

EXPERIMENTAL AND ESTIMATED STUDIES ON STEEL FIBRE CONCRETE USING DATA ANALYSIS

MD. Abrar Ahmad¹, C. Mahalingam²

¹PG Student, Department of structural engineering, vignan deemed to be university, abrarahmad1190@gmail.com

²Assistant Professor, Department of structural engineering, vignan deemed to be university, akcmahalingam@gmail.com

Abstract— Concrete is the most widely used material for construction. There has been exceptional growth to develop High Performance Concrete. High Performance Concrete takes High Standards of Durability. Durability in Concrete can be accomplished by addition of Fibres in the Mix Proportions. Fibres used in this Study are Carbon Steel Fibre with Different Volume Fractions. The Distinctive Properties of Fibre Reinforced Concretes are Improved Tensile and Bending Strength, Greater Ductility, Greater Resistance to Cracking and hence improved impact Strength and Toughness. At the point when these Fibres are added to the Concrete it improves the Ductile Behaviour and Energy Absorption Capacity. The Main Objective of the Study is to investigate the Shear Behaviour of Fibre Reinforced Concrete.

The Grade of Concrete utilized as a part of this Study are M40 Grade Specimens. These Specimens are Prepared with Different Percentage of Steel Fibre Volume Fraction Viz. 0.0%, 0.3%, 0.6%, 0.9%, 1.2%, 1.5%. The Specimens were tested after the age of 7,28 Days. The Test Performed are Compressive Strength, Split-Tensile Strength, Flexural Strength, Acid-Resistance test and Durability Test. The Obtained Results are Compared by Using of MATLAB, EXCEL with MULTI-VARIABLE NONLINEAR REGRESSION ANALYSIS. This gives us the Percentage Error Between the Experimental and Estimated Results.

Keywords— Natural aggregate, Steel Fibre, Steel Fibre Reinforced Concrete (S.F.R.C), Volume Fraction(v_f), Compressive Strength, Split Tensile Strength, Flexural Strength, Strength Prediction, Data Analysis.

I. INTRODUCTION

Concrete is the material of choice where strength, quality, toughness, performance, durability, impermeability, imperviousness to fire and abrasion resistance are required. High durability in concrete can be attained by the addition of fibre as they are having greater tensile, bending, impact strength, ductility, flexibility, break obstruction, crack resistance, energy absorption capacity. There are many types of fibres available they can be listed in the following: Natural Fibres, Synthetic Fibres, Metallic Fibre, Polymer Fibres, Glass Fibres, Micro Fibres etc. In this examination carbon steel fibre has been utilized as expansion of fibre in concrete. The grade of concrete used for this study is M₄₀ grade concrete and fibres are added in the concrete according to the percentage of volume fraction (V_f). The percentage of volume fraction is termed as the percentage of measure of concrete required to that of volume of the specimen.

II. DATA ANALYSIS

Now-a-days the non-destructive testing techniques are extremely prominent and research is in advance for improvement of these techniques. These techniques are utilized to predict the strength of the concrete. In such techniques the data analysis is one of the methods to predict the strength of the concrete. It is also called as the statistical analysis. In this method a mathematical model developed according to the concrete materials and the strength of the concrete is predicted. Such model called as mathematical regression model. As the concrete has distinctive materials with different units the equation is preferred as MULTI-VARIABLE NON-LINEAR REGRESSION ANALYSIS. It is a power equation. Statistical models are accurate, simpler to implement and once they are fitted they can be used for many number of predictions.

III. EXPERIMENTAL WORK

The main objective of this paper is to compare the hardened properties of concrete made with the estimated results by utilizing DATA ANALYSIS.

A. Materials Used

- 1) *Cement*: The Ordinary Portland Cement (OPC) of 53 grade confirming to Indian standard IS 12269-2013 was used. The properties of the cement are:
Specific gravity of cement = 3.16
Initial setting time = 40 min
Final setting time = 480 min
- 2) *Fine aggregate*: Fine aggregate used for this entire study of investigation for concrete was river sand confirming to zone-2 of IS: 383-1970(revision 2011). *The properties of fine aggregate are*:
Specific gravity = 2.5
Water absorption = 2.5%
- 3) *Coarse aggregate*: Crushed hard granite chips of maximum size 20mm, 12.5mm were used in concrete mixes.
Specific gravity = 2.9
Water absorption = 1.5%
- 4) *Water*: Potable water confirming to IS: 456-2000 was used for casting and curing.
- 5) *Carbon Steel Fibre*: The steel fibre had been obtained from the fibre zone, Ahmedabad. The length is 40mm and diameter of 0.60mm, The UTS is 128.21kg/mm² and the aspect ratio is 66.66.
- 6) *Super Plasticizer*: Fosroc CONPLAST SP430 (20 L) From YK ENTERPRISES was used.

