



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 4, April 2023

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

ijirset@gmail.com

www.ijirset.com

Experimental Study on Fiber Reinforced Concrete Beams by Fracture Mechanics and Comparison with Reinforced Concrete Beams

Riya Kangralkar

Assistant Professor, Department of civil Engineering, Jain College of Engineering and Research Udyambag,
Belagavi, India

ABSTRACT: Concrete has become very important construction material it was also necessary to study fracture properties of concrete. The aim of this research was to study the fracture behavior of FRC comparing RCC. In this study, fiber reinforced concrete beams of two different specimens of sizes 150x100x600mm and 150x200x1200mm with U notch at the mid-span were used. The specimens were reinforced with polypropylene fiber with different volume fraction. Then these specimens were tested under for three point loading and fracture properties were calculated. Finally by comparing experimental results of both type of beams it was observed that the values of fracture energy increases & flexural strength is directly proportional to percentage of fiber dosage. COD values for RCC is much higher than that FRC. The fracture toughness is directly proportional to grade of concrete & percentage of fibers and values of fracture toughness for RCC is more than FRC.

KEYWORDS: Fracture energy, Fracture toughness, FPZ, polypropylene fiber, SIF, COD, CMOD

I. INTRODUCTION

Concrete is used to construct large structures like highways, airports, bridges and ocean structures, which undergoes a large number of cycles of repeated loading. In view of the idea of structure, one has to focus on the significance of the material needed to construct a large structure. Now a days concrete is one of the most important building materials. Concrete has become popular building material since the 21st century, due to its low cost and easy raw material availability.

To study the behavior of concrete properties of concrete under various applied load and one of these fracture properties of concrete considered in the present study. Fracture mechanics is related to propagation of cracks in materials. In the other words the study related to crack and its scattering properties and phenomena is called fracture mechanics. It is important that to understand the nature of cracks in materials and it includes analytical and experimental study of crack propagation experimental is nothing but three point loading and analytical using ANSYS software.

1.1 OBJECTIVES

- To study the fracture energy of FRC beams with different grades and for different percentage of fiber dosage.
- To observe crack mouth opening displacement (CMOD) for FRC beams with varying percentage of fibers and grades of concrete.
- To obtain the stiffness for varying load for FRC beams
- To calculate and compare COD values for FRC with RCC for varying percentage of reinforcement and grade of concrete.
- To observe fracture toughness & stress intensity factor for FRC beams and compare with RCC beams
- Comparison of results with the available literatures.

II. METHODOLOGY USED IN THE STUDY

2.1 EXPERIMENTAL STUDY

To accomplish objectives of the research work proper methodology has to be set which includes materials, mix design, casting, curing & testing. The materials used for casting of FRC beams consist of coarse aggregate, fine aggregate, potable water, cement (OPC grade 43), and fibers.

2.2 MIX PROPORTION

In this study, various water cement ratio (0.5, 0.44 & 0.3), polypropylene fibers at 0.5%, 0.75% & 1.0 % by volume fraction were used. The M20, M40 & M60 grades mix design were prepared using IS code 10262-2019. Materials Details are as shown in table 1.

Table 1. Materials details					Table 2. Physical properties of polypropylene fiber	
Materials	M20	M40	M60			
Cement (kg/m ³)	338	350	368		Specific gravity	0.91
Coarse aggregate(kg/m ³)	1099.5	1144.6	1259		Melt point(°C)	165
Fine aggregate(kg/m ³)	861.8	899.4	812		Acid & alkali resistance	Excellent
Super plasticizer(kg/m ³)	-	3.5	2.3		Aspect ratio	400
Silica fume(kg/m ³)	-	-	69		Tensile strength(Gpa)	600
Fly ash(kg/m ³)	-	-	23			
w/c ratio	0.55	0.4	0.33			
Fiber (kg/m ³)	0.5%	1.75	2.3	1.69		
	0.75%	2.63	3.45	2.54		
	1%	3.5	4.6	3.38		

2.3 PREPARATION OF SPECIMEN

The FRC beam specimens were prepared of two different sizes, 150x100x600 & 150x200x1200mm with different grades & U notch at the mid-span of size 6mm thick and depth 16.636mm & 33.33mm respectively. The specimens were cast and kept for 28 days curing. After the curing period was complete the specimens were demolded and were tested for three point bending on the UTM. The fracture parameters were calculated for FRC beams and then compared with RCC.



