EFFECT OF STEEL FIBERS AND CEMENT KILN DUST ON SELF COMPACTING CONCRETE

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Abstract:

This paper was conducted to appraise the consequence of addition of steel fibers and cement kilns dust to the self compacting concrete (SCC). The use of waste product materials in concrete technology has been increasingly prominent as it makes the ambition of feasible development attainable. The objective was to appraise and compare the various mechanical properties of self compacting concrete with steel fibers. Various percentage of steel fibers viz. 0%, 1%, 3%, 5% and 7% were added. The effect on the properties of the fresh concrete was studied by means of slump test and V-funnel test. The properties of hardened concrete were investigated by assessing the compressive strength. An experimental study that aimed to find out the possibility of using the Cement Kiln Dust (CKD) as a cement replacement material. Different percentage replacements (10%, 20%, 30% and 40% by weight of cement) were used in producing Self-compacting concrete(SCC). The fresh and properties properties of four mixes were experimentally evaluated. The results showed that incorporating CKD led to deteriorate both fresh and hardened strength. Lastly the optimum dosage of steel fibers was suggested.

Keywords: Steel Fibers, Cement Kiln Dust, Self Compacting Concrete.

Introduction:

Construction industry dominate around four billion tons of cement annually and this amount is continuously increasing due to the increase in world population and the development in the infrastructures(basework, framework, groundwork etc). Cement production negatively influence the environment by consuming the virgin materials and releasing CO_2. Now a days, civil engineering structures desire high strength and high durability concrete for construction, but at the same time concrete should be economical. This concern leads to the advancement of concept of Self Compacting Concrete(SCC). As Self Compacting Concrete completely fills the formwork by virtue of its own weight without segregation so dense matrix is formed which increase the strength and durability of structure. But Conventional Self Compacting Concrete has low tensile strength, little cracking resistance and limited ductility. This limitation can be eliminated by addition of fibers. Fibers have the potential to increase the post cracking energy absorption and appreciate the ductile aspect of concrete structure. Also when, Steel Fiber Reinforced Self Compacting Concrete is correlated with Conventional Self Compacting Concrete,it shows clear technical dominance in terms of costs/benefit ratio. Furthermore, the flow-ability properties of the fresh SCC is favorable for the formation and homogeneous dispersion of steel fibers, which in case of normal concrete tend to acquire near the vibrating needle thus reducing the efficiency of fibers in concrete. On the other hand, steel fibers do not easily change with the dynamically changing shape of the cement paste located between the aggregates in concrete.

The cement manufacturing results enormous quantities of waste material called Cement Kiln Dust (CKD), where the quantity of CKD is estimated by 3-4% of the total produced cement. Such materials could be used as cement replacement material specifically in producing Self-compacting concrete (SCC). This is considered a forward step of the high performance concrete as;

i) it has high strength due to the used mineral and chemical admixtures in addition to the low w/c ratio, and

ii) high durable concrete that brought about high flowability and compactability.

In order to produce SCC, high volume/ high viscoser cement paste is needed in parallel with reducing both size and proportion of coarse aggregate. From the concrete technology view, using high cement content leads to generate high temperature that leads to thermal cracking which does not fit with durability requirement in addition to the fact that cement is relatively expensive. It was reported that the cement/binder content in SCC is 490-600 kg/m^3 therefore, cement replacement materials are usually used in producing SCC. . It was previously concluded that substituting up to 5% weight of cement with CKD did not significantly affect the compressive strength of cement paste and had no negative effect on the ingrained reinforcement passivity. Other research has investigated using CKD as an activator for other cementatious materials such as blast furnace slag, granulated slag and silica fume. More recent study conducted by Maslehuddin et al. suggested that the substitution of cement with CKD should be limited with 5% wt. since chloride permeability increased and the electrical resistivity decreased with CKD incorporation; therefore, there was a possibility of steel reinforcement to be corroded when CKD incorporated with 10% and 15% wt. of cement.

Material Used:

1.Cement: The cement used in this paper is ultra tech 53 grade. The compressive strength was 55 N/mm^2.

2. Coarse aggregate: The size of coarse aggregate were 12 mm having specific gravity of 2.82 water absorption 1.25% and compressive strength of 34.24 N/mm^2.

3. Fine Aggregates: The stone dust was used as fine aggregates with specific gravity of 2.79 and water absorption capacity 0.38%.

