Comparative Study of Structural Behavior in Steel Fiber Reinforced No-Fine and Lightweight Aggregate Concrete

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Abstract

Due to low values of mechanical properties of lightweight concrete , lightweight concrete is rarely used in structural members in buildings or structures , the lowest value of compressive strength can be used for concrete is 17 MPa, thus this investigation deals with improving the mechanical properties of two types of lightweight concrete , the first type is lightweight aggregate concrete (LWAC), and the second is no-fines concrete (NFC).The results show that adding steel fibers lead to high increment in flexural and tensile strength in NFC, the flexural strength increased from low value of 1.78 to 6.5MPa(more than 3 times) , the compressive strength also increased but less than the increment in flexural strength . compressive strength increased from 13.6 to 26.1 MPa (doubled) for optimum percentage of steel fiber which was 2.5% and also the study show increment in all mechanical properties in LWAC concrete when adding steel fibers.

Introduction

Lightweight concrete (LWC)mostly used in production of lightweight blocks or bricks and used in partitions of buildings , houses and framed structures , because of its low density that leads to reduce the total weight (dead weight) of building and hence low cost for structure. The use of steel fibers in concrete is very important to increase ductility **[1]** and also all mechanical properties , like compressive , tensile , and flexural strength the fiber reinforced concrete applications is very wide , it used in bridges ,precast products, structures in seismic regions, high loaded members and in concrete that needs to prevent cracks **[2]** , using fiber reinforced concrete leads to increase toughness , ductility and durability of concrete **[3]**.The need to improve the mechanical properties of LWC is important so that it may be used as structural members. This investigation show how can steel fibers take rule to improve two types of lightweight concrete the first is no fine concrete which is concrete without fine aggregate or sand , and the second type is lightweight aggregate concrete which using crushed thermo -stone as lightweight aggregates, the no-fines concrete used in study with density of 1787 kg/m3 , and for LWCA the density was 1550 kg/m3.

Experimental Program

No-Fines Concrete

Using mix proportion of 1: 5 (cement :gravel), the gravel with maximum size aggregate of 16 mm maximum size aggregate according to Indian standards IS-383 **[4]**,shown in table 1 , ordinary Portland cement used in all mixes.

Table 1 : Sieve Analysis Of Black Gravel In No-Fines Aggregate

IS –Sieve Size , Mm	% Passing By Weight (%)	Indian Specification (% Pass)
40	100	100
20	100	100
16	87.3	85 - 100
12.5	-	-
10	23.9	0 - 30
4.75	4.2	0 - 5
2.36	-	-

Lightweight Aggregate Concrete

Using 1: 1.5: 0.875 (cement : fine aggregate: coarse aggregate) by weight in this case to get another type of light weight concrete , the lightweight aggregate obtained by crushing thermo-stone blocks , and the maximum size aggregate is also 16 mm , and shown in table 2.

Table 2 : Sieve Analysis Lightweight Aggregates Made From Thermo-Stone Blocks For Lightweight Aggregate Concrete

IS –Sieve Size , Mm	% Passing By Weight (%)	Indian Specification (% Pass)
40	100	100
20	100	100
16	85.9	85 - 100
12.5	-	-
10	11.2	0 - 30
4.75	0.8	0 - 5
2.36	-	-

Table 3 : Sieve Analysis Of Sand (Fine Aggregates) For Lightweight Aggregate Concrete

IS –Sieve Size , Mm Or Mic.	% Passing By Weight (%)	Indian Specification (% Pass)
10	100	100
4.75	100	95-100
2.36	95.3	95 - 100
1.18	91.0	90 -100
600 Micron	83.8	80 - 100
300 Micron	44.2	15-50
150 Micron	3.7	0 -15

Steel Fibers

The steel fibers that used in this study is from type Micro-steel fiber show in figure 1, which have very high tensile strength and coated with brass to prevent corrosion , table 4 shows properties of micro steel fibers used in study.

Fig.1 Steel Fiber

Table 4 : Steel Fibers Specifications Used In The Study

Type And Manufacture	Length	Diameter	Aspect Ratio	Tensile Strength
Micro steel fiber ,coated with brass , China	13 mm	0.2 mm	65	2850 MPa

Specimens and Tests

Molds used in study were cubic moulds for compressive strength with (15*15*15)cm , cylindrical moulds of (10*20) cm used for tensile strength test , and cylindrical molds with (15 *30) cm for calculating the modulus of elasticity . the tensile strength done by using splitting test of cylinder , and Ft value was found by equation 1.

