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Shear Response of S.F.R.C. Beams with High Grade Steel Stirrups

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Abstract
New researches in material technology are improving material's properties day by day. Construction Industry uses composite materials to resist fire, wind, earthquake and catastrophes. Concrete being weak in tension in place of that, Steel is the major component that takes all the tensile loads in the buildings. Steel has bi linear and multi linear properties of stress strain behavior. BIS restricts use of shear reinforcement of yield strength not more than 415 MPa. Fe 415 now it's rarely available in market because of production and higher demand of Fe 500 steel. Also, some of the lead manufacturers in India started producing Fe 550 and Fe 600. To capture the response of the beams in shear numerical analysis conducted by using FEM based software ATENA 3D on beams, designed using Fe415, Fe500, Fe550 & Fe600 as shear reinforcement bars and Fe500 as longitudinal reinforcement. Total 15 numbers of beam were analyzed in the software with the dimensions of 150x150x700 mm with variation in steel fibers(0 , 1 and 1.5) . The mesh size was kept 0.03 . The result shows that the maximum load and maximum strain in stirrup was taken by the beam with steel stirrup grade of Fe 415 with both 1% and 1.5% steel fiber percentage . This conclusion is made on the basis that since it was found that the maximum force both in the longitudinal bars as well as the steel stirrups was generated in the beams with steel stirrup grade of Fe 415 . Also, the maximum strain in stirrups was also generated in the beams with steel stirrup grade of Fe 415 and the L-D graphs clearly showed that a proper yielding occurred in the beam . So, on this basis it is concluded that these beams underwent a ductile failure as compared to the other models of the beam .

Keywords: *Steel Stirrups, Shear failure of beams, Steel Fiber Reinforced Concrete Beams. ATENA software, Load-Displacement Graph*

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I. INTRODUCTION

New researches in material technology are improving material's properties day by day. Construction Industry uses composite materials to resist fire, wind, earthquake and catastrophes. Concrete being weak in tension in place of that, Steel is the major component that takes all the tensile loads in the buildings. Steel has bi linear and multi linear properties of stress strain behavior. Nowadays higher yield strength is available with steel reinforcement with good resistance to corrosion and other effects. Main component that we deal with steel reinforcement is the yield strength of steel. As reinforced concrete is a composite material of concrete matrix and steel placed in suitable fashion. It needs a balance between permissible stresses in the both materials. To capture the response of the beams in numerical analysis by using FEM study to be conducted with the test beams designed using Fe415, Fe500, Fe550 & Fe600 as shear reinforcement bars. BIS restricts use of shear reinforcement of yield strength not more than 415 MPa. Fe 415 now it's rarely available in market because of production and higher demand of Fe 500 steel. Also, some of the lead manufacturers in India started producing Fe 550 and Fe 600. The restriction of yield strength of steel stirrups directly influences the spacing of shear stirrups that ultimately control diagonal cracks and crack widths. The grade of longitudinal steel controls the parameters like deflection of elements. This matter provides a good hold over serviceability of structural elements also bond characteristics of different diameter of steel bars. Nowadays Finite element analysis programs are developed for simulating the composite sections like Reinforced concrete beams that can analyses the elements and predicts the behavior of members in flexure, shear, bond etc. with a good accuracy. Deflection of members, stresses at particular point, strains, deformations, slippage all the things can be calculated from such software. The results of Finite element analysis software can be validated by comparing it with experimental study by providing same data set to analysis software as considered for experimental testing. IS 456 ; 2000 suggest the use of steel stirrup of grade Fe415 but as we have seen in the latest technological advancements the use of steel fibers with higher strength like Fe500 , Fe550 are being used much more frequently in construction projects . It has also been seen that the of availability limited and is not much widely available as compared to Fe500 , Fe550 , Fe 600.

