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TESTING METHODOLOGY FOR THE MECHANICAL PROPERTIES OF MINERAL MATRICES

BY

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Abstract. The properties of concrete for civil engineering structures are directly connected to the binder properties, therefore the current developments tend to increase the concrete strength, also having in mind the decrease of energy consumption and the use of industrial waste in binder production. In Europe and as well worldwide the binders testing will have to be standardized enabling to characterize and use binders in all producing countries. The paper presents an update critical review on the experimental methodology aiming to evaluate the mechanical properties of mineral matrix according to the existing standards.

Key words: mineral matrix; testing methodology; elastic modulus; tensile and compressive strength.

1. Introduction

The fabrication in 1824 of a binder, based on a mixture of limestone and clay, brought a significant improvement for the construction area. This binder, the main ingredient of concrete, is now widely used and known under the name of *Portland cement*.

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There are many types of concrete available, created by varying the proportions of the ingredients or substituting them to produce a product that would meet a certain strength, stiffness, density, chemical or thermal properties.

The generally known properties of concrete are: its high compressive strength, a low tensile strength corrected with reinforcement, constant elasticity corresponding to low stress levels but decreasing for higher values as the structure of the material is map-cracking.

Concrete is the most known and utilized building material representing more than two thirds of all construction materials both in our country and worldwide, therefore it is a necessity to understand, determine and to efficiently use its properties. Standardized tests have been developed to evaluate the essential design characteristics of concrete and to ensure that the envisaged properties of concrete correspond to a specific application.

2. Mineral Matrix Concept

The matrix or the basic mass can be identified with the continuous phase of a composite material. It is a component with structural and protection functions providing the composite material with essential mechanical, physical and technological properties.

The ideal structure of a composite with mineral matrix, in fresh state, can be represented by a network created from aggregates, coated in a thin layer of paste or binder and a quantity of water strictly necessary for its hydration. This structure should be totally compact. The adherence between the matrix and the reinforcing particles is created mechanically and chemically through the bonding of the matrix or binder to the particles surface. A structure like this, for example hardened concrete, can be considered as a disperse system, created from a matrix (hardened mortar) in which exists gravel particles.

The binder directly influences the properties and the durability of the composite material. Qualitatively its mineralogical composition determines the matrix hardening and strength against the environmental factors. Quantitatively an optimum volume ratio can be determined above which the effects are hostile.

The mechanical strengths as well as the elastic moduli of the binders are influenced by a large number of factors namely

a) the chemical-mineralogical composition and the ratio between the main components;

b) the grinding distinction of the components, because finnier particles ensure a better hydration while the coarse ones remain with unhydrated material inside (like a hardened cement paste);

c)mixing water quantity, some chemical admixtures, temperature, preservation terms, etc.

3. Testing Methodology for Mechanical Characteristics

3.1. Samples Preparation

To reduce the variable factors that negatively influence the strengths, all standardized methods settle the samples dimensions, the manufacture process, the curing conditions as well as temperature and humidity during testing, etc. (Ionescu & Ispas, 1997).

The experimental programs and the tests are appropriate and have concluding results if the samples, testing equipment and test procedure are set up according to the specific standard for this type of experiments.

The manufacturing equipments consist of an automatic mixer, with a stainless steel paddle, for the constituent's mixture and a shock machine to vibrate the composition (Fig. 1).

a *b*

Fig. 1 – The automatic mixer (*a*) and the shock machine (*b*) utilized to manufacture test samples.

The compressive and tension strength are determined on prismatic samples with dimensions of 40 × 40 × 160 mm (Fig. 2). These are poured in steel or hard rubber moulds with three compartments that must be coated with a thin layer of mineral oil or other nonreactive material before reusing (SR 196-1, 2006).

For the elasticity modulus and Poisson's ratio cylinders with a length that is double the diameter, where the diameter is at least three times the maximum aggregate size, are required (Amer. Soc. for Testing a. Mater, C469, 2010). An example of the samples is presented in Fig. 3.

In both types of sample the pouring is made in several layers and then vibrated. The last layer is required to be perfectly levelled to obtain a flat straight surface. After the shuttering is removed the samples must be kept in a humid environment.

