Experimental Investigation on Performance of Steel Fiber Reinforced Self Compacting Concrete by Partial Replacement of Cement with Lime Sludge

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Abstract

Over 300 million tones of industrial wastes are being produced per annum by chemical and agricultural process in India. These materials pose problems of disposal and health hazards. The wastes like phosphogypsum, fluorogypsum and red mud contain obnoxious impurities which adversely affect the strength and other properties of building materials based on them. Paper making generally produces a large amount of solid waste. Paper fibers can be recycled only a limited number of times before they become too short or weak to make high quality paper. This paper mill sludge consumes a large percentage of local landfill space for each and every year. Fiber reinforced concrete becomes an option whenever durability (limited crack widths) or safety considerations are design criteria. They improve the performance (strength and toughness) of brittle cement-based materials by bridging cracks, transmitting stress across a crack and counteracting the crack growth .The steel fiber is the most common fiber type in the building industry; plastic, glass and carbon fibers contribute to a smaller part to the market. To reduce disposal and pollution problems emanating from these industrial wastes, it is most essential to develop profitable building materials from them. Keeping this in view, in this study low cost Self Compacting Concrete with steel fiber reinforcement incorporating lime sludge waste as partial replacement to cement is being done. The replacement level of lime sludge with cement is from 5% to 25%. The variation of steel fiber is from 0.5% to 2 %.
Keywords: Fibre Reinforced Self-Compacting Concrete, Lime Sludge, Paper Industry Waste, Portland Cement, Steel Fibres

I. INTRODUCTION

Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete. SCC is defined as concrete that is able to flow and consolidate under its own weight, completely fill the formwork even in the presence of dense reinforcement, whilst maintaining homogeneity and without the need for any additional compaction. Self-compacting concrete (SCC) was first developed in 1988 by Professor Okamura intended to improve the durability properties of concrete structures. SCC mixes usually contain superplasticizer, high content of fines and/or viscosity modifying additive (VMA). Nowadays, the ecological trend aims at limiting the use of natural raw materials in the field of building materials and hence there is an increased interest in the use of alternative materials (waste) from industrial activities, which presents significant advantages in economic, energetic and environmental terms. The interest of the construction community in using waste or recycled materials in concrete is increasing because of the emphasis placed on sustainable construction.

The steel fiber is the most common fiber type in the building industry; plastic, glass and carbon fibers contribute to a smaller part to the market. There are various types of steel fibers such as wave cut, end large steel fiber, deformed sheet and also hooked end steel fiber. Hooked end steel fibers are widely used in the fiber reinforced concrete because it has higher strengthening effect on the cement matrix as compared with other types of steel fibers .Merging steel fibers with SCC to produce steel fiber reinforced self-compacting concrete is therefore highly desirable and carries a lot of potential for the concrete industry

II. MATERIALS

The ingredients used in this self-compacting concrete are Portland cement, lime sludge, steel fibre, fly ash, fine aggregate, coarse aggregate, superplasticizer and water.

A. Portland Cement

Portland cement of 53 grade (Deccan) is used in this study conforming to IS specifications. The results of various tests conducted on cement are shown in Table – 1.

Table – 1
Physical Properties of Cement

Sl. No.	Properties	Values
1	Specific gravity	3.12
2	Standard consistency	32%
3	Initial setting time	75 minutes
4	Final setting time	280 minutes
5	Fineness	8 %
6	Compressive strength of mortar cubes	53.2N/mm^2

B. Lime Sludge

It is a by-product of paper manufacturing process. It contains Calcium and silica. Lime sludge obtained from Hindustan newsprint limited is used in this study.

C. Steel Fiber

Hooked end steel fibers are used for the study. Steel fibers have a length of 30mm and diameter of 0.5mm. It have an aspect ratio of 60. The steel fiber has a density of 7850 kg/m3 and modulus of elasticity of 2 × 105 MPa.

D. Aggregates

Fine aggregate of size less than 4.75mm and coarse aggregate of 10 mm maximum size is used in this study conforming to IS specifications. Various tests were conducted on aggregates according to IS specifications and it is shown in Table – 2 and Table – 3.

