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Experimental Study to Enhance Mechanical Strength Properties of Cement Concrete with Fly Ash and Natural Fibers

S. Vijayabaskaran[1*], A. Anandraj[2]
[1]Assistant Professor, Saranathan College of Engineering, Tiruchirappalli-1, Tamilnadu, India
[2]Assistant Professor, Saranathan College of Engineering, Tiruchirappalli-1, Tamilnadu, India

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***Corresponding author**
S. Vijayabaskaran

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Abstract: The production and consumption of building materials have increased to leaps and bounds in the past few decades due to tremendous increase in population. As the production of building materials gets increased, generation of waste materials such as fibers, granules, ashes, effluents etc. also gets increased. Nowadays wastes of different types are being used effectively in concrete either partially and fully which helps in making of green concrete. Fiber reinforced concrete is a special type of concrete in which natural or synthetic fibers with different aspect ratios are used to eliminate or reduce crack formation and to improve various mechanical strength properties when mixed along with fly ash, silica fumes etc. in optimal dosages. In order to study the influence of waste on various strength properties of cement concrete, different dosages of cement are replaced with fly ash and also with coconut fiber or wollastonite fiber were added. The compressive strength, split tensile strength and flexural strength were experimentally evaluated and modulus of elasticity was empirically determined. Based on the test results, the concrete with 20% replacement of cement with fly ash and fiber revealed effective results when compared to concrete without fiber. Coconut fiber along with minimum dosages of fly ash has greatly improved the flexural strength on the other hand it reduces other mechanical properties at higher dosages. Combination of Wollastonite fiber with fly ash helps in the improvement of overall mechanical strength of cement concrete.
Keywords: Cement Concrete, Fly ash, Coconut fiber, Wollastonite fiber, Mechanical strength.

INTRODUCTION

Plain cement concrete is regarded as a brittle material; hence it is significant to apply additive materials to the mixture that can enhance the ductility property [1]. While fibers are mixed with concrete, the brittleness of the concrete decreases appreciably, and under specific type of loads, especially the tensile loads, the concrete reaction will be more ductile [2]. Fiber-reinforced cement concrete is defined as concrete combining cement, aggregates, water and fibers (either natural or synthetic) [3]. It may also have other cementitious materials and/or chemical additives for definite design purposes. Various types of artificial and natural fibers are utilized to obtain different cement concrete mixes [4]. Mandatory improvement in concrete qualities is feasible when different fibers such as coconut fibers, wollastonite fibers are added in optimum dosages in concrete mix [5]. This research provides the experimental values acquired for the overall mechanical strength properties of cement concrete with Class F fly ash, Coconut fibers and Wollastonite fibers.

EXPERIMENTAL PROGRAM

A conventional concrete mix (CCM) with grade M 20 was designed as per IS 10262:2009 [6]. The conventional cement concrete mix consist of cement type Ordinary Portland Cement (OPC) 53 grade conforming to IS 12269:1987 [7]. Fine aggregate (River sand with size 1-4 mm) and two sorts of coarse aggregate (River gravel 5-9 mm and 10-20 mm) [8].

The Class F fly ash used in this research was obtained from Dalmia cements, Ariyalur, Tamilnadu, India. The above stated Class F fly ash was used at varying percentages from 10% to 40% as substitution of cement. The properties of fly ash were, Colour: Dark grey, Texture: Sandy silt, Specific gravity: 1.92, Spherical particles of diameter: 0.05-360 micro meter, Specific Area: 520-560 m^2/kg and chemical content of Si (20.3%), C (18.7%), Al(15.6%),etc. Coconut fiber and Wollastonite fiber each of length 50 mm in a dosage of 0.25% of volume-weight were used in the mix [9].

CCM-F1a to CCM-F4a in the Table 1 represents samples with fly ash. CCM-FC1b to CCM-FC4b in the Table 1 represents samples with fly ash with Coconut fibers. CCM-FW1c to CCM-FW4c in the Table 1 represents samples with fly ash with Wollastonite fibers.

