Interdependence between Structural Engineering and Construction Management
Edited by Ozevin, D., Ataei, H., Modares, M., Gurgun, A., Yazdani, S., and Singh, A.

ISBN: 978-0-9960437-6-2

THE EFFECT OF AGE ON THE COMPRESSIVE STRENGTH OF CONCRETE BY USING ULTRASONIC PULSE VELOCITY

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In this study, the effect of age on the strength development of concrete was investigated. For this purpose, specimens casted with ready mix concrete for different grades of concrete were obtained from ready-mix concrete firms available in Diyarbakir city which is the one of the biggest cities of Turkey. A few sets with different grade of concrete cube specimens were used in the experimental work. Each set included over 40 specimens. For measuring concrete strength development, two different tests were used: ultrasonic pulse velocity testing (UPV) and uniaxial compressive strength testing. After UPV and compressive strength tests, strength development for early ages was evaluated and defined. The aim of this work is to define the path of strength development of certain grades of concrete used in the east regions of Turkey. Another aim of the work is to be able to determine concrete strength through non-destructive UPV tests. As a result, it was seen that concrete strength development for early ages is not linearly proportional to age. Further, UPV measurements can give information on the progress of concrete strength.

Keywords: Nondestructive test, Ready-mix concrete, Axial compression test, Samples.

1 INTRODUCTION

Concrete is a composite material consisting of water, cement, sand, and gravel. It is a most widely used material in building construction, because of easily availability of aggregate that forms around 70% of the volume of concrete. Most of the existing buildings in developing countries suffer severe seismic damage due to insufficient concrete quality (Ilki *et al.* 2006, Bedirhanoglu 2009). Concrete quality that is used in any field of construction (i.e., buildings, bridges, roads) must be checked and controlled (Bedirhanoglu 2014). Fortunately, today's technology has more techniques and science branches that can be used in this area.

One of the techniques of physics and engineering sciences widely used to identify concrete quality, and physical or mechanical properties is called non-destructive testing (NDT), (ACI 228.2R 2014). NDT is a technique used to inspect the physical and mechanical properties of a material without causing any damage. In NDT, the major purpose is to determine errors in a piece being tested. One of the most important factors in the development of a measurement and control system, called Non-Destructive Inspection, is the need to minimize or even eliminate the risk that is caused by a destructive testing method, which is the fundamental method of classical quality control. Quality control of the material with NDT is economical due to not damaging the

materials. Non-destructive testing methods are used almost as a quality control tool at every step of production, during operation, during periodic maintenance and during the development of new products. Non-destructive testing evaluation is fast and sensitive (Hellier 2003).

The material inspection, which means the examination of the structural and internal properties of the materials, is divided into two sections: non-destructive testing and destructive testing (DT). Non-destructive material inspection can be used for different purposes such as examining of defects that occur in materials because of various reasons. Ultrasonic pulse velocity testing method (UPV) is one of the NDT test methods that works by sending high sound frequency wave through the material for analyzing physical and mechanical properties (Hellier 2003).

UPV method is used to ensure the properties of concrete and natural rocks. In this study, the physical and mechanical properties of concrete are aimed to define through measuring the velocity of ultrasonic pulse velocity. This test is carried out by travelling a pulse of ultrasonic wave energy through concrete and measuring the pass time of the pulse. Higher velocities indicate good quality and continuity of the material, but slower velocities through concrete structures indicate low-quality concrete or may indicate concrete with defects (cracks or voids) (Neville 1996 and Luthi 2013).

The UPV method is used to evaluate the quality of concrete with measurement of velocity propagating through the bulk of the material to find out whether the quality of concrete is good or bad in terms of density, uniformity, homogeneity etc. (IS 1992).

Compressive strength of concrete is evaluated more commonly by destructive methods compared to nondestructive testing. Destructive testing is the most reliable method for measuring properties of the concrete. On the other hand, this method damages the material and costs more labor. So, it is vital to improve new techniques for measuring properties of concrete. At this aspect UPV is a good alternative however more researches are needed to improve the reliability of the technique. For that reason, significant number of experiments are needed to be done with different types of concrete in different regions. This point has been our main source of motivation for carrying this study. For this purpose, a series of experimental and empirical studies were carried out by our research group (Bedirhanoğlu and Şahin 2005, Sahin and Bedirhanoglu 2014, Bedirhanoglu 2014, Zebari *et al.* 2017, Abdullah *et al.* 2017, Yousif 2018). In this study, the effect of the age of concrete on its compressive strength was investigated.

2 EXPERIMENTAL WORK

2.1 Specimens and Tests

Three groups of cube samples were tested in this section. Each group consisted of at least 40 samples. A total of at least 130 samples were prepared. Weights of each sample were measured, and then UPV and axial compression tests were performed (Figure 1). Therefore, three data sets for each sample were generated. These measurements were made on the days that we specified earlier. During tests specimens were kept in water with around 21^{o}C.

