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Structural Investigation of Steel Fiber Reinforced Concrete Subjected to Impact Loading

Anes Ebrahim Abo Horan[1], Sumant Shinde[2], Mrudula S. Kulkarni[3]

[1]Department of Structural Engineering Maharashtra Institute of Technology (MIT), Pune, India

[2, 3] Professor, Department of Structural Engineering Maharashtra Institute of Technology (MIT), Pune, India

Abstract: ***Normally concrete structures are designed for static loads. Sometime such structures are coming across the dynamic loads arising from military activities, terrorist activities. Therefore, this investigation will undertake to provide the needed information about the influence of various parameters on performance characteristics of steel fiber reinforced concrete and increased need to strengthen concrete structures. This study aims to investigate the impact resistance of fiber reinforced concrete (FRC), incorporated with steel fibers at various dosages. For this, a drop weight test was performed on the 28 days cured plain and fiber reinforced concrete specimens. End hook, Crimped and flat steel fiber of length 35 mm and an aspect ratio equal to 80, 50, 77.77, 46.66 were added to concrete in proportion 1.5% with water cement ratio of 0.40. The experimental test results of steel reinforced fiber concrete are compared with plain concrete and conclusions are arrived.***

Keywords: Steel fiber, reinforced concrete, impact loading, drop weight test, structural investigation

1. Introduction

Concrete is most widely used construction material in the world due to its ability to get cast in any form and shape. It also replaces old construction materials such as brick and stone masonry. The strength and durability of concrete can be changed by making appropriate changes in its ingredients like cementitious material, aggregate and water and by adding some special ingredients. Hence concrete is very well suitable for a wide range of applications.

The presence of micro cracks in the mortar-aggregate interface is responsible for the inherent weakness of plain concrete. The weakness can be removed by inclusion of fibers in the mixture. Different types of fibers, such as those used in traditional composite materials can be introduced into the concrete mixture to increase its toughness, or ability to resist crack growth. The fibers help to transfer loads at the internal micro cracks.

Such a concrete is called fiber-reinforced concrete (FRC) Concrete is characterized by brittle failure, the nearly complete loss of loading capacity, once failure is initiated.

2. Research Methodology

The experimental program consists of casting and testing of square steel fiber reinforcement concrete slab panels under drop weight impact test. The variables were the thickness of panels.

2.1. Materials Used

2.1.1 Cement:
Ordinary Portland cement of grade 53 conforming to IS: 12269 – 1987

2.1.2 Fine Aggregate (River sand):
Locally available, clean, well dried and good graded natural river sand was used throughout the IS sieve 2.36 mm.

2.1.3 Course Aggregate
Crushed blue granite aggregates passing through 10 mm sieve.

2.1.4Steel fiber

Table 2.1: bekaert steel fiber

Type of steel fiber	*Diameter*	*Length*	*Aspect ratio*
End hook	0.7	56	80
End hook	0.7	35	50

Table 2.2. Shaktiman steel fiber

Type of steel fiber	*Diameter*	*Length*	*Aspect ratio*
End hook	0.45	35	77.77
End hook	0.75	35	46.66
Cramped fiber	0.45	35	77.77
Cramped fiber	0.7	35	50
Flat fiber			50

2.2. Experimental set up and testing procedure

2.2.1 Impact test:
'Toughness' of a material is defined as the ability to absorb energy without fracture and it is generally determined by two methods:
1) By measuring deformation under an impact load and
2) By determining the energy required to cause complete failure of the specimen under an impact load. Several methods have been used for evaluating impact strength of materials such as:
3) (i)Weighted pendulum Charpy type impact test
4) Drop-weight test
5) Projectile impact test
6) Instrumented pendulum impact test.

Drop weight impact test is also known as "repeated impact test" and it is the simplest and widely used method.
$E_{imp} = E_p = N.g.h.m.$
Where Eimp- Impact energy; in joule
N - Number of blows
h - Height of drop weight (m)
m - Drop weight (kg)

g - Acceleration due to gravity (9.81m/s2)

Figure 2.1: Impact test Apparatus

3. Results

3.1 Drop Weight Impact Test Results

Specimens calculation for finding energy absorption capacity of steel fiber panels at initial crack and ultimate failure E_{imp} = N. g. h. m.

