Effect of Shear Span to Depth Ratio on Shear Strength of Steel Fiber Reinforced High Strength Concrete Deep Beam using ANN

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Abstract— **The feasibility of using an artificial neural network (ANN) to estimate the shear capacity of steel fiber reinforced high strength concrete deep beam and its behavior at different shear span to depth ratio for various influencing parameters has been evaluated in this paper. With 98 test results of the experimentations carried by previous researchers on SFRC deep beams, with shear span to depth ratio less than 2.5, have been used to develop the artificial neural network model. The trained model was compared with the empirical equations proposed by previous researchers. The effect of different values of shear span to depth ratio on shear strength of SFRC deep beam, associated with variation in effective depth, fiber volume fraction, fiber aspect ratio, longitudinal steel, compressive strength of concrete, are studied. The developed ANN model was found to be very robust in all situations.**

Key words—**artificial neural network, deep beam, steel fiber, shear span**

I. INTRODUCTION

A beam can be referred as a deep beam if its span (L) to overall depth (D) ratio is comparatively small. Somehow, the range of this ratio (L/D) varies in different codes of practices like IS456 ACI, CIRIA. [1]- [4]. The concrete being a brittle material possesses inherent micro cracks. When subjected to some loading, these micro cracks develop further and propagate. To avoid such crack propagation and brittle failure is the major concern of civil engineering industry. The factors that influence the types of failure are span to depth (L/D) ratio, longitudinal main steel (Ast) and shear span to depth ratio (a/d). The shear failure of deep beam is sudden and catastrophic and needs utmost care.

The position of load from the support point certainly causes diagonal tension failure for the range of values of shear span to depth ratio (a/d) less than two [1].In this case the crack propagates within shear span towards the point where the load is applied. The load transfer is then not possible between the compression concrete zone and longitudinal reinforcement across the crack. An unstable diagonal failure splits the beam into two pieces.[5] [9]. In deep beams, the load is observed to be transferred to supports directly through compression strut formed between support point and the applied load. This type of load transfer generally leads to shear failure in the form of splitting the beam in two parts. The addition of randomly distributed steel fibers causes increased number of haired cracks which are preferable to wider cracks. It is observed by previous researchers [6]- [18] that the crack and deformation characteristics of deep beams reinforced with steel fibers are improved fulfilling its primary objective as crack arrestors. The artificial neural technique (ANN) application is now a day being applied to complex civil engineering problems. [19]-[22].

II. OBJECTIVE

The objective of this paper is to study the effects of shear span to depth ratio (a/d) within the range of less than 2, on SFRC deep beams. The effect is studied for various a/d ratio associated with variation in beam width (‘b’ mm), effective depth (‘d’ mm), longitudinal steel (‘Ast’ %) compressive strength of concrete (‘fc’ MPa), fiber volume fraction (‘V_f’ %) and fiber aspect ratio (‘l_f/d_f’) using artificial neural network model developed for a/d ratio less than 2.5.

III. ARTFICIAL NEURAL NETWORK (ANN)

The developed ANN model is based on experimental test results of 98 experiments carried by previous researchers on SFRC deep beams with a/d less than 2.5. The data contained SFRC deep beams without stirrups. The range of various parameters observed is given in Table 1.

Table I: Statistic for NSC and HSC SFRC deep beams

Parameter	Min.	Max	Mean
Width(b)mm	55	200	109.75
Effective Depth(d) mm	80	558	245.39
Fiber volume(V_f)%	0.25	2	1
Fiber aspect ratio(l_f/d_f)	50	133	73.06
Shear span ratio (a/d)	0.29	2.5	1.64
Main steel(Ast)%	0	5.72	2.35
Comp. strength (fc)MPa	19	99.1	50.31

The Levenberg-Marquardt back propagation algorithm which is one of the fastest methods available for training feed forward artificial neural network is used in this investigation. The architecture of neural network developed is shown in Fig. 1. It consists of three layers: Input Layer with seven neurons representing width, effective depth, longitudinal steel, compressive strength, and fiber volume fraction and fiber aspect ratio. The Hidden Layer consists of 11 neurons and Output Layer with one neuron representing shear strength of SFRC deep beams. The links between the neurons represent weight and bias connections. A 'sigmoid' function is used in hidden layer. This function squashes the output in to the 0 and 1 as per following expression-

