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Regression Analysis for the Compressive Strength of Steel Fibre Reinforced Concrete

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Abstract:
Steel fibre has virtuous bonding properties, which when comes to compressive strength shows a better strength compared to normal concrete. In this study, the compressive behaviour of concrete when incorporating steel fibre content of 0%, 0.55%, 0.75%, 0.95%, 1.15%, 1.35%, 1.55%, 1.75%, 1.95% and 2.15% were investigated. Further, a regression equation was interpreted using a statistical software for 7 days and 28 days compressive strength of various steel fibre reinforced concrete cubes. Validation is also done with the previous research works for the Regression equation interpreted in this study.

Keywords: *Steel Fibre Reinforced Concrete, Compression, Regression equation*

I. INTRODUCTION

In the field of construction, concrete is one of the most widely used material. During ancient days, the technique used by Egypt and Babylon was to reinforce brittle materials with fibres [1]. Improvement in mechanical properties and spalling can be controlled by introducing steel fibres. [2] and [3] have found in their study that the steel fibres have partial effect on residual compressive strength after heating. [4] and [5] have done an experiment by adding randomly dispersed steel fibres to normal concrete. The steel fibres in concrete improved resistance against tensile forces, showed better ductility and slowed down inital flexural crack.

II. Experimental study

2.1. Materials

In this study, OPC 53 grade cement, fine aggregate, coarse aggregate, superplasticizer, hooked end steel fibres were used. Hooked end steel fibres of length 30 mm and diameter 0.5mm, with an aspect ratio of 60 was used. The physical properties of the materials tested are given in Table 1.[1-10]

Table 1. Property of the materials

S.No	Material	Properties	Value
1	Cement	Specific Gravity	3.14
2	Fine Aggregate	Specific Gravity	2.7
3	Fine Aggregate	Grading of sand	Zone II
4	Coarse Aggregate	Specific Gravity	2.6

2.2. Sample preparation

Mix design for M30 was done according to IS 10262 (2009) [6]. Cement content of 320 kg/m^3 is used. Primarily, concrete was mixed without the

TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 6959 - 6967

inclusion of steel fibres. Steel fibres were then added to concrete in small quantities, in order to prevent segregation and balling effect. The steel fibre reinforced concrete was then placed into a standard cube mould of dimension 100 x 100mm, to find the compressive strength of concrete. After 24 hours, the specimens were cured in water for period of 7 days and 28 days.[11-20]

2.3. Experimental setup

Compressive strength test was done at 7 days and 28 days according to IS 516 (1959) [7]. The load was applied to the specimen and was increased at a rate of 140/kg/sq. cm/min. The specimen breaks at a point when it cannot sustain any load further. The maximum load applied to the specimen was noted.

III. Results and discussions

3.1. Compressive strength results

The 7-days compressive strength of various steel fibre concrete with percentage of 0%, 0.55%, 0.75%, 0.95%, 1.15%, 1.35%, 1.55%, 1.75%, 1.95% and 2.15% is 22.20 MPa, 23.10 MPa, 23.90 MPa, 24.30 MPa, 24.60 MPa, 24.40 MPa, 24.70 MPa, 22.90 MPa, 22.70 MPa and 22.50 MPa respectively. The 28-days compressive strength results of various steel fibre concrete with percentage of 0%, 0.55%, 0.75%, 0.95%, 1.15%, 1.35%, 1.55%, 1.75%, 1.95% and 2.15% is 41.10 MPa, 42.70 MPa, 43.20 MPa, 44.50 MPa, 45.50 MPa, 45.00 MPa, 48.70 MPa, 46.90 MPa, 45.60 MPa and 40.75 MPa respectively. Compressive strength was enhanced with an increase in steel fibre percentage. The compressive strength was enhanced in concrete up to 1.55% of steel fibre content. Beyond 1.55% of steel fibre content, the concrete showed a decrease in the strength. Fig. 1 represent the compressive strengths of concrete cubes for 7 days and 28 days at various steel fibre content[21-29].

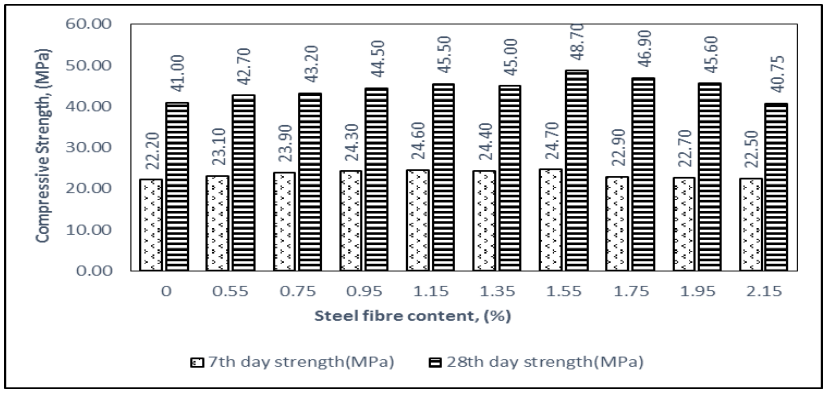

Fig. 1. Compressive strength for 7 and 28-days

3.2. Statistical analysis of test results

Statistical analysis was done for the compressive strength.

