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MECHANICAL PROPERTIES OF MINERAL MATRICES WITH ECOLOGICAL COMPONENTS
TENSION DETERMINATION FROM BENDING AND COMPRESSIVE STRENGTH

BY

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Abstract. The interest regarding the ecologically obtained materials and the advanced technology lead to the research of new types of additives or ingredients that can successfully replace Portland cements when creating concretes or mortars. With the view that concrete and micro-concrete some remain competitive compared to other building materials their main properties require improvements. The present study consists in determining the mechanical properties of some mixtures that have in their consistency an ecological binder, manufactured from recycled industrial waste called “Kerysten”. This gypsum based material was used mixed with Portland cement, sand, polypropylene fibers and water, to obtain a mineral matrix with superior workability, tensile and compression strengths higher than a regular concrete. In this paper the entire experimental procedure is described and the tests results play an important role on the behavior of this type of material.

Key words: microconcrete; mineral matrix; ecological concrete; ecological binder.

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1. Introduction

The objectives of the future research are to increase the concrete strength, reduce the energy use and reincorporate in binders higher quantities of industrial wastes. For the purpose of saving Portland cement clinker, in the production of which a high quantity of work and energy are used, and for revaluating some industrial subproducts and natural ones, starting from the begining of the XXth century, many attempts have been made to study the possibility of adding several active or inert admixtures during grinding, with the purpose of replacing in several proportions the Portland clinker. The concrete properties are directly connected to the properties of the binders.

In order to remain competitive concrete and micro-concrete compared with other building materials, progress of the main properties is required, so along with the growth of compression strength it must have an improvement of the cracking and tensile strength, an accelerated hardening in the first hours and days from casting, economy, etc. (Budescu *et al*., 2010).

To complete the knowledge refering to the behaviour of mineral matrix composites, fiber reinforced or not, a series of experimental tests according to the testing methodology have been made. Firstly the utilized materials and the theoretical aspects of the testing procedure are presented followed by the actual bending tests on prisms and compression tests on half prisms to determine the mechanical strengths of an ecological material. Tests on cylinders have been performed to determine the elasticity modulus according to the present standards.

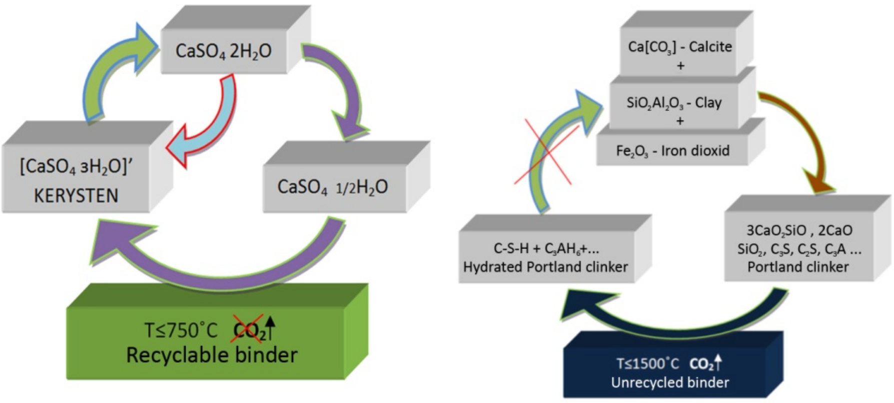
2. Experimental Program

The experiments have been performed based on the mechanical testing standards and other specialized studies. The experimental testing was conducted in the Mechanical Department of the Faculty of Civil Engineering and Building Services that has several appliances for testing of different weights. All results have been recorded using the testing machine computer. Images during the tests captured in detail the failure modes. The test results represent important data regarding the mechanical properties and the behaviour of this material.

2.1. Utilized Materials

The new generation of building materials comprises more and more products that protect the environment and help repel global warming.

The basic material used in this research study is obtained exclusively from industrial waste, mostly unretrievable like phosphogypsum, lactogypsum, cytrogypsum, etc., named according to the French patent, “Kerysten”. This ecological binder is a β-type anhydrous calcium sulphate – anhydride III. The fabrication process consists in burning these wastes at low temperatures, under 750˚C, compared to 1,500˚C required for Portland cement and does not involve CO_2 emissions, only water vapours (Fig. 1). Another benefit is that it is entirely recyclable after expiration date of storing, with no residues (Ţăranu *et al.*, 2010).



a *b*

Fig. 1 – Comparison among obtaining: *a* – Kerysten; *b* – Portland cement.

