Structural Behavior Due to Hybridization of Sisal and Nylon Fibers in Concrete

Syed Viqar Malik, Anil Achyut Kunte

Abstract: India being a populous country demanding construction on large scale. The change of environment since several years are more often generating seismic waves. Around 9 major earthquakes with magnitude scale of above 6 can be observed over an decade. The present study is to focus in increase in ductility without any earthquake resistance design but with inclusion of combination of fibers like nylon and sisal. Concrete due to its brittleness is very prone in case of seismic resistance alone. Reinforcing concrete with steel bars to strengthen the ductility was the traditional approach which is followed by all over the globe. The use of steel bars to strengthen a concrete beam is confined because of its limitation which causes sudden failure in concrete. Thus, making a concrete material which is more ductile than a normal concrete is basic aim of this experimental research work. T beam are casted to study their performance mainly due to know the behavior of column beam joint during seismic evaluation. The study shows the attributes of concrete due to inclusion of hybrid fibers and even generation of mathematical model to analyze the effect and variation of concrete properties due to inclusion of hybrid fibers. To study their seismic performance cyclic loading test is performed. An trial is made to increase ductility of concrete beams mainly near column beam joint which were very prone towards seismic waves by hybridizing sisal fiber and nylon fiber and can result in increase in ductility and load carrying capacity by 22% and 31% respectively in comparison with control specimen.

Keywords: FRC, Nylon-Sisal Fiber, Linear regression of HFRC, ANOVA in concrete technology.

I. INTRODUCTION

Concrete which is accredited as brittle material due to its performance during normal and impact loads. It has also published in IS 456:2000 that the "tensile strength of concrete is almost 0.7 time the root of compressive strength of concrete" [6]. Hence the percent elongation shows the brittle nature of concrete. The brittleness of concrete can be overcome by traditional method by implying steel rods in concrete. This method is confined because of the complications caused due to over reinforced sections which causes sudden failure in concrete without any prior warning. Hence, a trial is conducted to increase the ductility of concrete by including fiber in concrete to obtain a uniform homogeneous mix with much greater performance.

Recent years shows that the earth quakes are more predominately increasing which causes a lot of causalities both to life and properties even at low magnitude their performance is reduced. A study is conducted to show the behavior of column beam joint with prior to its ductility and physical resistance by making a homogenous mix of nylon and sisal. Nylon and sisal fibers have selected on base of their high modulus of elasticity, low density and tensile strength [3]. Combination of artificial and natural fiber may be a hope for increase in ductility factor of beam. Many researchers have already studied the effect of sisal fiber as well as nylon fiber separately and shows the positive interface of nylon fiber and sisal fiber when utilized in concrete. Of the three joints in beams like exterior joint, interior joint and corner joint, the study was conducted on column beam as an exterior joint. The length of nylon fiber was 10 mm whereas sisal fiber 50 mm has been taken with diameter 0.2 mm. Both the fibers have different aspect ratio to better understand the synergy of fiber in sealing micro and macro cracks as mentioned by Bantia et al. [2].

II. METHODOLOGY

A. Beam Specimen and casting

Plywood moulds are prepared of flange size 78.5x20 cm and web size 61x18.5 cm are prepared to cast T beam. The flange acting as a column contains of 4 number of 16 mm diameter bars consists of HYSD415 grade and web acting as beam consists of 2 main bars of diameter 16 mm and 2 hanger bars of 12 mm diameter HYSD415 grade. The total T beam comprises of stirrup evenly spaced at 50mm center to center of 8 mm diameter. Total 2 beams were casted with M20 grade of concrete with proportion 1:1.5:3 :0.5. One beam SN0, out of four was control beam and remaining beam consists of hybrid combination of nylon and sisal fiber which vary till 2% at interval of 1.0%. (SN1 i.e., 1.0% of sisal fiber+ 1.0% of nylon fiber). The beams are cured till 28 days to conduct experimental investigations.

