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Author(s)	**Ali Ajwad, Abdullah, Muhammad Usman, Shakir Ahmad, Usman Ilyas, Abdul Waqar Akhtar, Bilal Zahid**
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Enhancing Concrete Properties by Adding Shred-like Steel Fibres and Steel Dust

Ali Ajwad[1], Abdullah[1], Muhammad Usman[1], Shakir Ahmad[1], Usman Ilyas[1], Abdul Waqar Akhtar[1] and Bilal Zahid[1]

[1]University of Management and Technology, Lahore, Pakistan

*ali.ajwad@umt.edu.pk

Abstract

In this research, fine and coarse aggregates present in the concrete were replaced with steel dust and shred-like steel fibres respectively in different ratios and the effect of their replacement on the properties of concrete was studied. Eight batches of concrete were mixed, each with the mix proportion of 1:2:4 and water- cement ratio of 0.52. Batch A was of normal concrete. In batches B, C, and D, 5%, 10%, and 15% of sand was replaced with steel dust, respectively. In batches, E, F, and G, 2%, 5%, and 8% of coarse aggregates were replaced with steel fibres. In the last batch H, 5% of sand and 5% of coarse aggregates were replaced with steel fines and steel fibres, respectively. British as well as American standards were followed during the research. Slump test was performed in the fresh state of each mix to find the effect of these replacements on its workability. 12 cubes of 150mm × 150mm × 150mm for compressive strength test and 12 cylinders of 150mm diameter and 300mm height for tensile strength test were made for each batch to check their strength after every 3, 7, 14, and 28 days. It was found that the workability of fresh concrete decreases while the density of fresh as well as hardened concrete increases with these replacements. They also result in an increase in initial compressive strength and a decrease in final compressive strength as compared to those of normal concrete. As far as tensile strength is concerned, an increase in initial as well as final strength was observed.

Keywords: aggregate, mix ratio, replacement, steel dust, steel fibres

Introduction

Among the building materials used for construction, cement based materials are widely used as compared to any other building material in the world. The annual global production of concrete is estimated to be over eight billion tons. The construction industry is looking for ways and means to develop building products which will increase the life span and quality of buildings.

Since ages, high strength concrete has been used for construction of the columns of high-rise buildings, offshore structures, tunneling and other mass concrete works. However, with the passage of time, the definition of high strength has changed to high performance concrete and it has become important to predict the performance of concrete under different conditions. The performance of concrete under tension has been a critical issue since long. Concrete is weak in tension, so research is needed to find a material which can be used with concrete to increase its tensile strength.

The purpose of this research was to use that material which is easily available and also can affect the tensile strength of concrete. Fine steel dust and coarse steel fibres of 15-20 mm length, 4-6 mm width, and less than 1 mm thickness, which are easily available at the local steel industry, were used as replacement of sand and coarse aggregates. The object was to find the effects of this replacement on tensile strength as well as the compressive strength of concrete and also to find the way it can affect the workability of concrete.

A considerable amount of research has been done already in this field. Song and Hwang investigated the mechanical properties of high strength steel fiber reinforced concrete. The properties included compressive and splitting tensile strengths, modulus of rupture, and toughness index. Steel fibres were added at the volume fractions of 0.5%, 1.0%, 1.5%, and 2.0%. The compressive strength of the steel fiber reinforced concrete reached a maximum at 1.5% volume fraction, being a 15.3% improvement over HSC [1]. Chen and Liu used a premix method similar to the 'sand-wrapping' technique to make EPS concrete. Its mechanical properties were investigated as well. The research showed that expanded polystyrene PS concrete with a density of 800–1800 kg/m^3 and a compressive strength of 10–25 MPa can be made by partially replacing coarse and fine aggregates with expanded polystyrene beads [2]. Shafigh et al. studied the effect of steel fiber on the mechanical properties of oil palm shell lightweight concrete and the results indicated that an increase in the quantity of steel fiber decreased the workability of concrete and increased its density [3].

2. Methodology

2.1 Concrete Materials

i) Cement that was used for the preparation of samples was obtained from a local source and was ordinary Portland cement. Materials used to make cement were also native.

(ii) Both fine and coarse aggregates that were used in the preparation of specimens were well graded with a specific gravity of 2.7 for fine aggregates. According to BS-882: 1973, its grading lay in zone 4 [4]. Gradation of coarse aggregates fulfills the ASTM C 33-78 grading requirement [5].