Where E_{imp}- Impact energy; in joule

N - Number of blows

h - height of drop weight (m)

m - Drop weight (kg)

g - acceleration due to gravity (9.81m/s2)

Size of Panel = 250 x 250 x 50mm

First Crack- 4th blow (4 Blows)

I_{nitial} = 4 x 9.81 x 3.5 x 1= 137.34 J

Ultimate failure- 10th blow (10 Blows)

$E_{uitimate}$ = 10 x 9.81 x 3.5 x 1= 343.35 J

3.1.1 Energy absorption capacity of plain concrete panels

Table 3.1: Test result for 50mm thick panels without steel fiber

Size of specimen	Specimen No	No. of blow at first crack	No. of blow at ultimate crack	Impact energy at first crack (J)	Impact energy ultimate crack (J)
250 x 250 x 50	1	4	10	137.34	343.35
	2	5	12	171.68	412.02
	3	6	11	206.01	377.68
	4	5	10	171.68	343.35

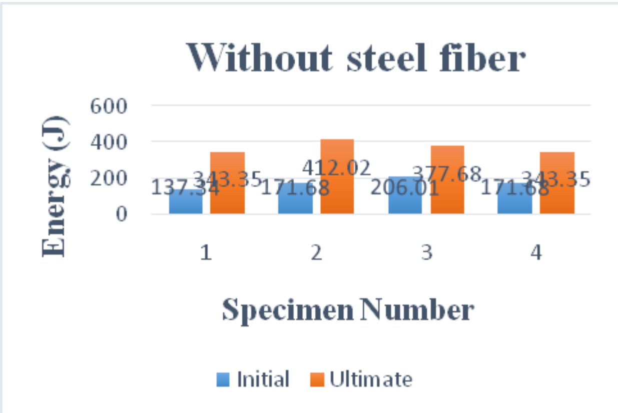

Figure 3.1: Initial and Final Energy Absorption Capacity of plain concrete panels

The number of blows required to cause the complete failure of specimen, which is used for calculating impact energy is shown in Table 4.1. Plain concrete (PC) resisted only eleventh blows prior to the failure of specimen and its corresponding impact energy was found to be 369.101 J.

3.1.2 Energy absorption capacity ofBeakart steel fiber panels with aspect ratio 80

Table 3.2: Test result for End hook steel fiber aspect ratio 80 with 50mm thick panels

Size of specimen	Specimen No	No. of blow at first crack	No. of blow at ultimate crack	Impact energy at first crack (J)	Impact energy ultimate crack (J)
250 x 250 x 50	E80 - 1	17	31	583.69	1064.38
	E80 - 2	15	32	515.02	1098.72
	E80 - 3	16	30	549.36	1030.05
	E80 - 4	14	30	480.69	1030.05

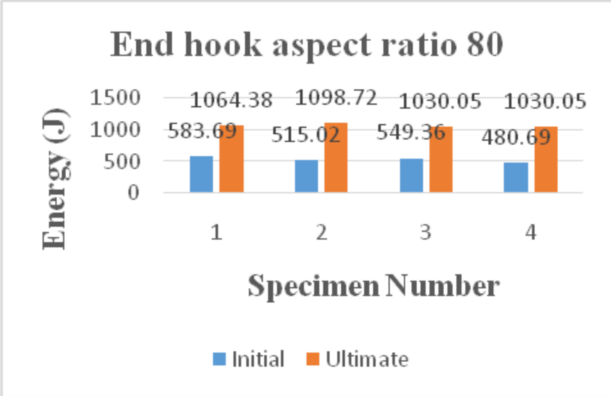

Figure 3.2: Initial and Final Energy Absorption Capacity of aspect ratio 80

3.1.3 Energy absorption capacity of Beakart steel fiber panels with aspect ratio 50

Table 3.3: Test result for End hook steel fiber aspect ratio 50 with 50mm thick panels

