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Research Article

Evaluation the Compressive Strength in Concrete Structures Using the *In-situ* Test Methods

Abstract

The new concrete Standards give rules for in situ checking if the hardened concrete in structure achieved the designed compressive strength according the request the class of concrete. Different concrete elements in structure request the different access during the examinations and different analytical analysis.

Using the different examination methods will be the main aim on evaluations of concrete strength, always in comparing with requested design class. Core testing and other nondestructive methods assessing strength of surface concrete are generally less reliable than cores, but less damaged will used for final evaluations.

More parameters influence the properties of concrete as the type and size of aggregates, cement type and content, placing the concrete, formwork parameters. The different factors analyzing in this paper are combine in the measurements from taking the core samples and results with hammer Schmidt, ultrasonic or other alternative methods. Also the evaluations of compressive strength for different concrete elements in different positions/different layers/ will be the detail expressed in analytical form, because in situ test isn't possible to implement.

Test selection for a particular examinations will be based on a combination of factors such as access, damage, cost, speed and reliability, but the basic features of visual inspection followed by a sequence of tests according to convenience and suitability will generally apply.

Introduction

Concrete mixtures will be designed to provide a high range of mechanical and durability properties and to meet the design requirements of a concrete structure. The compressive strength of concrete is the most common property and the measure used by the engineer in designed buildings and other structures if the concrete is structurally acceptable or not. It is often necessary to test concrete structures after the concrete has hardened and in this case to determine if the structure is suitable for its designed use. Ideally such testing should be done without damaging the concrete. The tests available for testing hardened concrete range between the completely nondestructive, where there is no damage to the concrete, through those where the concrete surface is slightly damaged, to partially destructive tests, where the concrete surface had to be repaired after testing. The range of properties that can be assessed using nondestructive tests is quite large and includes such fundamental parameter as density, modulus of elasticity, compressive strength, surface hardness and absorption as well as reinforcement size and location. The complexity of safety, reliability and durability issues in the conditions of modern building structures exploitation requires specialist testing methods to be continuously developed and improved. To correctly diagnose and assess the building structures the optimal in situ testing methods must be applied, which enable a sufficiently, accuracy of the assessment of limit states of buildings during its whole useful life. In accordance with the European Union principles, in general, the properties of construction elements and building structures are determined by way of basic requirements

determined in the form of technical norms and approvals [1].

Aims of *In-situ* testing

Three basic categories of concrete testing in structures are:

- Control testing- are normally carried out by the contractor or concrete producer to indicate adjustments necessary to ensure an acceptable supplied material [1].
- Compliance testing- are performed by, or for, the engineer according to an agreed plan, to judge compliance with the specification.
- Secondary testing- are carried out on hardened concrete in, or extracted from, the structure. This may be required in situations where there is doubt about the reliability of control and compliance results or they are unavailable or inappropriate, as in old, damaged or deteriorating structures. All testing which is not planned before construction will be in this category, although long-term monitoring is also included.

In this paper the focus will be oriented on a third category, which is one of the primarily concerned with the current adequacy of the existing structure and its future performance. Routine maintenance needs of concrete structures are now well established, and increasingly utilize in-situ testing to assist lifetime predictions. It is important to distinguish between the need to assess the properties of the material, and the performance of a structural member as a whole. The need for testing may arise from a variety of causes, which include.

- Proposed change of usage or extension of a structure
- Acceptability of a structure for purchase or insurance
- Assessment of structural integrity or safety following material deterioration, or structural damage such as caused by fire, blast, fatigue or overload
- Serviceability or adequacy of members known or suspected to contain material which does not meet specifications, or with design faults
- Assessment of cause and extent of deterioration as a preliminary to the design of repair or remedial schemes
- Assessment of the quality or integrity of applied repairs
- Monitoring of strength development in relation to formwork stripping, curing, pre stressing or load application
- Monitoring long-term changes in materials properties and structural performance.

Test methods

Non-destructive methods: The nondestructive testing of concrete is one of the technical and useful importance factors for evaluations of the concrete in structures. These techniques have been grown during recent years especially in the case of construction assessment.

All available methods for evaluating *in-situ* concrete are limited, their reliability is often questioned, and the combination of two or more techniques is emerging as an answer to all these problems.

The combination of several techniques of nondestructive testing is often implemented empirically, combining two techniques most often used to enhance the reliability of the estimate compressive strength of concrete; the principle is based on correlations between observed measurements and the desired property.