$$logsig(n) = 1/(1+exp^{-n}) \quad (1)$$

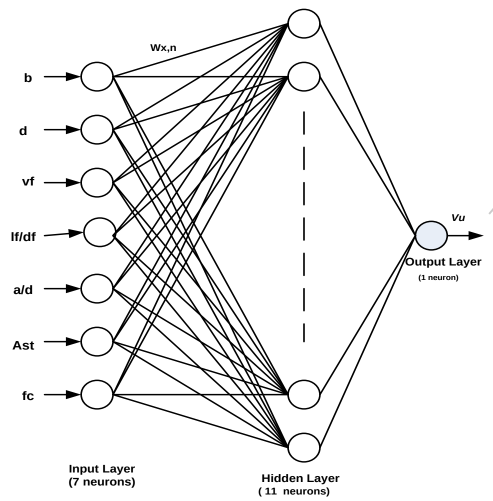

Fig.1: Two Layered Feed Forward Back Propagation ANN

A. *Scaling of Training data*

The network is supplied with 80% of the total data for the training and 10% each, of remaining data, for validation and testing. The MATLAB (R2009a) package is used for the development of present neural network. Preprocessing of training data processes the data in the range – 1 to + 1. The training data is preprocessed for normalization using –

$$y = (y_{max} - y_{min}) \times \frac{x - X_{min}}{X_{max} - x_{min}} + y_{min} \quad (2)$$

The data from output neuron was post processed to convert the output into actual value of shear strength

The network parameters considered in this approach are: Number of hidden layers=1, Number of hidden units= 11, Learning Rate= 1, Momentum Factor= 0.5 and learning cycles= 10000. The coefficient of correlation R^2 was 0.970. It indicates excellent correlation.

The performance of the developed ANN model is shown in Fig.2. The performance was monitored during training process as sum squared error over all the training data. The Fig. 2 shows the graph of targeted shear strength verses predicted shear strength by ANN model. The predicted shear strength is found in excellent agreements with experimental results.

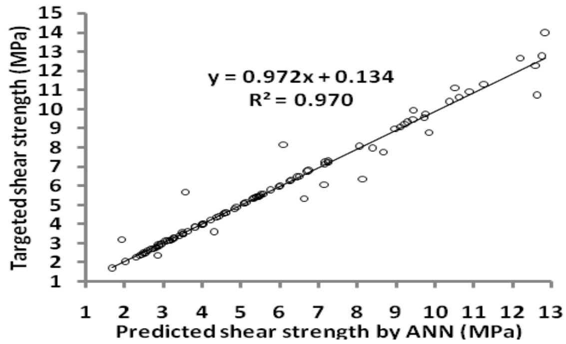

Fig.2: Comparison between targeted and predicted shear strength by ANN

IV. PARAMETRIC STUDY

To evaluate the effect of shear span ratio on the behavior of deep beam (*a/d*<2.5), the values of various parameters assumed are given in Table 2. The values considered are theoretical and assumed arbitrarily for the analysis by the developed artificial neural network. The results of ANN are then studied to understand the effects of variations in the influencing factors like effective depth, longitudinal steel, compressive strength of concrete, fiber volume content and fiber aspect ratio, span-depth ratio.

Table 2: Ranges of Parameters

Parameter	Range
Effective Depth (d) mm	300,350,400,450,500
Fiber Content (V_f)%	0.5,1,1.25,1.5,1.75,2
Fiber Aspect Ratio(l_f/d_f)	20,30,40,50,60,70,80
Shear Span Ratio (a/d)	0.5,1,1.5,2
Longitudinal steel (%)	0,0.5,1,1.5,2,2.5
Compressive Strength (f_c) MPa	30,40,50,60,70,80
Span to depth ratio (L/D)	1

V. RESULTS AND DISCUSSION

A. Effect of effective depth

Fig.3 depicts the effect of shear span to depth ratio on high strength concrete deep beam with increase in effective depth while other parameters are assumed constants. The fig.3 represents that at lower values of *a/d*=0.5, the shear strength increases at all depths considered. It is also observed that the further increase in a/d values causes decrease in shear strength at depths *d*=400mm and 450mm while increase in shear strength is noted for *d*=250mm to 300mm for values of *a/d*= 0.5 to 1.

It reveals that the shear strength of SFRC high strength (*fc*=70MPa) deep beams with width to depth ratio (*b: d*=1:2.33) up to 0.43, increases with increase in shear span to depth ratio. For *b: d* ratio greater than 0.43, the shear strength decreases with increase in *a/d*. The effect of increase in a/d is worst at *a/d*=1 for *d*= 400mm and 450mm (*b: d*> 2.33).