Fig.1: Preparation of Moulds



Fig 2: Polypropylene Fiber



Fig 3: After Fibers Mixed With Concrete Placed in the Moulds



Fig 3: After Demolding the Specimen is kept For Curing



|| Volume 12, Issue 4, April 2023 ||

| DOI:10.15680/IJIRSET.2023.1204229 |



Fig 5: After 28days testing on three point loading

III. CALUCLUSION AND RESULTS

3.1 Calculation of fracture energy (G_f):

$$G_f = \frac{A_o}{b[d-a_o]} \tag{1}$$

Where, A_o= Area under load-deflection curve,

b = Width of the Beam, d = Depth of the beam, a_o = Depth of the notch

Table 3. FE. For 600mm beams				Table 4. FE. For 1200mm beams			
% of fiber	GF (N/mm)			% of fiber	GF (N/mm)		
	M20	M40	M60		M20	M40	M60
0.50%	0.24	0.35	0.35	0.50%	0.27	0.28	0.28
0.75%	0.27	0.4	0.43	0.75%	0.32	0.32	0.42
1.0%	0.3	0.41	0.71	1.0%	0.33	0.40	0.43

3.1 Calculation of flexural strength:

$$F.S. = \frac{3 * PL}{2 * bd^2} \tag{2}$$

Where, P = Failure load (N)

L = Span of the specimen (mm),

b & d = Breadth and depth of the specimen (mm)

Table 5. : F.S. of M20			Table 6. F.S. of M40			Table 7: F.S. of M60		
% OF FIBER	600 mm	1200 mm	% OF FIBER	600 mm	1200 mm	% OF FIBER	600 mm	1200 mm
0.5%	3.6	2.4	0.5%	3.6	2.4	R		
0.75%	3.6	2.67	0.75%	3.6	2.79	0.5%	3.6	2.46
1.0%	3.6	2.68	1.0%	3.6	2.82	0.75%	3.6	2.79
						1.0%	6	3

3.3. Crack Mouth Opening Displacement (CMOD):

$$CMOD = \frac{4\sigma a}{E} * V_1(\alpha) \tag{3}$$

In which, $\sigma = \frac{3PL}{2BD^2}$ (4)



|| Volume 12, Issue 4, April 2023 ||

| DOI:10.15680/IJIRSET.2023.1204229 |

$$F(\alpha) = \frac{1.99 - \alpha(1-\alpha)(2.15 - 3.93\alpha + 2.7\alpha^2)}{\sqrt{\pi(1+2\alpha)(1-\alpha)^2}} \tag{5}$$

$$V_I(\alpha) = 0.76 - 2.28\alpha + 3.87\alpha^2 - 2.04\alpha^3 + \frac{0.66}{(1-\alpha)^2} \tag{6}$$

3.4. Calculation of Stiffness

$$\text{Stiffness: } K = \frac{P}{\Delta} \tag{7}$$

Where, P – Load (kN),
 Δ - Deflection (mm),
 K – Stiffness (kN/mm)

Table 8: Shows stiffness values for 0.5% of fibers

LOAD	0	2	4	6	8	8.2
GRADE M20	0	2.15	3.57	4.58	4.73	-
GRADE M40	0	5.71	7.84	8.57	8.08	-
GRADE M60	0	9.5	11.11	10.34	10.95	11.01

Table 9: Shows stiffness values for 0.75% of fibers

LOAD	0	2	4	6	8	8.7	8.95	9.3
GRADE M20	0	2.02	3.28	4.29	4.79	4.8	4.83	4.83
GRADE M40	0	3.13	5.0	6.12	6.67	6.69	7.0	7.04
GRADE M60	0	5.0	6.21	6.5	7.92	7.9	7.85	7.88

Table 10: Shows stiffness values for 1.0% of fibers

LOAD	0	2	4	6	8	8.7	8.95	9.4	10
GRADE M20	0	2	3.33	4.23	4.76	4.82	4.86	-	-
GRADE M40	0	11.76	12.5	11.32	13.56	13.58	11.3	9.89	-
GRADE M60	0	14.28	14.1	12.54	10.38	10.52	10.58	11.2	11.76

CALCULATION FOR COMPARISON OF FRC BEAMS WITH RCC BEAMS.