$F_t = 2P / \pi DL$ ---(1)
Where :
Ft : is the tensile strength of concrete specimen
P : Is the maximum force applied
D : diameter of cylinder and
L : Is the height of cylinder
For flexural strength , beams with (100*100*400) mm were used , then finding the average flexural strength of three specimens for each mix by equation 2

$F_b = PL/bd^2$ --(2)
Where :
Fb : is the flexural strength
P : max. load
L : Length of beam
b : is the width of beam
d : is the depth of beam

Figure 2 show the beam under machine of flexural strength test, the modulus of elasticity was done by using mechanical strain gauges to find strain values , and calculating the modulus from straight part of stress-strain diagram. Figure 3 shows the specimen before testing to stress-strain diagram.

Fig.2 : Lightweight Aggregate Concrete For Flexural Strength Test (Third Point Loading)

Fig.3 : Lightweight Aggregate Concrete Cylinder Before Testing To Stress-Strain Diagram.

Results and Discussion

For No-Fines Concrete

Table (5) shows the mechanical properties of no-fines lightweight concrete , compressive strength increased from 13.6MPa to 26.11MPa , also tensile strength increased from value of 1.5 MPato 4.9 MPa, this can be attributed to action of steel fibers that increase bond capacity of concrete and reducing propagation of cracks under loading **[5].**flexural strength increased also from 1.78 to 6.3MPa ,flexural strength is highly increased by adding steel fibers this can be attributed by the action of fibers that arrest cracking under increased load **[6]** , the modulus of elasticity is highly increased due to adding steel fibers as shown in table 5 , figures (4 -7) show the increment in mechanical properties for no-fine concrete by adding steel fibers to it , the modulus of elasticity increased from 11223 MPa for reference mixes without steel fibers to 22445 MPa by adding 2.5% steel fibers by volume , this can be attributed by two reasons , the first is by property of steel fiber itself that have a very high tensile strength , and the second , is the lowering of values of strain under loading and that gives higher values of modulus of elasticity comparing to reference mixes **[7]**, and also attributed by researcher S., Hamdi**[8]** ,which stated that the increasing of modulus of elasticity and mechanical properties is attributed by reducing cracks propagations under loading .

Table 5 : Mechanical Properties Of No-Fines Lightweight Concrete (NFC)

Concrete Type	Compressive Strength(Mpa)	Tensile Strength(Mpa)	Flexural Strength(Mpa)	Modulus Of Elasticity(Mpa)
NFC(1:5)Cement: Coarse Aggregate	13.65	1.50	1.78	11223
NFC with o.1 % steel fiber	14.05	1.83	2.01	11877
NFC with 0.5 % steel fiber	16.80	2.98	3.84	13400
NFC with 1 % steel fiber	18.86	3.66	4.42	15907
NFC with 1.5% steel fiber	22.27	3.90	4.75	19822
NFC with 2% steel fiber	24.61	4.61	5.37	21285
NFC with 2.5% steel fiber	26.11	4.90	6.33	22445

