Statistical Model for the Prediction of 28 Days Compressive Strength by 3 Days Compressive Strength using Response Surface Method

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ABSTRACT

Concrete design is done using compressive strength; 28th day strength of concrete represent its design strength. In prevailing constructionmechanism28 days is a significant time to delay for the test results of concrete strength, the quality control practice is also represented by this time. Concrete mix design is a practice based on codal reference and requires some previous practice. Due to certain imprecision in mix design or mix formulation if at situation the test results fail to achieve the designed strength, then recurrence of entire procedure become an massive task, which can be time consuming and costly. For each and every inaccuracy 28 days is required again, thus the need for an effort less and dependable method for estimating the final strength at an initial age of concrete is a long felt matter. Hence, speedy and suitable concrete strength estimation would be of huge significance. This paper is an effort to develop statistical model to estimate the 28 days compressive strength using 3 days electrical resistivity using Response Surface Method. The recommended model has a significant potential to estimate compressive strength of concrete at altered ages with great accuracy.

KEY WORDS: OPC, 3 Days Compressive Strength, 28 Days Compressive Strength, Coded Variables, Natural Variable.

1. INTRODUCTION

Several approaches for estimating the concrete had been proposed till now which is having regression functions and variables using regression and multiple regression techniques (Oluokun, 1990). Structural design using concrete needs the concrete compressive strength data to be used. In building construction works 28 days are substantial time to wait for the test results of compressive strength of concrete. For all sort coming it is required to wait for at least 28 days therefore early age estimation of concrete compressive strength is long felt matter. (Kheder, 2003) various traditional, mathematical and smart modeling techniques had been used so far, to forecast the behavior of concrete. (Nath, 2011) Researchers are very eager to open up the concrete behavior therefore estimation of concrete strength at early ages had been marked as an active area of research (Zain, 2010). Response Surface Methodology (RSM) has been used in the present work to give a statistical model. The theoretical ideologies of RSM and steps for its application are described to introduce readers to this multivariate statistical technique and symmetrical experimental design (Raymond, 2009). Here, it is attempted to develop a relation between 28 days concrete strength and 3 days compressive strength using response surface method and finally express this relationship with a statistical model.

Response Surface Method: RSM is an assembly of statistical and mathematical techniques useful for evolving, refining, and enhancing process. It is necessary to work out an estimating model for the true response surface for its real world application. A first order (multi linear) RSM model is given by

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_n x_n + \varepsilon \qquad (1)$$

Here, y_i is the practical compressive strength of concrete. After residual testing for present work linear model is suggested due to randomness of data. The term "linear" is used because Eq. (1) is function having linearity in relation with the unknown, factors $\beta_1, \beta_2, ...\beta_n$ are called regression coefficients and $x_1, x_2, x_3, ...x_n$ are coded variables which are regularly demarcated to be dimensionless with mean zero and identical standard deviation. In the multiple regression model natural variables are transformed into coded variable by equation 2,

$$x_{i1} = \frac{\xi_{i1} - \left[\max\left(\xi_{i1}\right) + \min\left(\xi_{i1}\right)\right]/2}{\left[\max\left(\xi_{i1}\right) - \min\left(\xi_{i1}\right)\right]/2} \qquad (2)$$

In above eq.1 represents natural variables with maximum and minimum values.

In the current study, RSM evaluation is performed using sole replicate 2n+1 factorial model to apt first order linear regression model, where n is the total number of input variables involved in the analysis and corresponding to these variables the no. of sample points required is 2n+1 (Andre, 2006). For example in the present case 1 variable is considered, here n is equaled to 1 and number of sample points required is 2. These 2 sample points are generated using "+"and "–" notation to denote the high and low levels of each factor respectively. Two runs in the 21+1 design are conducted and results are obtained (Raymond, 2009).