4. Silica Fume The silica fume used in this experiment was supplied by Elkem. This silica fume meets ASTM C-1240 standards.

5. Admixtures: The admixtures used for this experimental work was obtained from the BASF INDIA.

6. Steel Fibers: Steel fibers used were circular in cross section with diameter of 0.50 mm, fibers were continuously deformed. The steel fibers were 13.5 mm in length, hence having an aspect ratio of 27.

7. Cement Kiln Dust: CKD is defined as a fine-grained, solid, highly alkaline by product waste material, sized from few μm diameter to 50 μm that removed from cement kiln exhaust gas by air pollution control devices. The relative constituent concentrations in CKD can be varying significantly based on the fed raw materials; however, it generally contains relatively high percentage of alkalinities such as K_2O and Na_2O. CKD as by-product material forms in cement plants during cement production operation when the kiln's temperature exceeds 1000 C. It is categorized by Environmental Production Agency (EPA) as a nonhazardous solid waste material. Table 1 shows the chemical compositions of used CKD and Ordinary Portland Cement (OPC) for comparison.

Table 1: Chemical composition of CKD and OPC

	CKD	OPC
Component	Value %	Value %
CaO	59.70	64.02
SiO_2	17.80	21.10
Fe_2O_3	2.81	4.72
Al_20_3	4.31	4.53
MgO	2.54	2.31
SO_3	5.93	2.32
K_2O	0.90	0.69
Na_2O	0.2	0.18
Cl	0.40	0.02
Free Lime	20	0.96
Hydraulic modulus	2.40	2.25

Experimental Work:

The mix design for this experimental work was done as per Rational mix design guidelines . As per Rational mix design guidelines the coarse aggregates were fixed at 55% of volume of solids and fine aggregates to 45% of mortar volume. The Superplasticizer dosage and water cement ratio for mix were fixed as per trial and method to ensure self compactability of concrete. Steel fibers were added in quantities ranging from 0 to 7% by weight of cement. Steel fibers were directly fed into the mixer by hand to ensure that there is minimum clumping and clustering effect. Steel fiber content in SCC mixtures is detailed in Table 2. The mixing process was performed in drum mixer in laboratory. As SCC mixes requires no compaction, so the mixes were poured into the tight steel moulds and filled completely without compaction. The specimens were demoulded after 24 hours and were left for curing. The curing time was for two ages (7 and 28) days, until the specimens are tested.

Compressive strength for both cubic and cylindrical specimens, modulus of rupture and static modulus of elasticity were tested for the studied mixes. These were five mixes with 0%, 10%, 20%, 30% and 40% weight CKD replacement by weight of cement

Table 2: Different Mix Proportion

Mix Design	Sample1	Sample2	Sample3	Sample4	Sample5
Cement(kg)	550	540	530	520	510
Silca fume	80	80	80	80	80
Coarse aggregate(kg)	840	840	840	840	840
Superplasticizers (by weight of cement)	4.0	4.0	4.0	4.0	4.0
V.M.A. (by weight of cement)	0.6	0.6	0.6	0.6	0.6
Water(ltr)	160	160	160	160	160
W/C	0.30	0.30	0.30	0.30	0.30
Steel fiber(kg)	0	5.4	15.9	26	35.7
CKD	0	10	20	30	40

Table 3 : Steel fiber content in SCC mix

Mix	% of steel with SCC
Sample 1	0
Sample 2	1
Sample 3	3
Sample 4	5
Sample 5	7

Results and Discussion:

Fresh concrete properties:

The results obtained from tests conducted on fresh properties of SCC are given below:

a) Slump cone test: The slump cone test is used to determine the flowability property of fresh Self Compacting Concrete. The results of slump cone tests are given in Table (4) and Figure (1). The slump value represent slump flow final diameter i.e the maximum spread of concrete. Slump flow diameter is between 600-710 mm for all mix. It is clear from the Table 4 and Figure 1 that there is significant decrease in slump flow diameter after adding steel fibers and CKD in Self Compacting Concrete mixes. The decrease in slump value by adding steel fiber and CKD is due to the increase in the resistance to flow and reduces the flow-ability due to increasing the interlocking and friction between fibers and aggregate.