Compressive strength on cube samples 150mm x 150mm size on 3 samples was experimentally evaluated for 28 days. Split tensile strength on cylinder samples 150mm x 300mm on 3 samples was experimentally evaluated for 28 days. Flexural strength on prismatic samples 100mm x 100mm x 500mm on 3 samples was experimentally evaluated for 28 days according to standard codal provisions [10].

RESULTS AND DISCUSSIONS

Experimental investigation results on hardened fly ash concrete with fibers were presented in Table 1. The densities of all cement concrete mixes with fly ash and fibers are greater than 2200 kg/m^3 [11].

Table-1: Material Proportions, Characteristics and Mechanical Strength properties of Fly Ash Concrete with Fibers

Sample	Material Proportions						Addition			σ_C	σ_T	σ_F	E
	Cement (Kg/m^3)	River Aggregates 1-4 (mm)	River Aggregates 5-9 (mm)	River Aggregates 10-20 (mm)	Water (Kg/m^3)	W/C W/C + FA	FA (%)	Fibers Dosage (%)	Fibers Length (mm)	(MPa)	(MPa)	(MPa)	(10^4) (MPa)
CCM	413	696	400	1029	186	0.45	-	-	-	28.26	2.17	3.18	2.66
CCM - F1a	371	696	400	1029	186	0.45	10	-	-	24.52	1.74	2.87	2.47
CCM - FC1b	371	696	400	1029	186	0.45	10	0.25	30	26.71	1.97	2.32	2.58
CCM - FW1c	371	696	400	1029	186	0.45	10	0.25	10	27.47	2.08	3.09	2.62
CCM - F2a	330	696	400	1029	186	0.45	20	-	-	25.38	2.32	2.98	2.51
CCM - FC2b	330	696	400	1029	186	0.45	20	0.25	30	27.41	2.36	2.74	2.61
CCM - FW2c	330	696	400	1029	186	0.45	20	0.25	10	34.94	2.53	2.63	2.95
CCM - F3a	289	696	400	1029	186	0.45	30	-	-	20.32	1.93	2.06	2.25
CCM - FC3b	289	696	400	1029	186	0.45	30	0.25	30	24.28	2.26	1.92	2.46
CCM - FW3c	289	696	400	1029	186	0.45	30	0.25	10	26.63	2.53	2.68	2.58
CCM - F4a	247	696	400	1029	186	0.45	40	-	-	17.82	1.44	1.83	2.11
CCM - FC4b	247	696	400	1029	186	0.45	40	0.25	30	16.48	1.72	2.08	2.02
CCM - FW4c	247	696	400	1029	186	0.45	40	0.25	10	21.02	2.02	2.32	2.29

Compressive Strength

The compressive strength of cement concrete with higher values of fly ash gets reduced when compared with conventional cement concrete mix [12]. The maximum value of compressive strength was obtained when cement was replaced with 20% of fly ash with both coconut fiber and wollastonite fiber. Similarly there was a drastic reduction in the compressive strength when the cement content was replaced with fly ash at 40%. The compressive strength of cement concrete mix with fly ash and coconut fiber was found to be greater at 20%. When cement concrete was mixed with 0.25% wollastonite fiber and 20% fly ash, the value of Compressive strength so obtained is found to be enhanced by 23.64%.

