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MASA-ROCA: A NEW MEXICAN COMPOSITE MATERIAL THAT COULD CHANGE THE CONSTRUCTION INDUSTRY OF THE THIRD MILLENNIUM

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ABSTRACT

This article describes the preparation and characteristics of a new cement-based material known as Masa-Roca, a composite material constituted by Portland cement, fine granular aggregate, synthetic fibers and tyxotropic additives with great workability without slump and with better mechanical properties as compared to those of a traditional concrete. Also, the corresponding physical and mechanical properties, which show a similar behavior as a microconcrete with additional advantages such as: high early strength, minimum curing time and great ductility, are discussed. Additionally, the parameters of the ductile response on the stress-deformation curve in compression, such as the elastic moduli (elasticity, Poisson and resilience), toughness, elastic and plastic deformation energy are evaluated in this paper. Finally, some of the present and potential applications of Masa-Roca are presented.

KEYWORDS

Composite material; fibre-reinforced composite; early high strength; microconcrete; low curing time; low permeability; toughness; deformation energy.

INTRODUCTION

Recently, a novel composite called MASA ROCA (Fernández, 1993) and formed by Portland cement, fine aggregates, synthetic fiber and tyxotropic additives has been reported. In this new microconcrete, all the components are first dry mixed and then hydrated with water until a homogeneous mixture is formed. In fresh condition, it has great workability with non slump (Fig. 1). In hardened state, it shows improved mechanical properties when compared to a traditional concrete. According to the characterization performed so far by the author and several others people, this material has shown physical and mechanical properties similar to a standard microconcrete with additional advantages such as: early high strength, low curing time, more ductility before fracture and low permeability. The main disadvantage, however, lies on its modulus of elasticity which is relatively low (similar to that of wood). In the present contribution, a follow up of previous reports on the detailed mechanical characterization of Masa-Roca is presented, as well as a discussion on the current and potential applications of this composite.

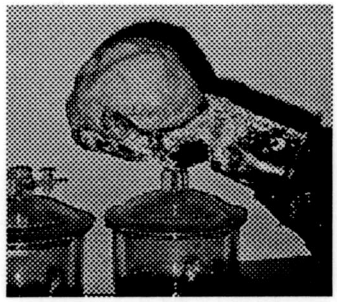

Fig. 1. Fresh condition of Masa-Roca

EXPERIMENTAL

The preparation procedure requires 200 milliliters of water for each kilogram of dry material. Three days is the minimum curing time in saturated condition. Due to its similarity with concrete, the Mexican official standards of construction (NOM-C-83, 109, 128, 159, 163, 303) were used for the testing. The mechanical tests carried out were compression, tension, bending and steel-reinforced adherence, using eight laboratory specimens for each test. Strength was measured at 3, 7 and 28 days of age. In Table 1, the physical and mechanical properties of Masa-Roca compared with concrete are presented.

RESULTS AND DISCUSSION

Elastic behavior

In general, the modulus of elasticity was lower than that of concrete because it presented more deformation in the elastic zone of a stress-strain curve, as can be appreciated in Fig. 2. The great ductility of the material, as observed in the curves, allows it to attain an enormous capacity for absorbing both elastic and plastic energies as compared to standard concrete, as can be seen in the data of Table 2. In none of the specimens prepared and tested, the material presented fragile collapse, which is the typical cause of failure of the non-reinforced cementitious materials. Moreover, the specimen continued resisting load after its first crack.