Destructive methods (Methods requiring sample extraction): Samples are most commonly taken in the form of cores drilled from the concrete, which may be used in the laboratory for strength and other physical tests as well as visual, petrographic and chemical analysis. Some chemical tests may be performed on smaller drilled powdered samples taken directly from the structure, thus causing substantially less damage, but the risk of sample contamination is increased and precision may be reduced. However the authors have seen results taken from a series of four drilled holes around core samples which showed superior precision and accuracy when tested for cement content. Making good the sampling damage will be necessary, as with partially destructive methods.

Rebound Hammer (RH) Test EN12504-2

The rebound (Schmidt) hammer is one of the oldest and best known methods. It is usually used in comparing the concrete in various parts of a structure and indirectly assessing concrete strength. The rebound of an elastic mass depends on the hardness of the surface against which its mass strikes.

The test is described in ASTM C805 and EN12504- 2:2001. The results of rebound hammer are significantly influenced by several factors such as: smoothness of test surface; size, shape, and rigidity of the specimens; age of the specimen; surface and internal moisture

conditions of the concrete; type of coarse aggregate; type of cement; carbonation of concrete surface.

According to EN13791:2003 Standard, rebound hammer test with calibration by means of cores test may be used for assessment of in situ concrete strength. In situ strength can be estimated using a basic relationship with a determined factor for shifting the basic relationship curve to take into account of the specific concrete and production procedure [3,4].

Ultrasonic Pulse Velocity (UPV) EN 12504-4

The method consists of measuring the ultrasonic pulse velocity through the concrete with a generator and a receiver. The tests can be performed on samples in the laboratory or on-site. Many factors affect the results, the surface and the maturity of concrete, the travel distance of the wave, the presence of reinforcement, mixture proportion, aggregate type and size, age of concrete, moisture content, etc., furthermore some factors significantly affecting UPV might have little influence on concrete strength [3,4]. The test is described in ASTM C597, EN12504-4:2004.

Core sampling *in situ* EN12504-1

Taking Cores is a direct measure of the in-situ strength of concrete. It is mainly used to provide a calibration of an in-direct method and rarely used for determining the rate of strength gain. Core sampling is a destructive test which is used to evaluate the suspicious concrete. At least 3 core samples should be taken from each area. The height of core cylinder is 2.0 diameters and maximum size of aggregate is 1/4 diameter or less.

Due to unknown effects of reinforcing bars in the samples and also in order to keep the integrity of structure, it is better to provide bar detection process before coring and to remove the bars from samples before putting them in compression machine. Any visual defect of concrete should be recorded before compression test and should be applied in analysis.

The objective of this work is to study the reliability of these nondestructive techniques and identify factors that affect the interpretation of their results.

The interpretation of results is given through a combination of correlations between nondestructive techniques and those of mechanical tests [1-3,5].

Number and location of tests in concrete structures

The number of tests is a compromise between accuracy, effort, cost and damage. Test results will relate only to the specific locations at which the readings or samples were obtained. Engineering judgment is thus required to determine the number and location of tests, and the relevance of the results to the element or member as a whole. The importance of integration of planning with interpretation is thus critical. This is discussed here with particular reference to concrete strength, since many other properties are strength-related. This should provide a useful general basis for judgments, and further guidance is contained in with the various test methods. If aspects of durability are involved, care should be taken to allow for variations in environmental exposure and test conditions. Test positions must also take into account the possible effects of reinforcement upon results, as well as any physical restrictions relating to the method in use.

Concrete elements variability

Variations in concrete supply will be due to differences in materials, batching, transport and handling techniques. These will reflect the degree of control over production and will normally be indicated by control and compliance test specimens in which other factors are all standardized. In-situ measurement of these variations is difficult because of the problem of isolating them from compaction and curing effects. Typical relative strength variations for normal concretes according to member type are illustrated in Figure 1.

In-situ strength relative to standard specimens

If the measured in-situ values are expressed as equivalent cube strengths, it will usually be found that they are less than the strengths of cubes made of concrete from the same mix which are compacted and cured in a 'standard' way. In-situ compaction and curing will vary widely, and other factors such as mixing, bleeding and susceptibility to impurities are difficult to predict. Nevertheless a general trend according to member type can be identified and the values given in Table 1 [2,5].

The relations between the Standard Samples and In-situ strength is presented through the algorithm (Figure 2).

