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Mechanical Behavior of Strain Hardening Cement Based Composite Concrete

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***Abstract:** In this research work we had to enhance the compressive as well as tensile strength of concrete with retrofitting method using the SHCC (strain hardening cement based composite). There are two critical issues with this type of cement replacement i.e. the changes in physical properties of concrete with respect to compressive, tensile strength and cost analysis of alternatives. The first stage of this research looks at the change in physical properties of concrete when cement is replaced by PVA fiber with respect to compressive strength and tensile strength. The result from this research shows a linear diminution in strength with linear increase in the relative %age of PVA fiber to cement. A traditional cost analysis looks only at the first or construction cost without considering the long-term cost to palliate for the increased global warming emission resulting from the manufacturing process of Portland cement.*

Experiments were performed on concrete mixtures with varying PVA fiber contents in concrete i.e. 0%, 1%, 2%, 3%, 6% and 9%. For SHCC the cubes specimens of size (150mmx150mmx150mm) with mild steel rods were used to early setting and hardening. We have to check the compressive strength at 3days, 7days and 28days and Tensile Strength at 28 days after the curing of sample.

***Keywords:** PVA Fiber, SHCC, Compressive Strength, Tensile Strength*

I. INTRODUCTION

A structure is supposing various loads like wind, seismic, dead load, live load etc. The reinforced concrete (RC) structures lying in the seismic zones are still being designed only for gravity loads. The conventional approach to earthquake resistant design of buildings depends upon the strength, durability, stiffness and inelastic deformation. In most cases, those structures are highly vulnerable to any moderate or major earthquake. Along with the seismic prone zones like Himalayan region in India, Iran, Turkey, New Zealand and fault regions in US etc., devastations from earthquake have also been seen at the places believed to be seismically not-so-active. We have to provide the retrofitting and strain hardening to the concrete to enhance the compressive strength and tensile strength of concrete structure as to make it less unviable to earthquakes.

The PVA fiber has the different properties and it is used in papermaking, construction, textiles, and variety of coating. PVA fiber has got wide acceptance as a less hazardous and reasonable cost alternative. In recent years, new type of PVA fiber for high performance fiber reinforced cementitious composites (HPFRCC) has been developed owing to development of theoretical study based on micromechanics. This fiber also starts to use widely because of its suitable characteristics for reinforcing cementitious composites.

Strain-hardening cement based composites, which are a type of fiber-reinforced cementations compositesare known as engineered cementitious composite (ECC).For strain hardening cement composite, we have to use the low fiber of 1% to 3% and check the compressive strength of the materials. SHCC is designed for the maximum compressive strength of 60 MPa and the tensile strength is about 3 to 6±0.3 MPa.The high ductility and strain capacity of SHCC is dependent upon the cement.The SHCC has the excellent mechanical strain hardening and multiple fine cracks. The strain hardening behavior improve the durability of concrete structure and multiple fine cracks enhance the performance of structure.

These properties are due largely to the interaction between the fibers and cementing matrix, which can be custom-tailored through micromechanics design.SHCC mixture are energy intensive. They require the more cement for increase the bond strength in the absence of coarse aggregates in mix design.For SHCC containing a combination of Portland cement 30% by mass and fly ash is 70% of mass, utilized as a binder. Super plasticizer and viscosity agent also used in SHCC for adjust its rheological properties. PVA fiber is about 2.25% by volume. And length of the fiber is 12 mm. The fine aggregates sizes should be 0.06 mm to 0.20 mm.

II. LITERATURE REVIEW

Dr.M.Devi (2017) This paper present data to support the argument that polyvinyl alcohol fiberreinforced concrete is an ideal material for achieving these goals. The research also discusses polyvinyl alcohol fiber reinforced concrete materials properties and mix design. The PVA fiber will be added to the conventional concrete 0%, 0.1%, 0.2%, 0.3% and 0.4% by its cement weight. The optimum level of PVA fiber was determined as0.3 based on the compressive strength, split tensile strength and modulus of rupture. The beam was casted with size of 125X150X1800mm with 0.3% of PVA Fiber. Then the flexural behavior was studied and compared with conventional concrete.