3.5. Fracture Toughness

$$K_{Ic} = \sigma N \sqrt{a} F(\alpha)$$

Where, $\sigma N = \text{Normal stress} = \frac{6M}{BH^2}$

Where, M = (P_u + P_o) * S / 4,
 S = Distance between two supports
 P_u = peak load, P_o = self-weight of beam
 H = depth of the beam,
 a = notch depth + length of crack

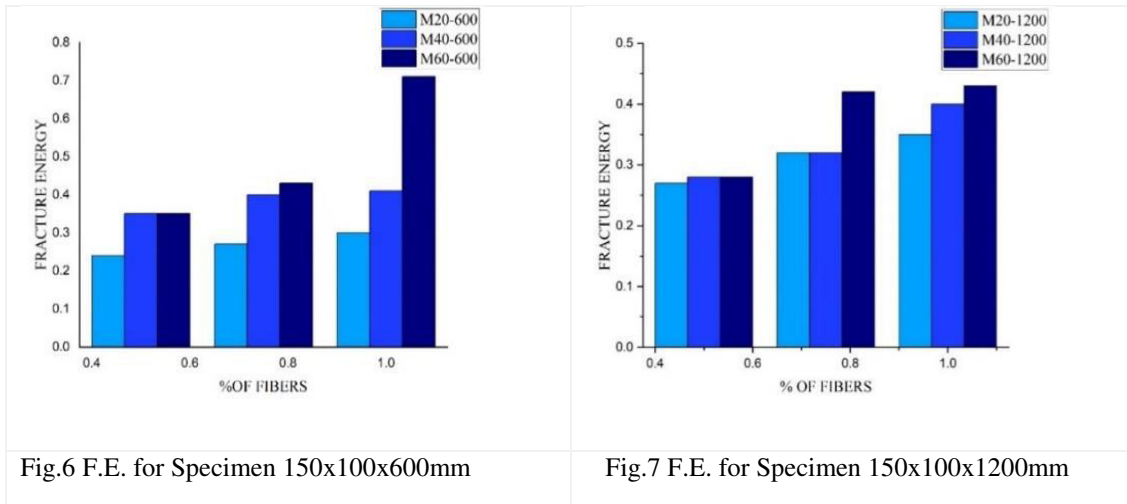
$$F(\alpha) = 1.99 - \alpha(1-\alpha) (2.15 - 3.93\alpha + 2.7\alpha^2) / (1+2\alpha)(1-\alpha)^{3/2}$$



Table 11 FRC values for specimen 600mm				Table 12 FRC values for specimen 1200mm			
FT(N-mm ^{-(3/2)})	M20	M40	M60	FT(N-mm ^{-(3/2)})	M20	M40	M60
0.5%	31.15	27.98	27.95	0.5%	31.15	27.98	27.95
0.75%	27.98	23.4	21.3	0.75%	27.98	23.4	21.3
1.0%	23.4	23.4	29.3	1.0%	23.4	23.4	29.3

Table 13 RCC values for specimen 600mm				Table 14 RCC values for specimen 1200mm			
FT(N-mm ^{-(3/2)})	M20	M40	M60	FT(N-mm ^{-(3/2)})	M20	M40	M60
Under	20.32	55.11	58.41	0.5%	31.15	27.98	27.95
Balance	47.5	71.11	80.26	0.75%	27.98	23.4	21.3
Over	63.5	88.89	127.0	1.0%	23.4	23.4	29.3

IV. DISCUSSION



The above graph shows fracture energy of specimen 100x150x600mm & 200x150x1200mm of different grade as mentioned in the above table for different percentage of fibers, from the graph we can notice that Fracture Energy for beams 0.5% of fibers & 0.75% fibers increases slightly for M20 & M40 grades. For beams 1% fiber of Grade M60 fracture energy values are comparatively higher than the rest for specimen.