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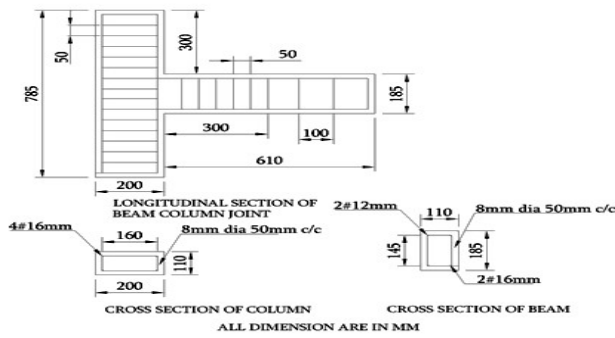
Fig 1: Detailing of Column- Beam joint

B. Experimental test set up:

The load is applied through hydraulic jack and recorded via dial gauge at a distance of 10 cm away from end cyclically at top and bottom and apply a load till 10KN at every cycle both in forward and reverse loading concurrently. The deflection were noted at every 5 KN increment in load cyclically[10].
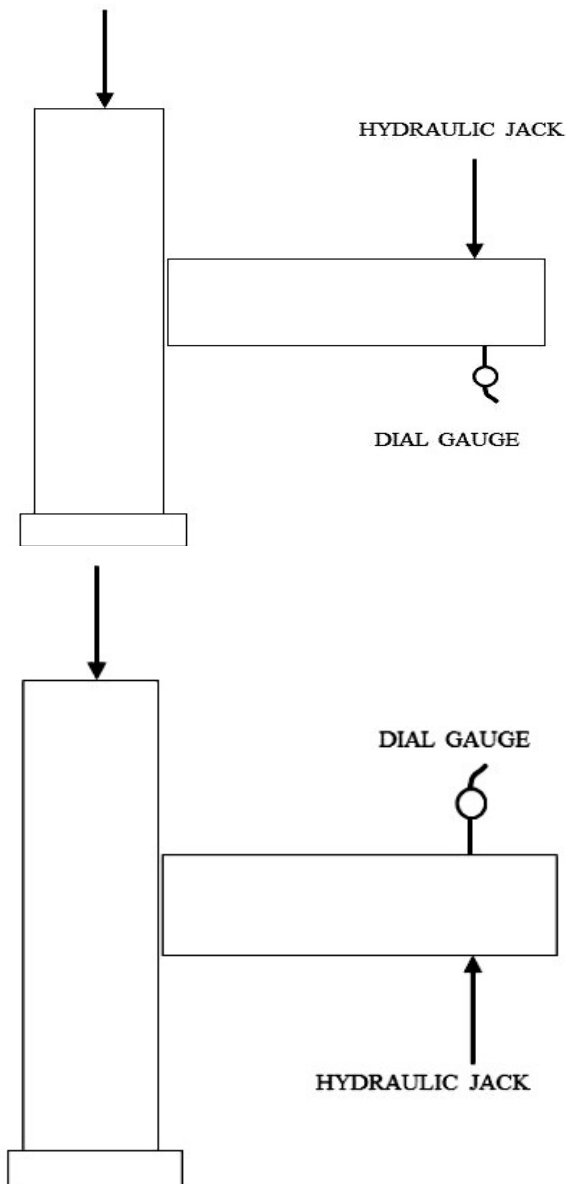