For each test a minimum number of three concluding results is required and for each mixing formula tests for strengths must be made at time intervals of 24 h, 72 h, 7 days and 28 days and for elasticity modulus at 7, 28 and 90 days (Amer. Soc. for Testing a. Mater, C 31; C 192, 2010).

For all tests the temperature and humidity must be kept constant during experimental program.

Fig. 2 – Preparing the samples for tensile and compressive testing.

Fig. 3 – Preparing the samples to determine Young`s modulus and Poisson`s ratio.

3.1 Evaluation of Tensile and Compressive Strength

The test to determine the tensile strength is performed by subjecting to bending a prismatic sample through a constant loading applied at its midspan with a loading rate of 0.05 kN/s. The samples must be positioned so that the loading is parallel to their pouring side (Fig. 4).

The test ends at the failure of the sample and the tensile strength from bending is calculated with relation

$$R_t = \frac{1.5 F_t l}{b^3}, \tag{1}$$

where: R_t is the tensile strength from bending; b – dimension of the square cross-section; F_t – load applied at the midspan of the prism; l – distance between the supports.

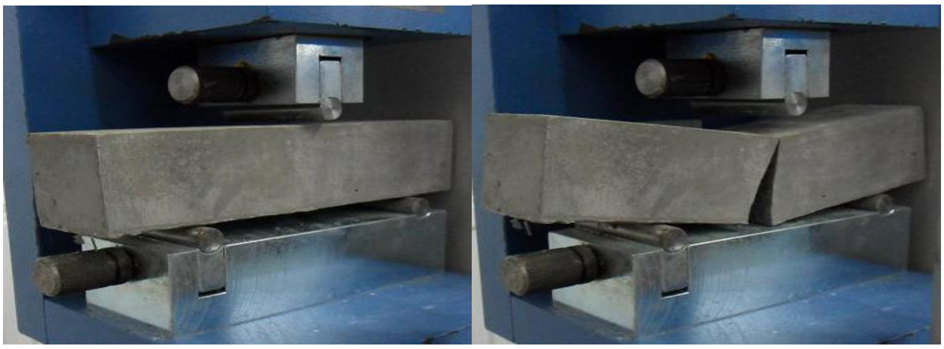

Fig. 4 – Flexural testing of prismatic sample.

For the compressive testing the half prisms obtained from the bending test are used. Every half prism is positioned similar like in the bending test and centred between the loading plates of the machine as shown in Fig. 5. The loading rate is imposed as 2.4 kN/s. Results in terms of ultimate load and stress are obtained for both tests.

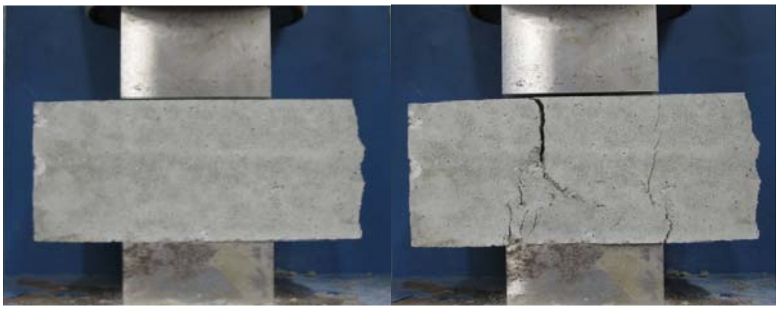

Fig. 5 – Compressive testing of prismatic sample.

The compressive strength can be calculated with relation

$$R_c = \frac{F_c}{1{,}600}, \tag{2}$$

where: R_c is the compresion strength, F_c – maximum load; 1,600 represents the loading pans area (40 × 40 mm) (SR 196-1, 2006).

3.3. Evaluation of Young's Modulus, Poisson's Ratio and Shear Modulus

These properties are determined by subjecting the cylindrical samples to compressive loading. The cylinders edges must be plane and perpendicular to their axes. The samples axis must be positioned between the pans and aligned with their centre of loading. For hydraulic equipment a 241 ± 34 kPa/s constant loading rate is applied.