1.1 Materials

1.1.1 Concrete

In this work, the mechanical properties of the concrete used are taken for the experimental analysis done by Semsi Yazıcı et. al (2007) with the following properties given in Table 1 :-

Table 1 : Properties of Concrete

PERCENTAGE OF STEEL FIBRE	COMPRESSIVE STRENGTH (MPa)	TENSILE STRENGTH (MPa)	ELASTIC MODULUS (MPa)
0	49.1	5.94	35035
1	53.7	6.32	36640
1.5	57.7	7.75	37980

1.1.2 Longitudinal Reinforcement

In this work, Fe500 grade of reinforcement is used with the following properties as shown in Table 2 **:-**

Table 2 : Properties of longitudinal Reinforcement

PROPERTIES	VALUES
Type	Bilinear
Elastic modulus (MPa)	200000
σy (MPa)	500

1.1.3 Stirrups

In this work, Fe415 , Fe500 , Fe550 , Fe600 grade of reinforcement is used with the following properties as shown Table 3 :-

Table 3 : Properties of stirrups

PROPERTIES	VALUES
Type	Bilinear with hardening
Elastic modulus (MPa)	200000
σy (MPa)	415 ,500 , 550 , 600

In this research work, total 12 number (four for each percentage variation) of beams were modelled and analyzed in ATENA to do this study. These beams are designed and over reinforced for flexural failure so that the shear response is predictable

1.2 Numerical Modeling

Numerical simulation is done to create the models of the respective beams with different steel grades ranging from Fe 415 , Fe 500 , Fe 550 , Fe 600 . The beams created are then analyzed to see for the results and then compare them with each other . In the same manner the SFRC beams were created by adding the properties of the concrete with steel percentage of 1% and 1.5% . , the mechanical properties of the concrete used are taken for the experimental analysis done by Semsi Yazıcı et. al (2007) and the A/D ratio is kept at 45. . The ATENA software has the following steps involved in its system and its results are comparable to the experimental investigation. In ATENA, analysis is done in three stages namely:-

1.2.1 In Pre-processing stage, geometry, material boundary conditions and loads are applied to the model. In the second stage analysis is done with required analysis information such as solution parameters and analysis steps required to find the solution. Post- Processing is used to extract the required results in terms of crack width, stresses, ultimate load and deflection, rebar strains.

1.2.2 Analysis can be initiated in ATENA by clicking RUN button on top right corner after that new window of analysis is appeared. By clicking the calculate button analysis start running and the progress can be tracked by load-deflection curve and the information on the bottom of the window.

1.2.3 After the analysis the ultimate load carried can be found out in post-processing mode In post processing load at each step, stress and strain on the beam and reinforcement can be found out. The result output and the discussion of the outcomes is discussed in the next chapter.

II. RESULT AND DISCUSSION

The results obtained are as discussed below

1. Load-Displacement Curve

The maximum load taken by the beam was 203KN with steel stirrup grade of Fe 415 and 1.5% steel fiber percentage . With addition of fiber, it was found that there is an increase in the load carrying capacity of the beam . It was also seen that with addition of steel fibers the crack width generated in the beam and the stresses developed can be reduced to certain extents. These all graphs showed the possible outcomes due to the proper bond formation that took place between the stirrup and concrete which eventually resulted in the ductile failure of the beam thereby giving the mentioned results shown in table 4.

Table 4 : Ultimate Load achieved

PERCENTAGEOF STEEL FIBRE	GRADE OF STIRRUPS	ULTIMATE LOAD (kN)
0	Fe 415	163
	Fe 500	172
	Fe 550	178
	Fe 600	164
1	Fe 415	160
	Fe 500	164
	Fe 550	167
	Fe 600	158
1.5	Fe 415	203
	Fe 500	180
	Fe 550	190
	Fe 600	188

2. Force Generated In Steel Stirrups

Table 5 shows that fe 550 steel stirrup grade with 1.5% steel fiber reinforcement percentage generated the maximum force in the longitudinal bar and has given a good yielding . The reason behind this might be the formation of proper bonds between the stirrup and the concrete which led to the proper transfer of load to the bars and stirrups.

Table 5 : Force generated in steel stirrups

PERCENTAGEOF STEELFIBRE	GRADEOF STEEL	MAX STRESS (MPA)	DIA OF STEEL (M)	FORCE IN BAR (KN)
	Fe 415	360	8	18.09

0	Fe 500	386.8	8	19.43
	Fe 550	362.2	8	18.20
	Fe 600	344	8	17.28
1	Fe 415	360.1	8	18.09
	Fe 500	334.5	8	16.81
	Fe 550	349.5	8	17.56
	Fe 600	356.2	8	17.90
1.5	Fe 415	429.6	8	21.58
	Fe 500	328.2	8	16.49
	Fe 550	365.7	8	18.37
	Fe 600	393	8	19.74

3. Maximum Crack Width Generated At The Ultimate Load

These crack width that are generated clearly show that the beam underwent a shear failure that might be caused due to the reason that the stirrups had formed a good bond with concrete that results in the proper transmission of forces in the stirrups and bars . The pattern of cracks generated can be seen moving from the tension face of the member back to the support and are shown in Table 6,

