RESEARCH INTO THE CORRELATION BETWEEN CONCRETE STRENGHT AND UPV VALUES

B. Tumendemberel, Ts. Baigalimaa

Centre of NDT, Mongolian University of Science and Technology

e-mail: tumen_must@yahoo.com
baigal5@yahoo.com

1 ABSTRACT

There are many test methods to assess concrete in situ, such as Non-destructive Testing methods (Ultrasonic Pulse Velocity), and this method consider indirect and predicted tests to determine concrete strength in situ, whereas this test affected by many parameters depend on the nature of materials used in production concrete. So, there is a difficulty in determine strength of hardened concrete in situ precisely by this methods. This research aim to find unified relationship connect the results of this test and correlate them with the results of compressive strength of cubes by using statistical methods in the analyzing process depending on laboratory tests carried on concrete cubes with different mixing ratios and different curing conditions, and finding correlation curves to predict the strength of concrete much better.

Keywords: Statistical method; Polynomial regression; Non-destructive testing;

2 INTRODUCTION

Instead of the good care in the design and production of concrete mixture, many variations are happened in the conditions of mixing, degree of compaction or curing conditions which make many variations in the final production. Usually, this variation in the produced concrete have been assessed by standard tests to find the strength of the hardened concrete, and inspire of the type of these tests, considered a good one to determine the quality during the process of producing concrete but they have some considerable disadvantages, such as the test sample may be not present the concrete in the structure actually.

So, as a results, many trials were carried out in the world to develop fast and cheap non-destructive methods to test concrete in the labs and structures and to observe the behavior of the concrete structure during a long period, such this test is Ultrasonic Pulse Velocity test.

3 ULTRASONIC PULSE VELOCITY TEST - UPV

Among the available non-destructive methods, the ultrasonic pulse velocity test is the most commonly used ones in practice. Test is described in ISO1920-7[1], ASTM C592 [2] and GOST 17624-87[3]. The principle of the test is that pulse of longitudinal vibrations is produced by an electro –acoustical transducer (transmitter), which is held in contact with one surface of the concrete under test. After traversing a known path length in the concrete, the pulse vibrations is converted into an electrical signal by second transducer (receiver) [4]. Electronic timing circuits enable the transit time of the pulse to be measured than the velocity of the pulse to be measured.

4 EXPERIMENTAL

The concrete strength taking from cubes made from the same concrete in the structure differ from the strength determined in situ because the methods of measuring the strength influenced by many parameters as mentioned previously, so the cube strength taking from the samples produced and tests in the traditional method will never be similar to in situ cube strength.

Also, the results taking from the non destructive tests, ultrasonic pulse velocity is predicted results and do not present the actual results of the concrete strength in the structure.

So, this research aim to find a correlation between compressive strength of the cube and results of the ultrasonic pulse velocity for the same cube by using compressive methods in the explanation of the tests results.

The research covers 126 test results taking from 126 concrete cubes with 150x150 mm. All of these cubes took from mixtures designed for the purpose of this research by using ordinary Portland cement compatible with the Mongolian standard (MNS 976:1999) [5], sand compatible with the Mongolian standard (MNS 2916:2002) [6] and using fine aggregate within the Zone 1, the maximum size of the coarse aggregate ranged between (5-20) mm. Table 1 shows the details of these cubes.

Table 1: Details of cubes used in the research

Mixtures No.	W/C	Materials used per batch, kg				
		Coarse aggregate (10-20)	Zone 1 (5-10)	Sand	Cement, M400	water
1	1,015	700	465	777	195	198
2	0,757	709	472	747	247	187
3	0,671	702	468	698	292	196
4	0,587	698	466	654	339	199
5	0,491	705	470	620	391	192
6	0,445	702	468	577	438	195
7	0,479	676	451	517	468	224

For determination of the compressive strength of cubes MNS 1272:99[7] procedures were used. Before the execution of destructive compressive test, the cubes were tested, using ultrasound for the determination of the velocities of the longitudinal ultrasonic waves. UPV test carried out for each cube, taking the average three reading (one reading for each opposite faces) [3], [4] by using the equipment known commercially as TICO and pulses with 54 kHz frequency, then the cube was crushed and the reading of the crushing force was recorded. Table 2 shows the tests results. The concrete strength varied between 9.96 and 42.6MPa and for different curing conditions. The curing conditions of the cubes in the two groups are: one is air curing another is water curing. The age of the cubes in the 3 groups ranged 7; 14; 28 days.

5 DISCUSSION AND CONCLUSION

We can turn to the statistical methods in the process of explanation the tests results and the prediction of concrete strength, in the case of the test was carried out in satisfactory way and standard tools. Whereas the statistical methods proved that have a good value.

The first steps in this research included predict the analytical relationships between compressive strength of the cube and UPV. The regression analysis method was used in the analysis process of the results by using MATHCAD 2000 professional, whereas this program depends on Least Square Theory in the analysis process. The goal of the regression method is to fit a line through points (results) so that the squared deviations of the observed points from the line are minimized. Regression allows the researcher to obtain a set of coefficients for an equation. The principle of the analysis concept depend on that the similar the variability, the better is our prediction. For example, if there is no relationship between the X and Y variables, then the ratio of the residual variability of the Y variable to the original variance is equal to 1.0. if X and Y are perfectly related then there is no residual variance and the ratio of variance would be 0 and 1.0 1.0 minus this ratio referred to as R –square or the coefficient of determination.

