber optic technique for health monitoring of structures. This study has been undertaken to investigate the mechanical properties (compression, tensile strength) in concrete. The preliminary test of cement and aggregates were done. Mix design is calculated as per the code IS 10262:2009. Compressive strength, tensile strength and Ultrasonic pulse velocity with and without functional fillers (carbon fiber) were measured. The results show that there is an increase in compressive, tensile strength of smart concrete as compared to conventional concrete.

Keywords: Self-sensing concrete, functional fillers (carbon fiber)

INTRODUCTION

Concrete is the worldwide most utilized construction material because of its very good performance, forming ability, long-term durability, and low costs. Concrete is a brittle material prone to cracking. Extensive cracking may impact durability and performance over time considerably. Concrete is the most acceptable construction material in the world. Since concrete is lack of some properties like low tensile strength, low post cracking capacity, brittleness, low ductility, limited fatigue life, not being capable of accommodating large deformations, low impact strength. The self-sensing concrete (SSC) refers to a structural material with the ability to sense such concrete conditions and environmental parameters as stress (or force), strain (or deformation), crack, damage, temperature, and humidity. This concrete is also called self-monitoring or self-diagnosing concrete. Recent advances in smart sensor technologies have provided various tools for structural health monitoring of civil engineering structures and introduced a concept of smart structures. At the early ages of concrete used for structural member, strength gain monitoring is important. Gaining information is useful in many cases to determine the readiness of the structures for service, such as determining the proper time of concrete mould removal or apply posttensioning forces in pre-stressed concrete. This concrete can sense itself, and hence there is no need of other external sensors or sensing materials. Concrete investigators agree that the strength of cement paste in concrete develops due to the hydration process via a series of consecutive In turn the mechanical properties of concretes are changed during this process. Conventional non destructive methods for estimating concrete strength such as ultrasonic pulse velocity can measure certain mechanical properties of the concrete indirectly from which information on the strength is derived. The important applications of self monitoring concrete is to detect the flaws and cracks in structure before its failure and to analyse the structure after subjected to dynamic loads.

OBJECTIVES

- To investigate the influence of carbon fibers on the concrete in compression and tension.
- To study the quality of concrete after adding carbon fiber.
- To determine the stress/strain behaviour of smart concrete by convenient method.

MATERIALS AND METHODOLOGY

Material used

- Cement: Cement is the most important binding ingredient which determines the fresh and hardened properties of concrete. Ordinary Portland cement of 53 grade confirming to IS 12269-1987 is used.

Table 1: Properties of Cement

Sl No	Properties	Values Obtained	Requirement as per IS 12269-1987
1	Specific Gravity	3.15	
2	Initial setting time	60 minutes	It should be more than 30 minutes
3	Final setting time	450 minutes	It should be less than 600 minutes
4	Fineness test	5%	It should be less than 10%
5	Consistency test	30%	It should varies between 25-35%

- **Fine Aggregate**: Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 4.75mm sieve and retain on 0.075mm sieve. Fine aggregates passing through 4.75mm sieve is used. Confirming to IS 383:1970.

Table 2: Properties of Fine Aggregates

Sl No	Properties	Values Obtained	Requirement as per IS 383-1970
1	Specific gravity	2.65	
2	Water absorption	2.5%	It should be less than 3%

- **Coarse Aggregate**: Coarse aggregates which are retained on 4.75mm sieve. Aggregate passing through 12mm sieve and retained on 10mm sieve are used. Confirming to IS 383:1970.

Table 3: Properties of Coarse Aggregate

Sl No	Properties	Values Obtained	Requirement as per IS 383-1970
1	Specific gravity	2.67	
2	Water absorption	0.5%	>2%

- **Water:** Those water utilized for both blending and curing might have been potablewater from that water-supply system framework.
- **Carbon Fiber :** Table 4: Properties of Carbon Fiber

Properties	Specification
Colour	Black
Length	6mm
Thickness	0.44mm
Tensile Strength	100MPa

- **Superplastizer:** Superplastizer used is Conplat SP430 to reduce water.
- **Methyl cellulose:** Methyl cellulose is a chemical compound derived from cellulose. Itis used as an admixture in cement paste. It is dispersion resistant agent for concrete. It isused to improve the bond strength between cement and reinforcement. Methyl cellulosehas got excellent thickening properties.
- **Silica Fume:** Densified silica fume with a specific gravity of 2.27 is used as a densifier as well as a dispersant.