This material based on gypsum was mixed with Portland cement, sand and water obtaining a final material different from both components but with a superior workability.

Fig. 2 – Utilised materials in obtaining the mineral matrix.

The cement used is a CEM I 42,5R manufactured according to SR EN 197-1 A1:2007. *CEM I 42.5R is a Portland cement with no additions and high initial strength. The main constituents are the Portland clinker* (95…100%) and some minor components (0…5%). This type of cement is intended for monolithic structures and elements made of simple concrete or reinforced concrete, that can be poured also during cold weather (Ţăranu *et al.*, 2010). The aggregate used was a silicatic sand with a volume fraction less than 0.3 mm.

The added water was drinkable, obtained from the water supply network of the city. The constituents are shown in Fig. 2.

Fig. 3 – Short polypropylene fibers used for mineral matrix reinforcement.

For reinforcement were used short polypropylene fibers (Fig. 3). This way the hybrid composite material resulted by associating the mineral matrix with polypropylene fibers has the capacity to form structural elements and buildings with a complex shape.

Table 1
Polypropylene Fiber Properties

Physical characteristic	Value
Density, [g/cm^3]	0.915
Tensile strength, [N/mm^2 (MPa)]	33
Young`s modulus, [N/mm^2 (MPa)]	1,450
Linear thermal expansion coefficient, [m/m.°C]	16×10^{-5}
VICAT softening point, [°C]	103
Thermal conductivity, [W/m.°C]	0.22

2.2. Description of the Test Equipment

In order to be exact the testing and the results to have the same reference parameters the testing equipment, the mixture, the mixing proportions and the testing procedure, respectively, must be according to the specific standard (SR EN 196-1/1995).

The press used to determine the compressive and tensile strength was an ELE semiautomatic model with a maximum loading capacity of 250 kN. The model used for these experiments is presented in Fig. 4.

To obtain the tensile strength resulted from bending the prism was placed in the bending device with its lateral side on the supports and the longitudinal axis perpendicular to it. The load was applied vertically, through the loading roll, on the opposite side of the prism and was constantly increased with 50 N/s up to failure.

The compression strength was obtained by testing the half prisms resulted from bending. Each half prism was centered with respect to the turntables of the device with a ±0.5 mm precision. A 2,400 N/s force was applied without interruption until failure (Ţăranu *et al*., 2010).

Fig. 4 – Compression and bending test equipment: *a* – bending; *b* – compression; *c* – testing equipment computer.

2.3. Sample Preparation

To determine the mechanical properties was necessary first to decide upon a number of mixtures with the view to observe the behavior of the mineral matrix with different percentages of binder, sand and water.

In Table 2 are presented the mixtures with their percentages of each component. Besides obtaining the mechanical properties remarks have been made on the workability and the setting time. All these aspects are essential in formulating conclusions connected to the material behavior, especially when numerical modeling is involved.

Table 2
Mineral Matrix Mixtures Created in the Experimental Program

Components	Binder		Sand 0…0.3 mm %	Water/Binder %	Polypropylene fibers, [%]
	Cement, [%]	Kerysten, [%]			
Mixture *1*	50	–	50	40	–
Mixture *2*	35	15	50	40	–
Mixture *3*	35	15	50	40	1
Mixture *4*	25	25	50	40	–

To determine the mechanical characteristics for each mixture a number of 12 prismatic samples, of 160 × 40 × 40 mm, were cast. The components percentages was determined with respect to their mass. The water percentage was calculated from the binders total mass (cement and Kerysten). After preparing the mixture in the stirrer (Fig. 5) one layer of material was poured in the mold and leveled with a spatula. This first layer was subjected to shocks for a better compaction. For the second layer the same procedure was repeated. The mold was taken from the shock apparatus and leveled with slow transversal moves obtaining a soft and straight sample surface. The molds were labeled for an easier recognition of the samples (date and hour of casting, mixture type). The samples were demoulded after 24 h and the mixture *1* samples were kept in a water recipient until the 7 days interval.