Magalhaes et al (2015) The study showed that temperature affects the mechanical properties of SHCC after exposure to temperatures up to 250°C. The deterioration of the composite was observed in terms of reduced stiffness, tensile strength, ductility and several changes in the cracking pattern. At 90°C the residual tensile properties are slightly altered. However, the toughness and crack density were reduced as compared to unheated specimens due to changes in fiber microstructure. Heating to 110°C showed similar tendencies as specimens heated to 145°C. However, the specimens exhibited only one single crack and the maximum post-cracking tensile stress, strain capacity and toughness were strongly reduced, while the first-cracking strength was slightly increased. At temperatures of 250°C the composite loses load-bearing capacity in the post-cracking stage, due to the melting and decomposition of PVA fiber.

In this case, the composite is therefore considered to be a quasi-brittle material with strain softening behavior with reduced strain capacity (about 92%), toughness and post-cracking tensile stress. Regarding the bending performance, the tendency was similar as reported in tensile tests.

The results also indicated that there are relatively good correlations between the results of bending and uniaxial tension tests. Compressive strength of the composite has indicated an increase up to 190°C due to a refinement of the matrix pore structure as indicated by the micro structural studies.

Slowik et al (2015) preformed comparative mechanical tests on Strain hardening cement based composite in laboratories. The purpose was to investigate and compare the crack patterns in terms of crack widths and spacing. The procedure was to use a base SHCC mix with 2 % by volume polyvinyl alcohol (PVA) short fibre for prepare the specimens. Finally, two types of SHCC were tested. One containing containing sand aggregate with maximum particle size less than 0.3 mm, and other prepared with coarse sand SHCC. Uniaxial tension tests on the specimens in setups developed by the laboratory. Suggested strain levels were 0.2, 0.5, 1 %, and subsequent 0.5 % intervals up to ultimate tensile strain. SHCC can be prepared from natural sand containing particles of size up to 1–1.2 mm, although a lower ductility and lower ultimate tensile strength than for specimens containing only fine sand with maximum particle size 0.2–0.3 mm have been found and the average crack width is stabilized in the range of 40–80 um for a large range in tensile deformation, the maximum crack width may exceed 100 um at a strain of 0.5 %, and reach beyond 200 and 250 um at strains of 2 and 3 %, respectively. Crack spacing appears to stabilize at roughly 3% average tensile strain for the SHCC tested here.

Ming Kun Yew (2014)This paper presents the effects of low volume fraction (Vf) of polyvinyl alcohol (PVA) fibers on the mechanical properties of oil palm shell (OPS) high strength lightweight concrete mixtures. The slump, density, compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity under various curing conditions have been measured and evaluated. The results indicate that an increase in PVA fibers decreases the workability of the concrete and decreases the density slightly. The 28-day compressive strength of oil palm shell fiber-reinforced concrete (OPSFRC) high strength lightweight concrete (HSLWC) subject to continuous moist curing was within the range of 43–49MPa.The average modulus of elasticity (E) value is found to be 16.1 GPa for all mixes, which is higher than that reported in previous studies and is within the range of normal weight concrete. Hence, the findings of this study revealed that the PVA fibers can be used as an alternative material to enhance the properties of OPS HSLWC for building and construction applications.

III.MATERIAL AND METHODOLOGY

The aim of this work is to optimize the mixture proportions for SHCC using various and cementitious materials. For the fresh state of SHCC, it must possess flow flowability, consistency and density while avoiding heavy bleeding as well as any significant segregation.

The objective for the developed mix with sufficient compressive and tensile strength suggested by the guidelines for strain hardening cement based composite An effort has been made to generate a mix of SHCC made by replacing building materials with industrial by-products.

A. PVA Fiber

This special type of fiber has been used in study. The abbreviation of PVA is polyvinyl alcohol fiber. It is also known as the Poval. PVA fiber has the idealized formula [CH2CH(OH)]n. The PVA fiber has the different properties and it is used in papermaking, construction, textiles, and variety of coating. PVA other names is PVOH, Poly(Ethenol), Ethenol, Homopolymer, Gelvatol, Lemol, Mowiol, Nelfilcon A, Polyviol, Vinol, Alvyl, Alcotex, Covol, Mowiflex, Alcotex, Elvanol, and Rhodoviol.Polyvinyl alcohol fiber or PVA is water soluble – soluble synthetic polymer. PVA fiber is designed for concrete products for purpose of controlling thermal cracking, plastic shrinkage, enhances durability, toughness excellent and improving abrasion resistance. When it added to mortar or concrete then the fiber develop the chemical and molecular bond with the cement during hydration that is 300% greater than other fiber. If the composition of PVA fiber is reinforced cement based is optimized, strain hardening and strain capacity of up to 6% can be reached.

