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Case study

Analysis of the single and combined non-destructive test approaches for on-site concrete strength assessment: General statements based on a real case-study

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ABSTRACT

The evaluation of the compressive strength of concrete in existing structures by coring is expensive, technically difficult in certain cases, and even impossible in others. The use of non-destructive testing (NDT) is an interesting alternative method (i.e. affordable cost, portable, fast, etc.). However, the NDT estimation of strength requires a procedure of calibration of the model between NDT and compressive strength. The robustness of this calibration is a crucial point allowing better choice of the optimal number of cores. Studies which treat the calibration of proposed models are often based on laboratory experiments or synthetic data. The present study aims at identifying and optimizing the methodology of the calibration model on site. This paper is based on a broad campaign of auscultation using NDT (Rebound and Ultrasound) and coring on an existing construction with 205 triplets of data (strengths and NDT results). Statistical data analysis enables to quantify the role of: the number of cores (NC) used for the calibration, the use of only one or two-combined NDT techniques and the calibration method. The conclusions are focused on the improvement of the relevance and the effectiveness of NDT techniques in such operational situations.

1. Introduction

Existing buildings need the evaluation of their structural capacity in a variety of situations like the prediction of their seismic performance, restoration purposes, change of use or assessment after a partial failure or structural damages. To achieve this evaluation, the mechanical properties of concrete need to be evaluated for a more accurate estimation of the structural capacity [1]. The destructive estimation of the mechanical strength of the concrete structural by coring is regarded as a reference [2,3]. However, this method allows only a limited number of tests, due to the fact that it is expensive and technically difficult in certain cases, even impossible in others. Non-destructive testing (NDT) does not eliminate the need for

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coring, but it can reduce the total amount of cores needed to evaluate a large volume of concrete [4], and to optimally locate coring on the structure.

Non-destructive tests in conjunction with destructive tests DT (cores) offer an interesting alternative for concrete strength estimation in existing constructions [3,5–7]. An empirical relationship (or conversion model) must be identified between NDT results and strength measured on cores taken from the same locations. For the non-destructive assessment of strength, the European standard EN 13791 [8] requires at least 18 pairs of data (cores and NDT measurements). In the same way, ACI 228.1R standard [4] requires six to nine areas of measurement with two cores in each area. However the professional practice is usually based on much lower number of cores (sometimes down to 3 cores), while the reliability of this estimation is disputable and rarely discussed [9,10].

Reaching a reliable estimate would suppose that specific attention is paid to the quality control of the conversion model which depends on several factors: (**a**) the number of data (cores) used for identification of model parameters, (**b**) the measurements quality and the choice of NDT techniques, (**c**) the strength variation range of the whole data, (**d**) the relevance of the empirical model, (**e**) the existence of uncontrolled factors. Even if these factors are well known, the analysis of their effects remains generally qualitative or limited to laboratory or synthetic data [9–11].

While estimating the precision quality of the conversion model, its statistical properties during identification phase and prediction phase (when the model is used on new data) are usually confused. However, the model precision in prediction phase may be significantly lower then the model precision in the first phase. The difference between calibration and prediction errors being mainly due to the involved error of the model extrapolation (generalization). The real challenge here is to test the precision estimate capacity of the conversion model in the prediction phase.

The NDT techniques based on rebound hammer and ultrasonic pulse velocity tests are often combined in order to obtain a better assessment of concrete strength [2,10]. Many empirical multi-parametric models had been proposed in the literature [12–16]. Some works showed that best precision of the strength assessment is obtained by combining those NDT techniques [14], whilst other works concluded the opposite [17]. It seems that combined Rebound Hammer (RH) and Ultrasonic Pulse Velocity (UPV) method does not have any significant effectiveness in certain conditions which have not been really clarified. In particular, if one of the used techniques is significantly less accurate than the other one (adding poor quality results may only lead to disappointing outcomes) [7,11,18,19]. This is also the case when the dataset is heterogeneous, for instance carelessly mixing measurements on carbonated and uncarbonated concrete. In addition, few works dealt with the effect of the number of data on the combined method effectiveness [10,11].

The aim of this paper is to identify the weight of the various factors on site, in particular the effect of the number of cores used for the calibration procedure by using two statistical indicators: the root mean square error “RMSE” and the determination coefficient “r^{2}” to estimate the precision quality of the model. The analyses are implemented on the basis of in situ data obtained on a real building, with a comparison between these two indicators.

2. Presentation of the case-study

There are some real study cases in the literature for the estimation of strength with NDT measurements. However, they are usually limited to the establishment of correlation laws between NDT and destructive tests. Besides that, some recent works were based on laboratory or synthetic data to analyze the methodology and the quality of strength assessment [9–11]. The main purpose of this paper is to explore how to proceed and optimize the first identification step to improve the quality of concrete strength assessment on a real case-study of an existing structure.

This study is based on a large campaign of sounding and coring on structural elements in an existing building. The rebound and Ultrasonic pulse velocity tests were used in conjunction with destructive tests. The studied building is

Fig. 1. Study case of an existing building.