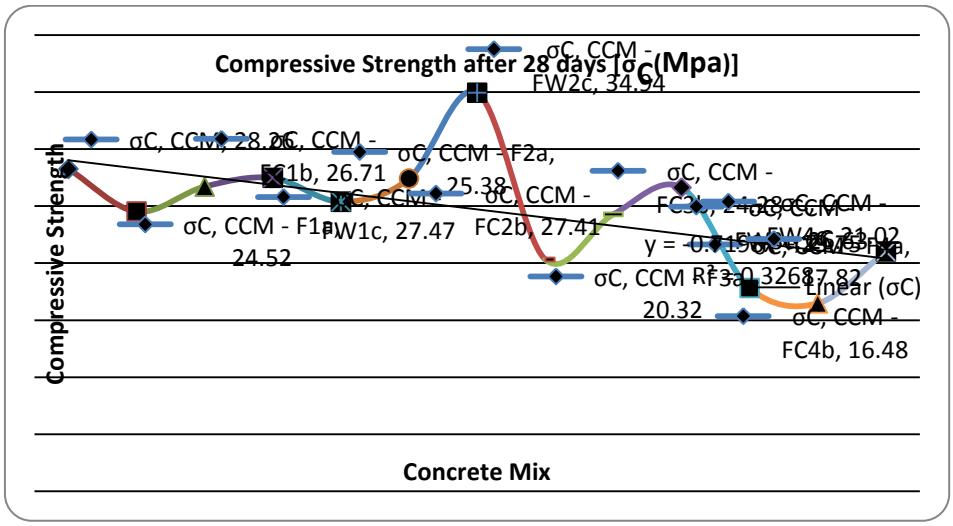

Fig-1: Compressive strength values of various concrete mixes

Split Tensile Strength

The values of split tensile strength was found to have a steady increase from 10% to 30% and the highest value of split tensile strength was obtained with 0.25% Wollastonite fiber and 30% fly ash in conventional cement concrete mix. It was also noticed that when the fly ash content was more than 30 % it followed a steep reduction in split tensile strength of concrete [13]. When cement concrete was mixed with 0.25% wollastonite fiber and 30% fly ash, the value of split tensile strength so obtained is found to be increased by 19.82%.

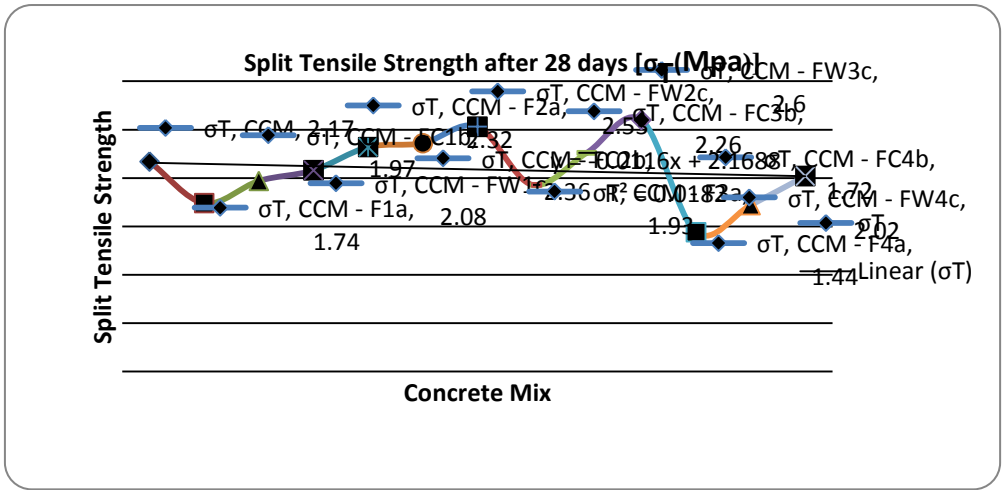

Fig-2: Split Tensile strength values of various concrete mixes

Flexural Strength

From the experimental investigation, the value of Flexural strength was obtained for conventional cement concrete mix without the addition of fly ash and fibers. When cement concrete was mixed with 0.25% wollastonite fiber and 20% fly ash, the value of Flexural strength so obtained is found to be enhanced by 7.55%. When the proportions of fly ash with both wollastonite and coconut fibers is increased it showed a gradual fluctuation in flexural strength of cement concrete [14].