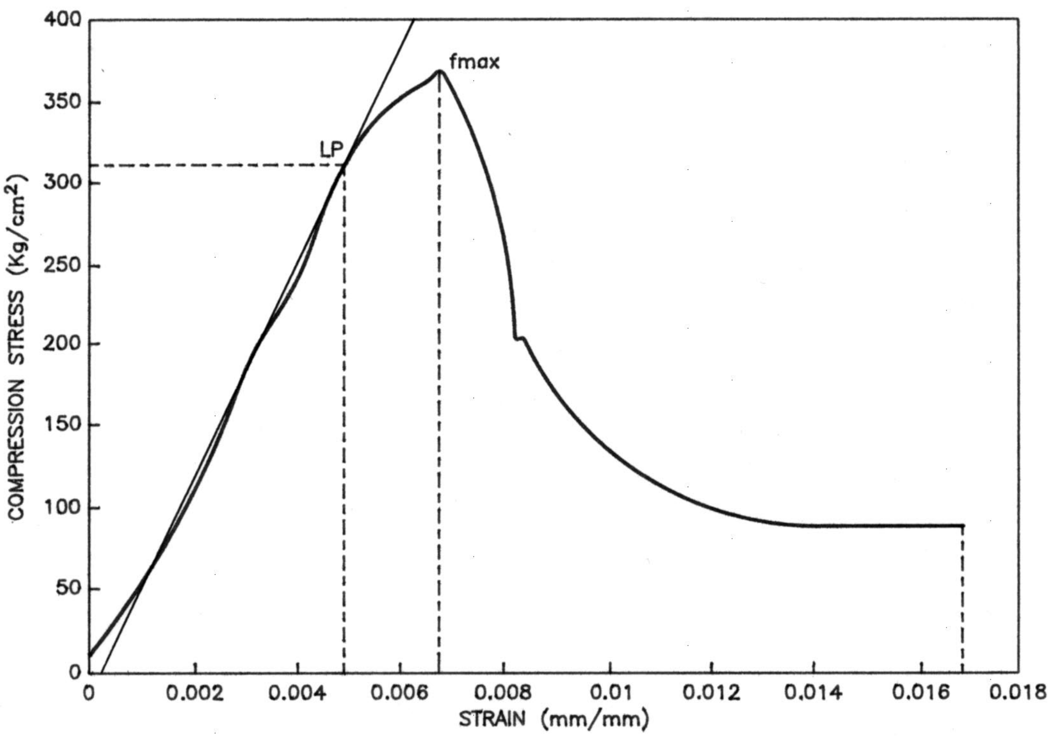

Fig. 2. Masa-Roca stress-strain curve: 28-days aging, 3-days curing time, LP=proport. limit, f_{max}=max. stress.

Table 1. Physical and mechanical properties of Masa-Roca compared with concrete.

PROPERTY	MASA ROCA **(Hernández, 1994)**	CONCRETE **(Mendoza, 1985)**
Specific weight (kg/m^3)	2 050	2 062
Slump (cm)	CERO	5.0
Use of casting	NO (OPTIONAL)	YES
Water/cementitious ratio	0.47	0.47
Cement amount (kg/m^3)	580	425
Adherence in (kg/cm^2) **(Neville, Tomo I, 1977)** * = corrugated bar + = smooth bar	(3 days) 27.9 * 14.6 + (7 days) 49.6 * 28.7 + (30 days) 58.7 * 32.2 +	 (7 days) 46.0 * 26.0 + (28 days) 64.0 * 35.0 +
Compression strength (kg/cm^2)	(3 days) 190.1 (7 days) 226.3 (28 days) 331.0	 (7 days) 211 (28 days) 306
Flexion strength (Fracture modulus) (kg/cm^2)	(3 days) 38.5 (7 days) 41.4 (28 days) 47.3	 (7 days) 29 (28 days) 38
Tensile strength (kg/cm^2)	(3 days) 21.1 (7 days) 22.7 (28 days) 29.5	 (7 days) 21.0 (28 days) 27.5
Elasticity modulus (kg/cm^2)	(3 days) 26 870 (7 days) 26 586 (28 days) 35 376	 (7 days) 131000 (28 days) 151000
Elongation at Maximum stress, in compression test	(3 days) 0.00681 (7 days) 0.00737 (28 days) 0.00834	 (7 days) 0.0029 (28 days) 0.0030

Table 2 Comparative elastic properties at 28-days aging.