Table 6 : Maximum crack width obtained

PERCENTAGE OF STEEL FIBRE	GRADE OF STIRRUPS	MAX. CRACK WIDTH (m)
0	Fe 415	0.00407
	Fe 500	0.00103
	Fe 550	0.00113
	Fe 600	0.000929
1	Fe 415	0.00157
	Fe 500	0.00107
	Fe 550	0.001057
	Fe 600	0.00103
1.5	Fe 415	0.00124
	Fe 500	0.000889
	Fe 550	0.00109
	Fe 600	0.00119

4. Detailed Representation Of The Strain , Forces Developed In The Longitudinal Bars And Steel Bars , Ultimate Load , Stress And Crack Width Of The Analyzed Beam Models Is Shown In Table Given Below :

The below given table 7 shows a detailed comparison between the different models of beam analyzed and it is clearly seen that Fe 415 with 1.5% steel fiber percentage is a much better and more suitable option that could be used as a grade of stirrup because of its high yielding and proper bond formation with the concrete. The reason behind this is likely due to the fact that Fe 415 had made proper bond with the concrete that resulted in complete yielding . Also, it is seen that the beam underwent a ductile failure as compared to other samples . All these are the reasons that led to the conclusion that Fe 415 steel stirrup grade performed better as compared with other beams .

Table 7 : Detailed representation of the strain , forces developed in the longitudinal bars and steel bars , ultimate load , stress and crack width of the analyzed beam models is shown in table given below :

%AGEOF STEELFIBRE	GRADEOF STIRRUPS	ULTIMATE LOAD (kN)	MAX. STRAIN	MAX. CRACK WIDTH (m)	FORCE INSTIRRUPS (KN)	FORCE IN LONGITUDI-NAL BAR (KN)
0	Fe 415	163	0.00176	0.00407	18.09	63.30
	Fe 500	172	0.00193	0.00103	19.43	72.35
	Fe 550	178	0.00181	0.00113	18.20	72.75
	Fe 600	164	0.00172	0.00093	17.28	63.30
1	Fe 415	160	0.0018	0.00157	18.09	70.34
	Fe 500	164	0.00167	0.00107	16.81	66.32
	Fe 550	167	0.00167	0.00106	17.56	63.10
	Fe 600	158	0.00178	0.00103	17.90	70.34
1.5	Fe 415	203	0.00214	0.00124	21.58	80.38
	Fe 500	180	0.00164	0.00089	16.49	72.35
	Fe 550	190	0.00182	0.00109	18.37	83.00
	Fe 600	188	0.00196	0.00119	19.74	72.35

III. CONCLUSION

The models made in the software were analyzed and the results generated for the ultimate load , crack width , forces generated in longitudinal steel reinforcements and steel stirrups and the Strain generated in steel stirrups were all mentioned in the previous chapter . This chapter deals with the conclusions that have been made after reading and analyzing the results and coming up with the required outcomes of the comparisons and their related optimum solutions .

Following are the conclusions made from the results :

- Numerical simulation on the beam of dimensions 150x150x700 mm has been done in ATENA software with the variations done in the percentage of steel fiber added and the grade of steel stirrups. In Reinforced concrete beams without any steel fiber Fe 500 has proven to be a better performing option when properties like the strain value , ultimate load and other mentioned aspects in the research are considered .
- In the case of Steel Fiber Reinforced Concrete with steel fiber percentage of 1% and 1.5% , Fe 415 with 1.5% steel fiber percentage has proved to be a better performing steel stirrup grade as the value of maximum load obtained was 203KN , , the value of maximum strain obtained was 0.0024 , the value of force generated in steel stirrups was 21.58 kN .
- From the above conclusions and the results in the previous chapters it is seen that in the Reinforced Concrete Beam structures , Fe 500 has proven to be a better performing option when properties like the strain value , ultimate load and other mentioned aspects in the research are considered . In case of Steel Fiber Reinforced Concrete with steel percentage of 1% , it is observed that Fe 415 has proven to be a better option when properties like strain value , ultimate load and other aspects

mentioned in the research are considered .In case of Steel Fiber Reinforced Concrete with steel percentage 1.5%, it is observed that Fe 415 has proven to be a better option when properties like strain value , ultimate load and other aspects mentioned in the research are considered .

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