Fig 2 : Load application set-up on beam

III. RESULTS

A. Development of cracks

The development of cracks has been initiated for control beam at an load of 14 KN and for hybrid fiber beam at a load of 22 KN. The deflection observed at initiation of cracks was 2.98 mm and 3.12 mm. The ultimate load carrying capacity was about 29 KN for control beam and about 38 KN for hybrid beam. The deflection at ultimate load was 5.46 mm for control beam and 6.96 mm for hybrid beam. The hysteresis of both the beams with respect to cyclic loading is been represented based upon the values of deflection obtained on loads. Load Cycle for control beam had finished within three cycles whereas for hybrid fiber beam can hold one more cycle loads.
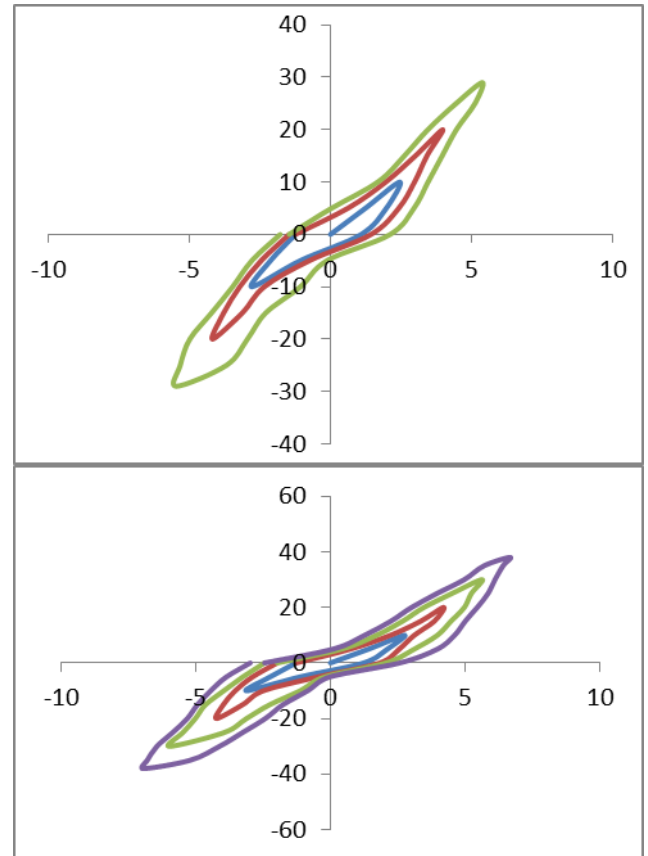

Fig 3 : Hysteresis for beam SN0 and SN1

B. Parameters in structural behavior:

The stiffness in beam SN0 has been pointed as 5.31 KN/mm whereas nearly identical stiffness can be observed even for beam SN1 which is recorded as 5.45. Ductility is an important factor in behavior of structure subjected to seismic zones. The ductility observed was about 1.83 in case of control beam and 2.23 in case of hybrid fiber beam. About 21.8% more ductility can be observed due to the effect of hybridization of nylon and sisal fibers. Energy absorption capacity has also plotted on a graph showing the behavior in all the cycles. It has also been pointed that in cycle 2, there has been some lagging in energy absorption by hybrid fiber beam which has later overcome through it in cycle 3 and 4. Maximum energy absorption can be observed for control beam was about 133.4 KN-mm, whereas for hybrid fiber beam it is noted as 222.5 KN-mm
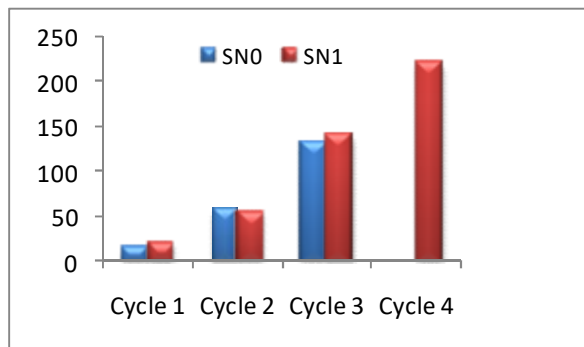
Fig 4 : Energy absorption capacity in cycles for SN0 and SN1 beam

IV. MATHEMATICAL APPROACH

The procedure of least square has been employed on the experimental data and linear regression analysis has been performed to analyze the experimental data. While performing linear regression, the correlation between two data sets i.e., control beam and hybrid fiber beams has been done by plotting the values and finding the correlation constant. Total 25 number of data has been correlated with plotting load on abscissa and deflection of correlated data on ordinate. The pearson's correlation constant was pointed out to be 0.9991 with R^2 = 0.9983 obtaining P= 0.001 (****-highly significant). It can notice that collenearity the data is linear with plotting between two beam SN0 and SN1 as shown in figure. The confidence limit is between 0.9980 to 0.9996, this could be because of less number of pairs used in analysis and even greater than 95% confidence limit. The maximum and minimum values for correlation to plot a line was observed from 5.38 to 5.64 and -546 to -5.98.
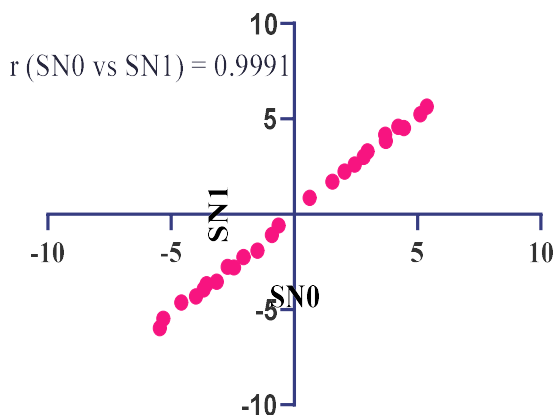

