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A Model for Compressive Strength of Concrete by Using Cylindrical Samples of 4 x 8 Inch

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Abstract— Compressive strength (Fc) of concrete is an important strength parameters used in the design of many civil engineering structures. For its evaluation a large number of testing procedures are available. Among them compressive strength test described in ASTM C39-86 recommends 6*12 inch cylindrical samples, which need more material and are difficult to handle as well. In order to overcome this difficulty, the effect of sample size on Fc was investigated and a prediction equation developed that replaces the use of 6*12 inch samples with 4*8 inch samples.

Index Terms— Compressive strength of concrete, ASTM C39-86, compression test, cylindrical samples

1 Introduction

Compressive strength (Fc) of concrete is an important parameter used in the design of civil engineering structures, such as building, bridges etc. These parameters are greatly influenced by variations in mixed design curing conditions, construction practices, and time.

Presently, a large number of testing procedures is available for compressive strength. Of these procedures, the American Society of Testing Materials (ASTM) recommends 6*12 samples for Fc, which need more material and are difficult to handle as well. Therefore the main concern of this study was to formulate a statistical model to predict Fc by making and testing 4*8 inch concrete samples. For this purpose, different sets of 6*12 inch and 4*8 inch samples were prepared. Each set having three samples of each size was made up of one mixed design. These samples were tested for compressive strength in order to develop a regression model, which is helpful for replacing 6*12 inch samples with 4*8 inch samples that require less material and are easy to handle as well.

2 Sample Preparation

All concrete samples were prepared according to ASTM procedure. Single use moulds recommended by ASTM C470-81 were used. The maximum size of coarse aggregate used in all of the samples was according to ASTM C192, which describes that the diameter of the samples shall be at least three times the maximum nominal size of the coarse aggregate. All of the samples were made according to the ASTM C192-81 procedure. Moreover, ASTM C617 was followed for the capping of these samples, which is the requirement for testing the samples for their compressive strength.

3 Experiment Design

The main concern of the experiment design in this study was to obtain data for the formulation of a statistical model, which allows to substitute small-sized concrete samples in place of 6*12 inch samples and should cover a wide range of values for compressive strength. For this purpose different sets of 6*12 inch and 4*8 inch concrete samples were prepared, in accordance with ASTM recommendations.

The total number of concrete samples made in this study was 108. Half the concrete samples were 6*12 inches and the other half were 4*8 inches. Since in each set three concrete samples of both sizes were made from one mix, a total of 18 sets of different mixes were used for the preparation of these concrete samples. Table 1 gives the mixes design of all the sets. The selection of the mixes was made in such a way that the minimum and maximum possible range of values for compressive strength could be obtained. It was achieved by knowing such facts as when the water cement ratio increases the strength decreases. Similarly, the strength increases with age because of the completion of hydration process.

4 Testing Program

All the samples made in this study were tested for their compressive strength. Before testing all the samples were capped according to ASTM C192-81 recommendations. Later these samples were places at the center of two steel bearing blocks of computerized testing arrangement of Figure 1. In this arrangement it is easier to apply a continuous load without shock. The calibration of the machine was made and the rate of loading was specified at the beginning of each test. Latter the upper steel bearing block was brought to the face of the concrete sample. The test was then started by hitting the RETURN key on the computer. After some time the concrete sample failed and the failing load was obtained from the printout from the computer, which was used for compressive strength of concrete samples.

5 Development Of Model

In this study, a total of 108 samples were made. Of these samples, 54 were 6*12 inches, and the other half were of 4*8 inch size. All these samples were tested for their compressive strength and the data base obtained was used for the development of the model.

For the development of this model bivariate linear regression (LINREG), polynomial (POLY), numerical optimization (NUMOPT), and Statistical Analysis Software (SAS), were used. The first three software programs were written by McCuen (1992). SAS is a popular software available on the

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market.