PROPERTY	MASA ROCA (1)	CONCRETE (2)	M.R./CONCRETE
Elasticity modulus, (k/cm²)	35376.0	151000.0	0.23
Poisson ratio	0.29	0.31	0.94
Total elastic energy, (k-cm)	304.0	81.5	3.7
Resilience modulus, (k-cm/cm³)	1.12	0.30	3.7
Toughness, (k-cm/cm³)	2.86	0.53	5.4
Deformation energy in pure flexion, (k-cm)	142.0	21.5	6.6

Notes: (1) The average values are: f'c=331 k/cm², Proportional limit= 281 k/cm², ε_{max} = 0.00834, curing time=3 days.
(2) The values for a typical Mexican concrete made are: f'c=354 k/cm², Proport. limit=301 k/cm², ε_{max} = 0.003, Curing time=28 days.

Also, the material was tested at temperatures of 310, 540 and 750 degrees Celsius to evaluate the residual strength in compression and modulus of elasticity. The results in Figs. 3 and 4 showed that Masa-Roca falls within the range allowed for the standard hydraulic concrete (Freskakis, 1980).

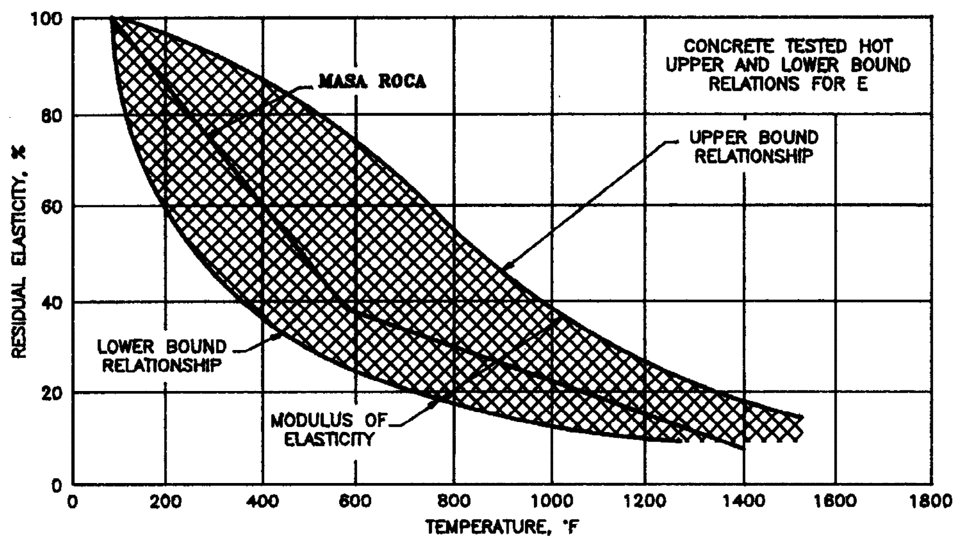

Fig. 3 Residual elasticity of Masa-Roca compared with concrete.