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B. Effect of fiber volume fraction

Fig.4 shows the effect of shear span to depth ratio along with change in fiber volume fraction (V_f %) on SFRC high strength deep beams while other parameters assumed constant. It predicts that the shear strength of SFRC high strength deep beam at a particular *a/d* increases with increase in fiber volume fraction. The enhancement in shear strength can be observed for volume fraction up to 1.5% at all a/d ratio assumed. But the percentage increase in shear strength reduces with increase in *a/d* ratio e. g. the % increase in shear strength for V_f =1% at *a/d* = 0.5 to 1 is 39% while at *a/d*= 1 to 1.5 is 32%. The percentages increase for *a/d*= 1.5 to2 is found 19%.

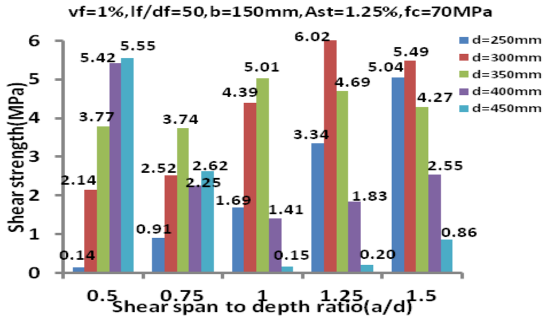

Fig.3: Effect of shear span to depth ratio on shear strength SFRC deep beam with varying depth

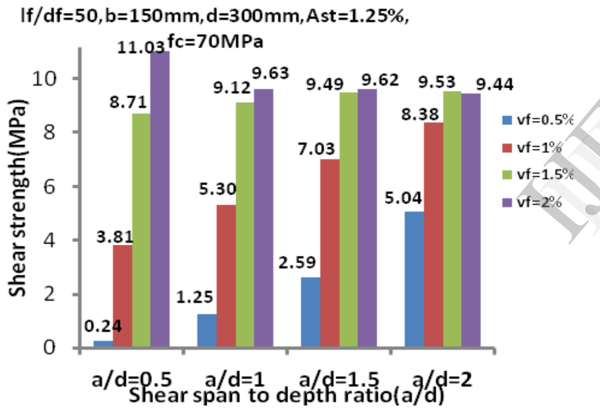

Fig.4: Effect of shear span to depth ratio on shear strength SFRC deep beam with varying fiber volume fraction.

On the contrary, it is seen that the shear strength decreases by 14% with increase in a/d ratio for fiber volume fraction of 2%. It suggests fiber volume fraction 1.5% to be the optimal fiber addition for *a/d*< 2 and for the assumed constant parameters.

C. Effect of fiber aspect ratio

The Fig.5 reflects the effect of shear span to depth ratio along with variation in fiber aspect ratio (lf/df) when other parameters are kept constant. It indicates that the shear strength for fiber aspect ratio 40 and 50 increases with increase in shear span to depth ratios. It is also observed that the shear strength decreases at *a/d*=0.75 for fiber aspect ratio greater than 50. The decrease in strength at *lf/df*= 80, 70 and 60 at *a/d*=0.75 is 20%, 25%, 15% respectively. It further increases by 29%, 36%, for fiber aspect ratios 80 and 70 at *a/d*> 0.75. The shear strength increases by 21% up to *a/d*=1.25 for *lf/df*= 60. This indicates that the optimal fiber ratio exists for SFRC strength.[25]

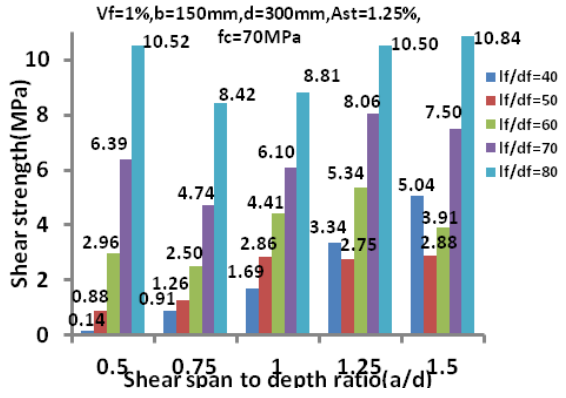

Fig.5: Effect of shear span to depth ratio on shear strength SFRC deep beam with varying fiber aspect ratio.