Table – 2
Physical Properties of Fine Aggregate

Sl. No.	Properties	Values
1	Specific gravity	2.53
2	Bulk density	1.57 kg/l
3	Water absorption	4 %
4	Fineness modulus	3.86

Table – 3
Physical Properties of Coarse Aggregate

Sl. No.	Properties	Values
1	Specific gravity	2.71
2	Bulk density	1.72 kg/l
3	Water absorption	0.45%
4	Crushing value	28.92%
5	Fineness modulus	3.1

III. MIX DESIGN

The self-compacting concrete used in this study is of grade M35 and mix design is done according to modified Nan-Su method. The material quantity as per mix design is shown in Table – 4.

Table – 4
Quantity of Materials as Per Mix Design (For 1m^3)

Contents	Quantity
Cement	384 kg/m^3
Fine aggregate	872 kg/m^3
Coarse aggregate	803 kg/m^3
Water	196 kg/m^3
superplasticizer	4.45kg/m^3

Table – 5
Mix Specification

Mix ID	Abbreviation
CM	Lime sludge 0%
LS_5	Lime sludge 5%
LS_{10}	Lime sludge 10%
LS_{15}	Lime sludge 15%

LS_{20}	*Lime sludge 20%*
LS_{25}	*Lime sludge 25%*
$LS_{10}SF_{0.5}$	*Lime sludge 5% , 0.5% steel fiber*
$LS_{10}SF_{1}$	*Lime sludge 5% , 1% steel fiber*
$LS_{10}SF_{1.5}$	*Lime sludge 5% , 1.5% steel fiber*
$LS_{10}SF_{2}$	*Lime sludge 5% , 2% steel fiber*

IV. RESULTS

A. *Optimum quantity of lime sludge*

For finding the optimum quantity of lime sludge, compressive strength test was done for each percentage replacement. The optimum percentage of lime sludge was obtained as 10% by weight of cement based on 28th day compressive strength. Also rheological properties were found out for all the mixes and it was seen that all mixes showed satisfying flow characteristics within required range.

Table – 6
Compressive Strength to Obtain Optimum quantity of lime sludge

Mix ID	*Average Compressive Strength (N/mm^2)*	
	7th day	*28th day*
CM	*22.7*	*37.4*
LS_5	*23.1*	*38.63*
LS_{10}	*24.8*	*39.34*
LS_{15}	*20.8*	*35.7*
LS_{20}	*14.7*	*34.1*
LS_{25}	*13.6*	*32.7*

B. *Optimum Amount of Steel Fiber*

For finding the optimum quantity of steel fiber, compressive strength test was done for each percentage addition. The optimum percentage of steel fiber was obtained as 1% by volume of concrete based on 28th day compressive strength.

Table – 7
Compressive Strength to Obtain Optimum quantity of steel Fiber

Mix ID	*Average Compressive Strength (N/mm^2)*	
	7th day	*28th day*
$LS_{10}SF_{0.5}$	*26.86*	*39.47*
$LS_{10}SF_{1}$	*27.62*	*40.1*
$LS_{10}SF_{1.5}$	*24.73*	*39.42*
$LS_{10}SF_{2}$	*22.9*	*39.7*

C. *Hardened Properties*

Self-compacting concrete mixes were prepared containing optimum lime sludge as well as optimum steel fibers. Specimens are cured by submerging it in clean, fresh water. The following data were obtained after carrying out various tests on the mixes.

1) Compressive Strength

The variations of compressive strength of different scc mixes at 28th day were shown in the Fig. 1.

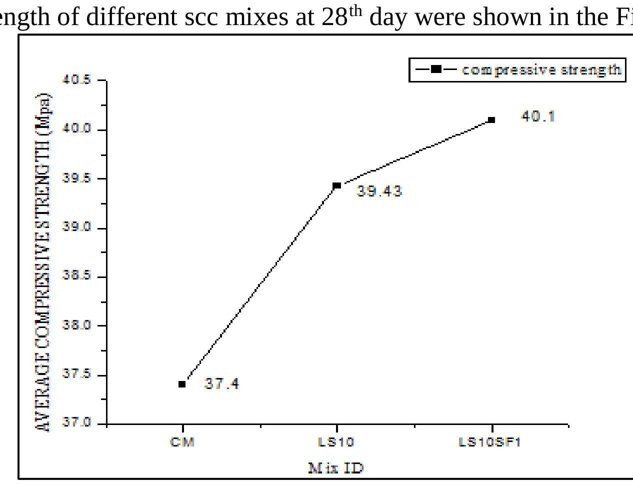

Fig. 1: Variation of Compressive Strength of Different SCC mixes at 28th day

2) Flexural Strength

The variations of flexural strength of different scc mixes at 28th day were shown in the Fig. 2.