Fig. 6 – Positioning of the longitudinal extensometer.

A first sample must be tested up to failure in order to record the ultimate load. On the other samples three loading–unloading cycles are applied from 2% up to 40% of the previously determined ultimate compressive loading. The results are recorded using an extensometer for the longitudinal deformation (Fig. 6) and a circumferential extensometer for transversal deformation (Fig. 7).

Fig. 7 – Tested cylinder with circumferential extensometer.

The following formula is used to determine the modulus of elasticity:

$$E = \frac{\varepsilon_2 - \varepsilon_1}{\sigma_2 - \sigma_1}, \tag{3}$$

where: E is the chord modulus of elasticity; σ_2 – stress corresponding to 40% of ultimate load; σ_1 – stress corresponding to 2% of ultimate load; ε_2 – longitudinal strain produced by σ_2; ε_1 – longitudinal strain produced by σ_1.

To determine Poisson's ratio the following formula is used:

$$\nu = \frac{\varepsilon_{t2} - \varepsilon_{t1}}{\sigma_2 - \sigma_1}, \tag{4}$$

where: ν is the Poisson's ratio; ε_{t2} – transverse strain at midheight of the specimen produced by σ_2; ε_{t1} – transverse strain at midheight of the specimen produced by σ_1 (Amer. Soc. for Testing a. Mater, C469, 2010).

Using the experimental values obtained above the shear modulus of elasticity can be obtained from

$$G = \frac{E}{2(1-\nu)}, \tag{5}$$

where: G is the shear modulus of elasticity; E – modulus of elasticity.

3.4. Testing Report

The testing report for every test includes for each sample the identification, the dimensions, the surface state during testing, details of the surface adjustment, date and time of pouring and testing, ultimate load, compression strength, type of failure and any deviation from the standard procedure. Other values that can be included for each sample can be: mass, apparent density, state before testing and curing conditions. Conclusions can be obtained also from the aspect of the samples failure. Favourable failure is presented in Fig. 8 (SR EN 12390, 2005).

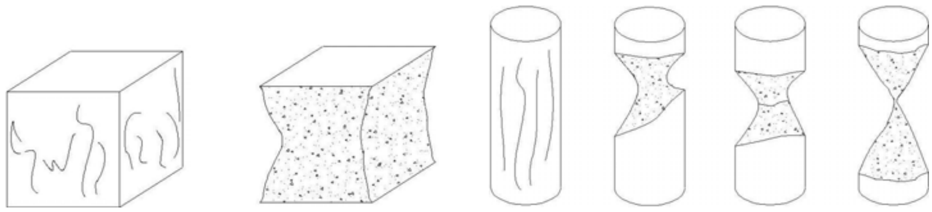

Fig. 8 – Sample failure due to compressive loading.

All results are tabulated and discussed according to all these parameters.

4. Conclusions

In the design of structures the fundamental demands safety are safety and stiffness. These requirements need a good knowledge the materials behavior, their elastic constants and ultimate resistances under various loadings which imply a first experimental test on small scale samples.

To determine the tensile strength from bending of mineral matrices composites prismatic samples of 40 × 40 × 160 mm must be cast, while to determine the elastic properties are required cylinders. Their testing is made at time intervals of 24 h, 72 h, 7 days, 28 days and 90 days, respectively, from the moment they were poured. The final values can be easily calculated using formulas provided in this paper.

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METODOLOGIA EXPERIMENTALĂ PENTRU DETERMINAREA PROPRIETĂȚILOR MECANICE PENTRU MATRICILE MINERALE

(Rezumat)

Proprietățile betonului pentru structurile civile sunt direct legate de cele ale liantului, de aceea dezvoltările curente tind să-i crească rezistența, totodată ținând cont de reducerea consumului de energie şi folosirea deşeurilor industriale în producția lianților. În Europa şi de asemenea în lumea întreagă testarea lianților urmează a fi standardizată permițând caracterizarea şi folosirea lor în toate țările producătoare. Se prezintă o privire de ansamblu actualizată a metodologiei experimentale de evaluare a proprietăților mecanice ale matricilor minerale conform standardelor în vigoare.