Size of specimen	Specimen No	No. of blow at first crack	No. of blow at ultimate crack	Impact energy at first crack (J)	Impact energy ultimate crack (J)
250 x 250 x 50	E50 - 1	13	26	446.35	892.71
	E50 - 2	15	28	515.02	961.38
	E50 - 3	14	25	480.69	858.37
	E50 - 4	12	24	412.02	824.04

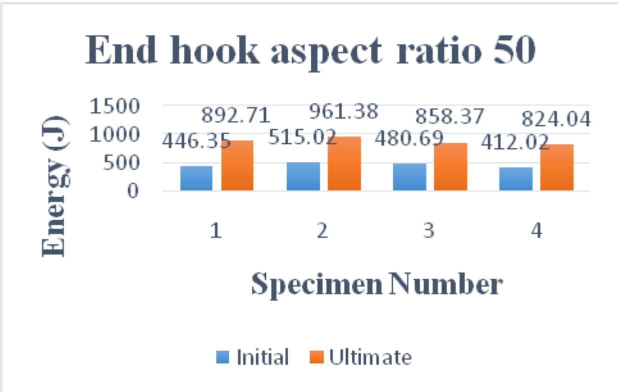

Figure 3.3: Initial and Final Energy Absorption Capacity of aspect ratio 50

3.1.4 Average value of energy absorption capacity ofBeakart steel fiber panels with aspect ratio 80, 50 and without steel fiber:

Table 3.4: Average value of test result for 50mm thick panels with aspect ratio 80, 50 and without steel fiber

Size of specimen	aspect ratio	Type of steel fiber	Average initial energy at absorption capacity (J)	Average ultimate energy at absorption capacity (J)
250 x 250 x 50	Without steel fiber		171.67	369.101
	80	End hook	532.19	1055.8
	50	End hook	463.52	884.125

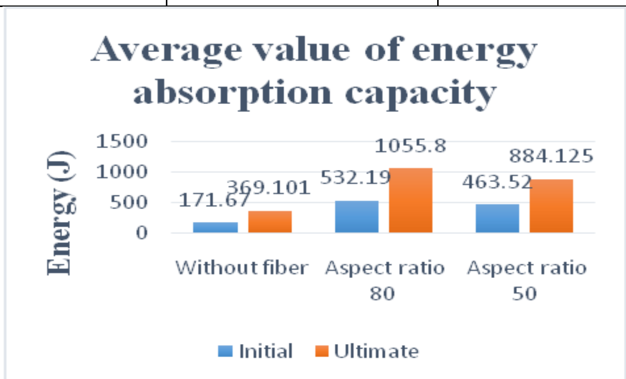

Figure 4.4: Average of Initial and Final Energy Absorption Capacity of aspect ratio 80, 50 and without steel fiber

For the Beakart steel fiber with end hook fibers (E 80, E 50) increase in the number of blows was 2.8 and 2.3 times as that of the plain concrete.

3.1.5 Energy absorption capacity of Shaktiman steel fiber panels with aspect ratio 77.77

Table 3.5: Test result for End hook steel fiber aspect ratio 77.77 with 50mm thick panels

Size of specimen	Specimen No	No. of blow at first crack	No. of blow at ultimate crack	Impact energy at first crack (J)	Impact energy ultimate crack (J)
250 x 250 x 50	E77.7 - 1	20	38	686.7	1304.73
	E77.7 - 2	18	37	618.03	1270.39
	E77.7 - 3	19	37	652.36	1270.39
	E77.7 - 4	20	39	686.7	1339.03

4.1.6 Energy absorption capacity ofShaktimansteel fiber panels with aspect ratio 46.66

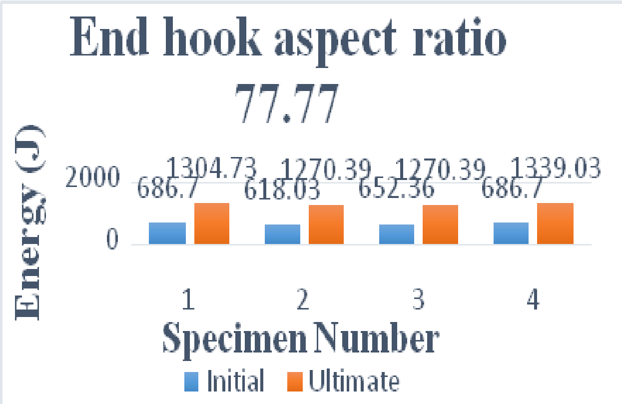

Figure 4.5: Initial and Final Energy Absorption Capacity of aspect ratio 77.77

Table 4.6: Test result for End hook steel fiber aspect ratio 46.66 with 50mm thick panels