B. Procedure

- 1) *Mix Design*: The control mixes were made of M₄₀ grade concrete. The various ingredients used in the mixes are as per Table-1. The mix ratio is 1:2.10:3.25.
- 2) *Casting of Specimens*: Casting of Specimens was done by batching of materials, preparation of moulds and placing of concrete in the moulds.
- 3) *Batching*: A proper mix of concrete is essential for the strength of the concrete. Before the concreting, all the mix material were weighed and kept ready for concreting as per design mix proportions.
- 4) *Preparation of Moulds*: Concrete moulds were oiled for easy stripping. The moulds for conducting tests on fresh concrete were made ready and inner surfaces were oiled.
- 5) *Preparation of Concrete*: Concrete was mixed in the pan mixer and dumped in a metal tray placed on a flat surface.
- 6) *Tests on Fresh Concrete*: Super plasticizer was used at 0.7% by weight of Cement and Compacting factor was found to be at 0.85. the fresh concrete had been prepared and slump cone test had been performed. The obtained slump was the true slump. The workability is 100-120mm
- 7) *Preparation of Samples*: During the placing of fresh concrete into mould, proper care was taken to remove entrapped air by using a table vibrator to attain maximum strength. Vibrator was used after every 1/3 filling of material into the mould and the top surface was properly levelled with cement paste at the end. Care should be taken that samples are prepared according to the percentages of volume fraction.
- 8) *Demoulding*: After levelling the fresh concrete in the moulds, it was allowed to dry for 24 hrs. The identification marks of concrete specimens were done with permanent markers and the specimens were removed from the moulds. The moulds were cleaned and kept ready for next batch of concrete mix.
- 9) *Curing*: Curing is an important process to prevent the concrete specimens from losing their moisture while they are gaining their required strength.. All concrete specimens were cured in water at room temperature for 7 and 28 days. After curing, concrete specimens were removed from the curing tank and air dried to conduct tests on hardened concrete.

C. Types of Tests:

- 1) *Compressive Strength Test*: Six specimens of size 100 mm x 100 mm x 100 mm were used for compression testing for each percentage of mix for both 7, 28 days. Clean and surface dried specimens were placed in the testing machine. The platen was lowered and touched the top surface of the specimen, the load was applied gradually and maximum load was recorded.

- 2) *Split-Tensile Strength Test*: Split tensile test was conducted on cylinders of size 150mm diameter and 300mm height. Clean and surface dried specimens were placed in the testing machine. The platen was lowered and was allowed to touch the top surface of the specimen. The force was applied and maximum load at which the specimen failed was recorded.
- 3) *Flexural Strength Test*: The prisms were tested to evaluate the flexural strength of the concrete by two point loading. The prism dimensions were measured accurately before testing and marked before testing for placing in exact position.

IV. REGRESSION ANALYSIS

In this study for prediction of results regression analysis had been adopted and the equation used is the MULTI-VARIABLE NON-LINEAR POWER EQUATION. The equation is:

$$Y = a_0.(C)^{a_1}.(C.A_{20mm})^{b_1}.(C.A_{12.5mm})^{r_1}.(F.A)^{a_2}.(K)^{r_2}.(S.F)^{a_3}.(D.C)^{h_1}.(w/c)^{m_1}.(S.P)^{a_4}.(W)^{d_1}$$

Y	=	Strength of concrete
C	=	Cement
C.A	=	Coarse aggregate (20mm)
C.A	=	Coarse aggregate (12.5mm)
F.A	=	Fine aggregate
S.F	=	Steel fibre
D.C	=	Days of curing
w/c	=	water-cement ratio
S.P	=	Super plasticizer
K	=	Density of concrete
W	=	Water

For this study the software used is the MATLAB. After providing the required dependent and independent terms in the above mentioned formula and executing it, we will obtain the co-efficient's and intercepts, upon substituting those we will obtain the predicted results.

TABLE I
QUANTITY OF MATERIALS

Mix Id	Cement	C.A(20)	C.A(12.5)	F.A	Super Plasticizer	Water	Density	Steel Fibre
Mix Id 1	382.22	771.4	556.44	786.07	2.296	160.139	2557.63	0
Mix Id 2	373.22	778.5	558.44	779.67	2.345	172.45	2526.22	7.2
Mix Id 3	376.28	769.4	549.78	775.62	2.127	175.61	2533.33	14.4
Mix Id 4	372.87	773.8	546.63	781.02	2.391	167.53	2537.12	21.6
Mix Id 5	379.16	765.2	551.43	773.92	2.218	163.47	2498.12	31.6
Mix Id 6	375.89	769.1	548.72	781.63	2.174	171.84	2551.61	39.6
Mix Id 7	509.62	798.5	572.32	808.21	3.911	164.81	2637.03	0
Mix Id 8	513.47	787.3	571.68	812.47	3.863	170.47	2711.81	7.2
Mix Id 9	503.62	789.4	574.73	807.91	3.847	168.32	2653.42	14.4
Mix Id 10	508.31	795.6	576.93	805.93	3.936	161.92	2597.31	21.6
Mix Id 11	505.93	791.4	568.63	803.36	3.812	167.34	2722.94	31.6
Mix Id 12	511.67	786.3	572.36	815.52	3.948	163.76	2693.47	39.6