Table 4: Slump value of SCC

Mix	% of Steel	CKD	Slump value(mm)
Sample 1	0	0	710
Sample 2	1	10	685
Sample 3	3	20	645
Sample 4	5	30	620
Sample 5	7	40	600

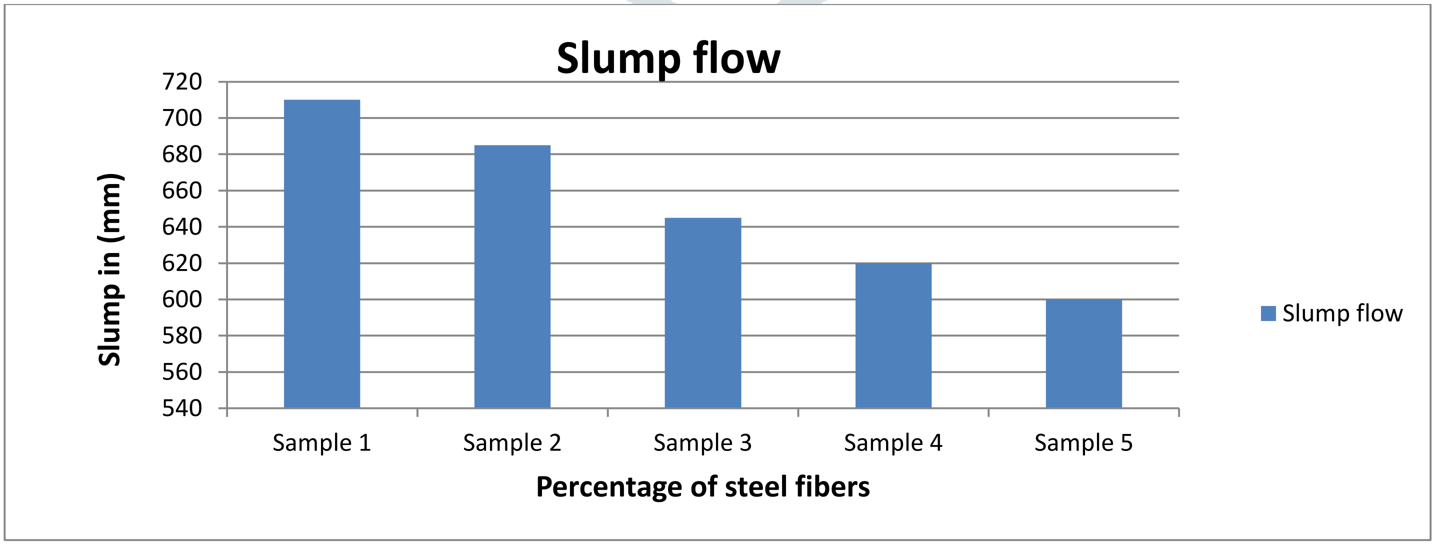

Figure 1: Slump flow of SCC

b) V-Funnel Test: The V-funnel test is used to determine the viscosity and filling ability of SCC. Table 5 shows the values of V-funnel test results. The V-funnel values are between 7.9-10 sec. As per European Project Group, 2005, Self Compacting Concrete is classified into two categories: VF1 -? 8 sec mixes having moderate viscosity and VF2 -9-25 sec mixes having high viscosity thus indicating reduced filling ability and better segregation resistance. From Table 5 and Figure 2 it is clear that as the percentage of steel fibers increases in the Self Compacting Concrete the value of V-funnel second increases, this means higher flow time required by concrete to fill formwork. This can be correlated to the increasing in fiber content leads to increase in the friction between the fibers and aggregates and the friction of the fibers with each other which could extend the required time to empty the V-funnel.

Table 5: V-Funnel test results

Mix	% of steel	V-Funnel (sec)
Sample 1	0	7.9
Sample 2	1	8.5
Sample 3	3	9.1
Sample 4	5	9.6
Sample 5	7	10