Size of specimen	Specimen No	No. of blow at first crack	No. of blow at ultimate crack	Impact energy at first crack (J)	Impact energy ultimate crack (J)
250 x 250 x 50	E46.6 - 1	17	36	583.69	1236.06
	E46.6 - 2	16	35	549.36	1201.72
	E46.6 - 3	19	37	652.36	1270.39
	E46.6 - 4	18	36	618.03	1236.06

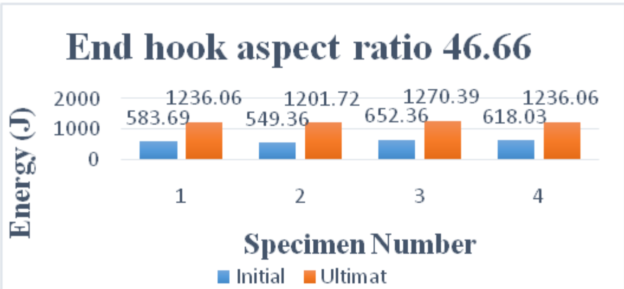

Figure 4.6: Initial and Final Energy Absorption Capacity of aspect ratio 46.66

3.1.7 Energy absorption capacity ofShaktiman steel fiber panels with aspect ratio 77.77

Table 3.7: Test result for Crimped steel fiber aspect ratio 77.77 with 50mm thick panels

Size of specimen	Specimen No	No. of blow at first crack	No. of blow at ultimate crack	Impact energy at first crack (J)	Impact energy ultimate crack (J)
250 x 250 x 50	C77.7 - 1	15	36	515.02	1236.06
	C77.7 - 2	17	39	583.69	1339.06
	C77.7 - 3	16	36	549.36	1236.06
	C77.7 - 4	15	38	515.02	1304.73

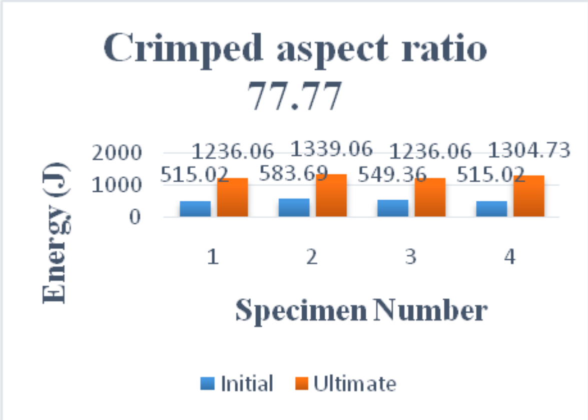

Figure 4.7: Initial and Final Energy Absorption Capacity of aspect ratio 77.77

4.1.8 Energy absorption capacity of shaktman steel fiber panels with aspect ratio 50:

Table 4.8 Test result for Crimped steel fiber aspect ratio 50 with 50mm thick panels

Size of specimen	Specimen No	No. of blow at first crack	No. of blow at ultimate crack	Impact energy at first crack (J)	Impact energy ultimate crack (J)
250 x 250 x 50	C50 - 1	12	27	412.02	927.04
	C50 - 2	14	29	480.69	955.71
	C50 - 3	14	28	480.69	961.38
	C50 - 4	15	30	515.02	1030.05