3.2.1. Pie chart

Statistical graph which is in circular shape and is divided into slices to represent a numerical ratio is called pie chart. The quantity of each proportion is represented as the slice which is mentioned in [8]. From the Fig. 2, it is shown that 30% of the specimens lies between the steel fibre percentage range of 0% to 0.75%, 40% of specimen lies between the steel fibre percentage range of 0.95% to 1.55% and 30% of specimen lies between the steel fibre percentage ranges of 1.75% to 2.15%. Fig. 3 shows that 60% of specimen lies between the compressive strength ranges of 22MPa to 24MPa, 40% of specimen strength lies between

January - February 2020
ISSN: 0193 - 4120 Page No. 6959 - 6967

the compressive strength ranges of 24 MPa to 25 MPa. Similarly, Fig. 4 shows that 40% of strength lies between the compressive strength ranges of 40 MPa to 43 MPa and 60% lies between the compressive strength ranges of 43 MPa to 48 MPa[30-31].

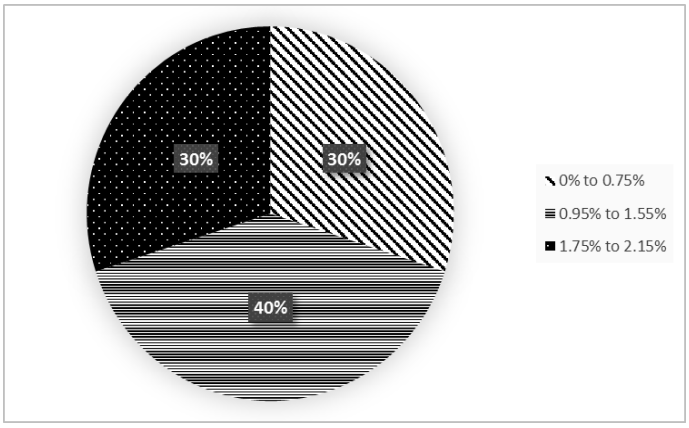

Fig. 2. Pie chart of Steel fibre content

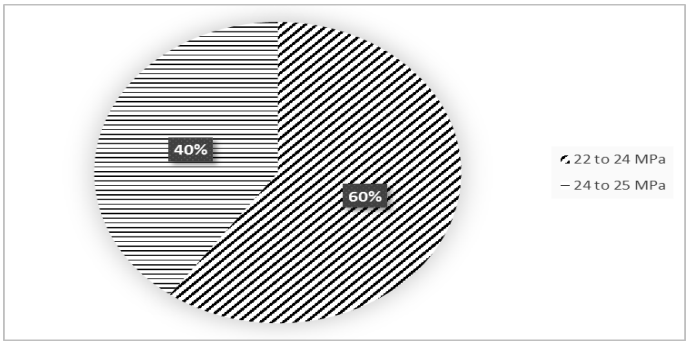

Fig. 3. Pie chart for 7 days cube compressive strength

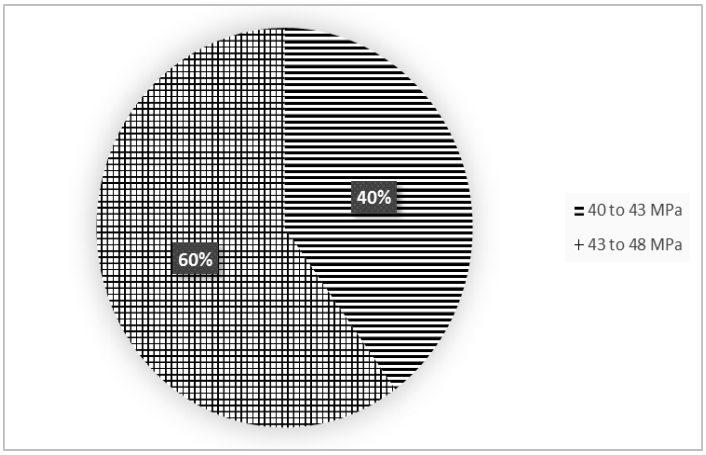

Fig. 4. Pie chart for 28 days cube compressive strength

Further, the correlation between the pie chart is explained. The steel fibre percentage within the range of 0% to 0.75%, 0.95% to 1.55% and 1.75% to 2.15% shows 7-days compressive strength of 22MPa to 24 MPa, 24 to 25 MPa and 22 MPa to 24 MPa respectively. In this, it can be clearly observed that there is a reduction in strength beyond 1.55% (i.e. the steel fibre content of

TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 6959 - 6967

1.75% to 2.15% shows the decrease in compressive strength). Similarly, for 28-days compressive strength, the steel fibre content within the range of 0% to 0.75%, 0.95% to 1.55% and 1.75% to 2.15% shows compressive strength of 40MPa to 43MPa, 43 to 48 MPa and 43 MPa to 48 MPa respectively, except 2.15% which shows a compressive strength of 40.75 MPa. Therefore, it is found that the strength upto 1.55% increased and beyond 1.55% started decreasing gradually and finally 2.15% steel fibre content was categorised under 40 MPa to 43 MPa, since the obtained strength is 40.75 MPa.

3.2.2. Regression Analysis

The relation between the variables can be estimated using regression analysis. The techniques is mainly based on the modelling and analysing of one dependent variable and one or more independent variable [8]. In this study, the independent variable is steel fibre content and the dependent variable is the compressive strength of concrete. The regression equation for 7-days compressive strength was interpreted as given in equation (1):

$$f_c = 23.51 + 0.0124\ V_f \qquad (1)$$

Where, f_c = compressive strength (dependent variable) and V_f = Volume of fibre (independent variable).

The regression equation for 28-day compressive strength was interpreted as given in equation (2):

$$f_c = 42.61 + 1.467\ V_f \qquad (2)$$

Where, f_c = compressive strength (dependent variable) and V_f = Volume of fibre (independent variable). Both the equations show that there is increase in compressive strength of concrete as increase in steel fibre content.

IV. COMPARISON OF EXPERIMENTAL AND PREDICTED VALUES

The experimental values obtained have been compared with the values predicted using the regression equation. Table 2 shows the obtained and the predicted compressive cube strength for 7 days and 28 days. From the table 2, it is found that the minimum percentage error for 7-days compressive strength is 1.58 for 0.75% steel fibre content and maximum percentage error is -5.90 for 0% steel fibre content. The predicted 7-days compressive strength value for 0.75% steel fibre content is 23.52 MPa and the obtained value is 23.90 MPa. The predicted 7-days compressive strength value for 0% steel fibre content is 23.51 MPa and the obtained value is 22.20 MPa. Similarly, the minimum percentage error for 28-days compressive strength is 0.28 for 1.95% steel fibre content and maximum percentage error is -12.29 for 2.15% steel fibre content. For 28-days compressive strength, the predicted value for 1.95% steel fibre content is 45.47 MPa and the obtained experimental value is 45.60 MPa. For 28-days compressive strength, the predicted value for 2.15% steel fibre content is 45.76 MPa and the obtained experimental value is 40.75 MPa.

Table 2. Comparison of experimental values and predicted values for 7-days and 28-days compressive strength

Steel fibre content, %	Actual value, MPa		Predicted value, MPa		% Error	
	7 days	28 days	7 days	28 days	7 days	28 days
0	22.20	41.10	23.51	42.61	-5.90	-3.54

January - February 2020
ISSN: 0193 - 4120 Page No. 6959 - 6967

0.55	23.10	42.70	23.51	43.41	-1.77	-1.68
0.75	23.90	43.20	23.52	43.71	1.58	-1.18
0.95	24.30	44.50	23.52	44.00	3.20	1.12
1.15	24.60	45.50	23.52	44.59	4.39	2.00
1.35	24.40	45.00	23.53	44.59	3.56	0.91
1.55	24.70	48.70	23.53	44.88	4.73	7.84
1.75	22.90	46.90	23.53	45.17	-2.75	3.68
1.95	22.70	45.60	23.53	45.47	-3.35	0.28
2.15	22.50	40.75	23.53	45.76	-4.57	-12.29

There is a higher strength enhancement upto 1.55% of steel fibre content and beyond 1.55% the strength gradually starts decreasing. The percentage error of 7-days compressive strength for 1.55%, 1.75%, 1.95% and 2.15 % steel fibre content is 4.73, -2.75, -3.35 and -4.57 respectively. The percentage error of 28-days compressive strength for 1.55%, 1.75%, 1.95% and 2.15 % steel fibre content is 7.84, 3.68, 0.28 and -12.29 respectively. From the study, it is clearly observed that the compressive strength is good upto 1.55% and beyond which there is a gradual decrease in the compressive strength. Specifically, for 2.15% steel fibre content, the 28-days compressive strength was 40.75 MPa which is lower than the 0% steel fibre content strength i.e. 41.10 MPa.

