Evaluation of Empirical relation between compressive, Flexural, Split Tensile Strength of Concrete by Partially Replacing Nano Silica

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Abstract **- In the present study correlation between compressive, Flexural and splitting tensile strength of concrete was studied using both experimental and analytically predicted results. Three grades of concrete M40, M50, and M60 were considered by replacing its cement content with nano-silica. Experimental results of compressive, Flexural and splitting tensile strength were evaluated using 150mm cubes,100mm×100mm×500mm and cylinders of diameter 150mm and height 300mm for 28 days of curing in water. An equation was proposed for correlation between compressive, Flexural and splitting tensile strength from experimental data using regression analysis and analytical results were predicted. Accuracy of empirical equations reported by researchers and the proposed equation was analysed employing Root Mean Square Error, Integral Absolute Error, Normal Efficiency and Mean Absolute Error statistical parameters. Good compliance between experimental and analytical results was observed.**

Index Terms **- cement, concrete, mechanical properties, nano silica.**

1.INTRODUCTION

Nano silica is an ultrafine material showing results of high reactivity and controlled particle size distribution [11] is being used as an additive to produce high-performance concrete. Use of Nano silica in concrete results in denser pore structure and high strength because maximum SiO2 and CaO content in it enables it to react both in the pozzolanic and hydraulic manner [10,12]. It enhances the mechanical properties like split tensile strength, compressive strength, and flexural strength [13] and durable against acidic environment [14] and also chloride penetration, chances of corrosion [15]. Nano particular sized nano-silica is progressively attracting the consideration of researchers to boost the strength and durability of high - performance concrete. The compressive strength and bond strength of concrete using nano - silica is much greater than control concrete mixes [16]. Nano silica fills up the pores and increases the hydration process [18].

Research significance

Mostly many researchers have investigated the behaviour of concrete and very few researches are there on the correlation between split tensile, flexural and compressive strength of concrete. Therefore, the present study investigates the correlation between split tensile and compressive strength of concrete using nano-silica by considering analytical and experimental results for 28 days of curing.

1. Experimental Programme

Nano silica was procured from Astrra Chemicals Chennai. The particular size, fineness, and specific gravity of Nano silica are 17nm, 202 m2/g, 2.2-2.4 as provided by suppliers. KPC cement grade 53 conforming to IS 12269-1987 used for the study was obtained from local suppliers. Locally available sand having the density of 1520 Kg/m3, confirming to Zone-II, having fineness modulus 3.18 was used. Coarse aggregate of density 1416 Kg/m3 having fineness modulus 7.6 and size 20mm was used. Locally available tap water was used.

All the concrete mixes of grade M40, M50, and M60 were designed as per IS10262:2019 and IS 456:2005. In the present research, all the grades of concrete were partially replaced by 3%,5% nano-silica (Ns) by weight of cement. Mix proportions for all the grades of concrete are given in table 1.

Table 1. Mix proportions for all the grades of concrete (Kg/m3)

Concrete grades	Fine aggregate CEMENT	(FA)	Coarse aggregate (CA)	w/c
M40	370	843	1073	0.48
M50	396	834	1060	0.45
M60	345	780	1218	0.40

Evaluation of experimental results of compressive strength was done using 150mm cubes and split tensile strength using cylinders of diameter 150mm and height 300mm for 28 days of curing in water using standard test methods confirming to IS:516-1959 and IS:5816-1999. Regression analysis was used to develop a proposed power-type equation to determine the correlation between compressive and splitting tensile strength. The predicted results of split tensile strength from the proposed power-type equation are compared with experimental results. A proposed power-type equation was compared with the equations developed by other researchers and the accuracy of the equations was measured using statistical parameters of Root Mean Square Error, Integral Absolute Error, Normal Efficiency, and Mean Absolute Error.

Table 2. Tests results of the compressive strength and splitting tensile strength (Mpa).

Concrete grade	Additives	Compressive strength (fck)	Split tensile strength (ft)
	0	49.50	8.28
M40	NS	60.45	10.12
	0	59.25	9.92
	NS	67.26	11.25
	0	69.15	11.70
	NS	78.35	13.34

2.RESULTS AND DISCUSSIONS

Experimental results of compressive and splitting tensile strength of concrete using nano-silica as additives for concrete grades of M40, M50, and M60 are given in table 2. Experimental results given in the table are average values of three specimens tested. It was observed that compressive and splitting tensile results using Nano silica were greater than control mixes for all the grades of concrete. Using regression analysis, a power-type equation was developed to determine the correlation between compressive and splitting tensile strength considering all the grades of concrete. From figure 1 it was observed that split tensile strength for all grades of concrete increases with an increase in compressive strength.

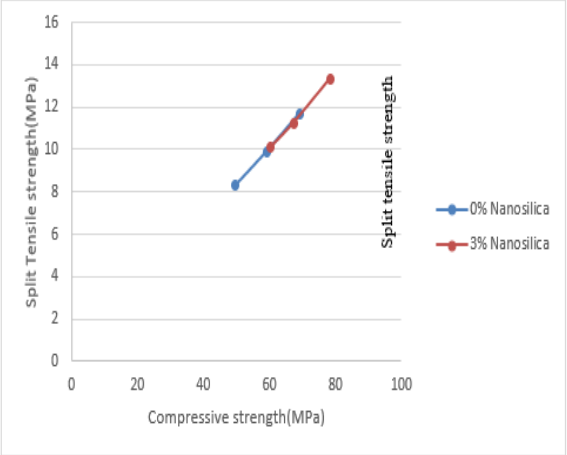


Figure 1 Correlation between compressive and splitting tensile strength

Equation 1 given below is the proposed power-type equation adopted for the correlation between compressive and splitting tensile strength of concrete considering all the grades of concrete at 28 days of curing obtained from figure 1 using regression analysis. R^2=0.9545 acquired from experimental results and power-type regression equation justifies that 95.45% of experimental results were correlated to the power-type regression equation and a good relation between compressive and splitting tensile strength was observed.