Table.1. Composition of Fine Aggregate

Constituent	GBFS (%)	Pond ash (%)
Silica (SiO_2)	58	67
Alumina (Al_2O_3)	24.2	17.44
Iron Oxide (Fe_2O_3)	11	8.5
Calcium Oxide (CaO)	3	2.44
Magnesium Oxide (MgO)	1.1	0.45
Sulphur (SO_3)	0.9	0.30
Loss of Ignition	1.8	3.46

Statistical Analysis: The solidification of concrete is a complex procedure involving many peripheral factors. A number of enhanced estimation techniques have recommended equations by inclusion of empirical and computational modeling techniques i.e. statistical techniques and artificial intelligence approaches (Vahid, 2004). Various efforts have been made for effective modeling of this process by using computational techniques, whereas a number of research attempts have been made focusing on using multivariable regression models, thus trying to improve the accuracy of estimation (Suhad, 2001). Statistical models have the magnetism, that once fixed they can be used to execute estimations much more speedily than any other modeling practices, and are correspondingly uncomplicated to put into operation in software (Mahmoud, 2012). Mathematical techniques are used for estimation of compressive strength of Portland cement concrete (Popovics, 1998). Concrete composition data is used to estimate 28 days compressive strength with judicious precision (Jee, 2004). For proposing a formula readily applicable for on-site use 3 days are sufficient to estimate compressive strength of concrete (Vivianiet, 2005). Apart from itsquickness, statistical modeling has the advantage over complementary practices that it is mathematically less laborious and can be used up to outline confidence interval for the estimation. This is exclusively correct when Fractional the associating statistical modeling with artificial intelligence method. Statistical assessment can also be responsible for understanding the key factors affecting 28 days compressive strength by correlation analysis. For these purposes statistical analysis techniques of RSM was chosen as technique for strength estimation.

Experimental Program: Physical properties of the constituents used in the study are displayed in Table (1). Locally produced ordinary Portland cement (OPC) was used. It has a specific surface of 3400 m^2/kg and specific gravity was reported as 3.12. Fineness modulus was 2.83 for fine aggregate and 2.7 for coarse aggregate having20 mm maximum nominal size of crushed stone. Partial replacement of fine aggregate 50% by weight with Pond ash and GGBSis done. In the study results due to effect of variable proportions with the ordinary constituents of concrete (cement, sand and gravel) are displayed in Table (3). Compressive strength test was performed and evaluated in accordance to IS Code 456:2000. Specimens were submerged in water until the day of testing for 3 and 28 days. Table 4 display the results of compressive strength test at an interval of 3 days and 28 days. For making statistical model a representative mix has been taken with varying fine aggregate and cement and various coefficients has been generated for all models individually. By further analyzing and optimizing the coefficient by performing iterations, best model is selected for estimation of 28 days concrete compressive strength using response surface method.

Table.2. Properties of Fine Aggregate Replaced

Material	Properties
Pond ash (PA) Ordinary Portland	Specific Gravity: 2.16 Fineness modulus: 1.49
Fine Aggregate (FA) Sand (S)	Specific Gravity: 2.60 Fineness Modulus: 2.34
Coarse Aggregate(CA) Crushed Stone	Specific Gravity: 2.7 Maximum particle size: 20 mm
GGBS(GBFS) Fine aggregate	Fineness modulus: 2.55 Specific gravity: 2.46

Table.3. Average Compressive Strength R of 4 Samples for Each Mix Separately

	3 Days COMP	28 Days COMP
M 1	25.5	31.5
M 2	17.0	32.0
M 3	22.3	33.0
M 4	23.5	28.0
M 5	20.0	29.0
M 6	22.0	35.0
M 7	17.0	30.0
M 8	15.5	31.0
M 9	18.0	31.0

Table.4. Mix design table With Pond ash, GGBS and Sand as fine aggregate

Mix	TYPE OF CEMENT	Cement (IN KG)	Water	Sand (IN KG)	GBFS (IN KG)	Pond Ash (IN KG)	Coarse Aggregate (IN KG)	W/C Ratio
M 1	OPC	378	189	757			1026	0.5
M 2	OPC	369	185	352	352		1026	0.5
M 3	OPC	424	212	287		287	1035	0.5
M 4	PPC	416	208	680			923	0.5
M 5	PPC	416	208	316	316		923	0.5
M 6	PPC	466	233	278		278	850	0.5
M 7	PSC	378	189	668			1068	0.5
M 8	PSC	378	189	312	312		1068	0.5
M 9	PSC	423	212	277		277	1000	0.5

