

Prediction of Compressive Strength of Fiber Reinforced Fly Ash Concrete by Multiple Regression Model

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ABSTRACT: There are two methods available for testing of concrete compressive strength, destructive and non-destructive. But, the main problem with these tests is lack of accuracy because, many of these tests are correlating some factors (input parameters) with strength or any other properties of concrete (output parameters). The compression test, for instance, the most commonly used, does not take into account the effect of transport, placing and curing of concrete. Thus, it cannot be ascertained as the most accurate method. Also, one has to wait for 28 days to get the results. From such a viewpoint, a cheap, reliable and fast method for estimation of the compression test has been developed. The proposed method, helps in achieving said results by deriving them from an empirical relationship established between concrete properties and material parameters. The formula that are thus developed, are based on the principle of multiple regression analysis.

KEYWORDS: Compressive Strength, Admixture, Fly Ash, Regression Analysis, Predicted Strength

I. INTRODUCTION

The tests on hardened concrete are classified into destructive tests and non-destructive tests (NDT) which includes rebound hammer test, Ultrasonic Pulse Velocity Tests and many others which are relatively simple to perform, though interpretation of the test results is quite subjective.

As strength cannot be ascertained in the early stages, test on workability is done to only check the concrete mix quality. For testing on compression by normal methods, the concrete should be cured for 28 days. This makes it difficult to dismantle the same at such a stage leading to money and time wastage. Prediction of strength in the early stages is also yet untouched by most in this field. Thus, a new approach that is capable of predicting reliably, the compressive strength of hardened concrete based on the properties of the ingredients and the wet concrete will be helpful to practicing engineers. Taking the compressive strength prediction as a by-product, these tests can always be used to check workability.

II. RELATED WORK

A lot of research efforts have been done towards prediction on these lines using soft computing tools. Some of them used the regression analysis approach while some used others. Prominent among these are those done by Kheder *et al.*(2003), Nagesha *et al.*(2003), Hwang *et al.*(2004), Jee *et al.*(2004), Ahmet *et al.* (2006), Kewalramani and Gupta (2006), Rajmane *et al.*(2007), Zain and Abd (2009). The present work is to establish a relationship which is complementary to the workability tests carried out. It purports to recognize mathematically the heterogeneous nature of concrete using the properties of materials and the wet concrete. Thus, a predictive approach based on regression analysis is proposed.

III. OBJECTIVE AND SCOPE OF THE WORK

The main drawback with the available destructive and non-destructive tests for the compressive strength of concrete is the lack of accuracy. The most common test for hardened concrete is the compressive strength at a particular setting period of time, from the time of casting the concrete. The concrete strength is generally specified by compressive strength and the further member design is carried out.

As the effects of factors such as placing, transporting, setting is not considered, this method cannot be considered as accurate. Despite that, it is the most acceptable method of measure of strength. In a cube test, one has to wait for 28 days to determine the strength of concrete cube. Also, due to many incidental miscellaneous reasons, this test cannot be effectively carried out for its 28-day period span. Considering these aspects, the present work aims at developing methods for predicting strength of concrete for 3, 7, 28 days. Regression formulae have been developed, deriving from a relationship between concrete block strength and the parameters that primarily affect it. The data required for this was generated in the laboratory. In the trial mixes, Ordinary Portland cement was used and a plasticizer was added for the effect of workability. The formulae can be used to predict the strength at 3, 7 and 28 days for the concrete cubes.

IV. EXPERIMENTAL PROGRAMME

The materials used in this investigation include cement (OPC), sand, aggregates, water, Fly Ash, Glass Fibers and admixtures. The physical properties of the constituents of concrete obtained through various laboratory tests are summarized in the Table 1. The admixture, a Plasticizer (trade name- Supercon[®] - 100) was also used in the present investigation. Supercon[®] - 100 is a pure melamine based super plasticizer which when added to concrete modifies the properties of concrete such as workability, strength, permeability and cohesion.