V. RESULTS

A. Compressive Strength Test:



Fig. 1 Compression testing machine

TABLE II
COMPRESSIVE STRENGTH TEST RESULTS OF 0.4% W/C RATIO

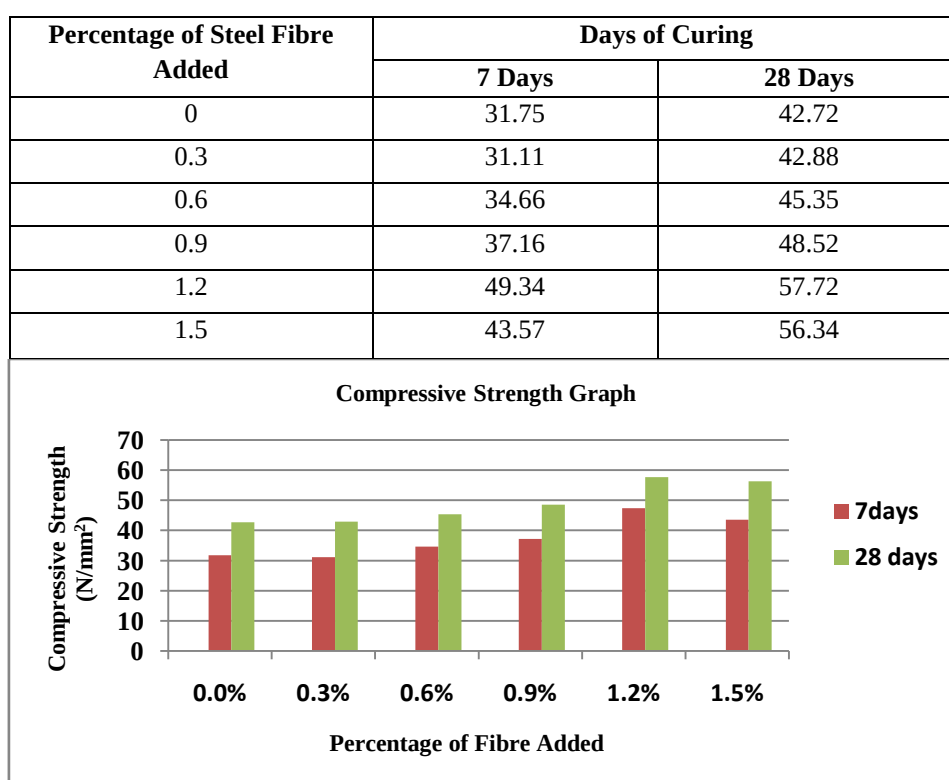


Fig. 2 Comparison of Compressive Strength Test Results (0.4% W/C Ratio)

TABLE III
COMPRESSIVE STRENGTH TEST RESULTS OF 0.3% W/C RATIO

Percentage of Steel Fibre Added	Days of Curing	
	7 Days	28 Days
0	33.54	44.13
0.3	32.31	42.68
0.6	36.48	47.38
0.9	39.92	51.25
1.2	51.62	59.73
1.5	45.91	57.28

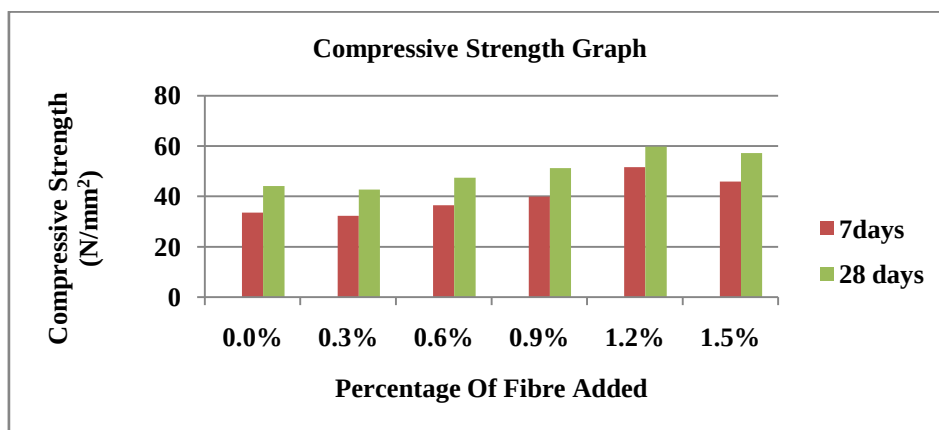


Fig. 3 Comparison of Compressive Strength Test Results (0.3% W/C Ratio)