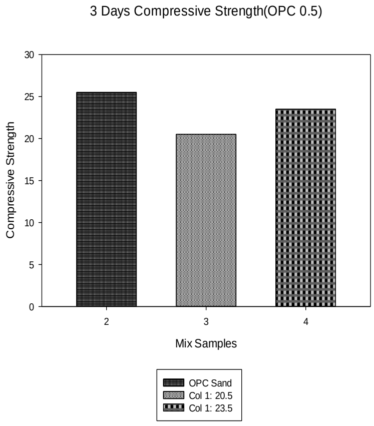

Figure.1. Three Days Compressive strength OPC 0.5 W/c

3. RESULTS AND DISCUSSION

Table.5. Input variables

Compressive strength 3 days	25.5	20.5	23.3	23.5	20	22	19	16.5	18

Strength for 3 days Compressive Strength and 28 days compressive strength are listed in Table 3. It can be seen that average Compressive strength value after 28 days for mix having GGBS and pond ash as fine aggregate replacement 50% by weight are more in all cases .In all cases we are getting better results for GGBS. The sample is selected so as to incorporate the variability in strength gain rate for the samples. Rate of gain of strength for GGBS is slow up to 3 days but it increases rapidly after 3 days. By using eq. 2 above Natural Variables are converted into a Coded Variable and Coded Variable matrix has been listed in the Table 6. Assumed and generated linear model had been given in Table 6.A

Fig.2. Shows Comparison between 3days compressive strength and 28days compressive strength where we can see the pattern of variation of compressive strength with different mix samples. Maximum error of 9.55% is obtained for mix sample with GGBS and PPC which is on lower side by 9.55% from Table 7. While we are getting maximum error of 3.5% on lower side for OPC mix samples and maximum error of 4% for PSC mix samples. Thus we can say that model generated using RSM is very accurate in predicting Compressive strength of concrete especially for mix samples with OPC and PSC.

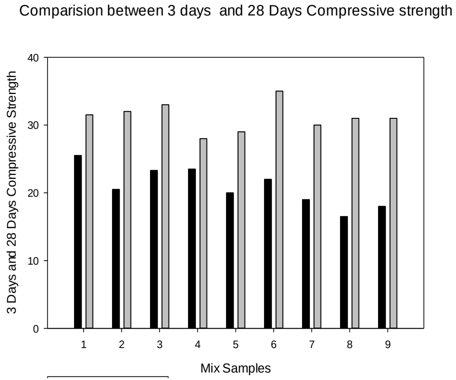

Figure.2. Comparison between 3 days and 28 Days Compressive strength

Table.6. Coded variables converted by RSM	Predicted Model

1	1
1	0.444444
1	0.755556
1	0.777778
1	0.388889
1	0.611111
1	0.277778
1	0
1	0.166667

C28=Q + R*C3
C28=28.427+0.1467*C3

Table.7. Verification of model using experimental results

C28 Observed	C28 predicted	Error%
31.5	32.16785	2.120159
32	31.43435	-1.76766
33	31.84511	-3.49967
30	31.87445	6.248167
32	31.361	-1.99688
35	31.6544	-9.55886
30	31.2143	4.047667
32	30.84755	-3.60141
31	31.0676	0.218065

4. CONCLUSION AND RECOMMENDATION

From this study, a statistical model was developed.

a) The importance of the influence of mix Constituents on the strength of concrete was approved; the input taken is dominated by constituents in the mix.

b) Previous models that deal with the prediction of concrete compressive strength were lacking the inclusion of other variables affecting strength gaining in concrete.

c) A statistical model using Response Surface Method for the prediction of Concrete compressive strength at the age of 28 days (using-linear function) is done using 3 days compressive Strength as input variable.

d) Properties like resistivity, chemical constituent's, age and test results of USPVT and weight can also be incorporated to increase the accuracy of prediction.

e) RSM can be used in various civil engineering applications.

Assumption:

a) Before performing experiments we assume that after replacing fine aggregate 50% by weight of fine aggregate it will give a satisfactory or same result.

b) Compressive strength increases as days of curing increases.

c) Environmental conditions like moisture, humidity, and temperature to be same throughout the experiment.

d) Properties of aggregate to be same which is used for experiment as it is from same source and same batch (20 mm down).

e) Curing has been done uniformly throughout.

Scope: Response Surface Method is very powerful tool .Here it is introduced for working with concrete. Further various typical predictions can be made using this method and various other mechanistic and statistical models can be suggested using n number of variables.

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