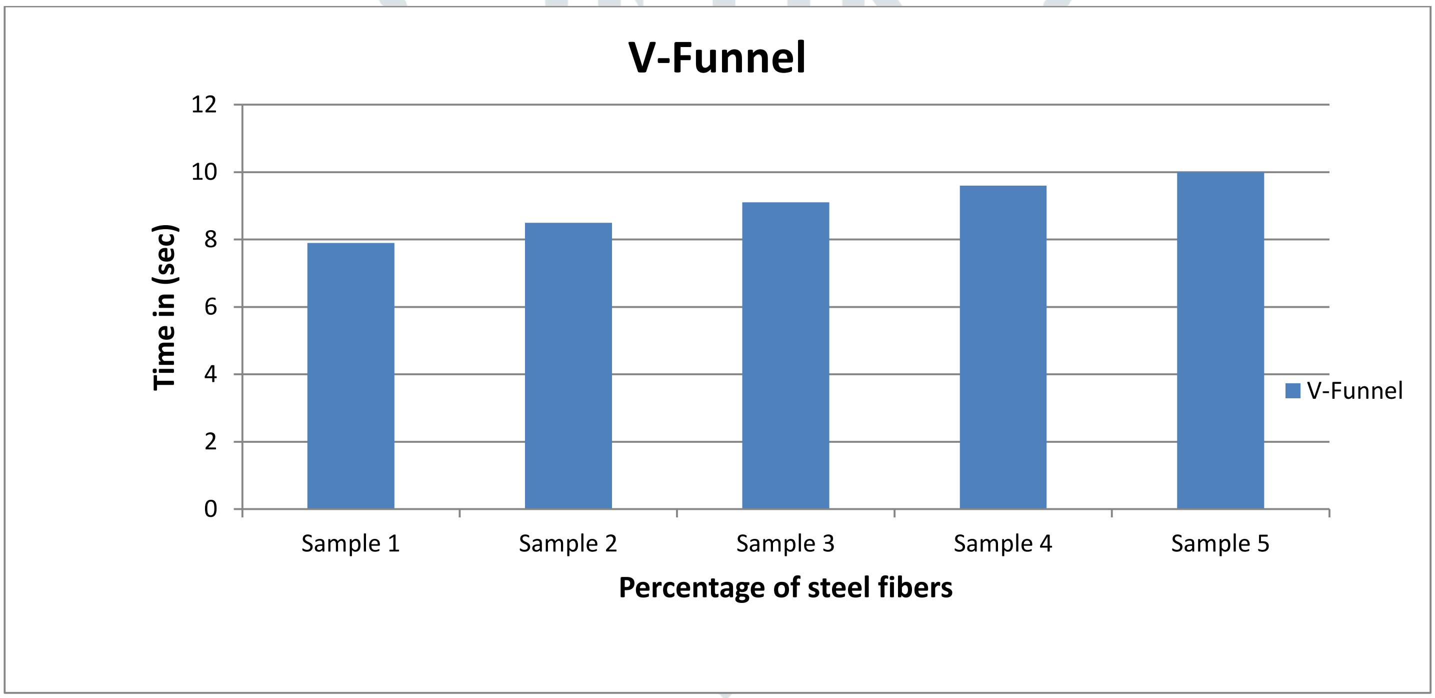

Figure 2: V-Funnel (sec) of SCC

Hardend Concrete properties:

The results obtained from tests conducted on harden properties of SCC are given below :

a)Compressive strength:

The compressive strength is an important property of hardened concrete. The average compressive strength of Self Compacting Concrete with different percentage of steel fibers obtained after 7 and 28 days test are given in the Table 6 and Figure 3. The results indicate continuous increase in compressive strength with progress in age of all specimens. This increase is due to the continuity of hydration process which forms a new hydration product within the concrete mass.

On the other hand, It can be seen that replacing OPC with CKD has led to decrease the compressive strength for both cubic and cylindrical specimens . This reduction in strength could be attributed to the reduction in the cement content, due the CKD replacement, which reduced both C_3S and C_2S (they are responsible for the strength) although both CKD and OPC have almost same hydraulic modulus as shown in Table1. The reduction in compressive strength could be due to the increase in free lime content in cement dust (see Table 1), which in turn increase the amount of $Ca(OH)_2$ that weakened the hardened matrix. This negative effect is attributed to the significant increase in Calcium hydroxide volume in comparison with CaO and H2O molecules volume. In the presented study, the free lime content was much larger for CKD in comparison to OPC.

The increase in compressive strength after adding steel fiber and CKD can be associated with two factors, firstly, the uniform dispersion of steel fibers in Self-compacting concrete leading to consistent internal integrity in concrete. Secondly, increase in post cracking ductility due to reduction in cracking and the mode of failure in Steel Fiber Reinforced Self Compacting as compared to conventional SCC.

