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COMPARATIVE STUDY OF THE DETERMINATION OF THE ELASTIC PROPERTIES IN RUBBERIZED MORTAR BY MEANS OF STATIC AND DYNAMIC TESTS

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Abstract

Cement mortar is a material with a high rigidity. It is possible to add rubber to the cement mortar in order to reduce the rigidity. In this paper we present a study in which the Young's Modulus is determined using two different techniques. On one hand, a static test with simply supported beams of rubberized mortar is used to calculate the deflection of the beam when it is subjected to an applied load. On the other hand, a dynamic test with the same beams is carried out in order to calculate the resonance frequencies when an impact force is applied using an impact hammer. With both methods, the Young's Modulus for each material is determined and the results are compared.

1.- Introduction

A great number of structures are constructed with concrete, which is a material with a high rigidity. Adding rubber to the cement mortar is a technique employed to reduce the rigidity, that is related with the modulus of elasticity.

This rubber comes from the tires out of use; so, this is a way to recycle. Moreover, these new materials can be used in applications where it is important to control the vibrations and the acoustic behaviour of the material.

Therefore, these materials provide new possibilities to use recycled materials. Reviewing the technical literature about these type of materials there are some previous studies that try to determine the influence of waste tire rubber in the modulus of elasticity in concrete materials [Fedroff, 1996, pp. 66-72; Topcu, 1995, pp. 304-310; Toutanji, 1996, pp. 135-139; Zheng, 2008, pp. 939-947; Zheng and Yuan, 2006]. We think that a more detailed study is needed to better understand the mechanical behaviour of the new materials. Keeping this idea in mind, static and dynamic methods are applied to compare the Young's Modulus, that allows us to determine this mechanical behaviour.

2.- Materials

2.1.- Cement mortar

The cement mortar used in this study is standard mortar with a ratio water/cement = 0,5 (W/C), Portland cement CEM 52,5R, and normalized sand CEN-Normsand EN 196-1.

2.2.- Ground rubber

The ground rubber comes from *End of Life Tires* (ELTs) and the grain-size used is in the range from 200 µm to 2000 µm, identified by the supplier INSATURBO S.A. That range means that both fine ground rubber and coarse are used.

2.3.- Samples

By mixing cement mortar with rubber in different proportions, some rubberized mortar beams have been made in a 600x40x40 mm mould. The test has been done 28 days after demoulding, and that was done 24 hours after moulding. Figure 1 shows the rubberized cement mortar beams.

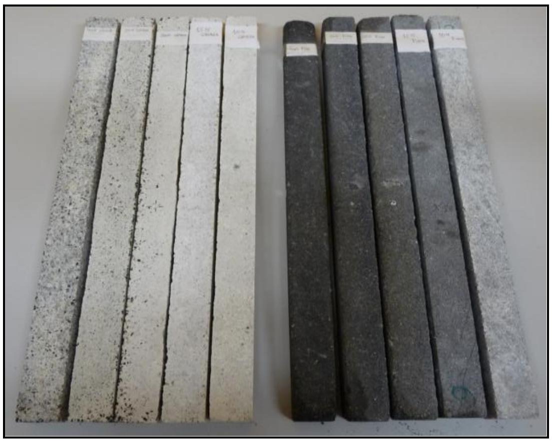

Figure 1. Rubberized cement mortar beams with different proportions of rubber.

3.- Experimental study

In this paper we present a study in which the Young's Modulus is determined using two different techniques. The first method is a static test with simply supported beams of rubberized cement mortar in order to calculate the deflection of the beam when it is subjected to an applied load.

The second technique is a dynamic test with the same beams in order to calculate the resonance frequencies by means of an impact force using an impact hammer.

3.1.- Static modulus of elasticity

Simply supported beams subjected to bending have been tested to calculate the static modulus of elasticity. Figure 2 shows the experimental set for the determination of the deflection in the beams.

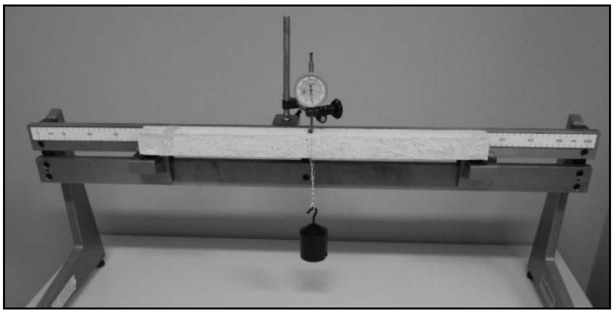

Figure 2. Determination of the static modulus of elasticity.

Applying loads in the middle of the beam, the deflection is related with the rigidity of the material. By means of the equation that provides the deflection in a simply supported beam with an applied force in the middle of the beam, the Young's Modulus is calculated:

$$\delta = \frac{P \cdot L^3}{48 \cdot E \cdot I}$$

P is the applied force; L is the length of the beam; E is the Young's Modulus; I is the moment of inertia of the cross section.

