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Development of the Elastic Modulus of Concrete under Different Curing Conditions

Dalibor Kocab[a], Barbara Kucharczykova[a], Petr Misak[a], Petr Zitt[a], Monika Kralikova[a]*

[a]Brno University of Technology, Faculty of Civil Engineering, Veveří 331/95, 602 00, Brno, Czech Republic

Abstract

The modulus of elasticity is a property of concrete, which is known for its high variability of values. A high enough value of the modulus of elasticity is a critical requirement in complicated concrete structures and in order to attain it, a number of factors must be taken into account, as it is subject to many. Curing is one of the most important influences. It can be described as an effort to maintain the temperature of concrete within the correct limits, prevent loss of water and the shrinkage connected with this. This paper describes an experiment focused on the observation of the development of the dynamic and static modulus of elasticity in dependence on the method of curing. The experiment worked with air-entrained as well as non-air-entrained concrete of the C 30/37 strength class. The results show that the curing method strongly affects not only the development, but also the final values of the concrete modulus of elasticity.

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Keywords: Concrete; curing conditions; dynamic modulus of elasticity; static modulus of elasticity

1. Introduction

The design of slender or pre-stressed concrete structures, or their structural assessment, considers the modulus of elasticity as one of the most important input values, especially in strain calculations. This explains why scientists

* Monika Králíková. Tel.: +420-541-14-7829.
E-mail address: kralikova.m@fce.vutbr.cz

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and construction engineers have been showing increased interest in the modulus of elasticity in recent years [1,2,3]. The modulus of elasticity is a property of concrete, which is directly dependent on its formula. A specific compressive strength can thus correspond to a variety of elastic modulus values, which can be seen e.g. in Fig. 13 presented in [4]. Apart from concrete composition, the development and final value of the modulus of elasticity is also affected by curing, especially during the first few hours and days after casting. An important component of concrete curing is maintaining its correct temperature, since both too low and too high a temperature can have a negative impact on the concrete [5,6,7]. Another important factor is the moisture content of the concrete, especially during the first stage of its setting and hardening. If concrete is cast at high ambient temperatures, it is necessary to administer appropriate curing [8,9]. If the concrete surface is not protected from water evaporation, there can be a massive risk of microcracks forming not only on the surface but inside the concrete member as well. A rapid loss of water from the concrete, especially during the first few hours, has a critical influence on cement hydration. This can result in a great magnitude of shrinkage, which is usually the first cause of microcracks that form in the internal structure of the concrete [10,11]. If these microscopic defects should occur, the development of the concrete's mechanical properties will be irreversibly affected throughout the whole time of its aging. A worsening of mechanical properties combined with extensive occurrence of microcracks can then result in an overall reduction of the whole structure's durability. It was also found that, apart from the method and quality of curing, the curing time impacts the final values of the concrete's material properties as well, including the modulus of elasticity [12,13].

The modulus of elasticity can be determined by means of two basic groups of test methods. The first group comprises dynamic methods, see [14,15], and the second group includes static methods, see [3,16]. The initial tangent modulus of elasticity, which reaches the highest values, is a result of the dynamic test methods, while the secant modulus of elasticity, the values of which are lower, can be obtained by means of the static tests [17]. It is therefore necessary to distinguish between the static and the dynamic modulus of elasticity.

2. Experiment

The goal of the experiment described here was to determine the development of the dynamic as well as static modulus of elasticity in dependence on the method of curing. Two sets of concrete prism specimens with the nominal dimensions of 100 × 100 × 400 mm were made for the purposes of testing; one of the sets was stored under water and the other one in standard laboratory conditions. The influence of curing on the modulus of elasticity was determined on concretes belonging to the C 30/37 strength class, both air-entrained and non-air-entrained.

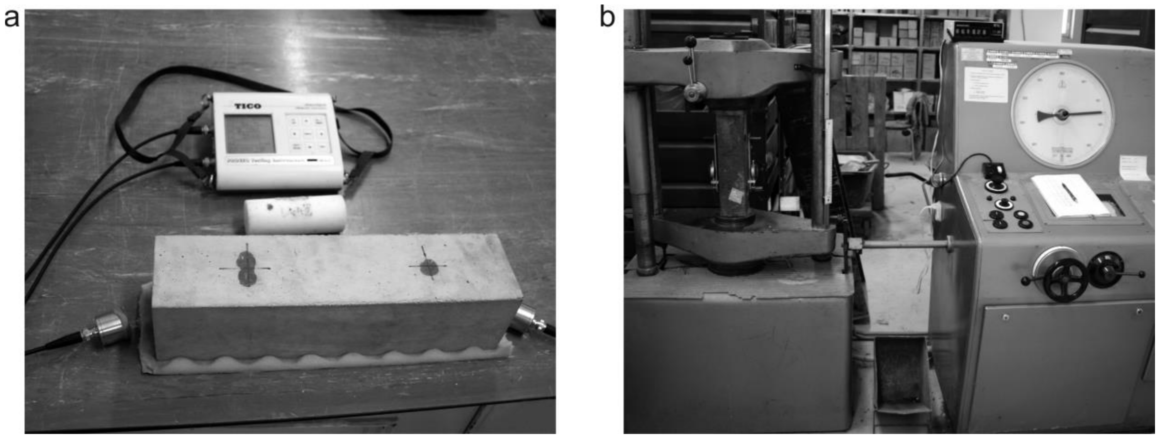

Fig. 1. (a) Determination of the dynamic modulus of elasticity E_{cu} using the ultrasonic pulse velocity test; (b) determination of the static modulus of elasticity E_c by cyclic loading in a press.