Many trials were carried to predict the correlation between UPV and compressive strength for the samples, and we obtained better correlation represented by the following power equation:

$$S = 1.356 * 10^{-5} V^2 - 0.076V + 111.502 \qquad (1)$$

Where: S - Compressive strength, M Pa

V - UPV m/ sec

And R –square for this equation was 0.63 which means that we could explain 63% of the variability for the data around the regression line and 37 % remained without explanation. Fig 1 shows the equation 1.

Table 2: Measurement of UPV and compression strength.

data :=

3359	9.96
3565	11.15
3600	13.81
3616	10.63
3665	14.55
3733	10.93
3737	12.92
3738	13.33
3744	12.22
3783	12.33
3786	17.45
3831	19.55
3869	17.44
3898	23.55
3900	18.63
3929	23.59
3954	16.72
3960	32.66
3973	30.15
3976	19.66
3988	19.89
4004	34.85
4014	15.77
4029	24.33
4083	22.73
4090	25.29
4101	35.48
4101	15.29
4103	21.41
4110	19.28
4123	19.55
4135	30.74
4153	27.78
4159	36.65
4166	34.88
4195	30.61
4233	32.59
4244	24.41
4267	25.48
4271	33.48
4327	42.61
4395	34.33

DATA ANALYSIS

Polynomial Regression

This QuickSheet demonstrates Mathcad statistical functions for polynomial regression of X-Y data.

Enter a matrix of X-Y data to be analyzed (x-coordinate in first column, y-coordinate in second):

Click on the **Input Table** above until you see the handles, and enlarge it to see the matrix data used in this example.

$X := data^{\langle 0 \rangle}$ $\quad Y := data^{\langle 1 \rangle}$ $\quad n := rows(data)$

Enter degree of polynomial to fit:

$k := 2$

Number of data points:

$n = 42$

$z := regress(X, Y, k)$

Polynomial fitting function:

$fit(x) := interp(z, X, Y, x)$

$coeffs := submatrix(z, 3, length(z) - 1, 0, 0)$

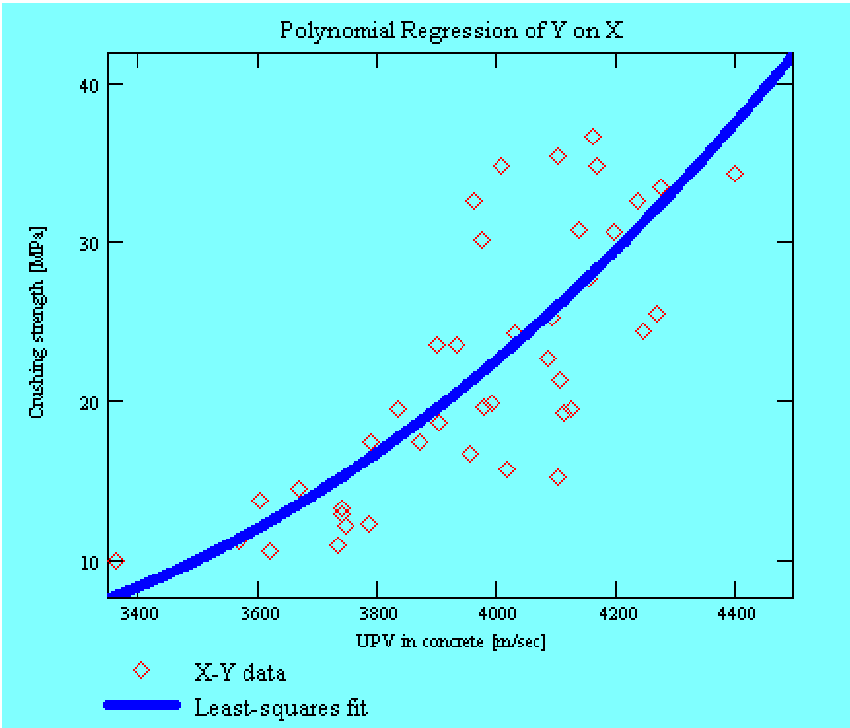
Coefficients:

$$coeffs^T = \left(111.502 \quad -0.076 \quad 1.356 \times 10^{-5} \right)$$

$$R^2: \quad \frac{\sum \overrightarrow{(\mathrm{fit}(X) - \mathrm{mean}(Y))^2}}{\sum \overrightarrow{(Y - \mathrm{mean}(Y))^2}} = 0.627 \qquad z = \begin{pmatrix} 3 \\ 3 \\ 2 \\ 111.502 \\ -0.076 \\ 1.356 \times 10^{-5} \end{pmatrix}$$

Degrees of freedom: $n - k - 1 = 39$

Plots



$Ax^2 + Bx + C$

$A = z6$

$B := z5$

$c := z4$

+

Figure 1. Relationship between concrete strength and UPV in

6 REFERENCES

1. ISO1920-7, Testing of concrete - Part 7: Nondestructive tests on hardened concrete, published by ISO.
2. ASTM C 592-02, Test Method for Pulse Velocity Through Concrete, ASTM, USA., 2002.
3. GOST 17624-87, Concrete, Ultrasonic method of strength determination, published by GOST.
4. IAEA Training Course Series 17: Guidebook on non- destructive testing of concrete structures, Vienna., 2002, pp 100-111.
5. MNS 976:1999, Sand used for constructional work, Testing method.,1999
6. MNS 2916:2002, Portland cement, Testing method.,2002
7. MNS 1272:99, Concretes, Methods for strength determination using reference specimens, MN., 1999
8. Dr. Isam., Finding an Unified Relationship between Crushing Strength of Concrete and Non-destructive Tests, www.ndt.net-32d MENDT.