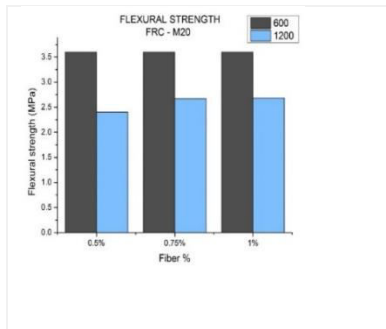


Fig.8 F.S. of M20 grade

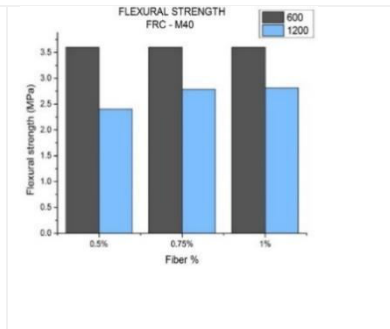


Fig.9 F.S. of M40 grade

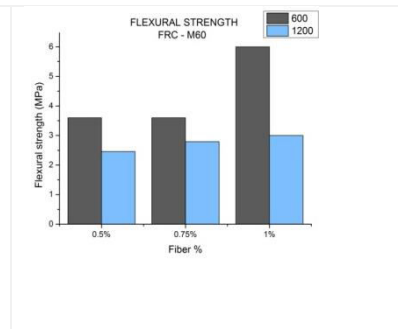


Fig.10 F.S. of M60 grade

The graph shows, flexural strength of grade M20, M40 & M60 specimen size of 600mm & 1200mm beams. As the specimen size increases the flexural strength decreases. For smaller size of specimen is observed with respect to varying fiber percentage. Larger specimen i.e. 1200mm beams in the flexural strength values with increase in percentage of fiber.

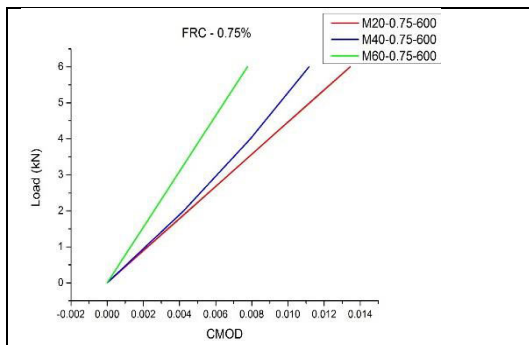


Fig11: CMOD Vs Loads for specimen 100x150x600mm

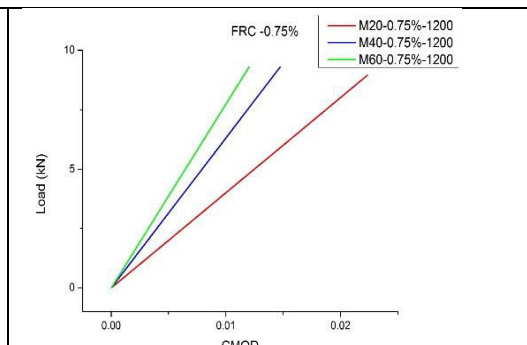


Fig11: CMOD Vs Loads for specimen 200x150x1200mm

From the above graph, we can notice that CMOD vs Load graph is a line graph with variation for 600mm & 1200mm beams. The M20 grade concrete beams show a slightly greater rise in the CMOD value with respect to the load. And for the 0.5% & 1.0% beams shows similar behavior.

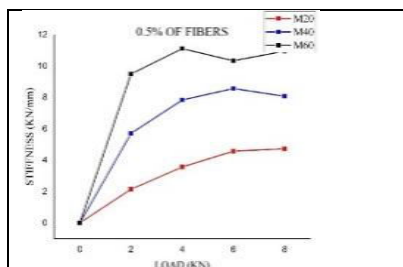


Fig13: stiffness Vs load for 0.5% of fibers

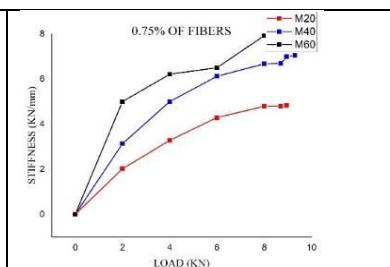


Fig14: stiffness Vs load for 0.75% of fibers

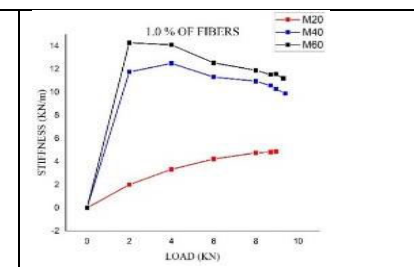


Fig15: stiffness Vs load for 1.0% of fibers

From the above graph, we can observe that the stiffness values with respect to load are much higher for M60 grade of concrete for the percentage 0.5%, 0.75% & 1.0%. The stiffness values are observed to increase with increase in the concrete grade. The stiffness values for each beam decreases gradually after reaching a certain load value. And for the 600mm beams shows similar behavior.