B. Split-Tensile Strength Test:

TABLE IV

SPLIT TENSILE STRENGTH TEST RESULTS OF 0.4% W/C RATIO

Percentage of Steel Fibre Added	Days of Curing	
	7 Days	28 Days
0	2.83	3.73
0.3	2.38	3.60
0.6	2.54	4.59
0.9	3.27	5.18
1.2	4.26	5.82
1.5	3.72	4.93



Fig. 4 Split tensile testing machine

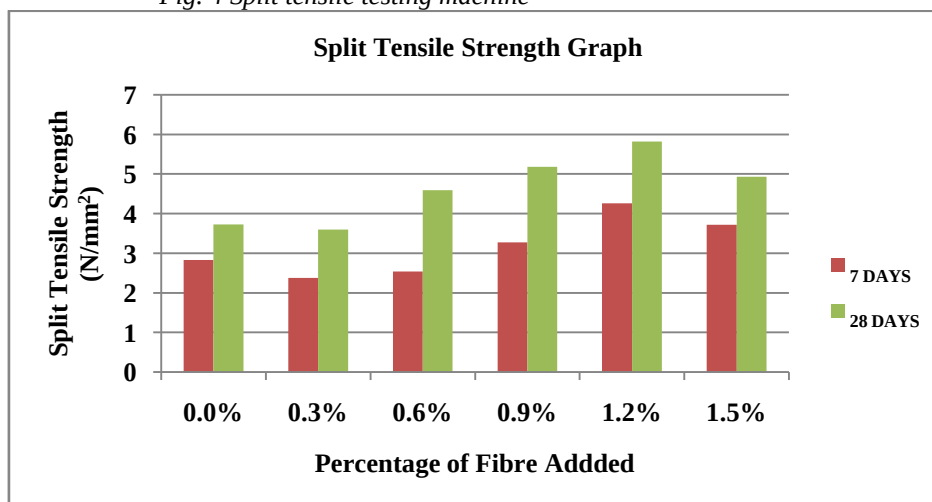


Fig. 5 Comparison of Split-Tensile Strength Test Results (0.4% W/C Ratio)

Table V

SPLIT TENSILE STRENGTH TEST RESULTS OF 0.3% W/C RATIO

Percentage of Steel Fibre Added	Days of Curing	
	7 Days	28 Days
0	3.01	4.21
0.3	2.71	4.43
0.6	3.21	5.29
0.9	3.78	5.58
1.2	4.59	6.34
1.5	4.18	6.07

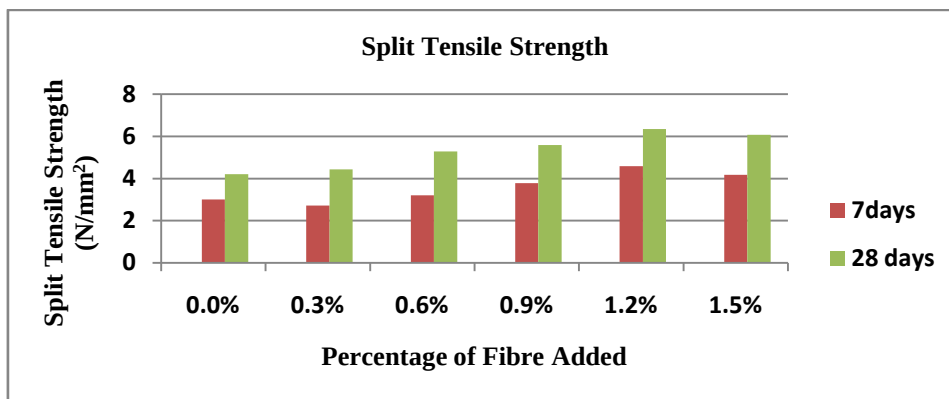


Fig. 6 Comparison of Split-Tensile Strength Test Results (0.3% W/C Ratio)

C. Flexural Strength Test:

TABLE VI

FLEXURAL STRENGTH TEST RESULTS OF 0.4% W/C RATIO.