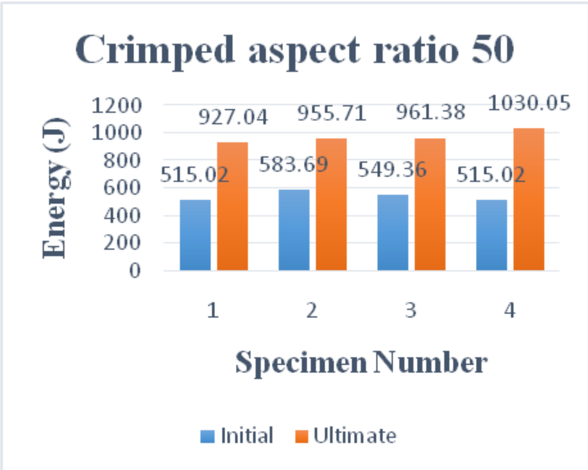

Figure 3.8: Initial and Final Energy Absorption Capacity of aspect ratio 50

3.1.9 Energy absorption capacity ofShaktiman steel fiber panels with aspect ratio

Table 3.9: Test result for Flat steel fiber aspect ratio 50 with 50mm thick panels

Size of specimen	Specimen No	No. of blow at first crack	No. of blow at ultimate crack	Impact energy at first crack (J)	Impact energy ultimate crack (J)
250 x 250 x 50	F50 - 1	11	24	377.68	824.04
	F50 - 2	10	26	343.35	892.71
	F50 - 3	13	25	446.35	858.37
	F50 - 4	14	27	480.69	927.04

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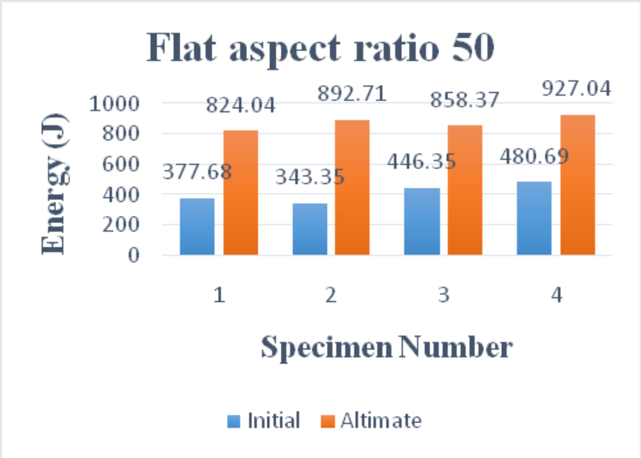

Figure 4.9: Initial and Final Energy Absorption Capacity of aspect ratio 50

4.1.10 Average value of energy absorption capacity ofShaktiman steel fiber panels with aspect ratio 77.77, 46.66, 77.77, 50, 50 and without steel fiber:

Table 3.10: Average value of test result for 50mm thick panels with aspect ratio 77.77, 50, 46.66 and without steel fiber

Size of specimen	aspect ratio	Type of steel fiber	Average initial energy at absorption capacity (J)	Average ultimate energy at absorption capacity (J)
250 x 250 x 50	Without steel fiber		171.67	369.101
	77.77	End hook	660.94	1296.14
	46.66	End hook	600.85	1236.06
	77.77	Crimped	527.89	1278.97
	50	Crimped	472.106	968.54
	50	Flat	412.01	875.54

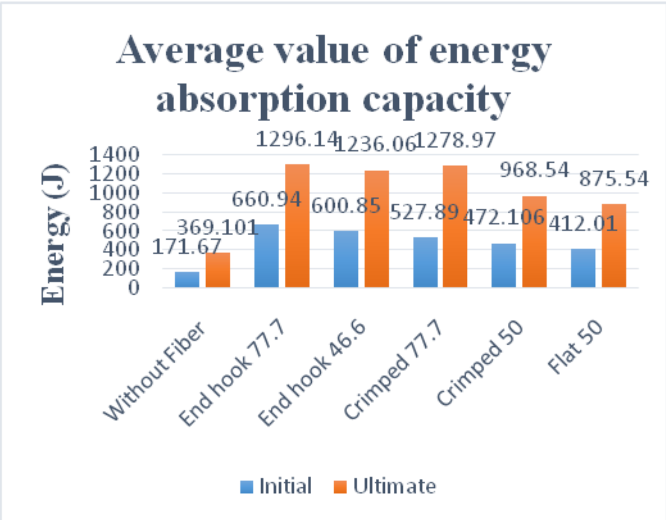

Figure 3.10: Average of Initial and Final Energy Absorption Capacity of aspect ratio 77.77, 50, 46.66 and without steel fiber