(iii) Fine and shred-like steel were used as the replacement of sand and coarse aggregates. Shred-like steel was broken to smaller sized particles less than 19mm of length. Their shape was elongated and their average width was between 3mm to 6 mm. The specific gravity of steel fines was 6.35.

2.2 Concrete Mix

1:2:4 mix ratio was used for all the eight batches. One batch was of normal concrete, three had sand replacement with steel fines, another three had the replacement of aggregates with steel fibres and one had the replacements of both fine and steel fibres. For all the given batches, w/c ratio was kept constant as 0.52 and 4% of aggregates absorption as well as 5% of sand absorption was taken.

Table 1. Batch Detail

Batch A	Normal Concrete with 1:2:4 mixes
Batch B	Concrete with 5% of sand replacement with steel dust
Batch C	Concrete with 10% of sand replacement with steel dust
Batch D	Concrete with 15% of sand replacement with steel dust
Batch E	Concrete with 2% of coarse aggregates replacement with shred-like steel fibres
Batch F	Concrete with 5% of coarse aggregates replacement with shred-like steel fibres
Batch G	Concrete with 8% of coarse aggregates replacement with shred-like steel fibres
Batch H	Concrete with 5% of sand and 5% of coarse aggregates replacement with fine and steel fibres

Twelve cylinders of 150mm diameter and 300mm height for splitting test and 12 cubes of the size $150mm \times 150mm \times 150mm$ for compression test were made for each batch to check tensile strength and compressive strength respectively after every 3, 7, 14, and 28 days.

2.3 Mixing of Concrete

Mixing of concrete was done in a pan of steel that was already available in the lab. All materials (cement, fine aggregates and coarse aggregates) were added and mixed until the mixture looked homogenous. In case of all batches except batch A, steel was also added before mixing. At that point, water was added to the dry blend and blended well for 3-4 minutes until it turned into a homogenous blend.

2.4 Workability Test

After all the mixings have been blended completely, slump test was performed for each cluster as indicated by British as well as American benchmarks.

2.5 Casting and Curing of Specimens

After usefulness test was performed, concrete was filled in steel molds and chambers, oiled first with diesel oil and afterward with portable oil. Then, it was set on the vibrating table for compaction. After compaction, completing of the best surface was done and concrete was put in a damp environment for restoration till the date of testing.

2.6 Casting and Curing of Specimens

During particularly long periods of testing, specimens were removed from the relieving tank and water was permitted to deplete out of the specimens for thirty minutes. Afterward, specimens were tried in a 1500 KN compression testing machine for compressive quality and part rigidity. Testing was done after every 3, 7, 14 and 28 days of casting.

For compressive quality, specimens were put in compression testing machine with smooth sides at best and their base and burden connected at a steady rate until failure occurred. Failure load was noted and partitioned by contact region to ascertain compressive quality.

For part elasticity, specimens were put inside the compression machine keeping the longitudinal hub flat. Burden was connected at a consistent rate until the failure of specimens by part along vertical plane occurred. Rigidity was determined by $2P/\pi Ld$, where P is the failure burden and L and d denote the length and distance across specimens, separately.

3. Results and Discussion

Table 2 represents all the results obtained from the experimentation. It also includes density, slump compressive strength and tensile strength values.

Table 2. Concrete Test Results

Batch	Density (pcf)		Slump (mm)	Compressive Strength (Psi)				Tensile strength (Psi)			
	Cube	**Cylinder**		**3 days**	**7 days**	**14 days**	**28 days**	**3 days**	**7 days**	**14 days**	**28 days**
A	142.2	147.5	19	1500	2300	2650	3300	115	165	185	250
B	143.5	148.5	16	1750	2150	2600	3200	135	185	240	290
C	144.2	150.1	13	1600	2200	2550	2850	130	200	225	270
D	145.6	151.2	10	1600	2150	2800	3000	120	140	155	210
E	142.4	148	4	1600	1950	2450	2850	110	160	195	240
F	142	148	4	1400	1750	2100	2550	120	175	215	240
G	142.2	149.4	0	1550	1900	2200	2700	130	175	200	245
H	143.4	149.6	0	1550	1950	2500	2850	120	170	200	260

3.1 Workability

Results of slump tests are given in Table 1. These are graphically presented in Figure 1 and 2.