Percentage of Steel Fibre Added	Days of Curing	
	7 Days	28 Days
0	2.93	3.38
0.3	3.17	3.86
0.6	3.74	4.42
0.9	4.38	4.94
1.2	5.125	5.42
1.5	4.77	5.08

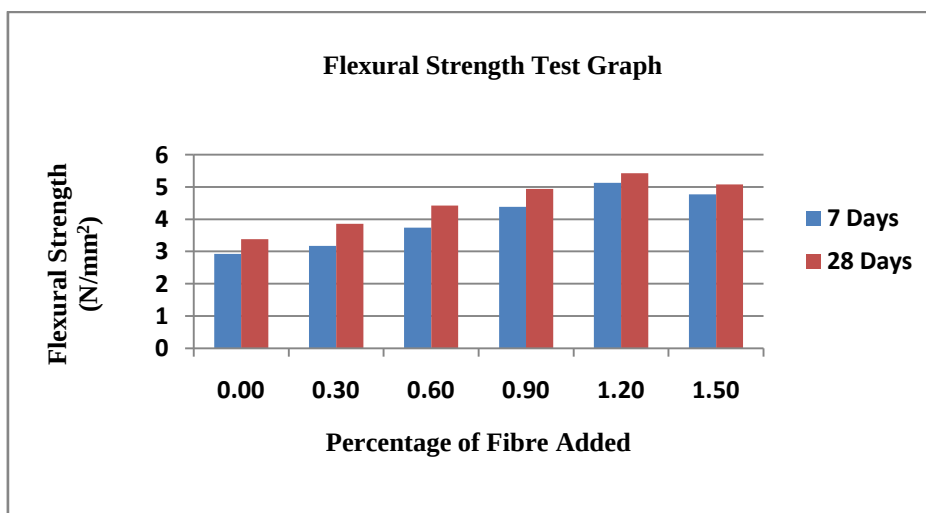


Fig. 7 Comparison of Flexural Strength Test Results (0.4% W/C Ratio)

TABLE VII - FLEXURAL STRENGTH TEST RESULTS OF 0.3% W/C RATIO.

Percentage of Steel Fibre Added	Days of Curing	
	7 Days	28 Days
0	3.28	3.74
0.3	3.64	4.38
0.6	4.03	4.74
0.9	4.42	5.16
1.2	5.67	6.13
1.5	5.13	5.39



Fig.8 Flexural Testing Machine

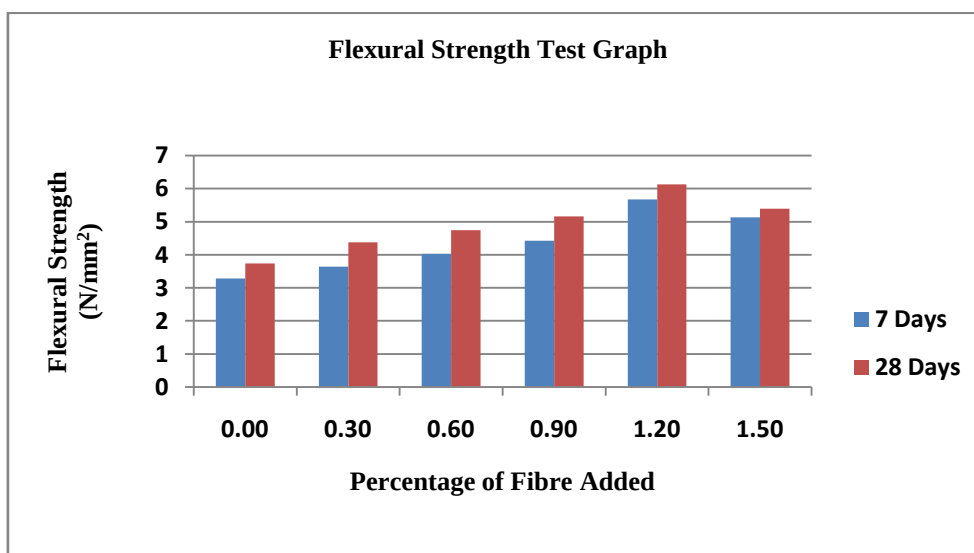


Fig. 9 Comparison of Flexural Strength Test Results (0.3% W/C Ratio)

VI. DATA ANALYSIS RESULTS

A. Compressive Strength:

TABLE IX
CO-EFFICIENT'S FOR COMPRESSIVE STRENGTH

Co-efficient's	7 days	28 days
a_0	0.5680	0.488
a_1	0.270	-0.7304
a_2	-1.2381	0.0531
a_3	-0.806	-0.9973
a_4	0.382	0.548
b_1	-0.8493	-0.8404
d_1	-0.1799	-0.0386
h_1	0.4265	0.3042
m_1	0.675	0.9538
r_1	-2.025	-1.9692
r_2	-0.2065	-0.4581

The obtained predicted values of compressive strength for 0.4%, 0.3% water content are listed below:

1) 7 Days:

