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Prediction on Mechanical Properties of Hybrid fiber concrete using MatLab

M.Rajaram[1], A.Ravichandran[2], A.Muthadhi[3]

[1]Research scholar, Dept. of Civil Engineering, Pondicherry Engineering College, Puducherry, India.
[2]Director, Christ College of Engineering and Technology, Puducherry, India.
[3]Assistant Professor, Dept. of Civil Engineering, Pondicherry Engineering College, Puducherry, India.

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Abstract - *In this study, Matlab software is used to predict the mechanical properties of concrete containing hybrid fibers with Ground Granulated Blast furnace Slag (GGBS) as partial cement replacement respectively. The data used in the model construction were obtained from laboratory experiments. The mechanical properties were experimentally determined for specimens containing 0%, 0.5%, 1%, 1.5% and 2% volume fractions of hybrid fibers with 20% of GGBS as partial cement replacement at curing ages of 28 days, accounting for a total of 150 observations. The various volume fractions were fed as the input parameters to achieve the mechanical properties as the target. The Matlab models demonstrated more accuracy and had higher correlation. In the models of the training and testing results have shown that Matlab have strong potential for predicting 28 days compressive, splitting tensile and flexural strength values of hybrid fiber concretes containing GGBS.*

Key Words: **Matlab, Prediction, Mechanical Properties, GGBS.**

1. INTRODUCTION

Natural disaster like earthquake will cause the massive damage to the buildings and structures which leads to the loss of human lives, economy and environmental issues. Development of longitudinal and transverse reinforcements has been introduced to overcome brittle failure in the beams which is the major drawback in the over-reinforced sections. By providing large amount of lateral reinforcement in the over reinforced sections will help to increase the ductility of the members. Hence, it is very important to develop new types of structures which utilize the materials which will enhance the ductility of the structures. Introducing fibers in the concrete is not a new theory which will leads to the change in material behavior from brittle to ductile. The ductility of the structure depends on the types of material used and also structural characteristics of the assembly. If care is taken during designing, it is possible to build ductile structure with reinforced concrete thus permitting it to deform plastically without breaking. When a ductile structure tends to deform inelastically if it is subjected to overloading, it will redistribute the excess load to elastic parts of the structure (Rajaram et.al., 2018).

In olden days horsehair and straw were the fibers used in the mud bricks. Later in 1900s, asbestos fibres were used in concrete and in the 1950s the concept of using composite materials and fibre reinforced concrete were used. By the 1960s, steel fibre reinforced concrete (SFRC) and by 1970s Glass Fibre Reinforced concrete (GFRC) and synthetic fibres such as polypropylene fibres were used in the concrete. Concrete contains more than one or two types of fibres will be termed as Hybrid fibre reinforced concrete (Rajaram et.al., 2017). The concrete involves fibres of different lengths or a combination of steel and synthetic fibres in different volume fractions. It is favorable to use two or more types of fibres in concrete according to American Concrete Institute (ACI) manual of concrete practice. Using of hybrid fibers in concrete will enhance the engineering properties of concrete which is higher than the concrete containing single fiber matrix (Ravichandran et.al., 2009).

Minimization of experimental task leads to the development of software which will predict the properties of the concrete in recent years (Atici 2011). Models have been created using these software and equations were also derived to predict the engineered properties (Palika et.al., 2014). Generating of models by Regression analysis is one of the traditional methods involved in model generation (Muhd et.al., 2015). Simplest and quickest prediction were the major advantage of regression analysis. Multiple regression will be performed for the accuracy of the model (Ferhat et.al., 2013). By performing multiple regression the accuracy of the model can be enhanced (Marek Slonski 2010). Increase in number of independent variables will result in the decrease in the accuracy of regression analysis (Sadrmomtazi 2013). In such complex cases, the use of methods like Artificial Neural Networks (Ramana et.al., 2009), adaptive neuro fuzzy inference systems, factorial design, genetic based algorithms, model tree and fuzzy logic (Ahmet et.al., 2013; Rahmat et.al., 2012; Tortum et.al., 2009) are employed to improve the accuracy of the predicted models. Models are developed in MATLAB software (Ravichandran et.al., 2009) in order to predict the mechanical properties of concrete specimens and the results of both models are compared with each other. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python. Although

MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing abilities.