In the development of a regression model, the first attempt is normally made to fit the data with a linear analysis because linear models are easy to apply and their statistical reliability can be assessed easily. Linear models may be rejected, however, for a number of reasons, theoretical or empirical. The reasons might suggest a non-linear model structure. Non-linear models may be classified as a power, polynomial, exponential, or some other complex model structure.

In this study, for the development of the model, a variety of different model structures were tried. All such model structures and the corresponding values of R^2 and Se/Sy and the value of relative biasedness are given in table-2. Comments about plots for prediction, constant error variate, and their distribution are also given in this table.

For comparison, all these equations are unbiased and the values of R^2 and Se/Sy are not significantly different. The plots of the predicted versus observed values of criterion variable and the degree to which the assumptions used for the residual analysis are met is equally good for all the models. However, predictive equation D-2 was selected as the final model because it gives the same trend for all values of $Fc_{(4*8inch)}$ used in this study [1]:

$$Fc_6 * 12 = 1.12485 * [Fc_{4*8} inch]^{0.9844365}$$

In this model the measured value of criterion variable ranged from 1226.7 to 5,558.9 psi and the values of R^2 and Se/Sy were 0.87 and 0.36, respectively. Figures 2 and 3 show the plots for the error variance and the distribution of the residuals. These plots indicate that the error variance is constant and the errors are normally distributed. For further verification of the actual versus predicted values of the criterion variables were plotted (see Figure 4).

The values of the coefficients of the developed model suggest that the 4*8 inch samples give high compressive strength. Possible reasons for these results are: [1] The difference in average unit weight of the samples, and [2] the effect of size of the sample. The strength of concrete increases with an increase in its unit weight (Neville, 1987). However, in this study, contrarily, the average unit weight of 4*8 inch samples was lower than the 6*12 inch samples. Therefore, the size of the sample is the dominant factor responsible for the coefficients of the developed model.

Fig. 1. Photograph of compression tester

TABLE 1

MIXIED DESIGN, CURING AND INFORMATION OF DIFFERENT GROUPS MADE IN PHASE 2.
(CEMENT : SAND : AGGREGATE FOR ALL THESE GROUPS IS 1 : 2 : 4)

Group	W/C (%)	Curing (days)	Testing Time (days)
A	45	28	28
B	45	21	21
C	49	28	28
D	49	21	21
E	53	28	28
F	53	21	21
G	57	28	28
H	57	21	21
I	61	28	28
J	61	21	21
K	65	28	28
L	65	21	21
M	69	28	28
N	69	21	21
O	73	28	28
P	73	21	21
Q	73	28	28

6 CONCLUSIONS

The developed model is helpful in replacing 6*12 inch samples

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(recommended by ASTM) by 4*8 inch samples and is useful in a sense that it is easier to handleFig smaller samples having less material. In addition, a higher value of compressive strength of 4*8 inch concrete samples indicate a dependency of concrete with size of the sample.

TABLE 2
(CEMENT : SAND : AGGREGATE FOR ALL THESE GROUPS IS 1 : 2 : 4)

Mode No.	Software Used	Model Structure	R^2	Se/Sy	Prediction Of Model	Error Variation+	PDF of Errors*
D-1	LINREG	$Fc_{(6x12)}=244.471÷0.9264609*[Fc_{(4x8)}]$	0.874	0.358	Acceptable	C	N
D-2	LINREG	$Fc_{(6x12)}=1.12484*[Fc_{(4x8)}]^{0.9844365}$	0.872	0.360	Acceptable	C	N
D-3	POLY	$Fc_{(6x12)}= -729.46+1.54532*[Fc_{(4x8)}]$ $0.0000868*[Fc_{(4x8)}]^{2.0}$	0.886	0.344	Acceptable	C	N
D-4	SAS NUMOP	$Fc_{(6x12)}=1.12559*[Fc_{(4x8)}]^{-0.01810065*}$ $[Fc_{(4x8)}]^{2.0}]^{0.5012293}$	0.872	0.364	Acceptable	C	N

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