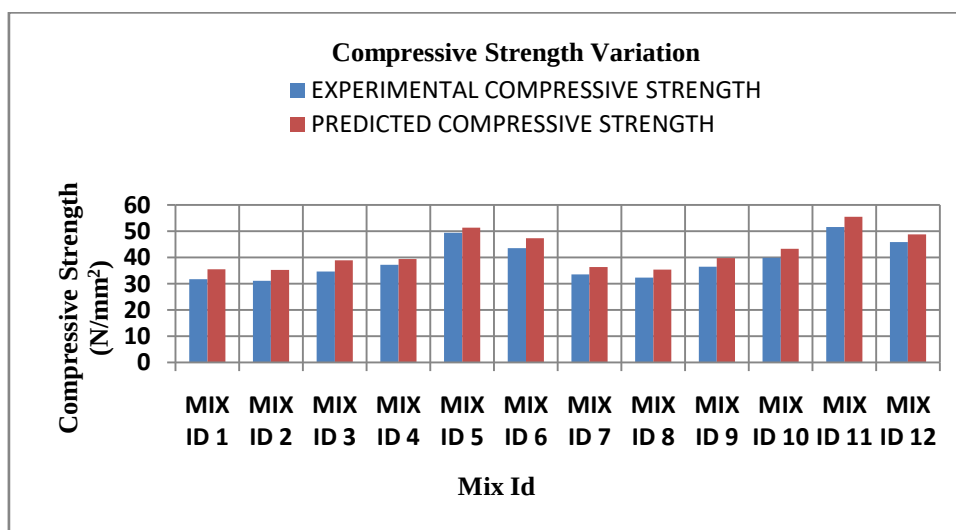


Fig. 10 Experimental and Predicted Compressive Strength Test Results

2) 28 Days

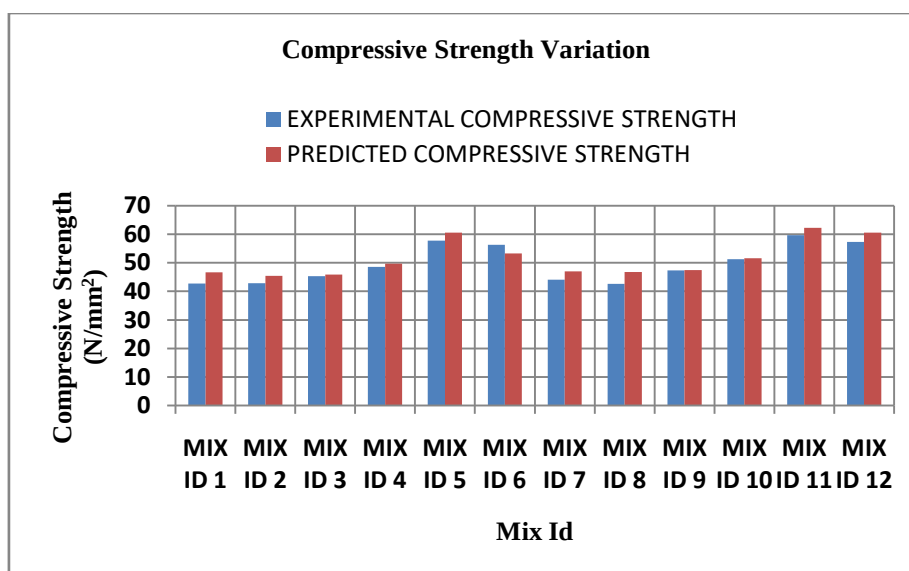


Fig. 11 Experimental and Predicted Compressive Strength Test Results

B. Split-tensile Strength:

TABLE X
CO-EFFICIENT'S FOR SPLIT-TENSILE STRENGTH.

Co-efficient's	7 days	28 days
a_0	0.4780	0.388
a_1	0.230	-0.8304
a_2	-1.1581	0.0461
a_3	-0.536	-0.7373
a_4	0.238	0.178
b_1	-0.7693	-0.5804
d_1	-0.1599	-0.0886
h_1	0.7365	0.5832
m_1	0.815	0.8458
r_1	-1.935	-1.7492
r_2	-0.6265	-0.6481

The obtained predicted values of Split-Tensile strength for 0.4%, 0.3% water content are listed below:

1) 7 Days:

