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NON-DESTRUCTIVE TESTING (NDT) OF CONCRETE STRENGTH: METHODS, PARTICULAR QUALITIES

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This paper reviews the most common non-destructive testing (NDT) methods of concrete strength as utilized by the structural engineering industry. The factors that influence the success of NDT methods are discussed and ways to mediate their influence are recommended. Reference is made to standard guidelines for the application and interpretation of the discussed NDT methods. Perceptions of NDT inadequacy were attributable to lack of understanding construction materials and NDT methods themselves. The intent of this paper is to address these concerns by describing the most common successful methods of NDT as applied to concrete structures.

Introduction. It is often necessary to test concrete structures after the concrete has hardened to determine whether the structure is suitable for its designed use. Ideally such testing should be done without damaging the concrete According to the standard guideline of the ministry of architecture and construction of the republic of Belarus «Control and assessment of concrete strength»: control and assessment of the strength of concrete must be carried out directly in the structures (in situ) with non-destructive testing (NDT) devices with the involvement of specialists from an accredited laboratory [1]. NDT methods have materialized as a response to the need for structural damage detection and prevention. The extensive use of NDT is driven by economics and safety [2].

Research part. NDT methods. Surface hardness methods (ГОСТ 22690-2015, СТБ 2264-2012) [3,4]. The two categories that define concrete surface hardness techniques are indentation methods and rebound methods. These methods attempt to exploit empirical correlations between strength properties of concrete and surface hardness as measured by indentation or rebound. The most commonly used surface hardness procedure is the standard rebound hammer test. **Penetration resistance methods** [3,4]. Penetration resistance methods are invasive NDTprocedures that explore the strength properties ofconcrete using previously established correlations. These methods involve driving probes into concrete samples using a uniform force. Measuring the probe's depth of penetration provides an indicationof concrete compressive strength by referring to correlations. **Pull-out resistance methods** [3,4]. Pull-out resistance methods measure the force required to extract standard embedded inserts from the concrete surface. Using established correlations, the force required to remove the inserts provides an estimate of concrete strength properties. The two typesof inserts, cast-in and fixed-in-place, define the two types of pull-out methods. **Pull-off resistance method** [3,4]. The pull-off test is an in-situ strength assessment of concrete which measures the tensile force required to pull a disc bonded to the concrete surface with an epoxy or polyester resin or registering the force required to shear a section of concrete on the rib of the structure. **Ultrasonic pulse velocity method** (ГОСТ 17624-2012) [5]. Ultrasonic pulse velocity methods involve propagating ultrasonic waves in solids while measuring the time taken for the waves to propagate between a sending and receiving point.

Testing. In the study of NDT methods for controlling the strength of concrete, the most famous and frequently used ones were considered, such as surface hardness methods, pull-out resistance methods and ultrasonic pulse velocity method. The concrete cubes 100x100 from one batch were tested: a concrete surface of the upper edges of the surface with beads and depressions, the side faces and the bottom did not have significant defects (Fig. 1).

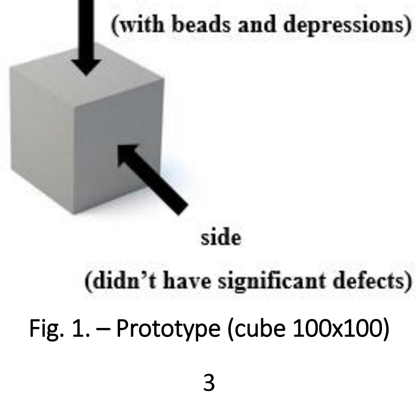

Fig. 1. – Prototype (cube 100x100)

After the experiments, the cubes were tested using a press to determine their true compressive strength and concrete class (C 25/30). In this case, the tests were carried out on all sides of the cubes without cleaning. After testing on an uncleaned surface, the samples were cleaned and the tests were repeated. In addition, foundation structures were tested on site (Fig. 2).