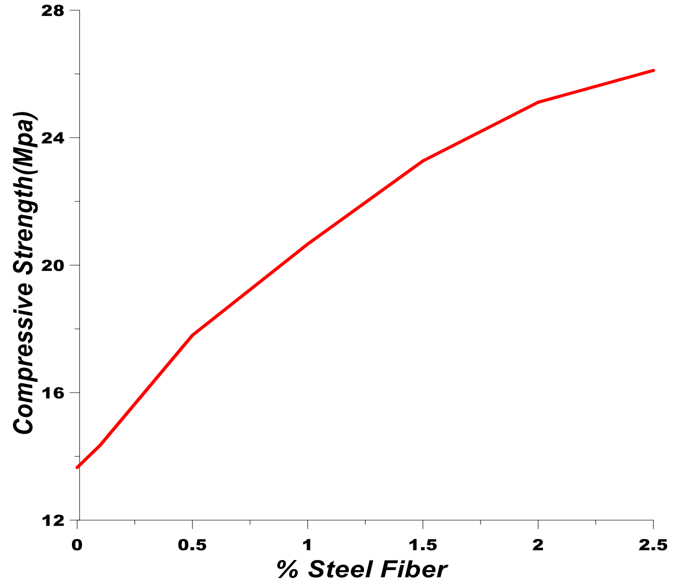

Fig. 4 Compressive Strength Test

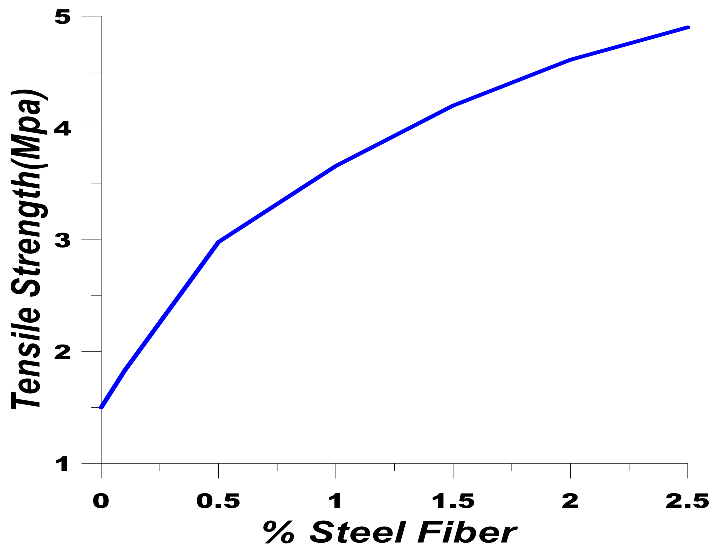

Fig. 5 Tensile Strength Test

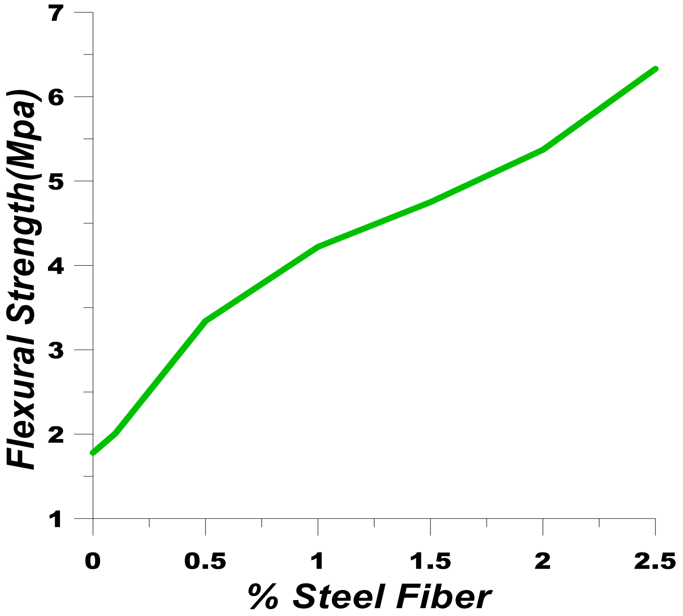

Fig. 6 Flexural Strength Test

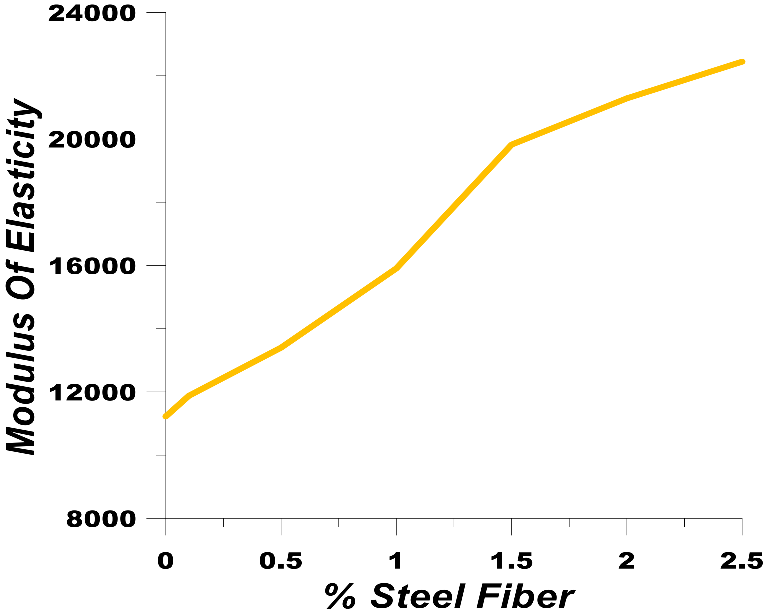

Fig. 7 Modulus Of Elasticity Test

Figures (4-7) The Mechanical Properties of (NFC) modified with steel fibers

For Lightweight Aggregate Concrete

Mechanical properties of Lightweight Aggregate concretetheir results appear as follows:Compressive strength increased from 11.4 MPa to 22.7 MPa , tensile strength increased from 1.3 to 2.59 MPa , and flexural strength increased from 1.8 to 5.2 MPa , and that were very good increments , also modulus of elasticity improved from 9800 MPa to20500 MPa , and that is an excellent improvement , figures(8- 11) show the improvement in compressive strength, tensile strength , flexural strength and modulus of elasticity for LWAC and table (6) shows the mechanical properties of Lightweight Aggregate concrete.

Table 6: Mechanical Properties Of Lightweight Aggregate Concrete (LWAC)

Concrete Type	Compressive Strength(Mpa)	Tensile Strength(Mpa)	Flexural Strength(Mpa)	Modulus Of Elasticity(Mpa)
LWAC	11.45	1.33	1.83	9810
LWAC , with micro steel fibers , 0.1%	12.85	1.56	1.90	9945
LWAC , with micro steel fibers , 0.5%	15.20	1.70	2.65	11227
LWAC , with micro steel fibers , 1%	17.86	1.88	3.87	15298
LWAC , with micro steel fibers 1.5%	20.89	2.16	4.01	17443
LWAC , with micro steel fibers 2%	22.70	2.55	4.78	19607
LWAC , with micro steel fibers , 2.5%	22.77	2.59	5.21	*20544*