$ft = 0.059f_{ck}^{1.087}$ 1

ft = Split tensile strength

fck = Compressive strength

$Pi=0.0625Fck^{1.092}$=Proposed empirical equation.

IS CODE et al =.070 $fck^{0.50=F1}$

ACI CODE et al=0.62 fck=F2

B.S.CODEet al=0.60 fck=F3

SELIM et al=0.034 fck=F4

CHHOMet al=0.47 fck=F5

SMADI et al=.0.58 fck=F6

	Comp strength Fck	Flex strength fr Ei	Pi	F1	F2	F3	F4	F5	F6

GRADE DESIGNATION	fck	fr	Pi	F1	F2	F3	F4	F5	F6
M40 0% NANOSILICA	49.50	4.95	4.41	4.92	4.36	4.22	5.13	3.45	4.08
M40 3% NANOSILICA	60.45	5.60	5.49	5.45	4.82	4.66	6.64	3.82	4.50
M40 5% NANOSILICA	54.25	5.16	4.88	5.15	4.56	4.41	5.78	3.61	4.27
M50 0% NANOSILICA	59.25	5.38	5.36	5.39	4.72	4.61	6.47	3.78	4.46
M50 3% NANOSILICA	67.26	5.95	6.17	5.74	5.08	4.92	7.02	4.03	4.75
M50 5% NANOSILICA	62.15	5.52	5.66	5.51	4.88	4.73	6.88	3.87	4.57
M60 0% NANOSILICA	69.15	5.85	6.35	5.82	5.15	4.98	7.86	4.09	4.82
M60 3% NANOSILICA	78.35	6.20	7.27	6.19	5.48	5.31	8.27	4.36	5.13
M60 5% NANOSILICA	71.45	5.92	6.58	5.91	5.24	5.07	8.26	4.16	4.90

Root Mean Square Error (RMSE)=$\sqrt{\frac{1}{n}\sum_{i=1}^{n}(E-P)^2}$ 2

Integral Absolute Error (IAE) = $\frac{\sum_{i=0}^{n}\sqrt{(Ei-Pi)^2}}{\sum Ei} \times 100$ 3

Normal Efficiency (NEF) = $(1 - \frac{1}{4n}\sum_{i=1}^{n}\frac{|Pi-Ei|}{Ei})$ 4

Mean Absolute Error (MAE) = $\frac{1}{n}\sum_{i=1}^{n}|P_i - E_i|$ 5

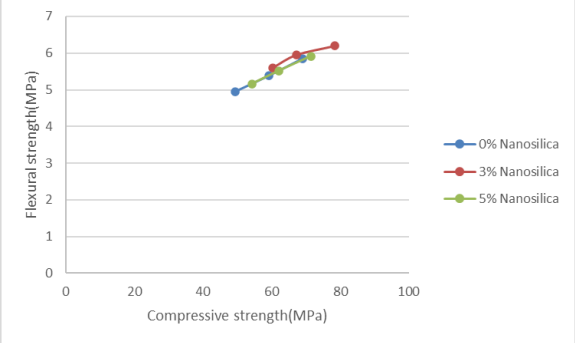
Ei= Experimental results

Pi=Predicted results from proposed equations

Table 4: Results of error analysis from statistical parameters

Source	Equations	RMSE	IAE	NEF	MAE
Proposed Equation	$0.059f_{ck}^{1.087}$	11.13	48.59	87.34	5.29
ACI318-14[1]	$0.56\sqrt{fck}$	18.70	57.31	125.05	14.16
Selim et al. [6]	$0.106f_{ck}^{0.948}$	15.74	48.22	86.04	5.25
Lavanya et al. [2]	$0.249f_{ck}^{0.772}$	13.63	41.78	65.98	4.56
Smadi et al. [5]	$0.46\sqrt{fck}$	18.65	57.10	102.24	4.77
Carino et al. [3]	$0.272f_{ck}^{0.71}$	17.14	52.45	67.32	4.61
Oluokun et al. [4]	$0.294f_{ck}^{0.69}$	16.58	50.76	95.45	5.48

From the error analysis values shown in table 4 split tensile strength calculated from the proposed equation based on experimental results is much accurate compared to those calculated using design codes and other equations obtained by researchers. The split tensile results calculated from the equation obtained from Selim et al. [6] were almost similar to predicted results. It can be concluded that the equation having power other than square root can also be used to calculate split tensile strength from compressive strength and this is in agreement with many other researchers [2-7]. As the regression equation is acceptable if the IAE value ranges within the limit of 0 to 10% [20], the proposed equation showed the lowest value of IAE i.e. 2.74 as compared to other equations. Equations showing the least value of Root Mean Square Error, Integral Absolute Error, Normal Efficiency, and Mean Absolute Error can be considered as best [2, 9, 19]. From table 4 RMSE, IAE, NEF, MAE values of proposed equation are11.13, 48.59., 87.34,5.29. Hence proposed equation can be used to predicted split tensile results from compressive strength results.



CORRELATION BETWEEN COMPRESSIVE STRENGTH&FLEXURAL STRENGTH

3.CONCLUSION

- Good compliance between experimental and analytical results was observed.
- R2=0.9545 acquired from experimental results and power-type regression equation justifies that

95.45% of experimental results were correlated to the power-type regression equation

- The split tensile results calculated from the equation obtained from Selim Pul [6] were almost similar to predicted results.
- Equation having power other than square root can also be used to calculate split tensile strength from compressive strength

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