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ULTRASONIC PULSE VELOCITY VERSUS STRENGTH FOR CONCRETE IN QATAR

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ABSTRACT

Compressive strength of concrete is widely accepted as a characteristic property indicating and representing its quality. The accuracy of both ultrasonic and mechanical strength is discussed and the advantages of ultrasonic testing are pointed out. Measurements of ultrasonic pulse velocity and mechanical crushing load of concrete cubes made from the aggregate and cement used in the State of Qatar are reported in this paper. Measurements on concrete cores from a local structure are also reported. The results are compared with previously published correlation between the velocity and mechanical strength of concrete.

INTRODUCTION

It is well known that concrete is a non-homogeneous material. Its properties vary from one location to another in a cast structural member and that the correlation between the various concrete mechanical properties are not the same for different concretes and hence, are not the same at different locations of a concrete member.

Non-destructive testing provides the means to check the properties and qualities of concrete at various locations of an existing structure. The ultrasonic pulse velocity testing method is probably the best and most reliable non-destructive method since the relation between pulse velocity and the elastic properties of concrete is well established (1, 2). The transit time of an ultrasonic pulse through concrete can be measured with great accuracy and velocity readings are always consistent. However, since the relations between the various properties are themselves variable, the correlation between the velocity and the magnitude of a specific property can only be considered as an indication to other properties. This is why experimental correlations are needed.

Compressive strength might not be the best way to represent the quality of concrete, but because a value for design is needed it has become acceptable to all engineers that the quality of concrete as cast be determined from the value of its compressive strength.

Therefore a correlation between pulse velocity and compressive strength is needed. To develop such a correlation, velocity readings should be compared with strength measured by an accurate method. But, unfortunately, a perfect method does not exist or is not yet known. When cubes or cylinders are cast from a concrete mix or when cores are taken from an existing structure, an assumption is immediately made that these are representative samples. Then, when samples are mechanically crushed, the following three factors at least come into effect (for the same age of concrete).

1. The size.
2. The non-uniform compression or capping.
3. The performance of mechanical crushing machine.

The variations due to these effects are considerable. An investigation about the performance of calibrated mechanical compression machines by the Concrete Society (3) indicated discrepancies up to 20% in crushing loads. Non-uniform compression might decrease the ultimate load by 30% and good capping might enhance the compressive strength.

It may be concluded that, although values of pulse velocity and cube strength need to be compared, neither should be considered the reference for accuracy. Nevertheless, since strength design values are required and are usually based on cube (or cylinder) strength, a prediction of this cube strength from pulse velocity is required.

ULTRASONIC PULSE TESTING OF CONCRETE

Ultrasonic pulse testing of concrete has the advantage of penetrating the whole depth of a concrete cast. The time taken by the quickest pulse to pass from one face of concrete to another is measured; the velocity depends on the elastic properties of the material (elastic modulus, Poisson's ratio and density). Large voids, cracks and material segregation are detected by observing the change in the pulse velocity. Research on ultrasonic testing had casted some doubt about its accuracy (4), possibly because the lack of accuracy in obtaining the crushing strength was not taken into account. It is true, however, that a velocity versus strength correlation developed for concrete made from materials available in a certain area, might not be applicable to other areas where the materials have different properties.

EXPERIMENTAL CONCRETE CUBES

Five mixes of concrete X1 to X5 were designed to simulate unsupervised concrete mixes at the construction sites. Table 1 gives the proportions used for the five mixes. The results of the sieve analysis for sand are given in Table 2 and those for coarse aggregate in Table 3.

Local limestone aggregate and locally manufactured ordinary Portland cement produced by Qatar National Cement Company at Umm Bab were used. The

Table 1
Concrete Mixes Proportions

Mix	Proportions Cement: Sand: Aggregate	W/C	Aggregate/cement A/C
X1	1: 2.50: 4.00	0.60	6.50
X2	1: 2.50: 4.00	0.65	6.50
X3	1: 3.00: 4.00	0.55	7.00
X4	1: 2.00: 4.00	0.60	6.00
X5	1: 3.33: 6.67	0.67	10.00

Table 2
Sieve Analysis for Fine Aggregate

Sieve No.	Retained (g)	Retained (Cumulative) (g)	% Passing
4	4.8	4.8	99.80
10	89.0	93.8	95.31
20	235.8	329.6	83.52
40	936.0	1265.6	36.72
50	509.0	1774.6	11.27
100	204.0	1978.6	1.07
200	18.9	1997.5	0.13
Pan	2.5	2000.0	0.0

Table 3
Sieve Analysis for Coarse Aggregate

Sieve Size	Retained (g)	Retained (Cumulative) (g)	% Passing
28.0	0.0	0.0	100.00
25.0	0.0	0.0	100.00
20.0	205.0	205.0	94.87
12.5	2627.5	2832.5	29.19
10.0	585.5	3418.0	14.55
5.0	534.0	3952.0	1.20
Pan	48.0	4000.0	0.0

The applicability of the curve in Fig. 1 to the experimental data developed by this work and reported above will now be examined.

The results of the cube and the core tests are plotted in Fig. 1. Two cubes were neglected because the crushing strength - marked thus *in Table 4 - is believed to be reduced due to non-uniform compression. The experimental points follow the curve with reasonable agreement, all of them, however, fall in the range of medium strength concrete.

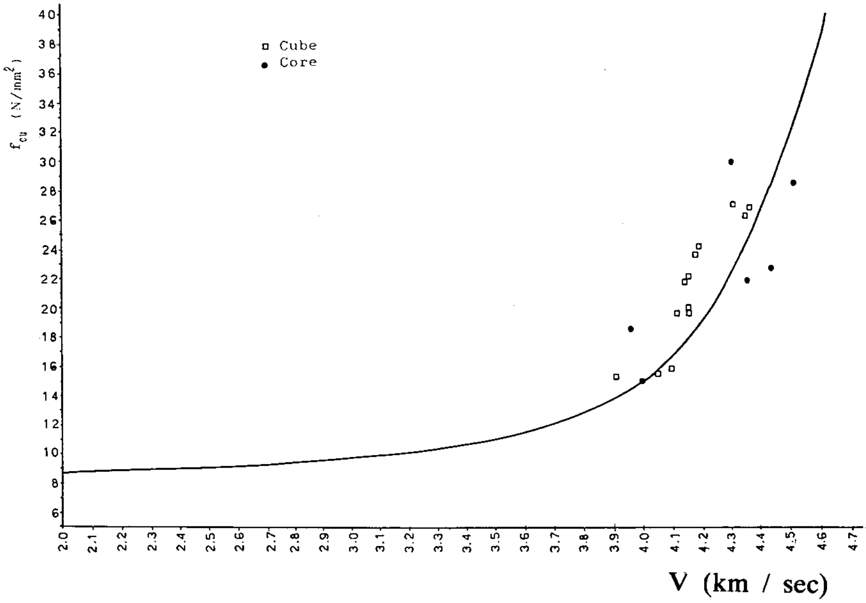

Fig. 1: U.P.V. Versus Cube Strength.

CONCLUSIONS

The correlation curve in Fig. 1 is a good start for correlating pulse velocity to strength of concrete made in the State of Qatar. However, more data is required on the various ranges of compressive strength namely high and low, so that the applicability of the lower and upper parts of the correlation curve could be examined.

Research is also needed to determine the possible variations to the curve due to variations in locally used aggregates.

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