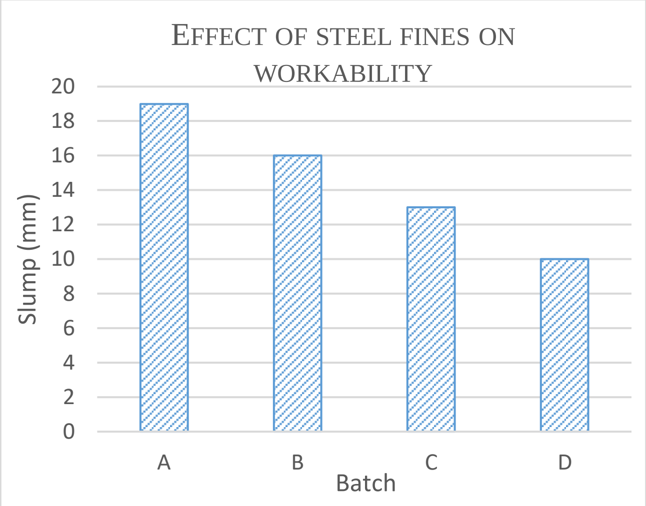

Figure 1. Effect of steel fines on workability

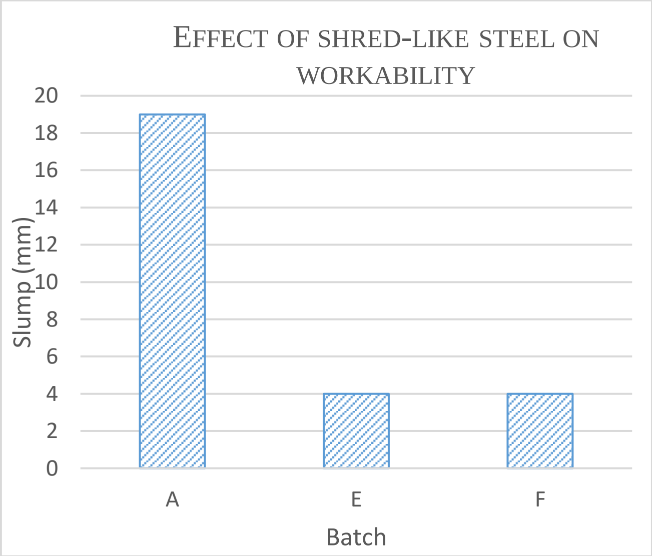

Figure 2. Effect of shred-like steel on workability

Figure 1 and 2 show that the workability of normal concrete is maximum and it decreases with the addition of steel. However, decrease in workability due to the addition of steel fibres is more than due to the addition of steel fines. This may be due to the interlocking of constituents of concrete with steel fibres. An increase in the percentage of steel fines, that is, from B to D decreases workability but an increase in the percentage of steel fibres, that is, from E to G leads to zero workability. Also, when both were used simultaneously as in batch H, there was zero slump noted.

During work after mixing, all batches showed segregation and this segregation was more prominent when steel fibres were used. During compaction on the vibrating table, normal concrete showed maximum bleeding and concrete with steel fines also showed bleeding; however, concrete with shred-like steel fibres showed less bleeding. Especially, batches F and G showed almost no bleeding and the samples looked porous when taken out of the moulds.

3.2 Density

Table I shows that with increased steel density the dead load of concrete increases.

3.3 Compressive Strength

Comparison of the development of the compressive strength of normal concrete with concrete of steel fines and shred-like steel fibres is given in Table 1 and graphically shown in Figure 3 and 4. Also, the effect of increasing percentages of these materials on the final strength of concrete is shown in Figure 5 and 6.

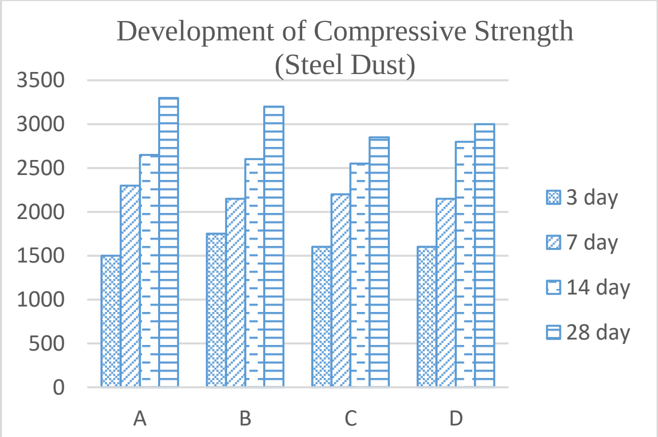

Figure 3. Development of compressive strength (steel fines)

Initial results, that is, 3-day compressive strength values show that the strength of normal concrete is less than the strength of concrete with steel fines, which means a high rate of development of early strength of concrete with steel fines. However, 28-day strength values show that the compressive strength of normal concrete is greater than the strength of concrete with steel fines.