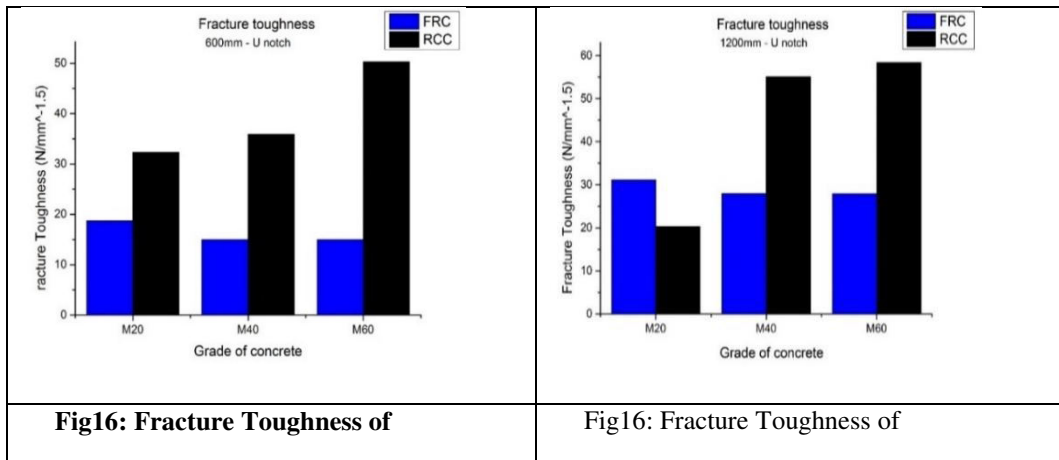


Fig16: Fracture Toughness of

Fig16: Fracture Toughness of

The graphs plotted for 0.5% of FRC beams and under reinforced RC beams of specimen size 100x150x600mm & 200x150x1200mm (fig16 & 17), we can observed that fracture toughness values for FRC beams is comparatively less than the RCC for different. A slight increase in fracture toughness values is observed with increase in grade of concrete. It can also be observed that Fracture Toughness values increase with increase in specimen size.

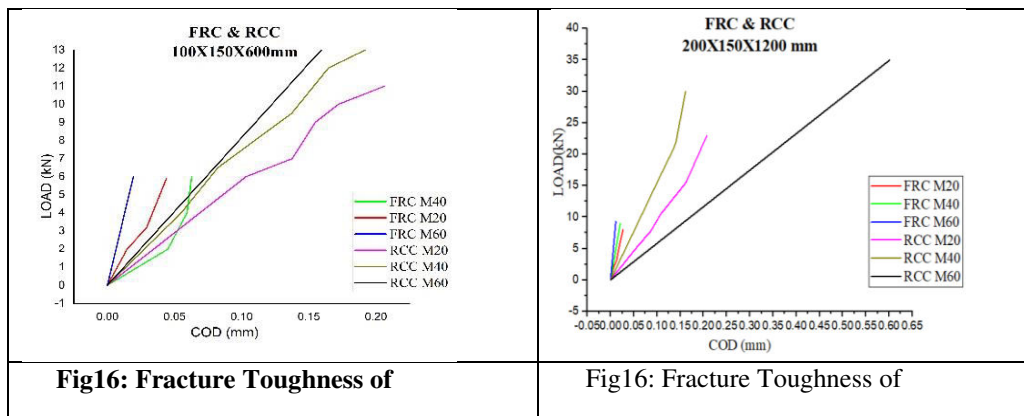


Fig16: Fracture Toughness of

Fig16: Fracture Toughness of

From the above graph (fig 18 & 19), it can be observed that the FRC beams of 1200mm with U notch show a steep variation similar to COD vs load as that of RCC under reinforced beam of 1200mm of M60 grade with V notch. M20 grade RCC beams show a slightly greater increase in COD values with respect to load than M40 and M60 grade of RCC concrete.

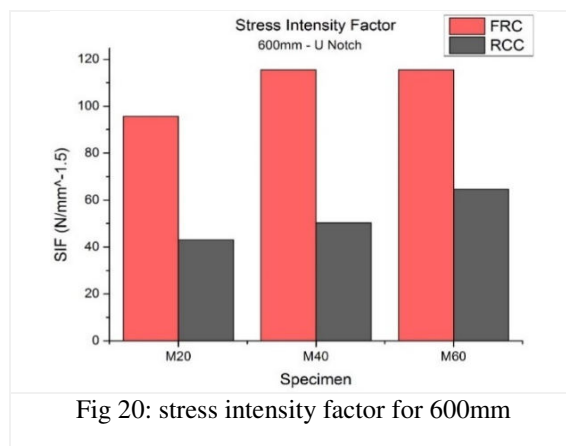


Fig 20: stress intensity factor for 600mm

The above is graph (fig.20) plotted for 0.5% of fiber and under reinforced beams shows, Stress intensity factor for FRC beams size 100x150x600mm is much higher than when compare to RCC beams .The values also observed to increase slightly with increase in grade. And for the 200x150x1200mm beams shows similar behavior.