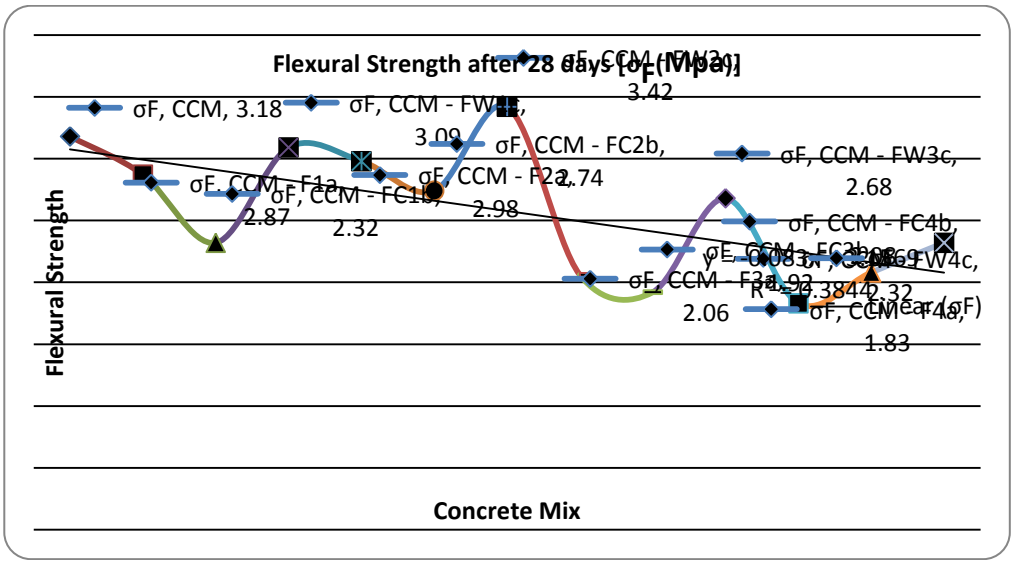

Fig-3: Flexural strength values of various concrete mixes

Modulus of Elasticity

Concrete is a material which is very good in compression but weak in tension [15]. The modulus of elasticity of concrete is a parameter which largely depends on the material properties of cement, aggregate and their comparative proportions [16]. Because of non-linear behavior of concrete it is very difficult to determine the modulus of elasticity value for concrete. Based on codal provisions given in IS 456:2000 the value of modulus of elasticity can be empirically determined by using the formula $E = 5000\sqrt{\sigma_c}$. When cement concrete was mixed with 0.25% wollastonite fiber and 20% fly ash, the value of modulus of elasticity so obtained is found to be improved by 11.32%.