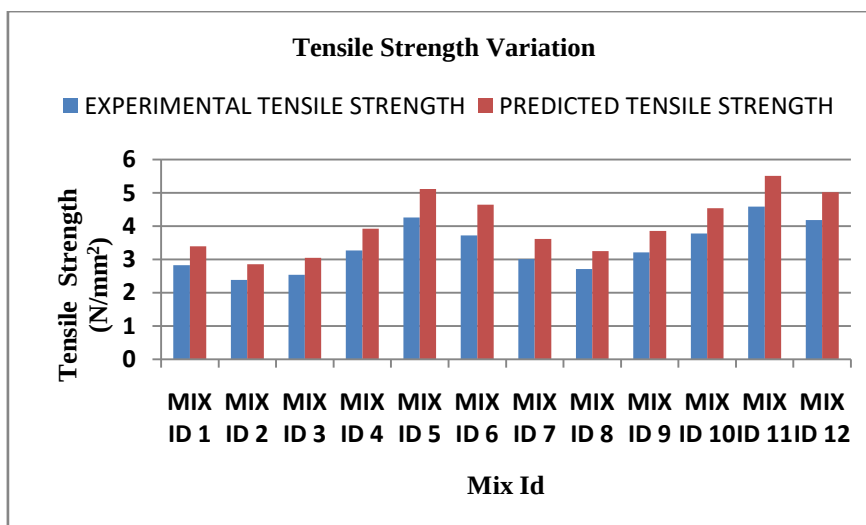


Fig. 12 Experimental and Predicted Split-Tensile Strength Test Results

2) 28 Days

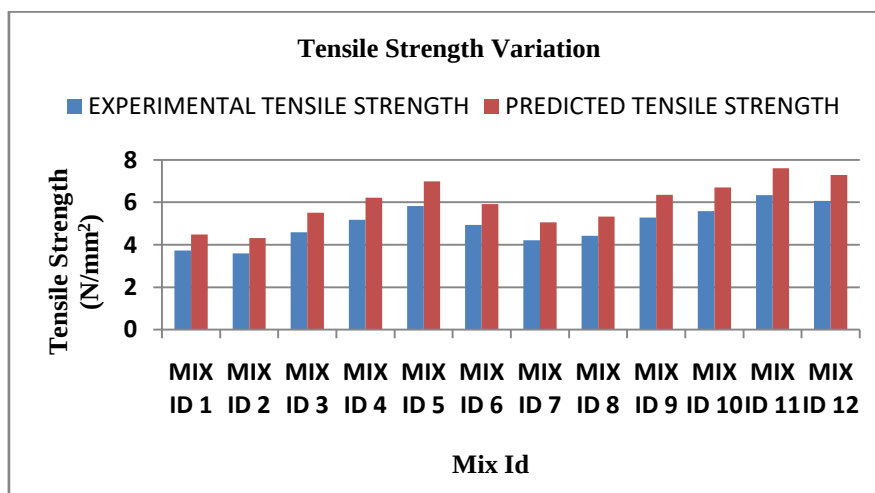


Fig. 13 Experimental and Predicted Split-Tensile Strength Test Results

C. Flexural Strength:

TABLE XI

CO-EFFICIENT'S FOR FLEXURAL STRENGTH

Co-efficient's	7 days	28 days
a_0	0.3980	0.578
a_1	0.470	-0.4904
a_2	-1.6181	0.0831
a_3	-0.826	-0.4873
a_4	0.532	0.628
b_1	-0.3993	-0.9304
d_1	-0.5799	-0.0486
h_1	0.3825	0.8362
m_1	0.3915	0.2638
r_1	-1.385	-1.4792
r_2	-0.8165	-0.2681

The obtained predicted values of Flexural strength for 0.4%, 0.3% water content are listed below:

1) 7 Days:

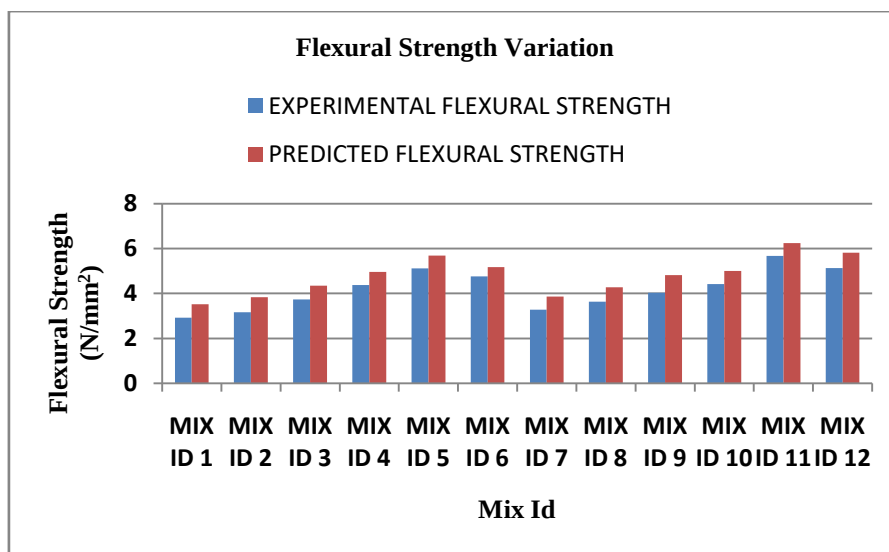


Fig. 14 Experimental and Predicted Flexural Strength Test Results

2) 28 Days

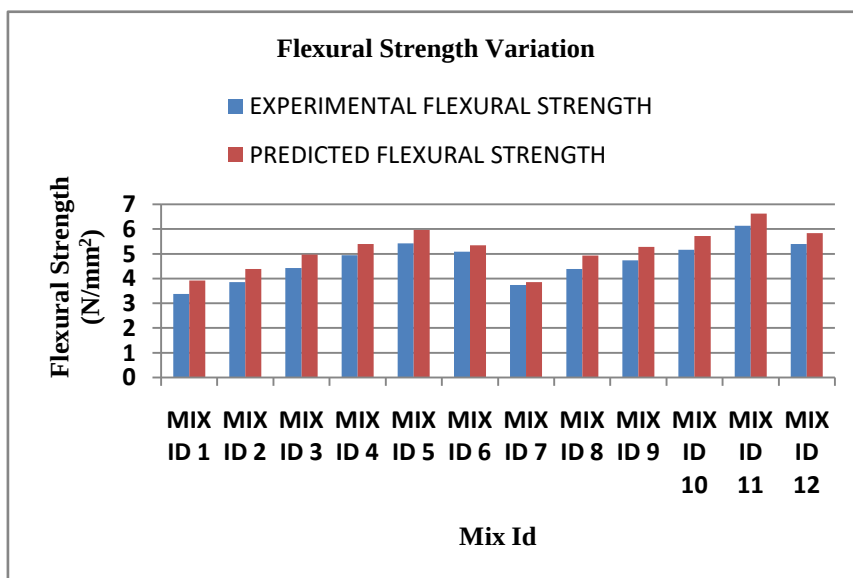


Fig. 15 Experimental and Predicted Flexural Strength Test Results

VII. CONCLUSION

A. Strength Properties on M40 Grade Concrete:

1) Compressive Strength:

- The compressive strength for 7, 28 days for the m40 grade with 0.4% w/c ratio is 31.75N/mm² and 42.72N/mm² respectively and for 0.3% w/c ratio is 33.54N/mm² and 44.13N/mm².
- Therefore we can observe that almost 10% and 15% increase in compressive strength than characteristic compressive strength for m40 grade concrete with 0.4%, 0.3% w/c ratio respectively.

2) Split-Tensile Strength:

- The split-tensile strength for m40 grade mix with 0.4%, 0.3% w/c ratio is 2.83N/mm² and 3.01N/mm² for 7 days and 3.73N/mm² and 4.21N/mm² for 28 days.
- Hence we can judge that there was 35% increase in the experimental strength than the characteristic tensile strength.

3) *Flexural Strength:*

- Similarly the flexural strength for same grade concrete with 0.4% w/c ratio for 7, 28 days is 4.93N/mm² and 5.38N/mm² and 0.3% w/c ratio is 5.28N/mm² and 5.74N/mm².
- We can come to a conclusion that there was 40% increase in flexural strength than that of the characteristic strength.

B. *Strength Properties on Steel Fibre Concrete:*

- When fibres have been added into the concrete in volume fraction (vf) the strength has been increased.
- Till 1.2% of (vf) the strength has been increased, from then the strength had been lowered due to the un-even distribution of fibres and its excess amount.
- Therefore 1.2% of (vf) is the optimum percentage of addition of steel fibres in concrete.

C. *Durability Effect:*

- In water absorption test the water absorption was increased as the percentage of the steel fibre had been increasing till the optimum percentage from then there was decrease in the water absorption.
- In acid resistance test, the resistance to the acid was increasing as the quantity of fibre goes on increasing.
- In the pH test there was increase in the pH value as there was increase in the steel fibre percentage.
- The sorptivity values ranges from 2.34-2.09 for all the mixes with and without fibre.

D. *Data Analysis Report:*

- By incorporating the material amounts into the equation and performing regression analysis. We have obtained the estimated values for the Compressive, Tensile, Flexural Strength's.

1) *Compressive strength:*

- The average difference between the experimental and estimated results ranges in between 3-5.
- Therefore 11% increased error between estimated and experimental results.

2) *Split-tensile strength:*

- The average difference between the experimental and estimated results ranges in between 0.5-1.5.
- Therefore 15% - 18% increased error between estimated and experimental results.

3) *Flexural strength:*

- The average difference between the experimental and estimated results ranges in between 0.2-1.4.
- Therefore 13% - 19% increased error between estimated and experimental results.

Finally, on an average 15% increased error between the predicted and experimental results.

Therefore, we can conclude that the non-destructive technique i.e. data analysis is a better technique to obtain the approximate results on strength properties of concrete rather than going for the experimental process.

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