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Full Length Research Paper

Determination of concrete compressive strength of the structures in Istanbul and Izmit Cities (Turkey) by combination of destructive and non-destructive methods

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Cylindrical concrete cores of 10 cm diameter and height were taken from the columns and shear walls of randomly chosen 5-40 years old reinforced concrete (RC) buildings located in different towns of Istanbul and Izmit (Kocaeli) in Turkey from 2000 to date. The ultrasonic pulse velocity (UPV) measurements and uniaxial compressive strength (UCS) tests were conducted on 200 concrete core specimens in our laboratory. The core UCS of the specimens regressed against UPV and linear regression equations were obtained.

Key words: Concrete, ultrasonic pulse velocity (UPV), Istanbul, Izmit, Turkey.

INTRODUCTION

The non-destructive testing (NDT) which estimates the strength of concrete without destroying the structure is the most practical and widely used. This method has been used successfully to measure either the strength property of concrete or a physical or mechanical property which can be correlated to strength. Several non-destructive methods of assessment have been developed (Malholtra, 1976). Anderson and Seals (1981) conducted two different experiments to establish the potential for using dynamic non-destructive test procedures to predict long term compressive, tensile and flexural strength based on six different concrete mixtures. Leshchinsky (1991) summarized the advantages of non-destructive tests for the point of view of labor consumption and structural damage. Rajagopalan et al. (1973) reported a correlation between ultrasonic pulse velocity (UPV) and compressive strength of concrete for some mixes.

The UPV method has been conducted successfully to evaluate the quality of concrete more than seven decades and the NDT method has seem to be the standards of many countries. Komlos et al. (1996) and Qasrawi (2000) reported the appropriate standards of some countries. This method has been using for detecting internal cracking void and variation of the physical properties in concrete due to severe chemical environment, freezing and thawing. The pulse velocity method is also used to estimate the strength of concrete test specimens. Several previous studies (Tanigawa et al., 1984; Kheder et al., 1998; Lin et al., 1998; Popovics et al., 1990; Turgut, 2004) concluded that there is a good correlation between ultrasonic pulse velocity and the compressive strength.

The objective of this study is to contribute to the development of the non-destructive determination of concrete strength using 200 concrete core specimens taken from randomly chosen columns and shear walls of various reinforced concrete structures in Istanbul and Izmit (Kocaeli), Turkey since 2000.

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Abbreviations: RC, Reinforced concrete; **UPV,** ultrasonic pulse velocity; **UCS,** uniaxial compressive strength; **NDT,** non-destructive testing.