Glass Fibers used in investigation were modified ANTI-CRAK HD (High dispersion). Anti-crack fibres do not protrude from the surface and require no further finishing. It is very effective at low dosages and easy and safe to handle. It controls and prevents early age cracking in concrete. The characteristic of the Glass Fibers provided by the suppliers are given in the Table 3. The fresh fly ash (Pozzocrete 60) was procured from Nasik Thermal Power Station, which in turn, was supplied by Novelty Business Corporation authorized distributors Dirk India Private Limited, Borivali Mumbai07, Maharashtra, India. The chemical composition and physical properties of the Fly Ash as provided by the Suppliers is shown in Table.4

Table 1: Properties of Materials

Property	Value	Property	Value
Cement		Fly Ash	
Consistency	27.5%	Sp. Gravity	<u>2.13</u>
Sp. Gravity	3.1	Sand	
Initial Setting Time	150 min	Sp. Gravity	2.72
Final Setting Time	225 min	Coarse Aggregates	
Compressive Strength	(N/mm ²)	Sp. Gravity	
7 Days' Curing	37	Metal I	2.7
28 Days' Curing	53	Metal II	2.82

Table 2: Technical Specifications for Plasticizer

Base	Sulphonated Melamine Formaldehyde resin
Dosage	0.5% upto 2% as per Workability requirements
Color	Clear to Little Hazy
Water Reduction:	Between 15% to 20% (Conforms to IS 9103 – 1999, ASTM – C – 494 Type F)
pH	> 8.0
Stability	12 months in closes container
Packing	5 Kgs, 30 Kgs, 230 Kgs

Table 3: Characteristics of Glass Fibres ANTI-CRACK HD

Length (mm)	35mm
Specific Gravity	2.68
Elongation	2.5-4.8%
Nature	Vulnerable to alkali
Water absorbing capacity	Nil
Tensile Strength	2-4 Gpa
Melting Point (0C)	>250°C
Heat Resistance (0C)	<130

Table 4: Chemical composition (%) of Fly Ash:

SiO ₂	58.040
Al ₂ O ₃	25.71
Fe ₂ O ₃	5.31
CaO	5.59
MgO	1.589
Na ₂ O	0.601
K ₂ O	0.60

The experimental procedure involved compressive tests on 90 concrete cubical specimens of size 150×150×150mm. This was further divided into two groups. For first group 50% cubes were used for regression analysis and the remaining half were used for validation. The mix proportions used with plasticizers for different set of trials are shown in Table 5.

Table 5: Mix proportion															
Combination-B-OPC + FLY ASH + GF (OFGF)															
Mix proportion (data for 0.0566 cum)															
Trial	W/Cm	Cementitious materials				Aggregates			agg- cement ratio	Water	Plasticizer		Fiber		Density
		Cement		Fly Ash		FA	CA-I	CA-II			a/c	W	SP		
		kg	%	kg	%	kg	kg	kg		kg	kg	%	kg	%	Kg/cum
	wc	ce		GGBS		FA	CA-I	CA-II	a/c		sp		fb		
1	0.51	310	85	54.71	15	742	556	556	5.08	186	0.00	0.00	0.48	0.02	240.5
2	0.49	300.41	80	75.10	20	739	554	554	4.92	184	0.04	0.20	0.96	0.04	2408
3	0.47	290.43	75	96.81	25	736	552	552	4.75	182	0.09	0.40	1.45	0.06	241.2
4	0.45	280	70	120	30	733	550	550	4.58	180	0.14	0.60	1.93	0.08	241.4
5	0.43	269.07	65	144.9	35	729	547	547	4.40	178	0.19	0.80	2.42	0.10	241.8
6	0.41	257.56	60	171.7	40	725	544	544	4.22	176	0.24	1.00	2.91	0.12	242.3
7	0.39	245.38	55	200.8	45	720	540	540	4.03	174	0.30	1.20	3.39	0.14	242.5
8	0.37	232.48	50	232.4	50	714	535	535	3.84	172	0.37	1.40	3.88	0.16	242.7
9	0.35	218.57	45	267.1	55	707	530	530	3.64	170	0.44	1.60	4.38	0.18	243.1
10	0.33	203.64	40	305.5	60	699	524	524	3.43	168	0.52	1.80	4.87	0.20	243.4

V. METHODOLOGY OF INVESTIGATION

The data from five trials mixes was used for the regression analysis. Equations were developed with four variables (w/c, Fly Ash, compaction factor and weight of cube) for the prediction of compressive strength for 3, 7 and 28 days. The data of other 5 trials was used for the validation of results obtained. ‘Multiple Regression and correlation Analysis’ was applied to derive these equations. In Multiple Regression Analysis, various formulae were developed, by varying the input parameters used to predict the 3, 7 and 28 days’ strength of concrete cube. Selecting the following equations with different inputs, which would help the user to predict the strength of concrete cube with available data parameters, is based on the results of analysis and the validation of formula.