In the current study, the mechanical properties of normal Concrete is taken as the dependent variable, whereas, hybrid fiber volume fractions form the independent variables. The objective of this study is to construct probabilistic models for the prediction of compressive strength, split tensile strength and flexural strength of Hybrid fiber Concrete with GGBS.

2. MATERIALS AND METHODS

2.1 Material and mix proportion

OPC 43 grade cement with reference to IS 12269-1987 and with a specific gravity of 3.08 was used in concrete mixtures. Sand passing through 4.75 mm sieve with reference to zone II of IS 383:1970 with a specific gravity of 2.45 and gravels available from native sources with conventional size of 20 mm with reference to IS 2386:1963 was used as fine and coarse aggregate in this work. Steel fiber having length a of 30mm with diameter of 0.75mm and glass fiber having a length of 25mm with diameter of 0.5mm were used. The aspect ratio of 40 for steel fiber and 50 for glass fiber were kept constant. Four different volume fractions (0.5%, 1.0%, 1.5%, and 2%) of hybrid fiber with 20% GGBS (as a replacement of cement) were used in this investigation.

2.2 Mixing and curing

The final mix proportion for M25 grade of concrete has been prepared with the reference of IS 10262:2009 and from the trial mixes. The values for the mix proportion and w/c ratio are shown in the table 1 and 2. The hybrid fiber concrete is prepared by as same to the conventional concrete. Primarily cement, aggregates & GGBS are mixed in a dry state. Further, fibres were mixed into the dry mixture for another 60 seconds. Finally the water was added to the dry materials and the mixing was done in an appropriate manner to confirm the distribution of fibers in concrete is uniform. After mixing, the concrete was placed in three portions of the cube. Every portion of the concrete was compacted at a rate of 60 to 80 manual strokes using tamping rod. A total of 248 specimens were casted and de-molded after 24 hours. After the curing age of 28 days, all the specimens were tested.

Table 1 Mix Proportion

Grade	Mix proportion	w/c
M 25	1 : 1.82 : 2.83	0.5

Table 2 Mix Proportion for 1m^3

Mix	W/C	Water Kg/m3	Cement Kg/m3	Fine Aggregate Kg/m3	Coarse Aggregate Kg/m3	Volume Fraction Vf	Steel fiber content Kg/m3	Glass fiber content Kg/m3	GGBS (20% Replacement) Kg/m3
Ref	0.5	195	390	712.64	1105.68	0	0	0	0
SC-0.5-100	0.5	195	312	712.64	1105.68	0.5	12.01	0	78
HC-0.5-80-20	0.5	195	312	712.64	1105.68	0.5	9.61	2.40	78
HC-0.5-60-40	0.5	195	312	712.64	1105.68	0.5	7.20	4.81	78
SC-1-100	0.5	195	312	712.64	1105.68	1.0	24.03	0	78
HC-1-80-20	0.5	195	312	712.64	1105.68	1.0	19.22	4.81	78
HC-1-60-40	0.5	195	312	712.64	1105.68	1.0	14.42	9.61	78
SC-1.5-100	0.5	195	312	712.64	1105.68	1.5	36.05	0	78
HC-1.5-80-20	0.5	195	312	712.64	1105.68	1.5	28.84	7.21	78
HC-1.5-60-40	0.5	195	312	712.64	1105.68	1.5	21.63	14.42	78
SC-2-100	0.5	195	312	712.64	1105.68	2.0	48.06	0	78
HC-2-80-20	0.5	195	312	712.64	1105.68	2.0	38.44	9.62	78
HC-2-60-40	0.5	195	312	712.64	1105.68	2.0	28.83	19.23	78

2.3 Compressive Strength

To find the compressive load behavior of conventional and hybrid fiber concrete, the compression strength was determined. The specimens were prepared and tested with reference to IS: 516-1959. The dimensions of the cube is 100 × 100 ×100 mm were cast and cured for 28 days to get the compressive strength at 7 days and 28 days. The cubes remained tested in the saturated surface dry condition and the load was applied gradually to find the maximum load carrying capacity of the cubes.