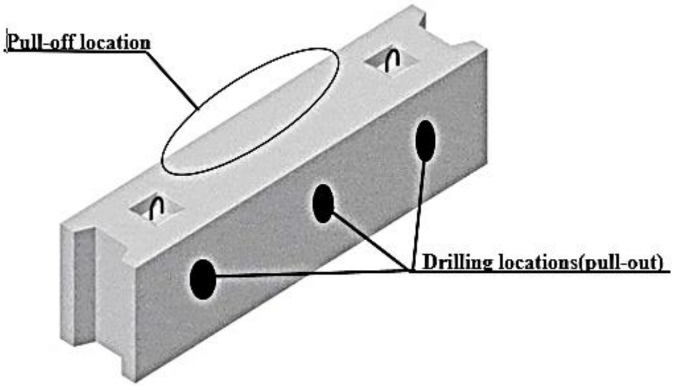

Fig. 2. – Prototype (foundation structure, tested in situ/laboratory)

Results. From a series of tests carried out, it can be concluded that the most accurate methods of non-destructive testing (NDT) of concrete strength are the pull-out/off resistance methods. Methods such as ultrasonic and surface hardness methods allow roughly assessing the strength of concrete (Fig. 3,4,5).

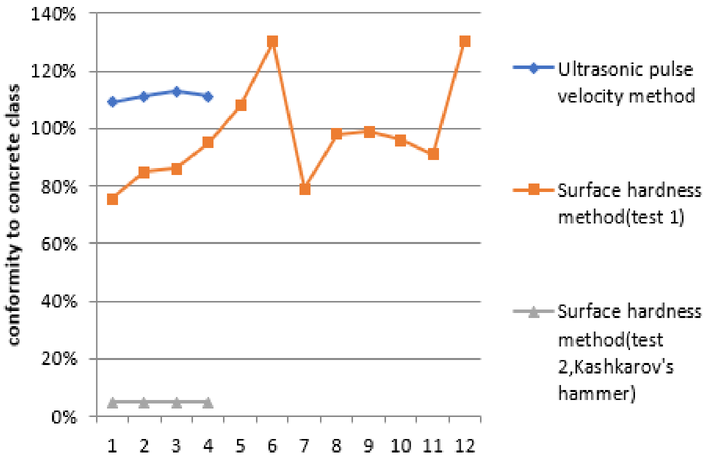

Fig. 3. – Cubes (100x100) test

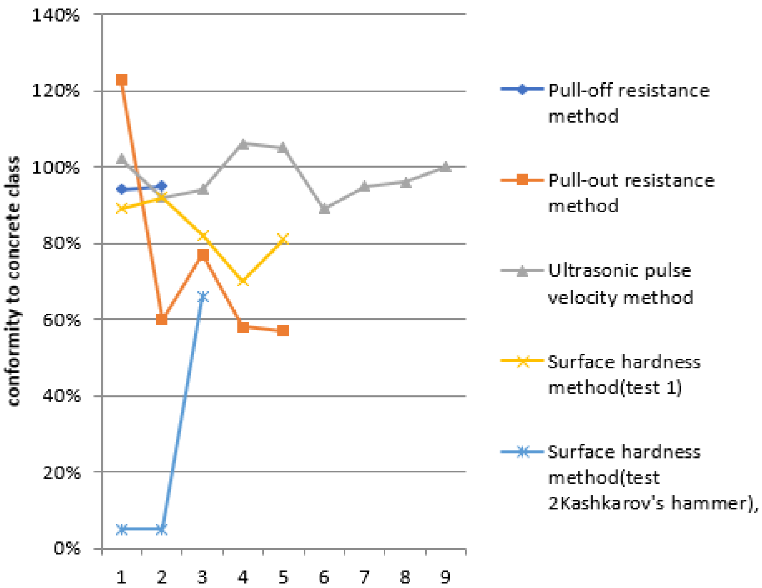

Fig. 4. – Foundation structures, tested in laboratory

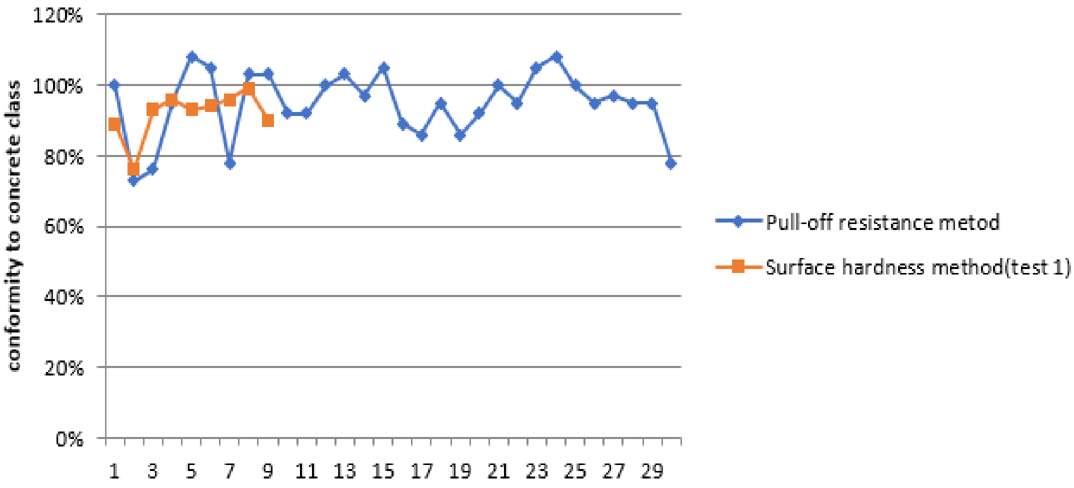

Fig. 5. – Foundation structures, tested in situ

Comparison of the actual and permissible errors of the methods of NDT of concrete strength are presented in Table 1.

Table 1. – Comparison of the actual and permissible errors of methods of NDT of concrete

Methods of NDT	Actual error	Allowable error
Ultrasonic pulse velocity method	2-15%	+/- 2%
Surface hardness methods (test 1)	10-30%	+/-8%
Surface hardness methods (test 2 Kashkarov's hammer)	50-100%	+/-12%
Pull-out/off resistance methods	5-15%	+/- 2%

Non-destructive testing (NDT) of concrete strength requires a comprehensive analysis of the factors that determine the strength of concrete to improve the accuracy, reliability and information content of standardized methods for controlling the strength of concrete in structures.

The table 2 shows the main parameters affecting the strength of concrete, which were identified analytically and experimentally.

Table 2. – Main parameters affecting concrete strength indicators during testing

Construction parameters	Technological parameters
Type of construction Type of construction surface(roughness) Test site (laboratory/in situ)	The composition of the concrete mixture (water-cement ratio, type and quality of aggregate, presence of additives) Concrete age Concrete hardening conditions (temperature, humidity, etc.) Compaction methods