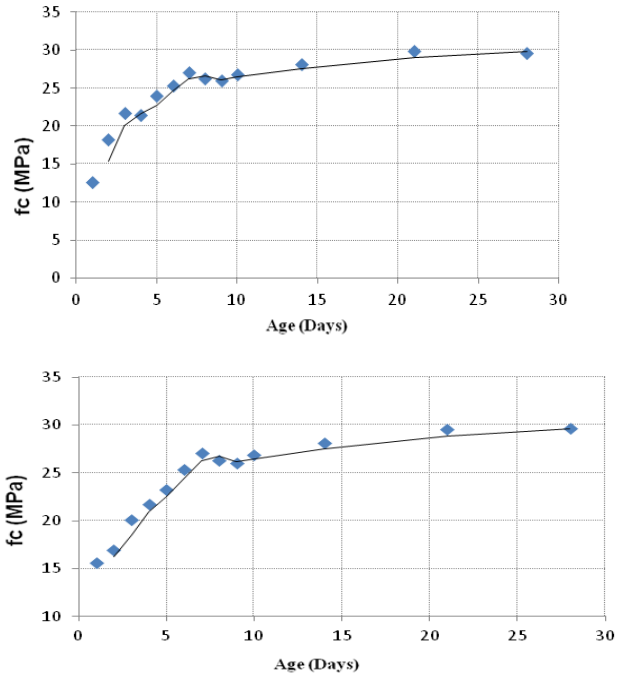
All these samples were taken from three different locations. So, we can split these samples into three groups. The first group is the C20 concrete produced by the Emirler Concrete Plant for the text building. The second group is taken from Bes Concrete Plant and has 25 concrete classes. The third group is again from Bes Concrete Plant C30 concrete.

After 24 hours from casting, specimens were removed from the plastic mold with air pressure. The fist measurements were done on three specimens and others were hold in water. In each day at least three specimens were tested. The UPV and compressive strength tests were made after 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 14, 21 and 28 days.

Figure 1. Testing set up of the UPV test.

2.2 Experimental Results

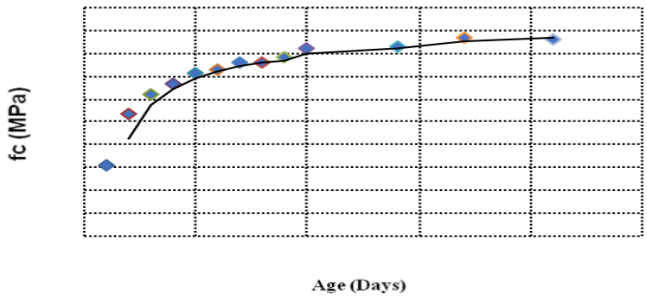
Compressive strength test was conducted by using three specimens at each testing day. Generally, for each day of testing compressive and UPV tests were carried out on three specimens while in order to have an idea about other specimens UPV test were carried on all other specimens, too. At each time of testing minimum three specimens were used and mean values of these three specimens were used to draw graphs given in Figures 2 to 3. Figures 2 to 3 show relationship between age and compressive strength of concrete both with UPV measurement and compressive strength tests for three groups of specimens. All graphs clearly show that strength of concrete suddenly increases with age at very early first few days. After, the increase in compressive strength stops suddenly for next few days.



Group 1

Group 2

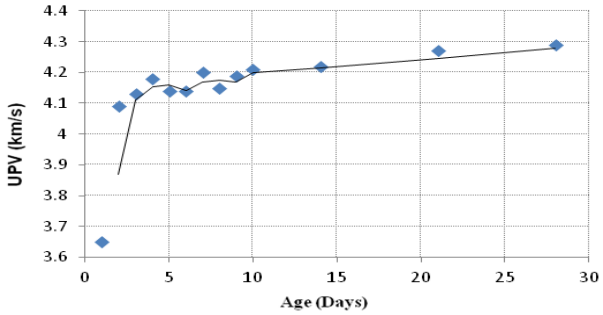
Figure 2. Compression strength and age relationships graphs for groups 1 and 2.



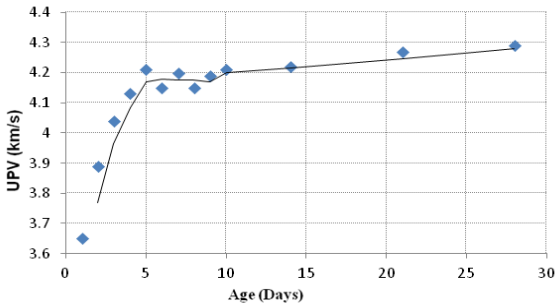
Group 3

Figure 2 (contd). Compression strength and age relationships graphs for Group 3.

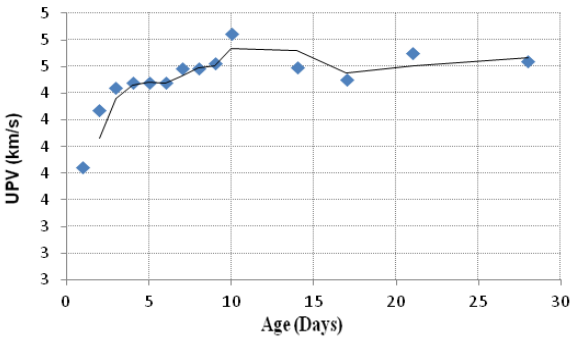
After a few days of recession, compressive strength of concrete starts to increase in a very slow manner. Relationships between UPV and compressive tests are given in Figure 4. It can be concluded that there are some reasonable relationships between UPV and compressive strength for different ages of different concrete grades.