Table 6: Compressive strength (N/mm^2)

% of steel fibers	Compressive strength(7 days)	Compressive strength(28 days)
0	40.21	51.34
1	41.54	53.65
3	43.24	56.05
5	45.56	60.34
7	47.82	64.18

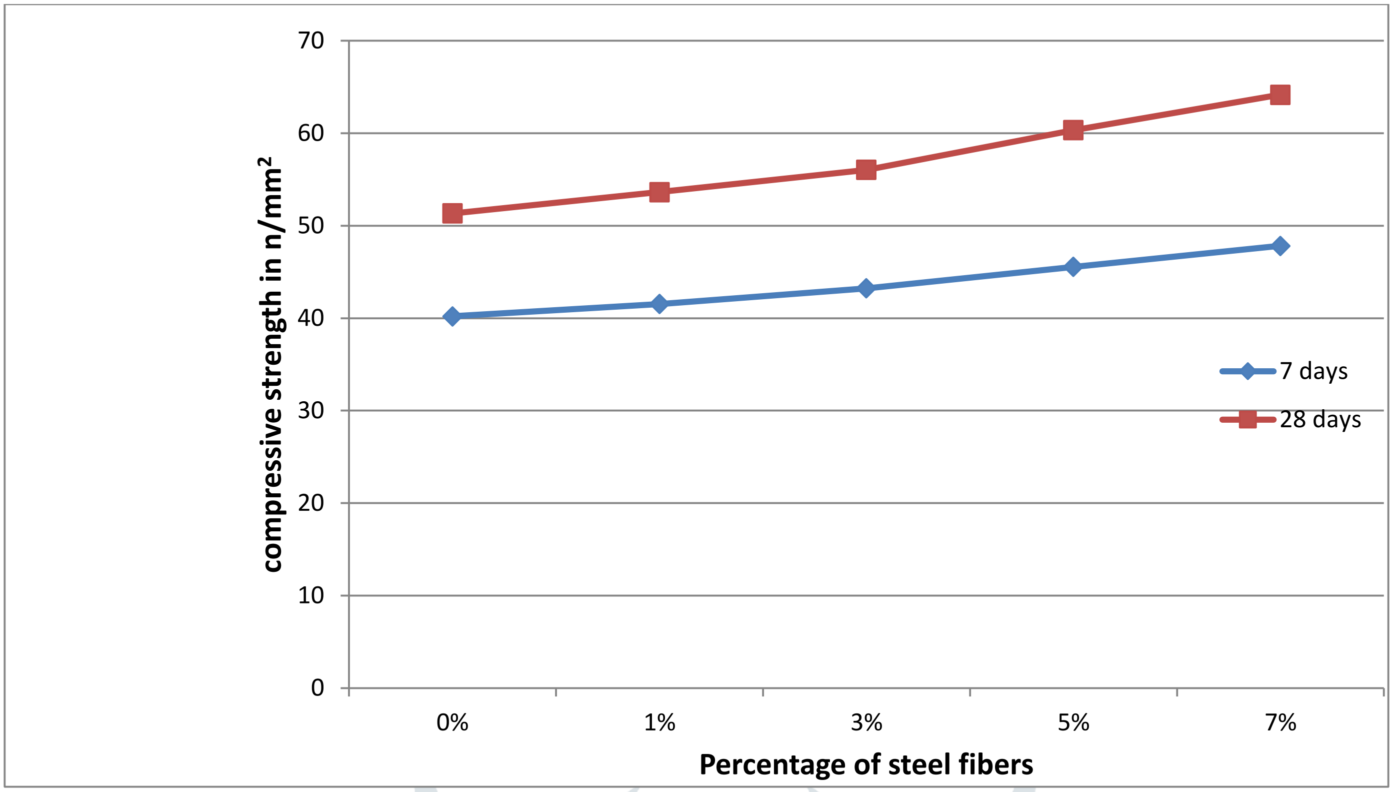

Figure 3: Compresive Strength (N/mm^2)

Conclusion:

1. With the increase in the percentage of steel fiber and CKD, the workability of Self Compacting Concrete decreases.

2. The slump flow diameter (flowability) decreases with the increase in steel fiber and CKD content. However, all mixes are satisfied to SCC requirements.

3. V-funnel flow time increase with the increase in steel fiber and CKD content of the concrete with respect to conventional mixtures**.**

4. With the percentage of steel fiber increases the compressive strength increases.

5. The crack width of the concrete is reduced as percentage of steel fibers increase as steel fibers arrests the propagation of cracking in the specimen.

6. Multiple cracking occurred in the specimen under compression test which shows that Steel Fiber Reinforced Self Compacting concrete inherited the characteristics of Fiber Reinforced Concrete.

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