Alternative non-destructive method for strength testing of structural concrete

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Abstract. This work proposes an original and active method for non-destructive testing of concrete and can also be used for other building materials. The proposed method includes the successive steps of: drilling holes into samples of building material with use of rotation or percussion drilling machine and simultaneously determining the power consumption necessary for drilling; strength determination of building material by destructive failure of samples; obtaining a positive empiric correlation between the power consumption necessary for drilling and determined strength values of material; control during drilling the holes in structure material being tested and simultaneously determining the power consumption necessary for drilling; determining the actual strength of structure material being tested by use of correlation between power consumption and material strength values derived in testing process. The application of the method makes strength determination of building materials simpler and faster and also increases the accuracy of testing.

1. Introduction

Non-destructive control is an important part of assessing the technical condition of existing concrete and reinforced concrete structures. When carrying out non-destructive testing, it is necessary, on the one hand, to make the most accurate assessment of the technical condition of the construction material, and on the other hand it is necessary to minimize possible damage to the structure as a result of the test.

Assessing the actual compressive strength of concrete in concrete structures is an important task in several stages of construction, from the production of construction materials to assessment technical state of existing old structures.

Sclerometric methods are most popular and useful in the non-destructive control of concrete strength, they are based on impact on the material and assessment of the effect of the produced mechanical action [2].

A pendulum hammer method [3] is a portable mechanical device based on a pendulum that is released from a 90- or 180-degree angle (pendulum position A) and struck against the concrete (pendulum position B) where it leaves a depression. By measuring the diameter and depth of the indentation and performing the necessary calibration, the strength of the concrete at the site can be determined.

The Schmidt hammer is a mechanical device used both on site and in the laboratory. It was invented by the Swiss engineer Ernst Schmidt in 1948 and has been the most popular concrete quality measuring device ever since. Schmidt hummer operating principle is based on an effect of a flexible rebound. The
peculiarities of using this method are described in the standard EN 12504-2 [4]. Despite the simplicity of the device, the accuracy of the Schmidt hammer additionally depends on many factors, such as the smoothness of the surface, the degree of solidity, the age of the concrete, humidity, etc. In addition, uneven surfaces require special preparation - leveling them with abrasive tools.

Adequate results can be obtained by a method of pull-out tests, the principle of which is to determine the force of extraction from hardened concrete using a built-in disc and bar, or a combination of similar elements, which is inserted by drilling into the hardened concrete structure. The pull-out method measures the force required to pull a concrete part into the structure. It should be noted that this is not technically a non-destructive method, so it is possible to perform it only in limited places of construction. However, this is one of the most reliable methods for testing the strength of concrete. Using this method, the strength can be determined by the correlation between the pulling force and compressive strength.

The standard EN 13791 [5] presents methods and procedures for the estimation of the in situ compressive strength for concrete in structures and precast concrete components using direct methods, based on core testing. It should be noted that core testing and pull-out methods is semi-destructive therefore these methods cause some mechanical damage to the structure. Other ones are and indirect methods in accordance to [5], e.g. rebound number and ultra-sonic pulse velocity.

Acoustic test methods are based on the propagation of sound in materials. In physics, sound is the propagation of mechanical waves of pressure in a material, which causes micro displacements, stresses, and complex particle interactions in the material. Determination of ultrasonic pulse longitudinal propagation velocity is the most famous and convenient method for determining the quality and strength of concrete [3]. The propagation speed of sound waves in solid materials is depends on the direction of wave propagation and is divided into longitudinal waves, transverse and surface (Rayleigh) waves, where each type of wave has a different amplitudes and different speeds of the sound. This method also has some drawbacks. Despite the fact that ultrasound penetrates deep into the structure, its propagation speed also depends on the moisture content of the material, the quality of the contact between the sensors and the sound direction in the surface, as well as the qualifications of the operator. The most complete summary of application field of different existing acoustic methods is summarized in the article [6] by Krzysztof Schabowicz.

2. Methods
Taking into account the advantages and disadvantages of the above mentioned methods it is proposed a fundamentally new method based on the determination of the energy required to drill holes in concrete of a certain diameter and a certain depth. It should be noted that the study of drilling processes in various materials has been studied previously by some authors [7]. The method is protected by Latvian patent No LV15041. Non-destructive strength testing method for building materials. Publication Date 20.07.2015 [1]. The invention describes a method for determining concrete compression strength by drilling the test specimen made from concrete and determination empirical correlation between obtained results.

When setting up the experiment, electric drilling machine Bosch PSB 1000-2 RE 1000W has been used: operating at constant power - 2800 rpm; torque 18 Nm. To determine the amount of electricity, we used a standard electric counter with a division value of 0.001kWh.

To calibrate this method, we used standard 15 cm concrete cubes that were clamped in the hydraulic press with a force of 20 kN. After drilling and recording the electricity consumed, the specimens were placed in a hydraulic press and destroyed to determine the compressive strength in accordance with EN 12390-3.

3. Results
A lab experiment is being conducted and the results are being treated by mathematical regression analysis and correlation equation is determined. Boreholes were drilled in ten samples of different sizes, eight of which were concrete samples with medium-grained granite aggregates and two of which were lightweight concrete cubic samples. The samples are characterized with different strengths and densities
to form a correlation curve over as wide a range as possible. The obtained results of the consumed electrical energy were related to the depth and diameter of the resulting hole. Obtained numerical results are summarized in figure 1.

![Figure 1. Correlation of the drilling energy and compressive strength of concrete. Determination coefficient $R^2=0.8209$.](image)

As a result of the analysis, a positive correlation and the values of the coefficients for linear regression equation were determined:

$$y = 343.6x + 2.12$$  \hspace{1cm} (1)

The value of the correlation coefficient $R^2 = 0.8209$ indicates a close correlation between the theoretical and experimental results.

During the laboratory experiment, it was observed that a typical drilling machine should be upgraded in order to be used at the construction site or in the laboratory. Important requirements regards the lever-adjustable mechanism with fixed dynamometer that allow controlling the drilling process with a predetermined force. This equipment allows to control the same drilling depth for all specimens.

4. Conclusion
The proposed method is a convenient method for practical application for assessing the strength of concrete. In addition, in practice, it would be convenient to use the drilling parameters obtained when obtaining technological holes during the construction process. Correlation coefficient $R^2 = 0.8209$ indicates a satisfactory correlation between the theoretical and experimental results.

Taking into account the advantages of the method, the presented correlation and the topicality of the industry, further theoretical research of the method is necessary to standardize and improve the proposed method.

References
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