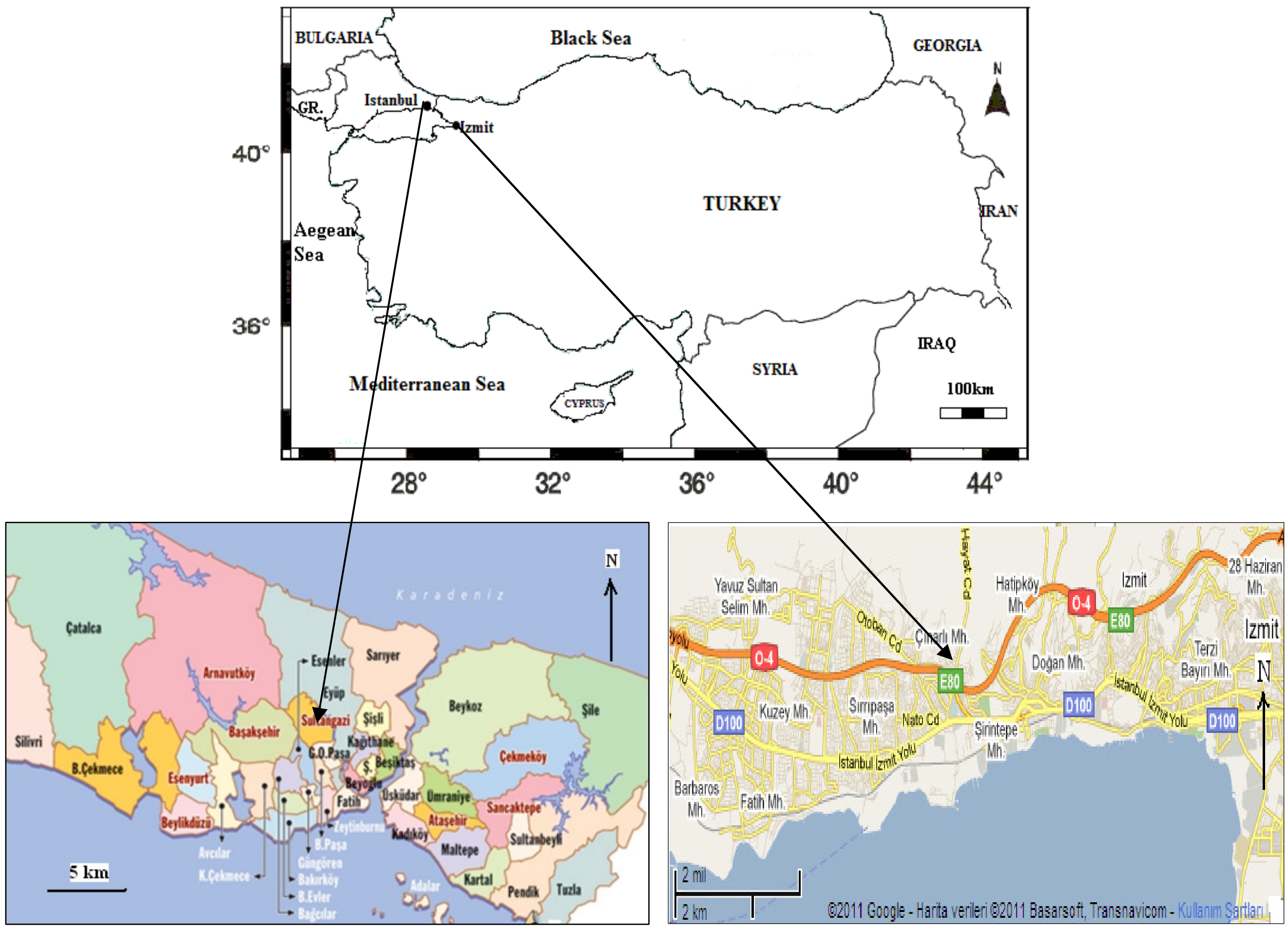

Figure 1. Cities where concrete core specimens collected in Turkey.

STUDY AREA

The concrete core specimens were taken from the columns and shear or retained walls of various reinforced concrete buildings within the towns of Kadiköy, Maltepe. Kartal, Pendik, Sultanbeyli, Beylikdüzü, Esenyurt, Fatih, Beşiktaş, Şişli and Sarıyer in Istanbul and within the districts of Kuzey, Sırrıpaşa, Çınarlı, Barbaros, 28 Haziran, Doğan, Fatih, Yavuz Sultan Selim, Terzibayırı Şirintepe in Izmit and Turkey (Figure 1).

Experimental program

Test specimens

6 test core specimens' were collected from the buildings within Kadiköy, 4 within Maltepe, 5 within Kartal, 4 within Pendik, 4 within Sultanbeyli, 5 within Beylikdüzü, 3 within Esenyurt, 6 within Fatih, 4 within Beşiktaş, 5 within Şişli and 4 within Sarıyer towns in Istanbul whereas 4 test core specimens were collected from the buildings within Kuzey, 6 within Sırrıpaşa, 5 within Çınarlı, 5 within Barbaros, 5 within 28 Haziran, 5 within Doğan, 6 within Fatih, 4 within Yavuz Sultan Selim, 4 within Terzibayırı, and 6 within Şirintepe districts in Izmit. The test core specimens used in this study were obtained from 2000 to date. Two specimens from each building were used and the means for 50 buildings were considered in each city. Before drilling, the longitudinal and transversal steel reinforcement bars were carefully detected with the help of a ferroscan and a covermeter (Figure 2) coring was done with a portable water-cooled drilling machine (Figure 3). The cores were taken between the steel reinforcement bars. The size of the cores was 10 cm diameter and height. There was no reinforcement present in the cores.

Ultrasonic pulse velocity measurments (UPV)

The UPV method is a non-destructive method, as the technique uses compressional waves resulting in no damage to the concrete element being tested. The method involves measuring the travel time over a known path distance of a pulse of ultrasonic waves. The pulses are introduced into the concrete by a piezoelectric transducer and a similar transducer acts as receiver to monitor the surface vibration caused by the arrival of the pulse. The test method for pulse velocity through concrete is described in ASTM-C597-97.

The UPV measurements of compressional waves were conducted using DT Qust-120t ultrasonic pulse generator instrument with the transducers with 50 mm in diameter, and had maximum resonant frequency of 54 kHz.

The end surfaces of the core samples were polished and greased to provide a good coupling between the transducer faces. The pulse velocity was measured pressing the transducer to the

Figure 2. Scanning with a ferroscan device.

Figure 3. Coring from concrete wall with a portable water-cooled drilling machine.

core samples firmly.

Compressive strength determination

The UCS is precisely the geotechnical property that is most often used in rock engineering practice. It provides a first approximation of the range of conclusions that are likely to be encountered in several of engineering. The compressive strength of concrete is the most common performance measure used by the engineer in designing buildings and other structures. The compressive strength of the concrete core specimens was measured by breaking the cyclindirical concrete specimens by the help of a (UTEST) compression-testing machine with the capacity of 200t. For determining of the compressive strength of the cores BS-1881-120: (1983), and ASTM C 42-90 procedures were used (Logothetis 1979; Mikulic et al., 1992; Trezos et al., 1993).