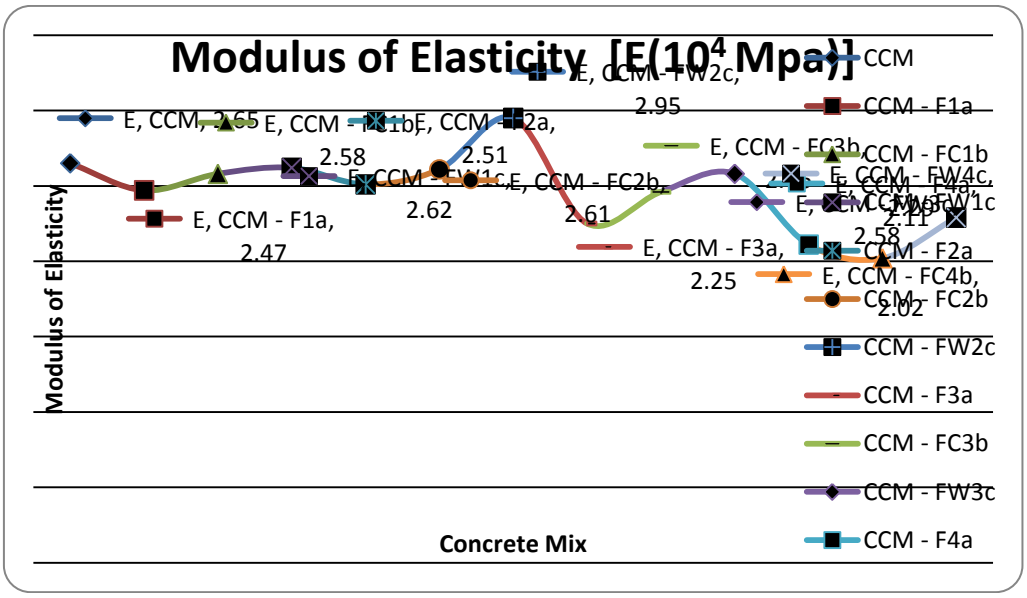

Fig-4: Modulus of Elasticity values of various concrete mixes

CONCLUSIONS

General

Concrete is a brittle material which shows formation of hairline cracks in the initial period of curing [17]. If the above problem is not addressed well then it may lead to pre mature collapse of the structural elements made with concrete. In order to reduce this set back improvement of ductility property of concrete becomes need of the hour [18]. In this research an attempt was made to improve the ductility and other mechanical properties of concrete by incorporating two different natural fibers, Coconut fiber and wollastonite fiber with 0.25% proportions and varying fly ash content from 10% to 40%. Since there is a partial replacement of fly ash in place of cement and usage of

natural fibers, the concrete comes under "Green Concrete".

Specific Findings

- The value of Compressive Strength, when cement concrete was mixed with 0.25% wollastonite fiber and 20% fly ash is found to be enhanced by 23.64%.
- The value of Split tensile Strength, when cement concrete was mixed with 0.25% wollastonite fiber and 30% fly ash is found to be increased by 19.82%.
- The value of Flexural Strength, when cement concrete was mixed with 0.25% wollastonite fiber and 20% fly ash is found to be enhanced by 7.55%.
- The value of Modulus of elasticity, when cement concrete was mixed with 0.25% wollastonite fiber and 20% fly ash is found to be improved by 11.32%.

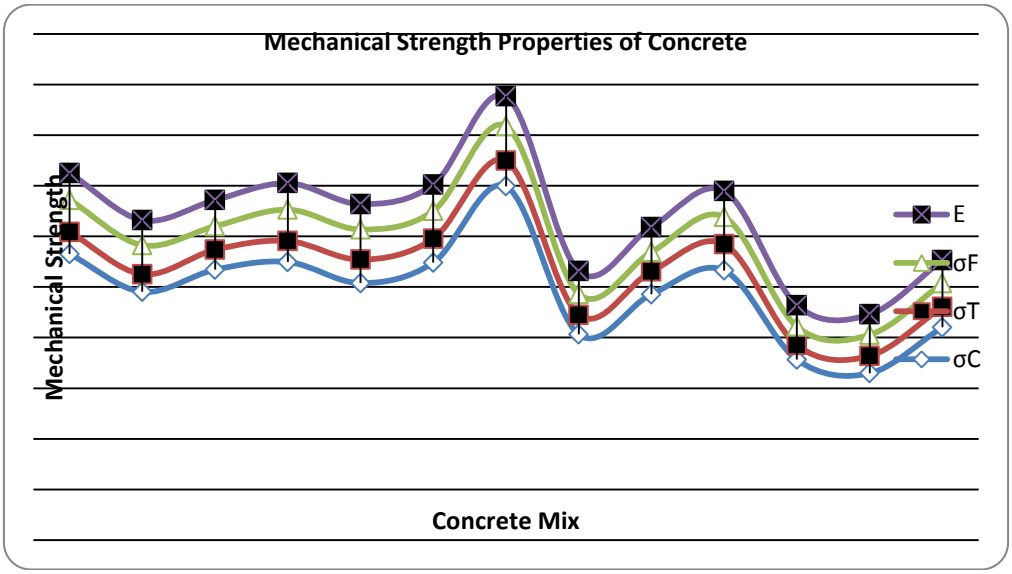

Fig-5: Mechanical Strength values of various concrete mixes

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