V. CONCLUSION

- For Fiber Reinforced Concrete the values of fracture energy increases with increase in percentage of fiber dosage. Also by increasing the grades (M20, M40, M60) the value of fracture energy also increases (Ref. fig 6 & 7).
- Flexural strength decreases with increase in specimen size. Flexural strength of M60 grade of concrete specimen size 600mm & 1200mm is comparatively greater than M20 & M60. Flexural strength increases gradually increases with in percentage of fibers (Ref. fig 8, 9 & 10).
- For M20 grade of concrete the CMOD values increase at greater rate with respect to load which implies the rate of increase of CMOD with respect to decreases with increase grade of concrete. (Ref. fig. 11 &12)
- For FRC beam, the stiffness increases with increase in grades concrete & also with increase in percentage of fiber dosage with respect to applied load (Ref. fig 13,14 & 15).
- The fracture toughness value increases with increase in grade of concrete & percentage of fiber dosage in the beams for FRC. The fracture toughness values for RCC is more than FRC beams because steel reinforcement of RCC beam increases the fracture toughness (fig 16 & 17).
- For FRC beams the Crack opening displacement (COD) values increase more with respect to the applied load. Whereas for RCC beams COD increases at slower rate. RCC beams give much higher values of COD compared to FRC beams (fig 18 & 19).
- As we increases the grades of concrete & percentage of fibers dosage of the fibers in the concrete the stress intensity factors also increases. The stress intensity factor for RCC beams in smaller compared to FRC beams (fig 20).

REFERENCES

1. A Ramachandra Murthy, G S Palani, Nagesh R Iyer, SmithaGopinath and B K Raghu Prasad, "Residual strength evaluation of concrete structural components under fatigue loading",
2. Aniket Bhosale, M. Abdur Rasheed, S. Supriya Prakash, Gangadharan Raju (2018) "A study on the efficiency of steel vs. synthetic vs. hybrid fibers on fracture behavior of concrete in flexure using acoustic emission". Indian Academy of Sciences, Vol. 37, Part 1, February 2012, pp 133-147. 3)
3. Andrea Carpinteri, GiovRonchei, anni Fortese, Camilla Daniela Scorza, Sabrina Vantadori(2017) "Theoretical and Applied Fracture mechanics"
4. Caggiano, A Gambarelli, S.Martinelli, E, Nistico, N., & pepe, M (2016) "Experimental characterization of the post- cracking response in hybrid steel/polypropylene fiber reinforced concrete "
5. Mohd Naquiddin Zamri et al., (2017) : Have conducted studies on "Effect of notch position on fracture energy for foamed concrete".
6. Mohammed Ishtiyaque and M.G.Shaikh (2018) "Fracture properties of concrete reinforced with steel fibres"
7. Prasanth, G et al., (2018): Determination of Fracture Parameters of Conventional Concrete Using ANSYS." International Research Journal Of Engineering And Technology (IRJET) ISSN: 2395-0056, Vol. 05 Issue:01 Jan 2018, Pp1492-1497. 4
8. Piotr Smarzewski (2018)"Influence of basalt- polypropylene fibers on fracture properties of high performance concrete". Composite Structures, 209, 23-33
9. SonaliBhowmik, Sonalisa Ray, "An Improved Crack Propagation Model For Plain Concrete Under Fatigue Loading", ELSEVIER, 8 January 2018
10. Sain, T., & Kishen, J. C. (2008). Fracture stability and residual strength assessment of reinforced concrete beams. Materials and Structures, 41(8), 1451-1463
11. Sain, T., & Kishen, J. C. (2008). Damage indices for failure of concrete beams under fatigue. Engineering fracture mechanics, 75(14), 4036-4051.
12. Trisha Sain , J. M. Chandra Kishen (2003), "Damage and residual life assessment of structures using fracture mechanics", 16th ASCE Engineering Mechanics Conference July 16-18, University of Washington, Seattle.
13. Yin chi ,Min Yu, Le Hung, Lihua Xu (2017) " finite element modelling of steel- polypropylene hybrid fiber reinforced concrete using modified concrete damaged plasticity



INNO SPACE
SJIF Scientific Journal Impact Factor
Impact Factor: 8.423



ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

9940 572 462 **6381 907 438** **ijirset@gmail.com**



www.ijirset.com

Scan to save the contact details