Group 1



Group 2



Group 3

Figure 3. UPV and age relationships graphs for all three groups.

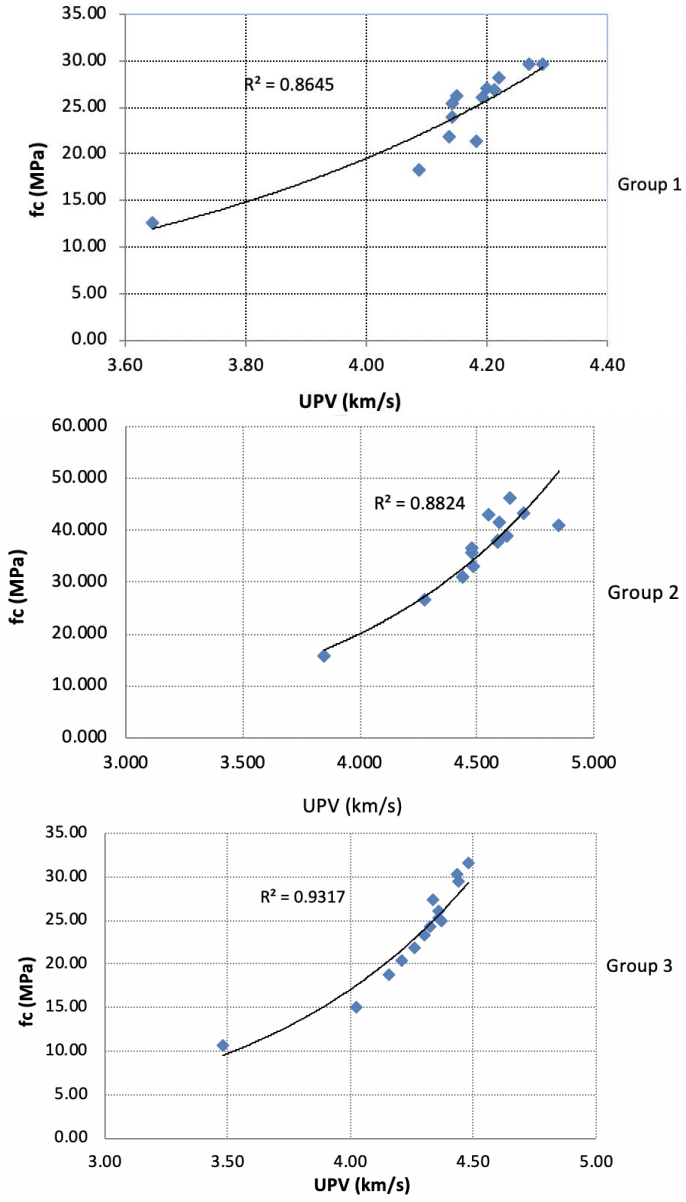


Figure 4. UPV and compressive strength relationships for all three groups.

3 SUMMARY AND CONCLUSIONS

This paper investigated the effect of age of concrete on the strength development through using UPV measurement compared with compression tests. This relation is schematically illustrated as in Figure 5. As a summary, it can be concluded that UPV values increase with age of concrete both in case of UPV and compression tests. However, this increase is not linear. Another important finding is recession in UPV values at certain ages such as between 5-10 days where this was not seen in relation between compressive strength and age of concrete.

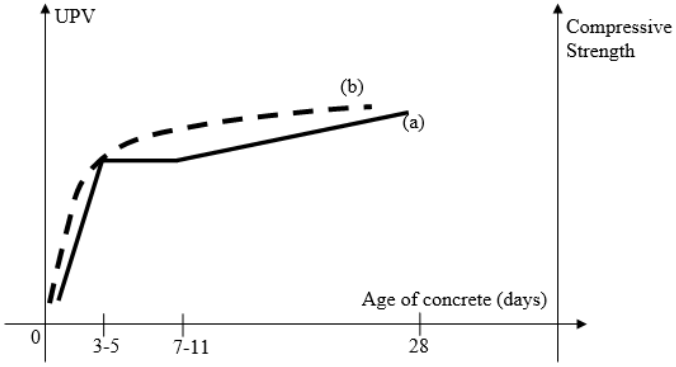


Figure 5. Schematic representation of relationships between a) UPV and age of concrete, b) compressive strength and age of concrete.

Acknowledgments

We thank our friends Vaheel Abdullah, Melik Osal and Emre Güven for their help during experiments. We also thank the Laboratory of Civil Engineering, Department of Dicle University, and Dicle University Department of Physics for the facilities that they provided. We appreciate the financial support provided by MASAKA General Trading – Import and Export LTD Company, KRG, Iraq.

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