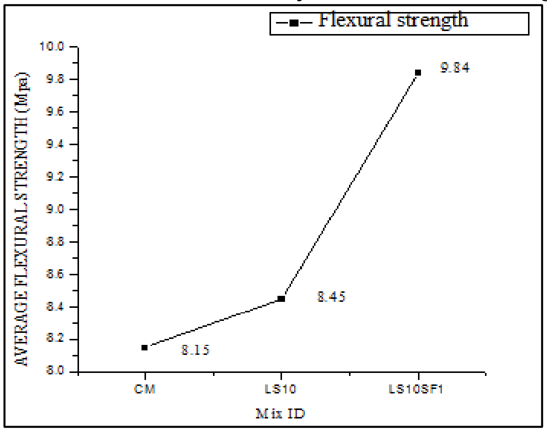

Fig. 2: Variation of Flexural Strength of Different scc mixes at 28th day

3) Split Tensile Strength

The variations of split tensile strength value of different scc mixes at 28th day are shown in the Fig. 3.

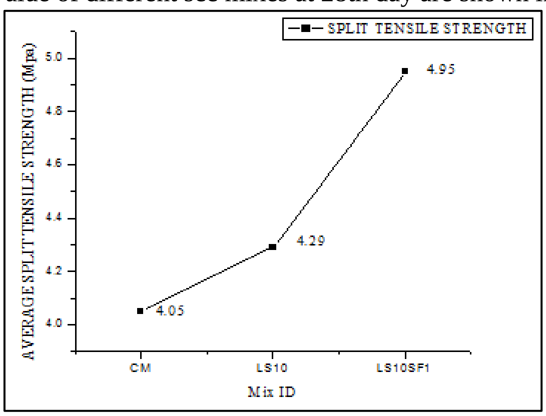

Fig. 3. Variation of Abrasion Value of Different scc mixes at 28th day

V. CONCLUSIONS

According to the results of this study it is clear that optimum lime sludge content should be 10% by weight of cement. When lime sludge content is increased above this quantity, compressive strength decreases. The optimum amount of steel fibre addition is 1%. By analysing the results of compressive strength, flexural strength and split tensile strengths, it is observed that the addition of steel fibers improves all the properties. It should also be noted that the rheological properties were also satisfied to be within required range. It was found that for split tensile strength increased by 15% and flexural strength increased by 17% on addition of steel fiber to optimum lime sludge replacement. This clearly shows the improved bond strength and tensile strength of lime sludge replacement with steel fiber addition.

ACKNOWLEDGEMENT

It is my privilege to express sincere thanks to my project guide, Dr. Mathews M Paul, Professor, Civil Department, MACE for his valuable guidance and encouragement throughout my humble endeavour. Finally, I would like to express my gratitude to all my friends and classmates for their help.

REFERENCES

[1] Kennouche .S.,Zerizer .A, Benmounah .A, Hami .B, Mahdad .M, Benouali .H and Bedjou.S "Formulation and characterization of self-compacting concrete with silica fume", Journal of Engineering and Technology Research , Vol. 5(5), pp. 160-169, June 2013.
[2] Prof. Shriram H. Mahure , Mayur B. Vanjare "Experimental Investigation On Self Compacting Concrete Using Cement Kiln Dust", International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 1, January- 2013 .
[3] MD Nor Atan, Hanizam Awang "The compressive and flexural strengths of self-compacting concrete using raw rice husk ash" Journal of Engineering Science and Technology Vol. 6, No. 6 (2011) 720 – 732
[4] IS 12269:1989, Specification for Ordinary Portland cement 53 Grade, Bureau of Indian Standards, New Delhi.
[5] IS 456:2000: Plain and Reinforced Concrete - Code of Practice: Bureau of Indian Standards: New Delhi. All rights reserved by www.ijste.org 5
[6] IS 10262:2009: Concrete Mix Proportioning – Guidelines: Bureau of Indian Standards: New Delhi.