Methodology

The constituent materials used were obtained locally and were Ordinary Portland Cement (OPC 53 Grade) , M-sand , coarse aggregate. Potable water was used for mixing and curing. The tests are carried out as per IS code.

Mix Design

M25 grade concrete was designed as per IS 10262-2009. Quantity of materials per cubic meterof concrete and dosages of carbon fibers used are listed in Table 5. A constant water cement ratio of 0.48 is used.

Table 5: Quantity of materials used per cubic meter of concrete

Contents	Values(kg/m^3)
Cement	360.42
Fine Aggregate(M-Sand)	691.9
Coarse Aggregate	1198
Water	173
Water cement ratio	0.48
Carbon Fiber	0% , 2% , 5% (by volume of concrete)
Silica Fume	0.3% (by weight of cement)
Methylcellulose	0.4%(by weight of cement)
Superplastizer	1.60

RESULTS

Compression test

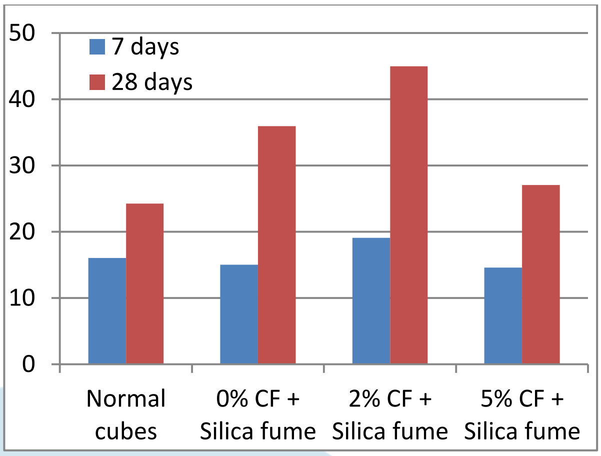
The cube specimens of size 150mm*150mm*150mm were casted for different dosages ofcarbon fibers of 0% , 2% , 5% . The results are tabulated in Table 6 and Chart 1.

Table 6 : Compression test results

Chart 1: Compression strength for different % of Carbon fiber

Specimens	Compression strength (N/mm^2)	
	7 days	28 days

Normal cubes	16.03	24.26
0% Carbon fiber +Silica fume	15.05	35.95
2% Carbon fiber +Silica fume	19.10	45.01
5% Carbon fiber +Silica fume	14.60	27.06



2% Carbon fiber with silica fume gives high strength compared to other specimens.


Figure 1 : compression test

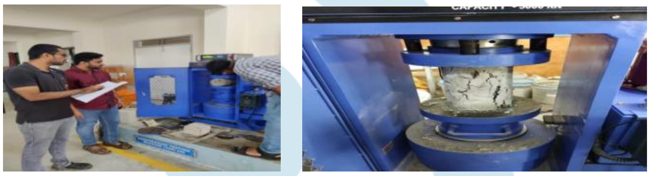


Figure 2: Tensile test

Tensile test: Cylindrical specimens of size 150mm diameter and 300mm length were casted for varyingdosages of carbon fiber 0%, 2%, 5%. The test results are tabulated in Table 7 and Chart 2.