3.2.- Dynamic modulus of elasticity

In order to determine the modulus of elasticity in these materials, a dynamic method has been used since the rigidity of the material depends on the natural frequencies. Considering the free-free beam, the Young's modulus is determined using the following equation [Ala, 2004; Hernández-Olivaresa, 2002, pp. 1587-1596]:

$$E = \left(\frac{4 \cdot \pi^2 \cdot f_n^2}{4{,}73^4} \right) \cdot \left(\frac{\rho \cdot A \cdot L^4}{I} \right)$$

Where E is the dynamic modulus of elasticity; f_n is the frequency of the first mode; I is the moment of inertia; ρ is the density of the material; L is the length of the beam.

Figure 3 shows the experimental method used to determine the natural frequencies of the beams.

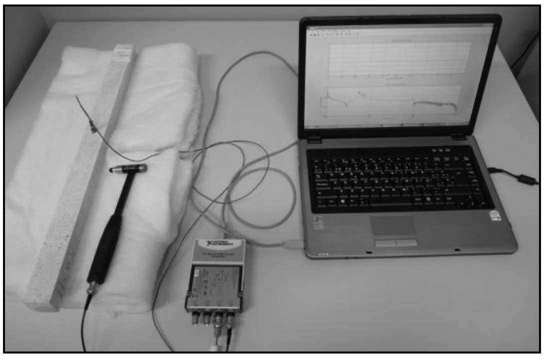

Figure 3. Experimental set for the dynamic test.

4.- Results

Table 1 compares the obtained results with the static and dynamic methods.

TABLE 1. RESULTS OF THE MODULUS OF ELASTICITY

MATERIALS	Static modulus of elasticity (MPa)	Dynamic modulus of elasticity (MPa)
Cement mortar	30 326	36 472
C. mortar with 10% coarse	16 629	18 216
C. mortar with 15% coarse	14 704	16 497
C. mortar with 20% coarse	10 320	13 382
C. mortar with 30% coarse	6 876	8 907
C. mortar with 40% coarse	2 724	4 033
C. mortar with 10% fine grain	13 560	13 396
C. mortar with 15% fine grain	8 688	8 403
C. mortar with 20% fine grain	2 368	2 589
C. mortar with 30% fine grain	1 163	1 187
C. mortar with 40% fine grain	675	429

Figure 4 shows a graph with the obtained results.

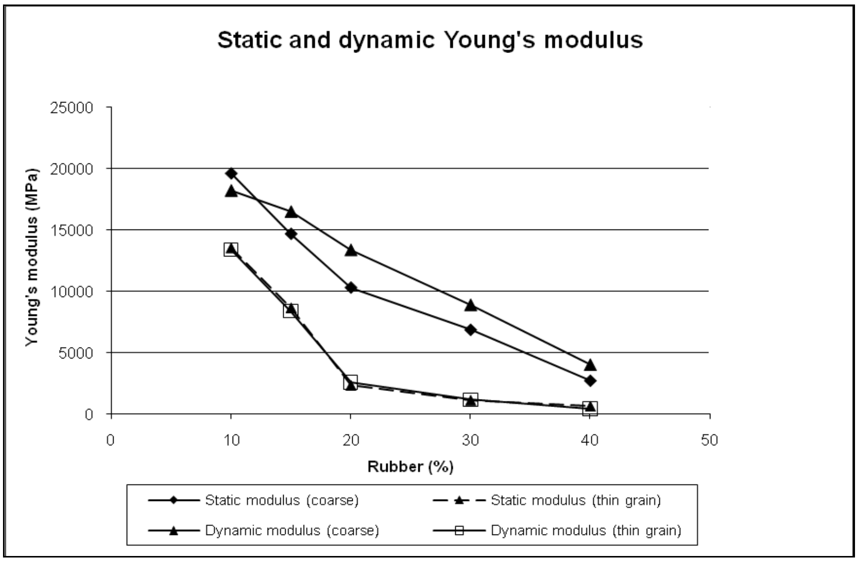

Figure 4. Static and Dynamic Young's Modulus.

5.- Conclusions

First of all, it is observed that the results are similar with both methods. As it would be predicted, the rigidity of the material decreases when more rubber is added.

The Young's Modulus obtained with fine grain GTR is lower than the coarse GTR. We must assume that the amount of rubber particles is greater with fine GTR that with coarse for the same volume. The mixtures of different percentages were done introducing a mass percentage of GTR. In a first approximation and considering isostrain conditions, the modulus of elasticity would follow the rule of mixtures, so a higher percentage of the GTR area would represent a decrease of the Young's Modulus, since the rigidity of the rubber is lesser than the one of the cement mortar.

It is interesting to note the coincidence in the results when comparing with two methods. These results are much more accurate for the mortar mixed with fine grain rubber. On the other hand, dynamic methods usually offer slightly higher values than those obtained with static methods, which agrees with the scientific literature. In this sense, it is worth to say that in the static method, there are much more uncontrolled factors that can cause some errors than in the dynamic test.

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