Conclusion. 5 methods of non-destructive testing of concrete strength were considered. From a series of tests carried out, it can be concluded that the most accurate methods of non-destructive testing (NDT) of concrete strength are pull-out/off resistance methods. Methods such as ultrasonic and surface hardness methods allow only a rough estimate of the strength of concrete.

The factors contributing to the variability of NDT methods as applied to concrete are aggregate properties, cement type, water- cement ratio, admixtures and age of concrete, as well as the type of construction, construction surface, test site. It was found that the majority of NDT methods rely on comparing tested parameters with established correlations. Empirical relationships provided by manufacturers were found to often provide unsatisfactory results. Where applicable, it is recommended to conduct test-specific correlation procedures for the NDT of concrete. It can be noted that the experience of the person conducting the test has a significant impact on the results.

Advances in sensors, development of new materials, and miniaturization of devices are all paving the way for new NDT methods. Data fusion techniques are being developed to integrate several NDT methods in the aim of enabling effective data-acquisition, processing, and interpretation of test parameters in relation to material integrity.

REFERENCES

1. Письмо министерства архитектуры и строительства РБ от 11 сентября 2015 года № 02-1-05/10168. «О проведении контроля и оценки прочности бетона» (Электронный ресурс). – 2015 – Режим доступа: http://mas.gov.by/uploads/documents/beton.PDF. – Дата доступа:13.04.2021.
2. Guidebook on non-destructive testing of concrete structures. INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2002. – 220 с.
3. ГОСТ 22690-2015.Бетоны. Определение прочности механическими методами неразрушающего контроля. Москва ,2016.
4. СТБ 2264-2012. Испытание бетона. Неразрушающий контроль прочности. РУП "Стройтехнорм",2012.
5. ГОСТ 17624-2012. Бетоны. Ультразвуковой метод определения прочности. Москва, 2014.