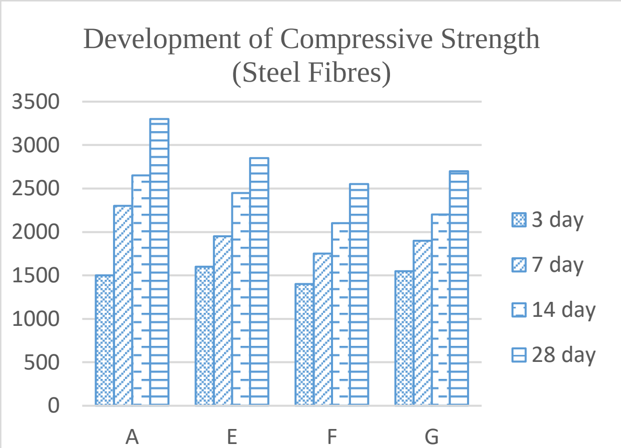

Figure 4. Development of compressive strength (steel fibres)

In case of the addition of steel fibres, the initial strength of normal concrete is less than that of concrete with steel fibres except in batch F with 5% replacement of coarse aggregates with steel fibres, where initial strength is less than that of normal concrete. However, the final strength of normal concrete is greater than the concrete with steel fibres in all cases. In concrete with steel fibres, the rate of development of final strength is even less than that of concrete with fine steel and the final strength of concrete with fine steel is more than that of concrete with steel fibres.

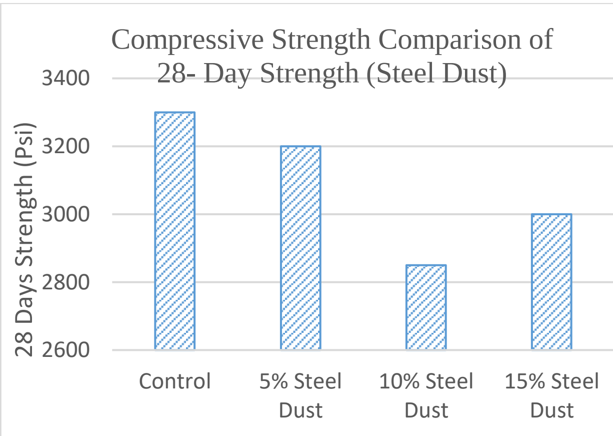

Figure 5. 28-Day compressive strength (steel fines)

In batch B, when 5% of fine steel is added, final compressive strength comes out to be 3200 psi. However, when in the same mix 5% of coarse steel is also added (batch H), the strength decreases up to 2850psi, which shows that steel fibres decrease strength more than that of concrete with steel fine.

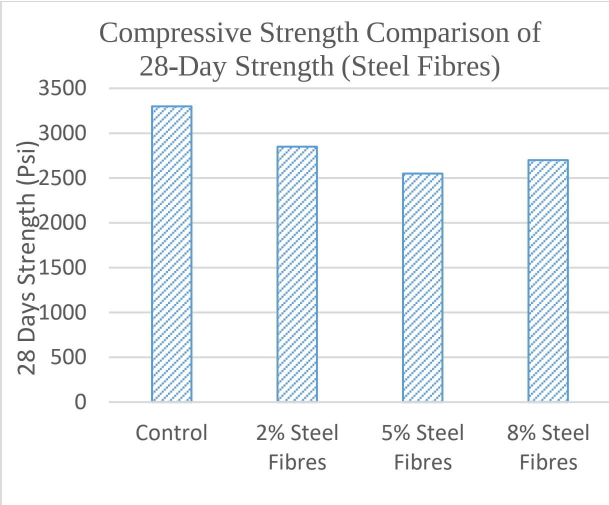

Figure 6. 28-Day compressive strength (steel fibres)

Figure 6 shows that when 5% of fine steel is added, 28-day compressive strength decreases. When 10% of fine steel is added, compressive strength further decreases. However, a further addition of 5% of steel fines results in an increase in compressive strength but this strength remains less than that of concrete with 5% of steel fines.