Equation for four variables:

For 3 days’ compressive strength

$$\text{Str}_3 = 220.360 - 665.049 \times \text{wc} - 462.463 \times \text{fb} + 52.327 \times \text{cf} + 11.529 \times \text{wt}$$

For 7 days’ compressive strength

$$\text{Str}_7 = 103.912 - 393.634 \times \text{wc} - 264.199 \times \text{fb} + 14.567 \times \text{cf} + 13.406 \times \text{wt}$$

For 28 days' compressive strength

$$\text{Str}_{28} = -384.118 + 238.395 \times \text{wc} + 264.199 \times \text{fb} + 3.620 \times \text{cf} + 33.439 \times \text{wt}$$

where,

wt = weight of cube before curing

fb = fiber

cf = compaction factor

wc = water cement ratio

VI. RESULT AND DISCUSSION

Multiple Regression Analysis technique is the one adopted to develop equations and estimate the strength of concrete cube samples. These equations were derived from the Statistical Analysis Package SPSS- 16. The data generated is used for two parts, one for strength calculation and one for analysis. The formulae derived by regression analysis are applied on ten trial mixes, to predict their 3, 7 and 28 days' strength of concrete cubes and the same are shown in Table 6.

As can be seen from Table, all formulae were found to give satisfactory results. The given formula with four variables does fairly better prediction of 3, 7 and 28 days' strength. The confidence level in terms of coefficient of correlation (R) for all formulae is between 0.94 to 0.99.

The model having four variables, is found to underestimate the actual 3 days' strength by 13.23% on an average in case of four trials whereas in the remaining one, it is found to overestimate the actual strength by 49.02%.

Table 6: Summary of strength in MPa

Days	Variables	Strength			Average percentage variation
		Actual	Predicted	% increase or decrease	
3	Four	17.78	13.76	-22.60	-13.23 49.02
		22.22	18.04	-18.82	
		20.44	19.92	-2.56	
		19.56	17.81	-8.94	
		11.11	16.56	49.02	
7	Four	27.11	21.74	-19.81	-13.03 10.17
		26.96	25.28	-6.25	
		24.00	25.53	6.39	
		23.85	24.10	1.04	
		18.81	23.16	23.09	
28	Four	34.52	27.97	-18.97	-8.78 40.33
		43.26	37.62	-13.04	
		39.85	38.94	-2.28	
		38.67	38.35	-0.82	
		27.70	38.88	40.33	

Similarly, the model, is found to under estimate the actual strength obtained corresponding to 7 days' curing by 13.03% on an average in case of three trials whereas in remaining one trial, it is found to overestimate the actual one by 10.17%. For the 28-day strength, the actual strength has been underestimated by 8.78% on an average for four trials and overestimated by 40.33% for one trial.

VII. CONCLUSIONS

Based on the investigation reported in this paper leading to the development of the multiple regression models, following conclusions can be deduced.

1. Earlier and accurate estimation of concrete strength are valuable to the construction industry as a whole. The presence of models like these as they were developed in the present study would possibly obtain the balance and equality between controlling the quality (quality control process) and economics (saving time and expenses).
2. These models could be used in construction to make the necessary adjustments on mix proportion used, to avoid situations where concrete does not reach the required design strength or by avoiding concrete that is unnecessarily strong.
3. Prediction of strength of concrete cube with regression analysis is easy and handy. The regression analysis would save time and reduce waste of materials.
4. The coefficient of correlation obtained in view of the various equations developed being in the range of 0.94-0.99 speaks of the reliability of the equations or its use in the field to predict the strength of mixes to be prepared using such materials employed in the present study beforehand.

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