Design and specification are usually based on a 150mm cube, but the variation is depend of the Class of the concrete, presented in Figure 3.

Example of evaluation the compressive strength in-situ according to the EN 13791

The reduction of the influence of several factors affecting rebound

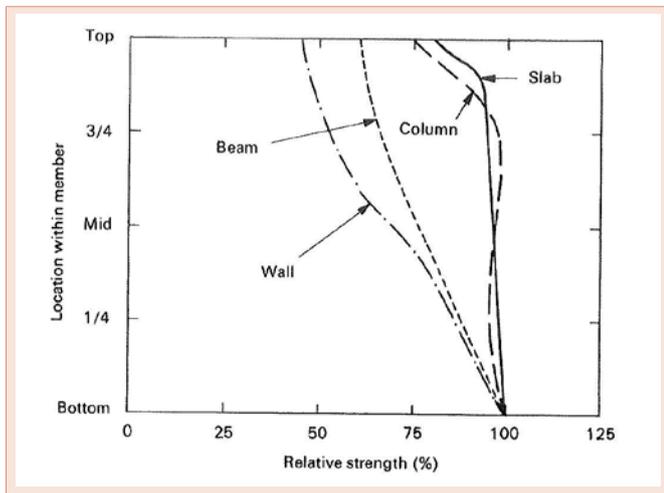


Figure 1: Relative strength according to the member type.

Table 1: Comparing the In Situ test and 28 Days Strength.

Member type	Typical 28-days in-situ equivalent wet cube strength as % of 'standard' cube strength.	
	Average	Likely range
Colum	65	55-75
Wall	65	45-95
Beam	75	60-100
Slab	50	40-60

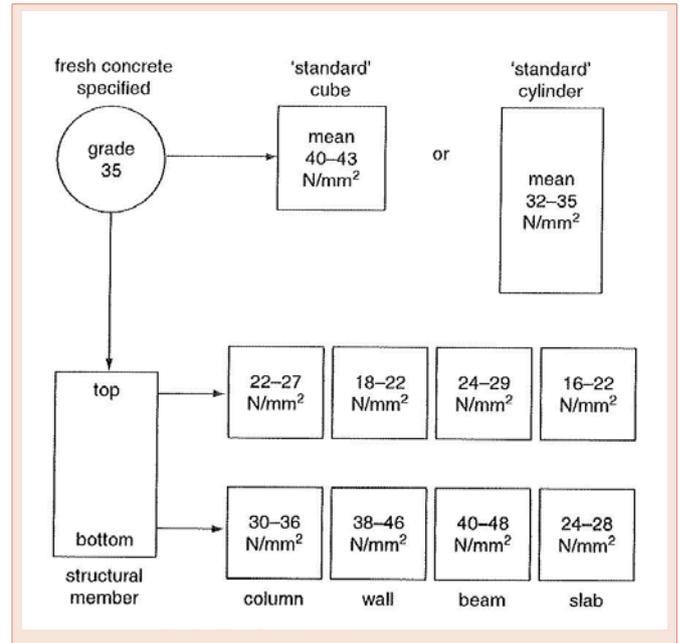


Figure 2: Typical In Situ equivalent 28 Days Cube Strength.

hammer test we can using also the Methods of Core Samples taking in concrete elements of structures.

According to the EN 13791 [8], the results will used for comparing the methods and finally to evaluate the concrete strength in different concrete elements. The data are presented in Table 2.

According to the number of samples we can used the Approach B-EN 13791, with following expression:

$$f_{ck,is} = f_{m(n),is} - k \tag{1}$$

Or

$$f_{ck,is} = f_{is,lowest} + 4 \tag{2}$$

For the taking core samples with dimensions 100x100 mm, and the expression using for indirect test using the EN 12504-04; rebound number.

$$f_{ck,is} = f_{m(n),is} - 1,48 \times s \tag{3}$$

Or

$$f_{ck,is} = f_{is,lowest} + 4 \tag{4}$$

Using the expression the calculation is presented in Figure 4.