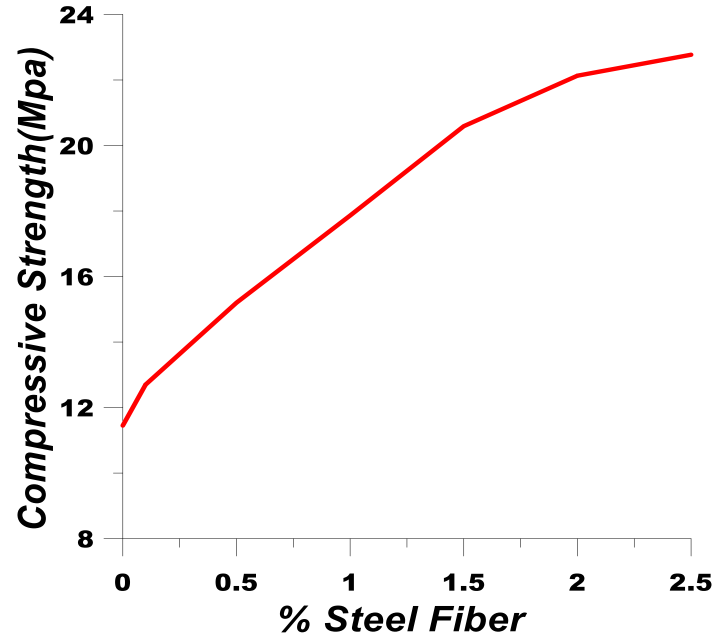

Fig. 8 Compressive Strength Test

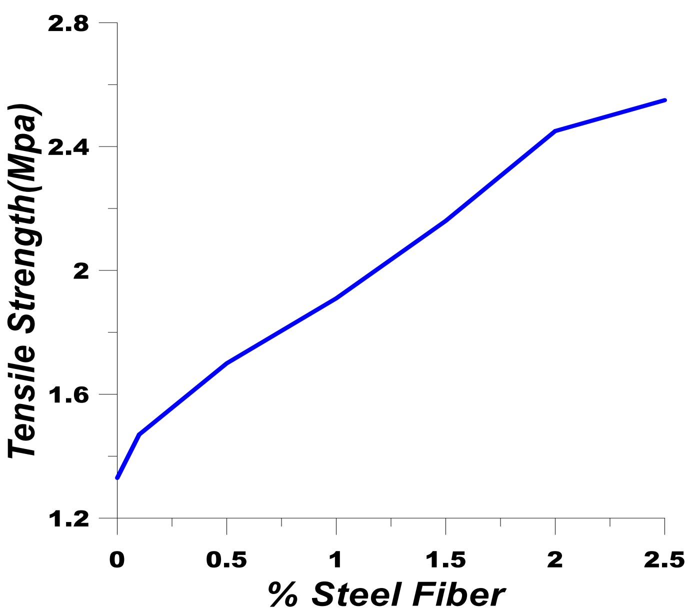

Fig. 9 Tensile Strength Test

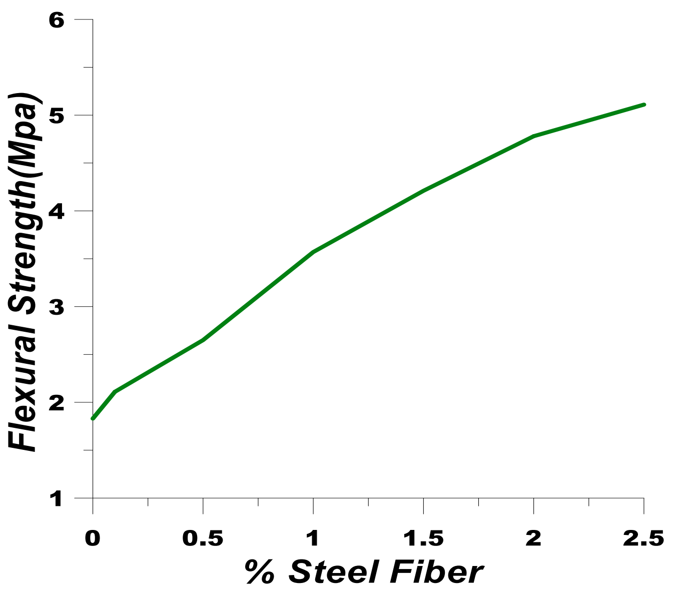

Fig. 10 Flexural Strength Test

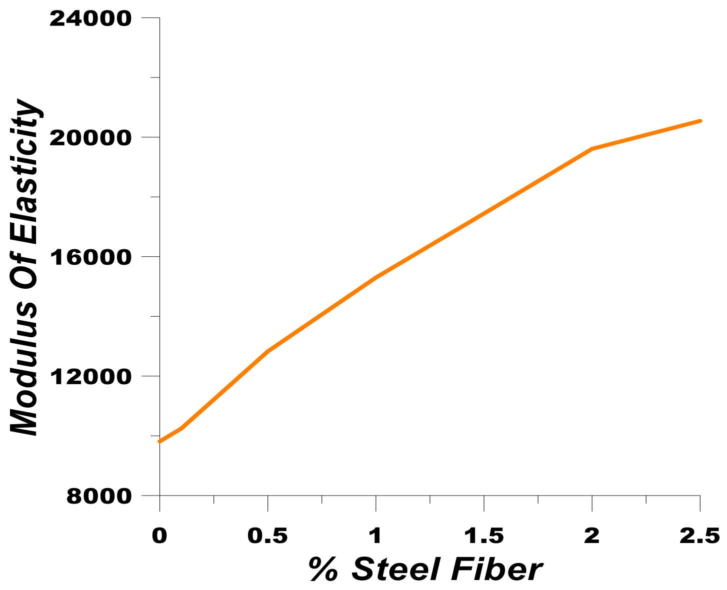

Fig. 11 Modulus Of Elasticity Test

Figures (8-11) The Mechanical Properties Of (LWAC) Modified With Steel Fibers

Conclusions

Mechanical properties of lightweight concrete both two types (lightweight aggregate concrete and no-fines concrete) can improved by using steel fibers . the following items achieved in this research :

1- Compressive strength increased in (LWAC) by adding steel fibers until 2% fibers , the increment was about 98% then the increment after that (until 2.5%) was very small.
2- Flexural strength was highly increased with adding steel fibers , the increment in flexural strength was 184% and this is perfect .
3- Modulus of elasticity also increased highly from 9800 to 20500 MPa , and this increment attributed by behavior of fiber specimens that shows less strain values under loading .
4- The mechanical properties for no-fines concrete also increased by adding steel fibers , compressive strength increased from 13.6 to 26.1 MPa , the tensile strength increment was about 226 % , flexural strength increment was high also and it was about 255% , and modulus of elasticity increment was about 200%(doubled).

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