Chart 2 : Tensile Strength for different % of Carbon fiber

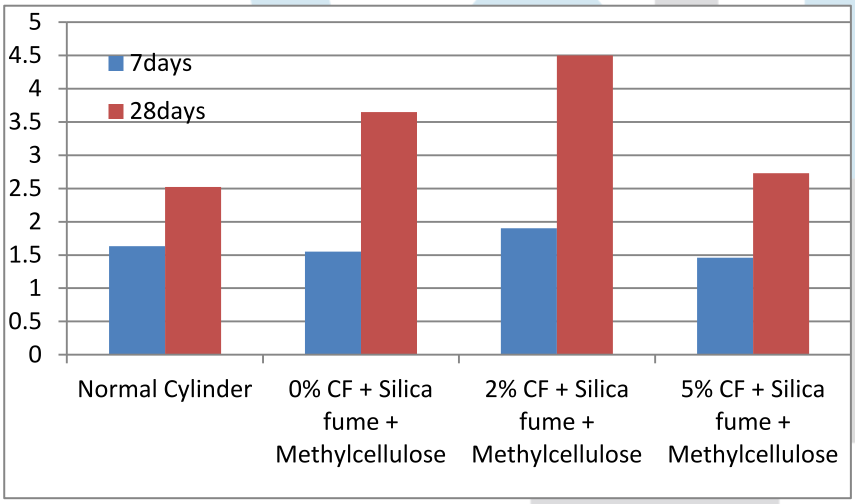


Table 7: Tensile test results

Specimens	Tensile Strength , N/mm^2	
	7 Days	**28 Days**
Normal cylindre	1.63	2.52
0% CF + Silica fume + Methylcellulose	1.55	3.65
2%% CF + Silica fume + Methylcellulose	1.90	4.5
5%% CF + Silica fume + Methylcellulose	1.44	2.73

2% Carbon fiber with Silica fume and Methyl cellulose gives high tensile strength compared to other specimens

Ultrasonic Pulse Velocity test

When mechanical impulses are applied to a solid mass, three different kinds of waves are generated. These are known as longitudinal waves, shear waves and surface waves. These waves travel at different speeds. The velocity of these waves gives the characteristics of thegiven specimen. The test results of UPV are tabulated in Table 8.

Specimens	**Velocity , m/sec**	**Quality of Concrete**
Normal cube	4242	Good
0% Carbon fiber + Silica fume	3990	Good
2% Carbon fiber + Silica fume	3580	Good
5% Carbon fiber + Silica fume	4210	Good
0% CF + Silica fume + Methylcellulose	4310	Good
2%% CF + Silica fume +Methylcellulose	3740	Good
5%% CF + Silica fume +Methylcellulose	3860	Good

Table 8: UPV Test Results

It is found that all the specimens are in appropriate values and the quality of specimens aregood.
From the experimental studies it is observed that concrete with carbon fiber have highest strength in compression such that 2% carbon fiber with silica fume mix is preferred as a smart material.

Stress –Strain behaviour of Smart material with Nominal cubes

Table 9 : Stress-Strain behaviour of nominal cubes

Load , KN	Deformation, mm	Stress, N/mm^2	Strain
50	1.9	2.23	0.987
100	3.35	4.45	0.977
150	4.60	6.67	0.969
200	7.55	8.89	0.949
250	12.3	11.12	0.918
300	14.0	13.34	0.906
350	16.9	15.56	0.887
400	18.6	17.78	0.876
450	22.5	20	0.85
500	24.8	22.24	0.834
Ultimate Breaking Load = 536KN			

Table 10 : Stress- Strain behaviour of Smart material

Load , KN	Deformation , mm	Stress , N/mm^2	Strain
100	5.2	4.45	0.965
200	8.65	8.89	0.942
300	12.1	13.34	0.919
400	16.4	17.78	0.890
500	21.1	22.24	0.859
600	26.5	26.66	0.823
700	29.9	31.12	0.800
800	33.2	35.56	0.778
900	38.0	40	0.746
1000	46.2	44.45	0.692
Ultimate Breaking Load = 1013.5KN			