C. Effect of concrete compressive strength

The effect of a/d ratio on SFRC high strength deep beams with variation in concrete strength along with variation in fiber volume fraction is shown in Fig.6 and Fig.7.

Fig.6 shows decrease in shear capacity with increase in concrete grade from 60MPa to 80MPa even with fiber content of 1% at all shear span to depth ratio considered. On the contrary, the shear strength increases for concrete grade from 50MPa as seen from Fig.7.

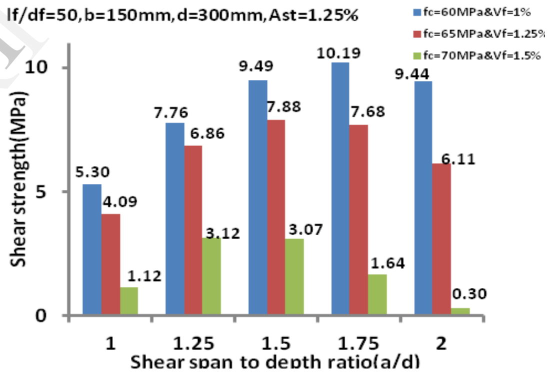

Fig.6: Effect of shear span to depth ratio on shear strength SFRC deep beam with varying grade of concrete and fiber volume fraction.

It clearly shows that shear strength increases with increase in shear span ratio while strength goes on decreasing for high strength SFRC deep beam. For volume fraction 1% and concrete grade 50MPa,the enhancement is observed 4.5% as against decrease in strength by 8% for concrete grade 80MPa.For 1% volume fraction and L/D=1, the shear strength increases with compressive strength up to 70MPa and further reduces at 80MPa.

E. Effect of longitudinal steel

The Fig.8 represents the effect of shear span to depth ratio with variation in longitudinal steel combined with 1% of fiber volume fraction. The shear capacity is found increasing with increasing area of longitudinal steel at a particular *a/d* ratio as shown in Fig.8.It can also be observed that the shear capacity is reduced as a/d ratio increases. The rate of variation in shear strength is also reducing as the compressive strength of the concrete constant shear strength.

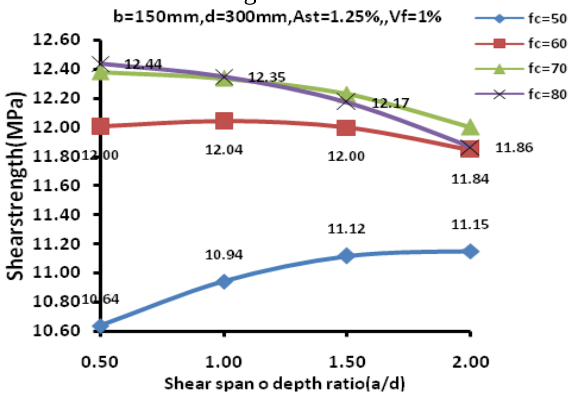

Fig.7: Effect of shear span to depth ratio on shear strength SFRC deep beam at different grade of concrete

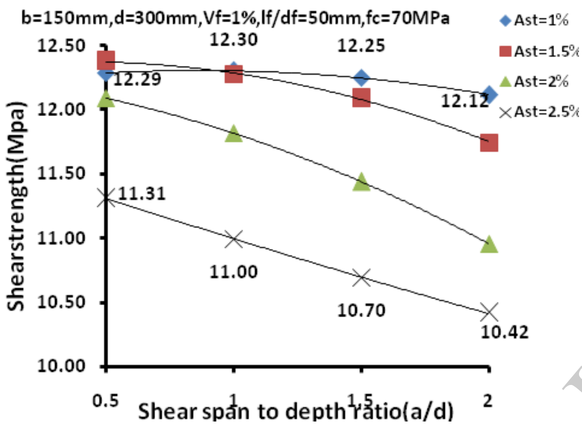

Fig.7:

Effect of shear span to depth ratio on shear strength SFRC deep beam at varying area of longitudinal steel.

VI. CONCLUSION

The shear strength of steel fiber reinforced concrete is affected by various factors and its complex behavior. The artificial neural network developed with one input layer with eight neurons, hidden layer with twenty neurons and output layer with single neuron proves to be very successful in predicting this complex behavior of SFRC deep beam in shear.

The results predicted by developed ANN resembles with the findings of previous researchers. This shows the validity and versatility of developed neural network.

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