Fig 5: Correlation data of SN0 and SN1 Beam

The values of load to percentage deflection are been plotted with mean and error bars while performing linear regression. As the beam SN1 completes 4 cycles and can also been observed the stack values and closely spaced values of deflection. The maximum error can be observed at the load 29 KN both in forward cycle and reverse cycle. The positive and negative error can be plotted at that point was 0.6133 for SN0 and 0.717495 for SN1.
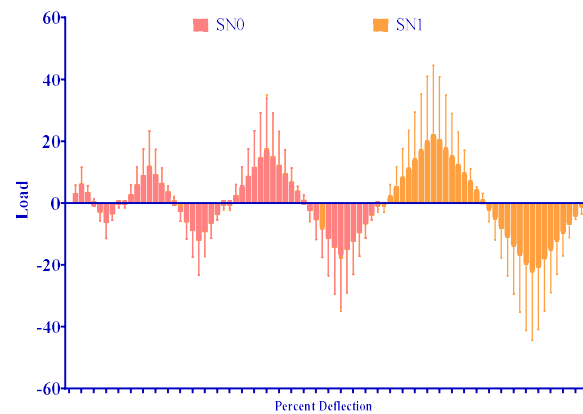

Fig 6: Error in Load Cycles corresponding to cyclic loading

With application of linear regression the slopes of both the data of beams has been checked. By taking 107 degrees of freedom. One d.o.f with respect to load and 106 d.o.f with respect to deflection. The distribution value of F=0.7940 with P=0.3749. It can be pointed out that about 37.49% of difference in slopes of SN0 and SN1 beam. Therefore the slopes of both the values are not same. The slope for SN0 was observed as 0.2075 with intercepts -0.06327 to 0.3049 where as for the beam SN1 as 0.2206 with intercept -0.07036 to 0.3190. The standard error in slope and Y-intercept was observed as 0.009504 and 0.1324 for beam SN0 and for beam SN1, it is noted as 0.0112 and 0.1549. Since the slopes of both the beams SN0 and SN1 are not same, it is even possible to determine the single slope for two data sets of beam SN0 and SN1 with respect to standard errors and was determined as 0.2140. The two equations can be plotted while performing linear regression and shows as below for beam SN0 and SN1.

$$\delta = 0.2075 xP - 0.06327$$

$$\delta = 0.2206 xP - 0.07036$$

Where, δ = deflection and P = load

It can observed that the loads were identical up to the cycle 3 and for cycle 4, beam SN1 undertakes more loads. When linear regression is applied in view of this load and deflection, the distribution is varied as only 0.001212 with same number of degree of freedoms which was discussed earlier. The value of P was pointed as 0.9723. It means that 97.23% of loads were identical for both the cases. About 2.77% of performance has been increased in the case of SN1 beam and hence the loads were also not significantly different. The deflection in both the cases are not same. There is a possibility to calculate the deflection with pooled intercept equal to 0.06682.

The residuals are also been plotted for two different beams which are nearly same for both the beams. The residuals are more in case of beam SN1. The residuals for beam SN0 was observed in between -1.397 to a maximum of 2.183 where as for the beam SN1, the residuals were observed as a limit from -2.38 to 2.13.

All the values are observed when the loads are brought back to rest stage at 0 KN while changing cycle from forward to reverse order.
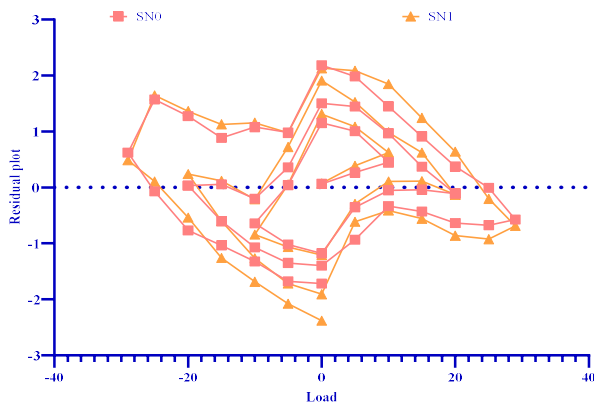

Fig 7 : Residual plot for beam SN0 and SN1

The combined effect total experiment is performed with the aid of two way anova. By analyzing the variance of load and deflection.