Conclusions

The aim of the in situ testing is to obtain an estimate of the properties of concrete in the structure. Very often the desired property is the cube compressive strength. To make a strength estimation it is necessary to have a known relationship between the result of the in-place test and the strength of the concrete for the particular concrete mix concerned. The results presented in this paper are only part of examinations of existing structures, and based on that we can presented the main conclusions point:

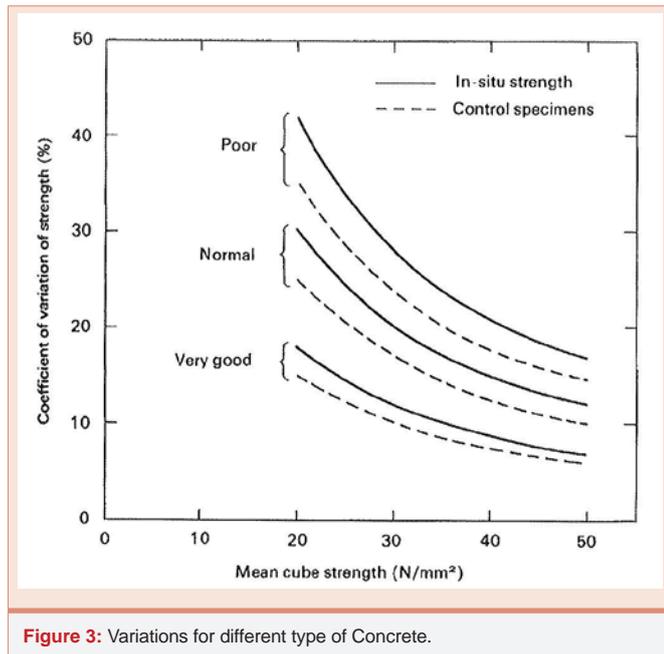


Figure 3: Variations for different type of Concrete.

Table 2: The collected results in Concrete Structure.

Level	Element	Rebound Number	28 days Compressive Strength	Core samples
Level -1	Column	32.0	34.8	31.0
Level -1	Column	28.0	34.5	32.0
Level-1	Column	30.0	34.5	31.0
Level -1	Column	30.0	34.5	30.0
Level-0	Column	29.0	35.0	26.0
Level-0	Column	28.0	35.0	28.0
Level-0	Column	31.0	34.0	28.0
Level-0	Column	26.0	34.0	30.0
Level-0	Beam	28.0	34.0	32.0
Level-0	Beam	27.0	34.0	34.0
Level +1	column	28.0	33.0	33.0
Level +1	column	30.0	33.0	35.0
Level +1	Beam	32.0	32.0	35.0
Level +1	Beam	30.0	32.0	34.0
Level +1	Beam	32.0	32.0	33.5
Level +1	Beam	35.0	32.0	34.5

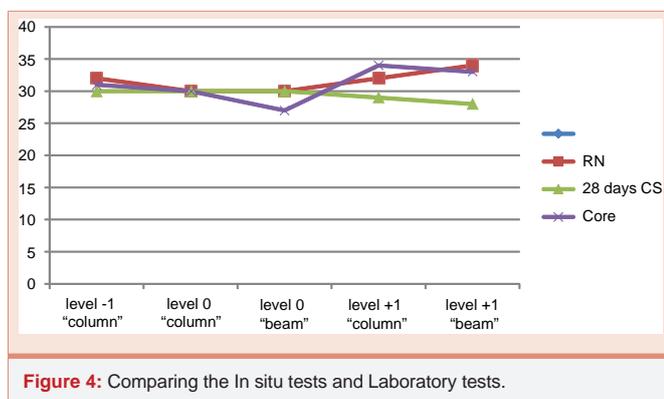


Figure 4: Comparing the In situ tests and Laboratory tests.

- The combined method seems more promising to evaluate the compressive strength of concrete in construction.
- It noted that correlations between destructive testing and non-destructive techniques in our study provide more meaningful results for the specimens cast and stored under the same conditions as the concrete structure than taken cores.
- The analysis for cores gives correlations that are not really satisfactory, this is explained by the fact that: the quality and means of implementation of concrete which are often inadequate, in terms of social housing programs often attributed to small companies without major resources.
- The sampling areas of taking cores are not really representative of concrete, since most often taken at random, because hardly feasible.
- The core drilling way and conditions can affect the integrity of the cores.

In general combined non-destructive methods can inform us about the quality of concrete and it will be better for a good quality-control monitoring of concrete; to establish correlations between mechanical tests on specimens cast and stored in same conditions as the concrete structure rather than using cores that are very difficult to achieve less representative and more expensive to obtain.

The practical use of this technique is gaining recognition on a large scale; it provides contracting authorities with accurate and objective information for monitoring quality-control of concrete construction.

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