Similarly, in case of shred-like steel fibres, when 2% of coarse aggregates are replaced by shred-like steel, compressive strength decreases. When 5% of coarse aggregates are replaced, compressive strength further decreases. However, the replacement of further 3% of coarse aggregates with shred-like steel results in an increase in compressive strength but it remains less than that of when 2% of aggregates are replaced.

3.4 Tensile Strength

Comparison of the development of the tensile strength of normal concrete with concrete of steel fines and shred-like steel fibres is given in Table 1 and graphically shown in Figure 7 and 8. Also, the effect of the increasing percentages of these materials on the final strength of concrete is shown in Figure 9 and 10.

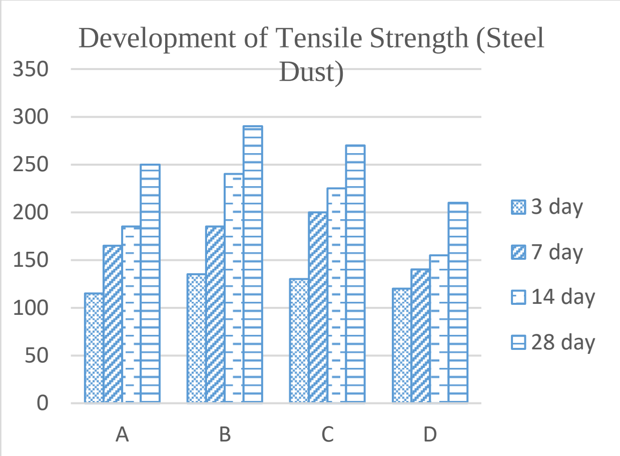

Figure 7. Development of tensile strength (steel fines)

Initial 3-day tensile strength of normal concrete is less than that of concrete with steel fines, while 28-day tensile strength of normal concrete is less than the strength of concrete with steel fines except in batch D with 15% replacement of fine aggregates with steel fines. Here, 28-day strength is less than that of normal concrete.

The addition of steel fines at 5% increases the tensile strength. However, further addition of steel fines decrease the tensile strength and at a replacement of 15%, tensile strength becomes even less than the strength of normal concrete.

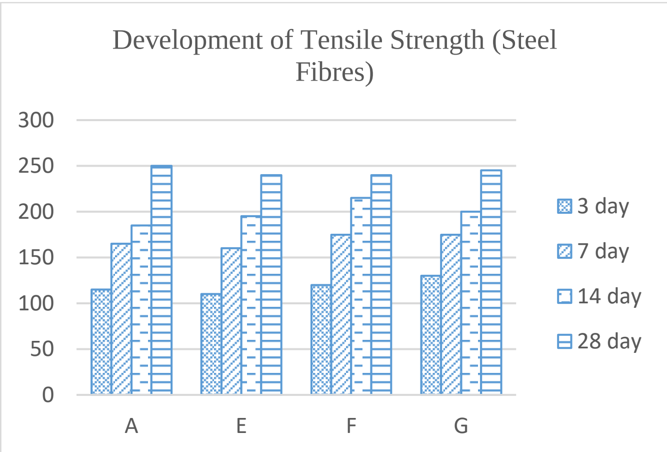

Figure 8. Development of tensile strength (steel fibres)

In case of the addition of steel fibres, initial 3-day tensile strength is greater than that of normal concrete except when 2% of steel fibres are replaced (batch E). However, the final 28-day tensile strength is less than that of normal concrete.

An increase in the percentage of steel fibres increases 28-day tensile strength.

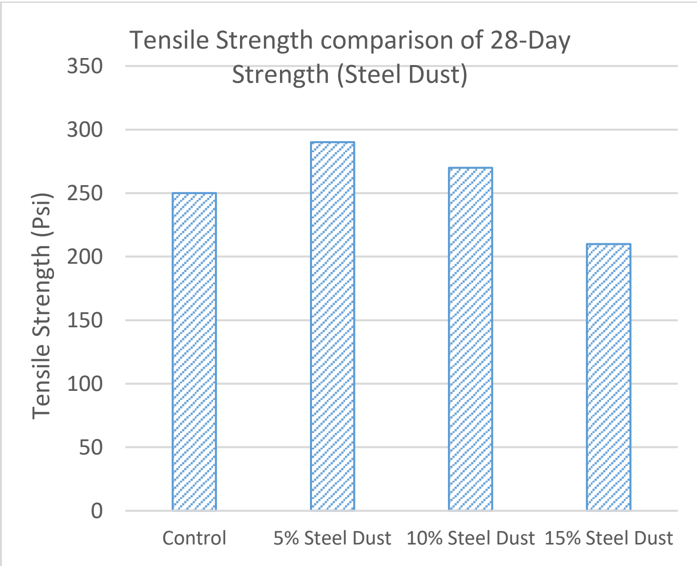

Figure 9. 28-Day tensile strength (steel fines)