2.4 Split tensile strength

To determine the tensile load behaviour of conventional and hybrid fiber concrete, the split tensile strength was found. The dimensions of cylindrical specimens consists of 100mm diameter and 200mm length were casted and kept in curing for 28 days. The test was accompanied on cylinders at the curing stage of 7 days and 28 days endorsing to IS: 5816-1970. The maximum load was noted for the split tensile strength for both conventional and hybrid concrete.

2.5 Flexural strength

To find the flexural behavior for conventional and hybrid fiber concrete the flexural strength was determined. The specimens were prepared and tested with reference to IS: 516-1959. The dimensions of the prisms is 100 × 100 × 500 mm were cast and cured for 28 days to get the flexural strength at 7 days and 28 days. The prisms was tested under two point loading condition in the universal testing machine and the load was applied gradually to find the maximum load carrying capacity of the prism under flexure. The mechanical properties of the hybrid concrete with GGBS was given in Table 3.

Table 3 Mechanical Properties of Hybrid fiber concrete with GGBS

Mix	Compressive Strength (N/mm2)		Split Tensile Strength (N/mm2)		Flexural Strength (N/mm2)	
	28 days Strength	**Strength effectiveness (%)**	**28 days Strength**	**Strength effectiveness (%)**	**28 days Strength**	**Strength effectiveness (%)**
Ref	32.25	0.00	3.02	0.00	5.66	0.00
SC-0.5-100	36.26	12.43	3.34	10.60	7.13	25.97
HC-0.5-80-20	35.78	10.95	3.34	10.60	7.83	38.34
HC-0.5-60-40	37.53	16.37	3.52	16.56	8.00	41.34
SC-1-100	37.16	15.22	3.43	13.58	7.58	33.92
HC-1-80-20	39.23	21.64	3.62	19.87	8.35	47.53
HC-1-60-40	50.27	55.88	4.32	43.05	7.31	29.15
SC-1.5-100	38.05	17.98	3.52	16.56	8.00	41.34
HC-1.5-80-20	38.41	19.10	3.53	16.89	9.39	65.90
HC-1.5-60-40	37.81	17.24	3.53	16.89	9.04	59.72
SC-2-100	36.39	12.84	3.14	3.97	7.68	35.69
HC-2-80-20	39.48	22.42	3.36	11.26	8.96	58.30
HC-2-60-40	36.54	13.30	3.25	7.62	8.48	49.82

Inclusion of hybrid fibres leads to an increase in strength efficiency of the concrete. The compressive, split tensile and flexural strength was increased at every fiber volume proportion with compared to the conventional concrete mix. The maximum strength effectiveness for compressive strength is 55.88% which is occurred at mix HC-1-60-40. For split tensile strength, the concrete has reached its maximum strength effectiveness at mix HC-1-60-40 is 43.05%. For both compressive and split tensile strength, the strength effectiveness have reached at the same mix proportion. But for the flexural strength the strength effectiveness reached its maximum strength at HC-1.5-80-20 is 65.90%.

2.6 Matlab

MATLAB is a multi-paradigm numerical computing environment and proprietary programming language developed by Mathworks. It is a high-level language and interactive environment for numerical computation, visualization, and programming. Using MATLAB, you can analyze data, develop algorithms, and create models and applications. The language, tools, and built-in math functions enable you to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages, such as C/C++ or Java. MATLAB is used for a range of applications, including signal processing and communications, image and video processing, control systems, test and measurement, computational finance, and computational biology. More than a million engineers and scientists in industry and academia use MATLAB, the language of technical computing. In this study, the models has been created by MatLab and the equation were also developed to predict the mechanical properties of concrete containing hybrid fibers and GGBS.

3. Result and Discussion

3.1 Compressive Strength

Matlab was used to predict the compressive strength of the concrete containing hybrid fibers with GGBS. A program was written to plot the graph between the experimental values and hybrid fiber volume fractions. The hybrid fiber volume fraction has kept as independent variable to predict the compressive strength of the concrete. Based on the plotting and selection of quadratic equation the predicted curve has been generated in the Matlab which is shown in the Figure 1. From the predicted curve the compressive strength of the concrete was predicted by simply substituting the relative hybrid fiber volume fractions. The predicted values with their corresponding prediction error were given in Table 4.