V. Validation

The Regression equation interpreted in this study is used to validate the previous work done [9]. Primarily, this work is chosen because of the concrete mix M40 and the steel fibre content. Moreover, there are no other cement replacement materials were used in yazici study. In his study, he experimented the effect of aspect ratio and volume fraction of steel fibre on the mechanical properties of Steel Fibre Reinforced Concrete (SFRC). Yazici used concrete mix of M40, cement content of 438kg/m^3, steel fibre volumes of 0.5%, 1.0% and 1.5%. Different aspect ratio of 45, 65 and 80 was also considered in his study. Table 3 shows the validation done for Yazici work using the regression equation found in this study. The minimum percentage error in the validation is 13.21 for 0% steel fibre content and the maximum percentage error is 24.40 for 1.0% of steel fibre content. For the 28-days compressive strength, the predicted value for 0% of steel fibre content is 42.61 MPa and the obtained value is 49.10 MPa. There is more percentage error in this validation of yazici, because of two main reasons, (i) the concrete mix (M40) and (ii) cement content of 438 kg/m^3. Whereas, in this study M30 concrete mix with cement content of 320 kg/m^3 is used.

Table 3. Validation done for Yazici et al (2007) work using Regression equation

Steel Fibre content, %	Actual value, MPa	Predicted value, MPa	% Error
0	49.10	42.61	13.21
0.5	53.50	43.34	18.99
1.0	58.30	44.07	24.40
1.5	56.40	44.81	20.54

TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 6959 - 6967

Validation is also done for various other research works as mentioned in table 4, based on the cement content. The validation is done for M30 and M40 concrete mix. The cement content in the validation lies between 300 kg/m^3 to 450 kg/m^3. In this validation, it is found that the minimum error percentage is -0.92 for cement content of 305 kg/m^3 and the maximum error percentage is -10.96 for cement content of 300 kg/m^3. The maximum cement content is 450 kg/m^3, for which the percentage error is -3.17 and the minimum cement content is 300 kg/m^3, for which the percentage error is -10.96. Thus, the regression equation can be used to predict the compressive strength, if in case the cement content lies between 300 kg/m^3 to 450 kg/m^3.

Table 4. Validation done for previous research works using Regression equation

S. No	Research work	ConcreteMix	Cement Content (Kg/m^3)	Actual Value (MPa)	Predicted Value (MPa)	% Error
1	Study on compressive behaviour of steel fibre reinforced concrete [10]	M30	390.17	46.97	42.61	9.28
2	Effect of steel fibres on compressive and tensile strength of concrete using M-sand as fine aggregate [11]	M30	-	38.64	42.61	-10.27
3	Mechanical properties of steel-Polypropylene fibre reinforced concrete under elevated temperature [12]	M40	-	45.66	42.61	6.68
4	Effect of high temperatures on compressive strength of concrete [13]	M30	-	40.89	42.61	-4.20
5	Effect of high temperature on high performance steel fibre reinforced concrete [14]	M30	311	39.00	42.61	-9.25
6	Effect of silica fume and steel fiber on the mechanical properties of the concretes produced with cold bonded fly aggregates [15]	M30	450	41.30	42.61	-3.17
7	Effect of pond ash and steel fibre on engineering properties of concrete [16]	-	-	38.10	42.61	-11.83
8	Fracture behavior and mechanical properties of concrete with artificial lightweight aggregate and steel fiber [17]	M30	400	43.10	42.61	1.13
9	Study on hybrid length steel fiber reinforced concrete subjected to elevated temperature [18]	M30	400	40.20	42.61	-5.99

January - February 2020
ISSN: 0193 - 4120 Page No. 6959 - 6967

10	A study on properties of steel fibre reinforced roller compacted [19]	-	305	42.22	42.61	-0.92
11	Behavioural study of steel fiber and polypropylene fiber reinforced concrete [20]	-	360	38.90	42.61	-9.53
12	Corrosion effects on the strength properties of steel fibre reinforced concrete containing slag and corrosion inhibitor [21]	-	449	43.70	42.61	2.49
13	Strain hardening properties of steel fibre reinforced latex concrete composite [22]	-	300	38.40	42.61	-10.96

VI. CONCLUSIONS

Compressive strength results for the 7-days and 28-day cube strength was obtained by compression testing. The results show that there is strength increase up to 1.55%, beyond which there is a reduction in strength. The compressive strength have been incorporated in the statistical software to obtain the regression equation. Therefore, the regression equations have been analysed for 7-days and 28-day compression strength of various percentages of steel fibre concrete. Validation is also done for the experimental data of yazici and other researchers. Henceforth, it is found that using the regression equation the maximum error percentage for this study i.e. M30 concrete mix is -12.29% and for the previous study of Yazici, who used M40 concrete mix is 24.40%. The regression equation when used for other researchers work, it is found that the error percentage for 300 kg/m^3 is -10.96 and for 450 kg/m^3 is -3.17. Thus, the regression equation is applicable for the cement content range from 300 kg/m^3 to 450 kg/m^3.

VII. ACKNOWLEDGEMENTS

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