Fig. 5 – Mineral matrix mixture for sample preparation.

The sample were tested at four intervals of time namely 24 h, 3 days, 7 days and 28 days.

2.4. Testing Development

For the bending and compression tests an ELE International apparatus was used. At each time interval three prisms out of each mixture were tested. The test to determine the tensile strength from bending required a loading rate of 0.05 kN/s maintained constant. The prisms were positioned in the device so that the loading was applied perpendicularly to the pouring direction of the samples (Fig. 6).

Fig. 6 – Sample tested at bending.

Compression testing was made on the half prisms that resulted from bending tests. Every half prism was positioned as for bending, centered between the turntables of the device. The loading pace rate was of 2.4 kN/s, according to the standard (SR EN 196-1/2006).

Fig. 7 – Sample tested at compression.

The results were automatically displayed on the screen of the testing equipment computer (Fig. 7).

2.5. Testing Results

After gathering all the data, a table with medium values for each time interval of each mixture was written (Table 3).

For a better visualization of the results in terms of strength on each time interval two comparative graphs are presented in Figs. 8 and 9.

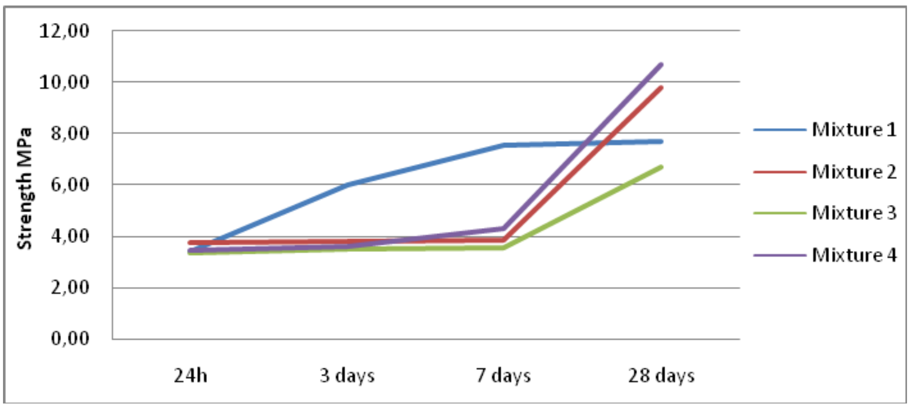


Fig. 8 – Tension from bending strength values obtained for the four mixtures.

Table 3

Average Values for Tensile and Compressive Strengths Obtained on Prismatic Samples

Mixtures	Mixture *1*		Mixture *2*		Mixture *3*		Mixture *4*	
Strengths	R_t MPa	R_c MPa	R_t MPa	R_c MPa	R_t MPa	R_c MPa	R_t MPa	R_c MPa
24 h	3.41	20.96	3.74	15.72	3.36	15.03	3.48	14.03
3 days	5.97	37.26	3.78	19.65	3.50	25.24	3.61	20.55
7 days	7.52	50.44	3.87	32.95	3.58	32.60	4.31	31.29
28 days	7.68	76.18	9.78	42.17	6.71	36.64	10.68	40.53

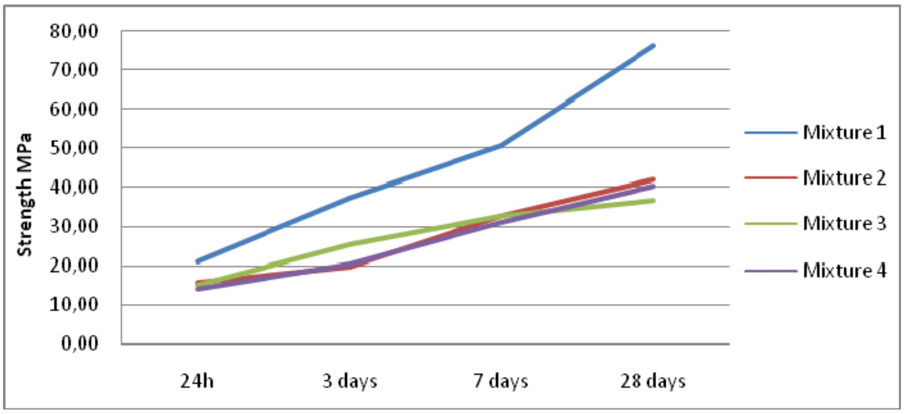


Fig. 9 – Compressive strength values obtained for the four mixtures.