Based on the results, the average prediction error is 1.40% which shows a good relation among the experimental and predicted values. The quadratic equation were also developed for the further prediction by changing the hybrid fiber volume fractions. The coefficients of the quadratic equation with their values are given as $Y= -3.5x2+8.4x+34$.

Table 4 Predicted values for Compressive strength

Mix	Hybrid Fiber Volume Fraction		Experimental values	Predicted values	Prediction Error in %
	Steel	**Glass**			
Ref	0	0	32.25	33.6	4.19
SC-0.5-100	0.5	0	36.26	36.9	1.77
HC-0.5-80-20	0.4	0.1	35.78	36.4	1.73
HC-0.5-60-40	0.3	0.2	37.53	35.8	-4.61
SC-1-100	1	0	37.16	38.5	3.61
HC-1-80-20	0.8	0.2	39.23	38	-3.14
HC-1-60-40	0.6	0.4	50.27	37.3	-25.80
SC-1.5-100	1.5	0	38.05	38.3	0.66
HC-1.5-80-20	1.2	0.3	38.41	38.6	0.49
HC-1.5-60-40	0.9	0.6	37.81	38.3	1.30
SC-2-100	2	0	36.39	36.3	-0.25
HC-2-80-20	1.6	0.4	39.48	38	-3.75
HC-2-60-40	1.2	0.8	36.54	38.6	5.64

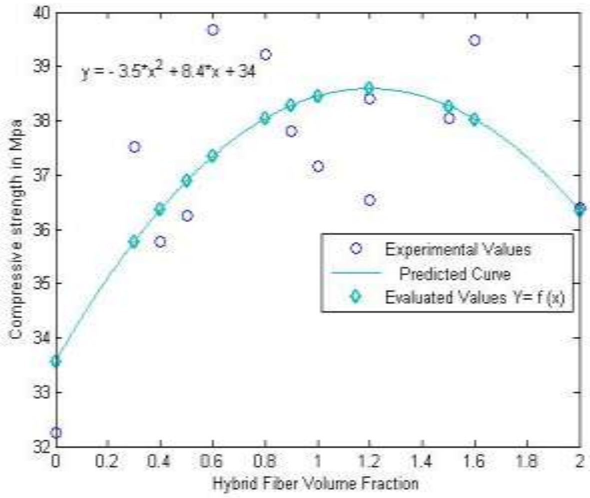

Fig- 1. Predicted curve for Compressive Strength

3.2 Split Tensile Strength

To predict the split tensile strength of the concrete containing hybrid fibers with GGBS, Matlab was used. In the matlab, an algorithm was created to plot the graph between the experimental values and hybrid fiber volume fractions. The hybrid fiber volume fraction was kept as independent variable to predict the split tensile strength which is a dependent variable for the prediction. Based on the plotting and selection of quadratic equation the predicted curve has been generated in the Matlab as shown in the Figure 2. From the predicted curve the split tensile strength of the concrete has been predicted by simply substituting the relative hybrid fiber volume fractions. The predicted values with their corresponding prediction error were given in Table 5.

Based on the results, the average prediction error is 0.43% which shows a good relation among the experimental and predicted values. The quadratic equation were also developed for the further prediction by changing the hybrid fiber volume fractions. By using that quadratic equation the split tensile strength of the concrete was predicted. The quadratic equation with their corresponding coefficients values were given as Y= -0.47x2+0.88x+3.2.

Table 5. Predicted values for Split Tensile strength

Mix	Hybrid Fiber Volume Fraction		Experimental values	Predicted values	Prediction Error in %
	Steel	**Glass**			
Ref	0	0	3.02	3.19	5.63
SC-0.5-100	0.5	0	3.34	3.51	5.09
HC-0.5-80-20	0.4	0.1	3.34	3.47	3.89
HC-0.5-60-40	0.3	0.2	3.52	3.41	-3.13
SC-1-100	1	0	3.43	3.6	4.96
HC-1-80-20	0.8	0.2	3.62	3.59	-0.83
HC-1-60-40	0.6	0.4	4.32	3.55	-17.82
SC-1.5-100	1.5	0	3.52	3.44	-2.27
HC-1.5-80-20	1.2	0.3	3.53	3.56	0.85
HC-1.5-60-40	0.9	0.6	3.53	3.6	1.98
SC-2-100	2	0	3.14	3.05	-2.87
HC-2-80-20	1.6	0.4	3.36	3.38	0.60
HC-2-60-40	1.2	0.8	3.25	3.56	9.54