Figure 3.1 PVA fiber used in study Trade names of Polyvinyl Alcohol

B. Cement

Cement is a binder that used in construction. Cement binds the other materials together. when cement used with fine aggregates it produce mortar and when used sand, fine aggregates and coarse aggregates it produces concrete. Portland cement is the most common type of cement used widely across the world. Ordinary Portland cement (OPC) of 43 grades was used in the course of investigation.

C. Coarse Aggregates

Coarse aggregates are particles are greater than 4.75mm, but the generally range between 9.5mm to 37.5mm in diameter. Aggregates are the important constituents of the concrete, which give body to the concrete and reduce the shrinkage. Aggregates occupy 70 to 80% of total volume of concrete. Aggregates are derived from naturally occurring rocks by blasting or crushing etc. so it is impossible to obtain required shape of aggregates. Shape of the aggregates is affecting the workability of the concrete. Increase the volume of concrete, thus reduces the cost and Provide dimensional stability.

D. Fine Aggregates

A fine aggregate is basically sand found from the land or the marine environment. Fine aggregates consist of natural sand and crushed stone and the most of particles passing through a 4.5mm sieve and 0 to 15% passes 150 micron IS sieve depending upon its grading zone.An important factor considered to control the behavior of SHCC is the type and size of fine aggregates used in the mix. Fine aggregates were used in oven dry condition to check the change in moisture content of sand due to various environmental factors. Sand was classified as fine sand. The sand was having grain size less than 300 um where used in the study.

E. MIX design: M20 Concrete (IS 10262:2009)

Mix design is a process of selecting ingredient and determining their relative proportion with the objective of producing concrete having suitable workability, durability and strength as economically as possible. Mix design can be in two ways. First is nominal mix and other is design mix. We proceed with the design of M20 grade using 43 grade OPC.

Table 3.5 Composition by weight of ingredients used in study

Samples	Designation	Cement (kg)	Fine aggregates (kg)	Coarse Aggregates(kg)	PVA fiber(kg)
CL-0	100% Cement	1	1.89	2.87	0
CL-1	Cement 99%, Fiber 1%	0.99	1.89	2.87	0.01
CL-2	Cement 98%, Fiber 2%	0.98	1.89	2.87	0.02
CL-3	Cement 97%,Fiber 3%	0.97	1.89	2.87	0.03
CL-6	Cement 94%, Fiber 6%	0.94	1.89	2.87	0.06
CL-9	Cement 91%, Fiber 9%	0.91	1.89	2.87	0.09

IV.CONCLUSIONS

The In this chapter, we discuss the result obtained by carrying out compressive strength and Tensile Strength on PVA fiber concrete. Various specimens are tested to determine the compressive strength and tensile strength of concrete with varying amount of polyvinyl alcohol fiber (PVA). We had to used the compressive test machine for compressive strength test and Universal Testing Machine (UTM) for tensile strength test. It includes the test results of SHCC control mix C1 (0% PVA, C2 (1% PVA), C3 (2% PVA), C4 (3% PVA), C5 (6%), C6(9% PVA) used in the concrete mix.In order to achieve the objective of study for the development of SHCC, an experimental program making use of various industrial by-products and evaluate their effect on the behavior of SHCC to determine the best proportion of materials that can provide the enhanced properties.

A. Compressive Strength

The test was conducted on CL0, CL1,CL2, CL3, CL6, and CL9 control mix of SHCC and tested for compressive strength. In compressive strength test, we have to test the specimens after the curing of 3 days, 7 days and 28 days. We are using the three specimens for each percentage of polyvinyl alcohol fiber (PVA). Compressive strength of the different samples were measured as shown in the Table 5.1

Table 4.1 Compressive strength variation at 3, 7 and 28 days

S No	Mix Designation	Compressive strength (MPa) at3 days	Compressive strength (MPa) at 7days	Compressive strength (MPa) at 28 days
1	CL0	9.20	15.91	20.50
2	CL1	10.40	17.00	26.70
3	CL2	10.20	13.77	18.50
4	CL3	10.00	13.40	16.80
5	CL6	6.44	12.14	12.59
6	CL9	6.00	8.22	10.66