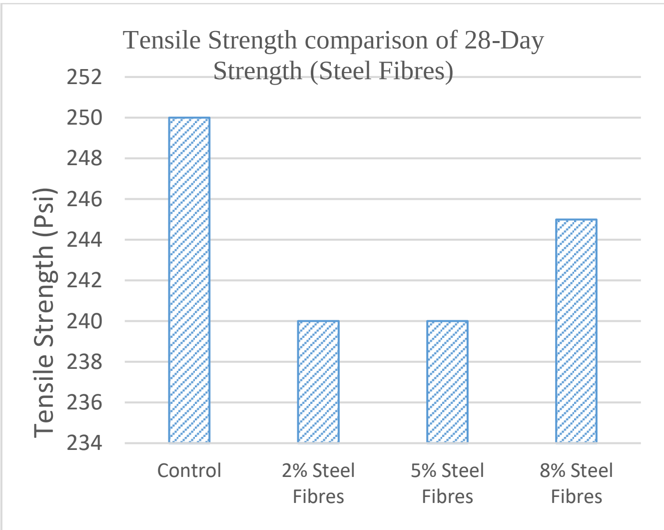

Figure 10. 28-Day tensile strength (steel fibres)

When 5% of coarse and 5% of fine aggregates are replaced with fine and shred-like steel respectively (batch H), then both initial and final tensile strengths are greater than that of normal concrete but to a very small extent.

4. Conclusions

1) In normal concrete, initial tensile strength comes out to be 7.6% of compressive strength and final tensile strength is also 7.6% of compressive strength. It means that in normal concrete, the rate of development of compressive and tensile strength is almost exactly the same. In case when fine and coarse aggregates are replaced with fine and shred-like steel, the percentage of tensile strength to that of compressive strength at initial stage is less than that of the final stage of result. This shows that at the initial stage, compressive strength development of special concrete is high but it decreases substantially with the passage of time.

2) Use of 5-15% of steel dust increases the initial compressive strength from 7-14% respectively but decreases the final compressive strength from 3-14 %. Especially, a replacement of 5% of fine aggregates with steel dust is associated with 16% increase in tensile strength and only 3% decrease in compressive strength. Also, the loss of slump is only 3 mm. So, at places where tensile strength is important and decrease in small amount of compressive strength is tolerable, 5% of fine aggregates can be replaced with steel fines.

3) Use of 2-8% of shred-like steel increases the initial compressive strength from 3-6% but decreases the final compressive strength from 14-23%, with a substantial decrease in slump as compared to normal concrete. Also, initial tensile strength increases only 3-12% while final tensile strength decreases from 2-4% with no workability at all. So, it is not beneficial to use such replacements in any condition.

4) When both 5% of fine aggregates and 5% of coarse aggregates are replaced with steel dust and shred-like steel, the loss of final compressive strength is 14% and gain in tensile strength is only 4% with zero slump value. So, this mix should also be avoided.

5) Replacement of fine and coarse aggregates by steel dust and steel fibres is associated with an increase in the density of concrete. Hence, it results in an increase in the dead load of the structure.

References

[1] Song PS, Hwang S. Mechanical properties of high-strength steel fiber-reinforced concrete, *Construction and Building Materials.* 2004;18(9): 669–673.

[2] Chen B, liu J. Properties of lightweight expanded polystyrene concrete reinforced with steel fiber, *Cement and Concrete Research*. 2004;34(7): 1259–1263.

[3] Shafigh P, Mahmud H, Jummat MZ. Effect of steel fiber on the mechanical properties of oil palm shell lightweight concrete, *Materials & Design*. 2011;32(7): 3926–3932.

[4] British Standard Institution. B.S. 12: 1991, B.S. 4550, B.S. : 882: 1973. *Specification for Portland Cement*. London: BSI; 1991.

[5] ASTM International. C 33-78. *Washed concrete sand*. West Conshohocken, PA: ASTM International; 2009.

[6] Neville AM. *Properties of Concrete.* 5th ed. Essex, England: Pearson educational Limited; 2011.

[7] Neville AM, Brookes JJ. *Concrete Technology.* 2nd ed. Essex, England: Pearson educational Limited; 2010.