3. Conclusions

After interpreting the results of this experimental program the following conclusions can be drawn:

1. Considering the workability parameter the mixtures that does not contain Kerysten (mixture *1*) was very viscous making the pouring with the pump impossible.

2. As it can be noticed in Fig. 8 and Table 3 the three mixture that contain Kerysten have values for the tensile strength almost equal in the first 7 days, after which the values grow up to three times for the 28 days period.

3. The tensile strengths obtained on the mixtures *2*, *3* and *4* are slightly superior to those of a class C50/60 concrete (R_t = 2.78 MPa).

4. For mixture *3*, that has in its composition short polypropylene fibers, the medium results obtained at 28 days are smaller than for the other mixtures. This fact is due to using a high percentage of fibers that lead to the breaking of the binder particles connection.

5. In the graph presented in Fig. 9 can be noticed that mixture *1* (standard mixture) has values for compressive strength superior to the mixtures that contain Kerysten.

6. The compressive strength values of the mixtures *2*, *3* and *4*, obtained at 24 h, are almost equal with the ones of a class C16/20 concrete (obtained at 28 days; R_t =1.43 MPa), and the ones obtained at 28 days are almost equal with the ones of a class C40/50 concrete (R_t = 2.51 MPa).

7. Replacing cement with Kerysten in certain percentages leads to a mineral matrix with tensile and compressive strengths superior to those of a standard concrete.

8. These mineral matrices can be easily used in creating resistance elements in a structure.

REFERENCES

Budescu M., Ţăranu N., Hohan R., Grădinariu I.D., *A Novel Hybrid System for Floor Beams*. The 3rd Internat. Adv. Mater. a. Syst. (ICAMS 2010), Bucharest, 2010, 483-488.

Ţăranu G., Budescu M., Lungu I., Ţăranu N., Pleşu G., Susan M., *Materiale compozite cu fibre sintetice, o soluţie eficientă pentru lucrările de construcţii*. Asoc. Ing. Constr. Proiect. de Struct. (AICPS), Edit. MorLink, Bucureşti, 2010.

Ţăranu G., Budescu M., Grădinariu I.D., *Studiu experimental privind influenţa modulatorilor bio-fito-dinamici de tip A.D. asupra materialelor de construcţii*, Bul. Inform. al Centr. de St. şi Cerc. Biosinerg. Dinca Ancu, Edit. TipoAlex, Bucureşti, 2010.

* * * www.holcim.ro

* * * *Metode de încercare ale cimenturilor*. Partea **1**: *Determinarea rezistenţelor mecanice*. SR EN 196-1, 2006.

PROPRIETĂŢI MECANICE ALE MATRICELOR MINERALE CU COMPONENŢI ECOLOGICI

Determinarea rezistenţelor la încovoiere şi la compresiune

(Rezumat)

Interesul faţă de materialele obţinute ecologic dar şi tehnologia avansată au condus la cercetarea unor noi tipuri de aditivi sau substanţe care pot înlocui cu succes cimenturile Portland, parţial sau integral, în obţinerea betoanelor sau a mortarelor. Pentru ca betoanele şi microbetoanele să ramână competitive în comparaţie cu celelalte materiale, sunt necesare progrese, perfecţionări şi îmbunătăţiri sub aspectul principalelor proprietăţi. Acest studiu constă în determinarea proprietăţilor mecanice a unor amestecuri care au în componenţa lor un liant ecologic, fabricat din deşeuri, industrial denumit „Kerysten”. Acest material, pe bază de ipsos, a fost folosit în combinație cu ciment Portland, nisip, fibre de polipropilenă şi apă, rezultând o matrice minerală cu proprietăți de lucrabilitate superioare, rezistențe la întindere şi la compresiune mult mai mari față de un beton obişnuit. În cadrul lucrării este descris întreg procesul de realizare a experimentului. Concluziile încercărilor formulează date importante cu privire la modul de comportare a acestui tip material.