• The total variance of sample columns containing strength can be observed as

$$S^2 = \frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n-1}$$

• Generally the quantities were referred as total sum of squares in Anova. In general it is the sum of square of all standard deviations and calculated as

$$SS_T = \sum_{i=1}^{n}(y_i - \bar{y})^2$$

• The sample of variance when divided by degree of freedom gives mean square, as it is diving total sum of squares with degree of freedom.

$$MS_T = \frac{SS_T}{df}$$

The sum of squares for mathematical model generated

$$SS_R = \sum_{i=1}^{n}(\bar{y}_i - \bar{y})^2$$

• the mean square of this mathematical model can be calculated as

$$MS_R = \frac{SS_R}{df}$$

The sum of squares for this error value can be claculated as

$$SS_E = \sum_{i=1}^{n}(y - \bar{y}_i)^2$$

The total variance data can be given as

$$SS_T = SS_R + SS_E$$

It can also be noted that loads were same in this case and limitation of one way anova due to only two cases of beams were there. It needs nearly 3 cases to perform one way anova. So, knowing the fact that loads are identical two way anova is performed to check the significance of experiment with respect to deflection. 24 d.o.f w.r.t to deflection and one d.o.f w.r.t load. The interaction therefore has 24 d.o.f with matrix order 24x1. As already known the load does not have any significant effect on experiment as the loads were kept

constant in both the cases. It can be observed that about 93.68% of observing the same load in both the cases even with reference to interaction between load and deflection. When it counts for deflection, having 24 d.o.f with 60 d.o.f in interaction forming a matrix of size 24x60. The distribution between the data of SN0 and SN1 in this case is observed as 135.26 with the value of P is less than 0.0001. The results of deflection are 0.01% identical when the beam specimen values are randomly chosen. Hence, about 99.99% change in values of deflection can be observed when the whole experiment is analyzed with the variance. Thus, deflection of SN1 has a lot of affect in this experiment and the effect is considered as extremely significant. The deflections were also found out from the mathematical data and pointed out against actual deflection as shown in figure.
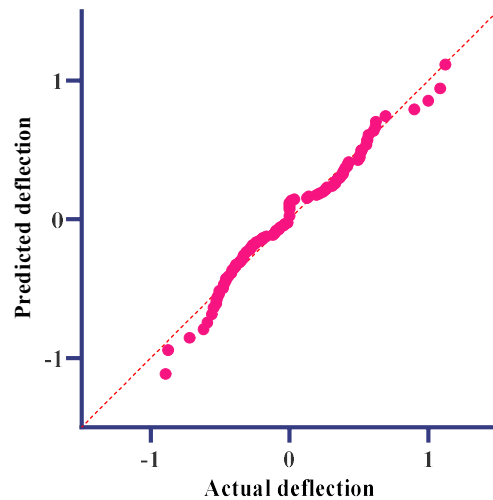

Fig 8 : Quantity plot between predicted and actual deflection.

V. CONCLUSION

• It can be observed that the beam containing combination of nylon and sisal fiber are more resistant when subjected to seismic waves due to higher ductility than normal beams. This Hybrid combination of beam is about 22% more ductile than control concrete.

• Not much difference in stiffness can be observed which could relate to young's modulus of two beams will also be closely related.

• About 66.76% in energy absorption capacity has been increased in case of hybrid fiber reinforced concrete beams.

• The mathematical model also represents the experiment is significant and the values of deflections in most the cases are same as actual experimental deflection. The error that can be observed in mathematical models are very less which states most of the values obtained are under machine precision.

• The ductility of hybrid fiber reinforced concrete beam has been increased by 22% whereas load carrying capacity has increased by 31% in comparison to control T beam.

• The increase in ductility states more resistance against seismic waves which endures more durability when subjected to seismic forces.

• The hybridization of Sisal and Nylon fiber has also increases the load carrying capacity and energy absorption which implies increase in mechanical properties of concrete. Hence, the concrete would be more endurable when fibers have implied in fresh mix.

• The experiment of this size shows extremely significant when ANOVA has been implied.

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