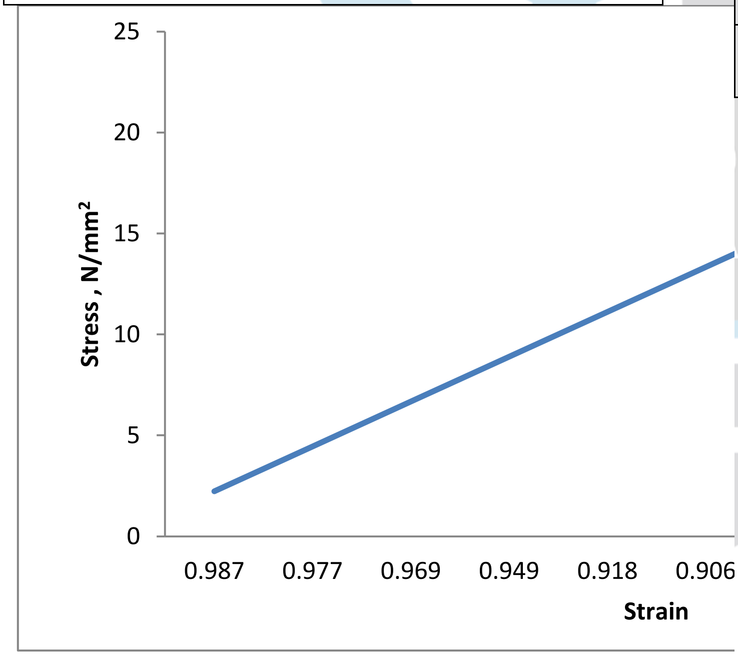


Chart 3 : Stress – Strain curve for Nominal cubes

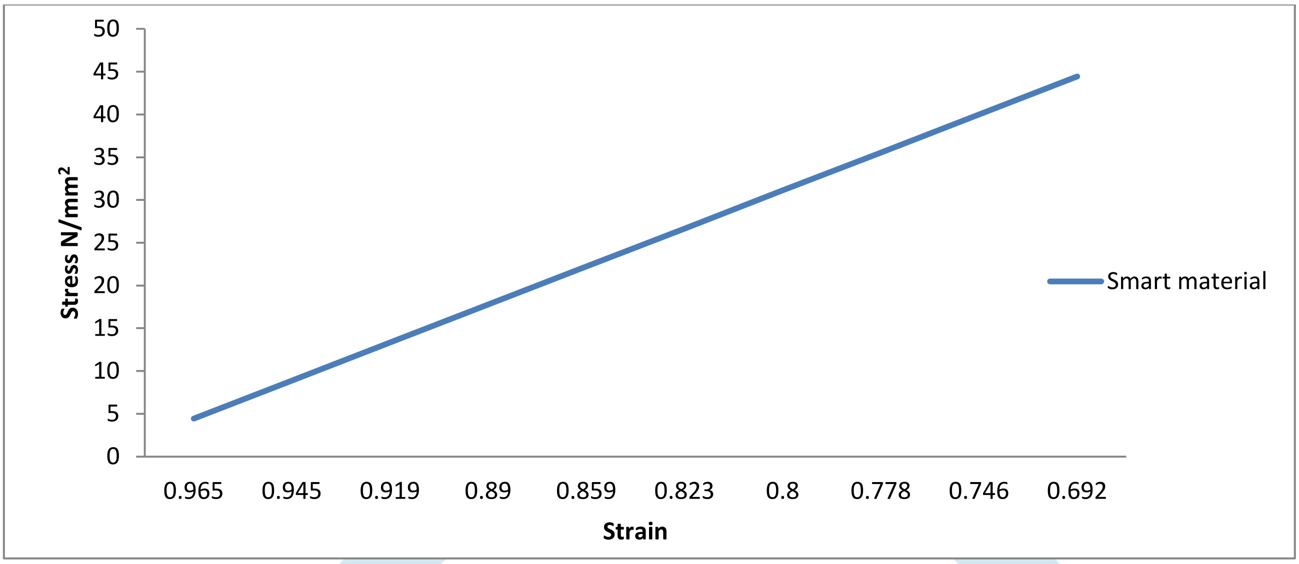


Chart 4 : Stress v/s Strain curve for Smart material

CONCLUSION

Smart concrete is stronger than conventional concrete by the use of carbon fiber.It takes greater force for smart concrete to bend or break, and it absorbs more energy before fracture.Even by adding carbon fibers, the extra cost of material will increase about 30%, this expense is still significantly less than attaching or embedding sensors into structure. Monitoring can be a real time and continuous effort.

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