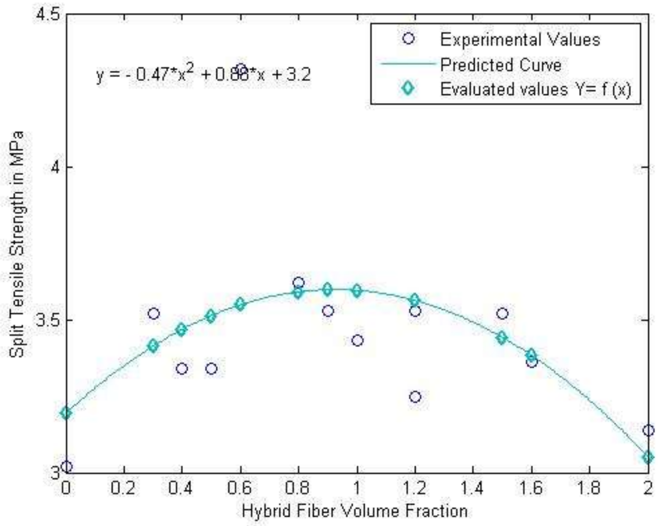

Fig- 2. Predicted curve for Split Tensile Strength

3.3 Flexural Strength

Flexural strength of the concrete containing hybrid fibers with GGBS was predicted with the use of the Matlab software. A program was written to plot the graph between the experimental values and hybrid fiber volume fractions. The hybrid fiber volume fraction has kept as independent variable to predict the flexural strength. Based on the plotting and selection of quadratic equation a curve was generated to predict the flexural strength in the Matlab as shown in the Figure 3. From the predicted curve the flexural strength of the concrete was predicted by simply substituting the relative hybrid fiber volume fractions. The predicted values with their corresponding prediction error were given in Table 6.

Based on the results, the average prediction error is 0.52% which shows a good relation among the experimental and predicted values.

The quadratic equation were also developed for the further prediction on flexural strength by changing the hybrid fiber volume fractions. The coefficients of the quadratic equation with their corresponding values were given as Y= -1.6x2+4.2x+6.

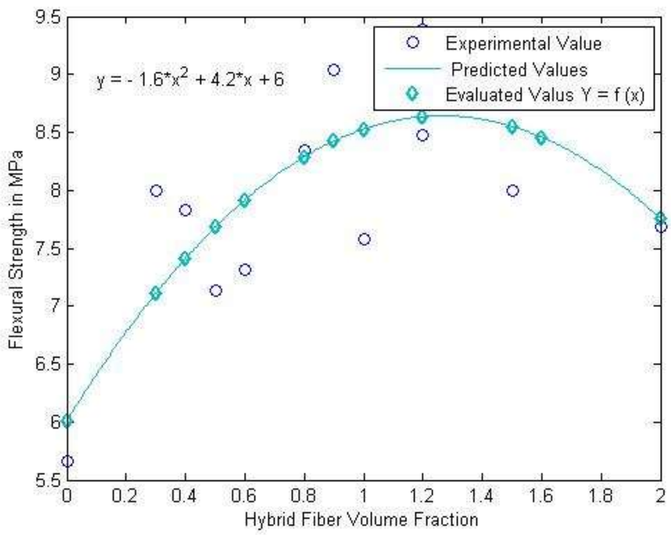

Fig- 3. Predicted curve for Split Tensile Strength

4. CONCLUSION

In the models constructed in MatLab, a quadratic system with its basic fitting was used. The models were developed with hybrid volume fraction as input data and the corresponding strength as output data. Only by using the input data in the Matlab the 28 days compressive, splitting tensile and flexural strengths values of hybrid fibre concretes containing GGBS were found. The values are closer to the experimental results obtained from curve generated in the Matlab. As a result, compressive and splitting tensile strengths values of hybrid fiber concretes containing GGBS can be predicted in Matlab without attempting any experiments in a quite short period of time with tiny error rates. The obtained conclusions have shown that Matlab has the potential to predict the mechanical properties of concrete.

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