- For the Shaktiman steel fiber with end hook fibers (E 77.7, E 46.6) increase in the number of blows was 3.45 and 3.27 times as that of the plain concrete.
- The impact energy at failure was increased by 251% and 235% for end hook steel FRC (E 77.7-E 46.6) respectively.
- For the Shaktiman steel fiber with crimped fibers (C 77.7, C 50) increase in the number of blows was 3.3 and 2.63 times as that of the plain concrete.
- The impact energy at failure was increased by 246% and 162.4% for crimped steel FRC (C 77.7-C 50) respectively.
- For the Shaktiman steel fiber with flat fibers (F 50) increase in the number of blows was 2.3 times as that of the plain concrete.
- The impact energy at failure was increased by 137.2% for crimped steel FRC (F 50) respectively.

3.2 Compressive Strength Test Results

Table 3.11: Compressive strength

Type of fiber	Compressive strength
Plain concrete	45.03
Beakart steel fiber	
End hook 80	55,55
End hook 50	51,55
Shaktiman steel fiber	
End hook 77,7	59,1
End hook 46,6	55,5
Crimped 77,7	57,18
Crimped 50	54,1
Flat 50	51,1

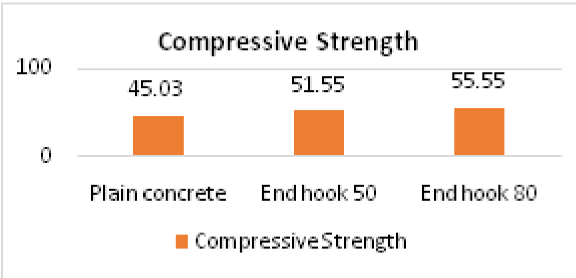

Figure 3.11: Compressive strength plain concrete - Beakart steel fiber

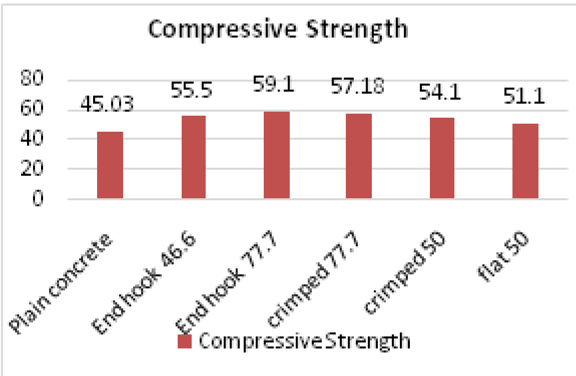

Figure 3.12: Compressive strength plain concrete - Shaktiman steel fiber

The compressive strength of Beakart end hook steel FRC (E 80 - E 50) was increased by 23.37%, and 14.47% respectively when compared to PC.

The compressive strength of Shaktiman end hook steel FRC (E 77.7 - E 46.6) was increased by 31.24%, and 23.25% respectively when compared to PC

The compressive strength of Shaktiman crimped steel FRC (C 77.7 – C50) was increased by 26.98%, and 20.14% respectively when compared to PC

4. Conclusions

For the Beakart FRC with end hook fibers (E 80, E 50) increase in the number of blows as that of the plain concrete. For the Shaktiman FRC with end hook fibers (E 77.7, E 46.6, C 77.7, C 50 and F 50) increase in the number of blows as that of the plain concrete.

The impact energy at failure, increases in all the cases of end hook, crimped and flat Shaktiman FRC when compared to plain concrete and this increase in energy is slightly greater in case of end hook fiber when compared to crimped and flat fibers. Also, the impact energy at failure, increases in both the cases of end hook Shaktiman FRC and end hook Beakart FRC when compared to plain concrete and this increase in energy is slightly greater in case of end hook Shaktiman FRC when compared to end hook Beakart FRC.

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