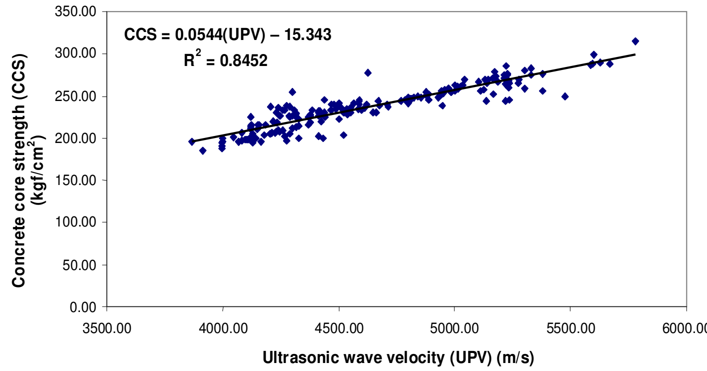

Figure 4. Relation between concrete core strength and UPV with cores taken from Istanbul.

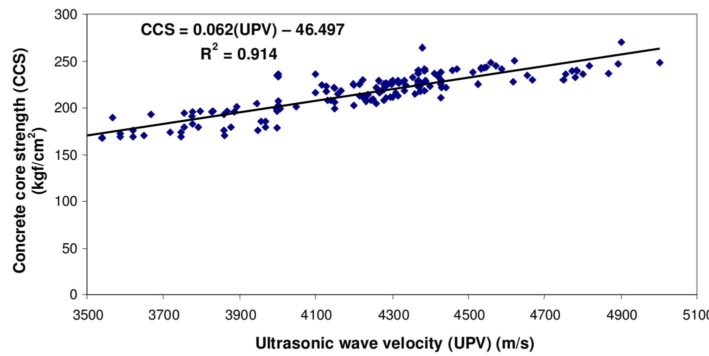

Figure 5. Relation between concrete core strength and UPV with cores taken from Izmit.

Regression analysis

The result of the compressive strength versus UPV obtained as summarized above from the buildings in Istanbul is given in Figure 4. The differences in strength and UPV values of cores stem from having different concrete ages and mixture ratios are shown in Figure 4. The core strength and UPV data exhibit the most appropriate relationship as:

$$CCS = 0.0544(UPV)-15.343 \quad (1)$$

where, CCS = concrete core strength (kgf/cm^2) and UPV = ultrasonic pulse velocity (m/s).

The best correlation between concrete core stength and ultrasonic pulse velocity was obtained with linear function with a correlation coefficient of R^2 = 0.8452. The relationship between the compressive strength and UPV obtained for the buildings in Izmit are shown in Figure 5.

As can be seen from Figure 5, concrete core strength increases with increase in UPV. The best correlation between concrete core strength and ultrasonic pulse velocity was obtained with linear function with a correlation coefficient of (R^2=0.914). Equation for the correlation is given in Equation 2.

$$CCS = 0.062(UPV)-46.497 \quad (2)$$

Where, CCS = Concrete core strength (kgf/cm^2) and UPV = Ultrasonic pulse velocity (m/s)

DISCUSSION AND CONCLUSION

The results of hardened concrete specimens taken from the buildings in Istanbul and Izmit show good correlations of compressive strength and UPV. The ranges of concrete core strength and UPV collected from Istanbul and Izmit cities vary between 186-289 kgf/cm^2 and 3915-5627 m/s, and 128-248 kgf/cm^2 and 2298-4900 m/s respectively.

The correlation coefficient of Izmit data set (R^2=0.914) indicates better correlation than that of Istanbul data set (R^2=0.854). The actual compressive strength of the concrete specimens of reinforced concrete buildings located in Istanbul and Izmit can be estimated by Equation 1 and 2 with an admissible accuracy. Usage of these equations prevents time-consuming, exhaustive charge of core drilling, cutting, crushing and capping. The only needed device would be an ultrasonic pulse tester. Qasrawi (2000) and Haktanır et al. (2002) determined regression-based equations similar to Equation 1 and 2. Qasrawi (2000) used cubic concrete specimens of 15 x 15 cm dimensions to figure out their compressive strength. However, this process is used to determine the compressive strength of fresh concrete specimens being kept in the water for 28 days in laboratory conditions. Therefore, the regression-based equation obtained by Qasrawi (2000) does not show in-situ conditions. Haktanır et al. (2002) used concrete cores of 10 cm dimensions and followed the same process that we used. For that reason, the equation given by we and Haktanır et al. (2002) are more descriptive.

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