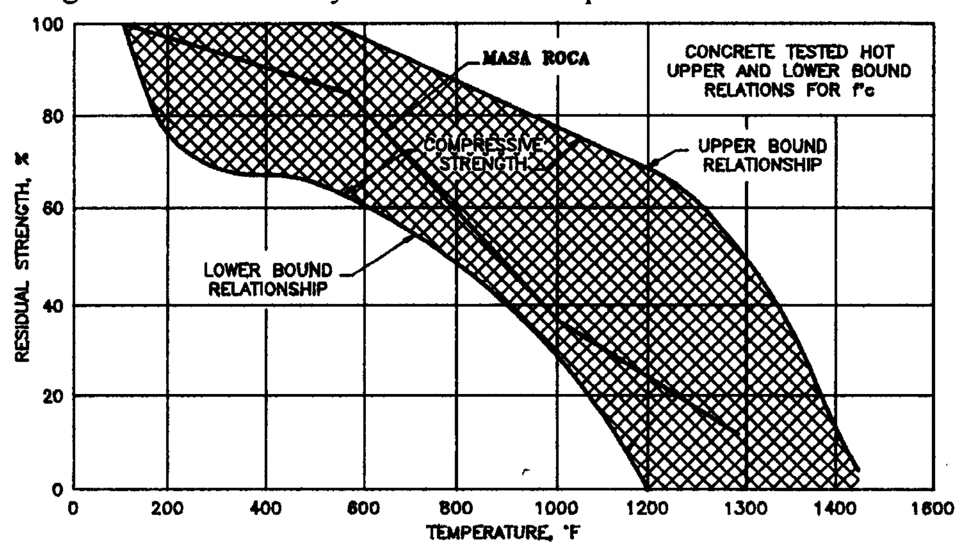

Fig. 4 Residual compression strength of Masa-Roca compared with concrete.

Petrographical and mineralogical analysis

Specimens were analyzed by petrographycal and mineralogical methods after the compression testing. The results show that the material is isotropic and has an homogeneous matrix without cracks or bubbles. Also, the analysis showed the circular mold of the fiber and the angular and well defined grains (Fig. 5).

Fig. 5. Petrographic photo of Masa-Roca matrix.

Permeability test

Permeability was tested in six specimens of Masa-Roca. A device designed at the Instituto de Investigaciones Eléctricas was employed with the following characteristics: Percolating Fluid: distilled water in one-dimensional flow along the axis of the probe; Technique employed: steady state flow; Pressure gradient: 10 kg/cm^2; Testing period: form 3 to 5 hours; Probe length and diameter: 3.98 cm and 3.79 cm, respectively. Table 3 contains the measured permeability (k) and the corresponding Hydraulic Conductivity (CH) equivalence.

Table 3. Measured values of **Permeability** (k) and **Hydraulic conductivity** (CH)

SPECIMEN	**k** (darcys)	**CH** (1) (m/s)	OBSERVATIONS
MR-C1	0.39×10^{-6}	3.77×10^{-12}	(1)
MR-C3	0.25×10^{-6}	2.42×10^{-12}	
MR-C4	0.17×10^{-6}	1.64×10^{-12}	
MR-B2	$< 0.36 \times 10^{-8}$	$< 3.48 \times 10^{-14}$	(2)
MR-B5	$< 0.36 \times 10^{-8}$	$< 3.48 \times 10^{-14}$	
MR-B7	$< 0.36 \times 10^{-8}$	$< 3.48 \times 10^{-14}$	

Notes: (1) CH (in m/s) = 9.66×10^{-6} (k) (in darcys), considering the flow of water at 20 ^{o}C (density = 1 g/cm^3, viscosity = 1 centipoise).
(2) The value is below the resolution limit of the device employed.

The standard permeability test performed to the composite, according to Darcy's Law, corresponds to a Hydraulic Conductivity in the order of 10^{-12} to 10^{-14} meters per second. According to Neville (Tomo II, 1977) this means from Ten to a Thousand times more than the concrete used in construction of dams, which opens an interesting potential applications for this material.

APPLICATIONS OF MASA ROCA

The main practical applications of this material have been up to this date: domes, shells, waterproofing of roofs, cisterns and water natural containers, covering of elements that need protection against aggressive agents, general repairs and restorations. There are some of the applications that, according to its characteristics, have been visualized for Masa-Roca in the construction industry. Many more remain to be explored in detail.

CONCLUSIONS

A simple, yet potentially very important microconcrete has been reported. Besides the technical advantages described above, Masa-Roca also presents an excellent workability that allows many applications as a restoration agent and as a tool for complicated architectural designs. The great energy absorption capability of the composite represents one of its main advantages, for it could be used in the construction of earthquake-resistant buildings.

The low permeability measured in the material poses a tremendous potential on its use as a good water-proofing agent for thicknesses up to 2.0 mm. Moreover, this characteristic would allow Masa-Roca to be utilized for protecting structures subjected to highly aggressive environments (water treatment plants, special tubing's, etc.). Future studies are aimed to obtain the full physical and chemical characterization of this material and the development of the optimum composition by using alternative aggregates such as rice husk, sugar cane, non-biodegradable classified garbage, puzzolans and other additives.

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