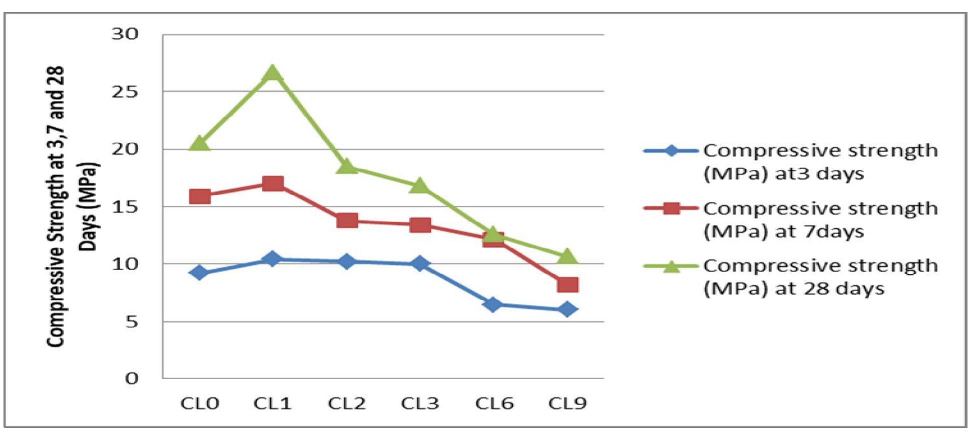

Figure No 4.1: Graphical representation of Compressive strength at 3, 7 and 28 days (MPa)

B. Tensile Strength Test

The test was conducted on C1, C2, C3, C4, C5 and C6 control mix of SHCC and also the replacements of polyvinyl alcohol fiber in increment of 0%, 1%, 2%, 3%, 6% and 9% were tested for tensile strength. The tensile strength of the different samples were measured as shown in the Table 5.3

Table 4.2 Tensile strength variation in 28 days

S No	Mix Designation	Tensile strength (MPa)
1	CL0	1.70
2	CL1	4.10
3	CL2	3.32
4	CL3	2.90
5	CL6	1.90
6	CL9	1.10

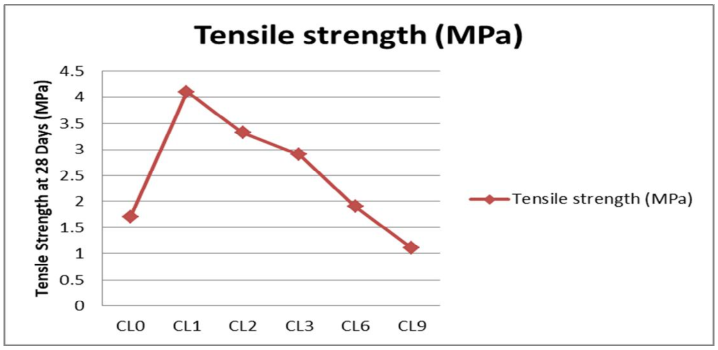

Figure No. 4.2; Graphical Representation of Tensile Strength at 28 Days (MPa)

V. CONCLUSION

A. Compressive Strength Result

1) The addition of PVA fibers from 0%, 1%, 2% to 3%, 6% and 9% in SHCC mixes by volume showed increases the compressive strength of the mix after the curing of 28 days.
2) With the addition of polyvinyl alcohol fiber leads to increase in compressive strength and tensile strength with age and with increase of PVA fiber content up to 1% or 2% only compare to control concrete at 28 days.
3) Higher the volume of polyvinyl alcohol (PVA) percentage fiber in cement based on composite the value in compressive strength test is decreasing after 1% by weight of cement.
4) The value of compressive strength at 28 days is 26.70 MPa for 1% PVA fiber by weight of cement.
5) The percentage increase of compressive strength from 3 days to 7 days is 63.46% and from 7 days to 28 days is 57%.
6) In strain hardening, cement composite(SHCC) is only 1% of PVA fiber to gain the higher compressive strength as compare to other percentage of PVA fiber.
7) After addition of PVA fiber in concrete mix a significant increase in workability can be achieved.
8) Higher the percentages of PVA fiber in specimens it will be decrease the workability.

The supplementary cementitious material plays a significant role in increasing the flow ability of the SHCC mixes

B. Tensile Strength Result

1) We had to conclude that the tensile strength is also give the maximum strength at the 1% of fiber used in SHCC. The value of tensile strength is 4.1 Mpa after the 28 days.
2) The increase parentage of tensile strength from varying PVA fiber 0% to 1% is 98% after 28 days. It means to get the good tensile strength at only 1%.
3) When increases the percentages of PVA fiber is more than 1% or 2% then tensile strength is decreases.
4) More than 1% polyvinyl alcohol fiber is used in SHCC, lower the value of tensile strength.
5) Higher the percentages of PVA fiber in specimens it will be decrease the workability.

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