ID-1568

STUDIES ON NATURAL AGGREGATES UNSATURATED POLYESTER COMPOSITE MATERIALS: INCREASING THE RESISTANCE THROUGH REDUCING THE MOISTURE OF THE AGGREGATES

Olivares Santiago, M.[1] , Galán Marín, C. [1], Roa Fernández, J.. [1]
[1] *Departamento de Construcciones Arquitectónicas I.*
Escuela Técnica Superior de Arquitectura.
Univertsity of Seville. Avda Reina Mercedes 2. Seville. Spain.
e-mail: olivaresan@arquitectura.us.es, cgalan@arquitectura.us.es

SUMMARY:

The main objective of the present investigation is to develop a new building material, a polymeric mortar (PM), that we have named *Polialbero*, after the words Polymer and *Albero* (a rare and special rock).

The *Albero* natural aggregates used always came from the same kind of crushed or sifted rock: the row material came form a quarry under exploitation in Alcalá de Guadaira (Seville). The aggregate used in our tests always had the same grain mixture, sifting to eliminate sizes over 5mm and under 0.16 mm. The granulation used was corrected to have the highest compacity possible.

In spite of the fact that the Albero rock is rather homogeneous in natural quarries, its characteristics as row material differ depending on the area and level in an interval that was considered acceptable.

We also had to face another difficulty: the moisture degree of Albero. This rock has in general a considerable quantity of moisture: moisture degrees over 10% are not rare in rainy weather, decreasing up to five points less in hot weather.

It is also important to point out the difficulty of totally drying the grains. They easily become darker when they are heated for a long time, becoming what is called (due to the shade) toasted or burnt Albero.

The conglomerating mixes used in our experiences and tests were always composed of a standard commercial polyester resin mixed with an aggregate made of sifted *Albero* with a variable granulometry over 0.16 mm and under 5mm.

For the very first experiments the aggregates were not dried before their addition to the polymeric mortar. The natural moisture degrees of the aggregates (as they are served directly from the quarry) is used, as we wanted to establish a hypothesis as similar as possible to a real working site, were sometimes facilities for drying the aggregates are not available.

The moisture degree of the aggregates of a polymeric mortar is very important, as it has a great influence in the final strength. It has been experimentally demonstrated (Ohama 1973), moisture degrees over 0,1% have a negative influence on polyester P on Polyester PM mechanical strengths, and thoughtfully in PCs in general.

Based on this, it was considered to be interesting to analyse the Polialbero characteristics under different moisture degrees of the aggregates.

In the frame of this investigation, we have established a practical classification to identify different moisture degrees of the aggregate. This rate, based on average moisture percentages in expressed in the table enclosed:

ALBERO MOISTURE CLASSIFICATION					
Qualification	HA-0	HA-1	HA-2	HA-3	HA-4
% of moisture	<1	1-4	4-6	6-9	>9
Albero Type	Dry	Half dry	Half wet	Wet	Very wet or soaked

Table 1: Classification of Albero moisture degree

The present work intends to establish the influence of moisture in Albero polymeric mortars, through testing different aggregates with different moisture degrees. The compression strength can be increased up to a 35% when using fully dried Albero, compared to the one with 4-6% moisture degree.

KEYWORDS: Composite, natural aggregates, polyester resine, moisture influence.

INTRODUCTION

The influence of aggregate's moisture in mechanical properties of polymeric mortars is a subject already studied by some researchers, due to the surprising reduction in final strength values. This paper intends to analyse the influence of the aggregates moisture in a polymeric mortar prepared with a specific orange-yellowish aggregate named *Albero*. This aggregate can only be found in the province of Seville. We have prepared and named the new material *PoliAlbero* as an answer to the widespread use of this colour in Sevillian and Andalusian architecture. It is used not only in the aesthetic composition of the facades but also in granular pedestrian pavements.

The main goal was the search of a material with the same colour and texture than *Albero*. This new material should have appropriate characteristics to be used in building construction, basically as a coating material. We intended to supply architects with a new design tool to substitute and extend the applications already known of both *Albero* aggregates and the colour itself.

It has been considered necessary a very brief definition of the nature of this polymeric mortar made with *Albero* aggregates before exposing the specific test carried out for the present research.

In Andalusian architecture and more often in Seville (Spain) the use of Albero colour is very common in the aesthetic composition of the façades. Besides, *Albero* is a widely used material as a granular pavement in pedestrian's pathways in parks and gardens. Well-known examples of this use are the Plaza de Toros de la Maestranza (Seville's Bullring), the sidewalks of the Feria de Abril (Seville's Spring Fair) and the pathways in Maria Luisa's Park also located in Seville.

First results obtained were very promising in spite of the use of natural moisture aggregates: approximately 7%. An *Albero* polymeric mortar that could be used for the fabrication of thin coating tiles was obtained. Other applications for the building industry were also possible.

In spite of the high quality of the results obtained we have continued the research through the previous drying of *Albero* and preparing series of specimens with a moisture rate of 4% and lately with totally dried *Albero*, with a moisture rate of 0%. Results obtained from the latest tests and a comparative study between different polymeric mortars with different moisture degrees are shown in this communication.

The research work carried out demonstrates that a previous drying of the aggregates increases considerably *PoliAlbero* mechanical characteristics respecting to the PM done with the aggregates under natural moisture conditions.

THE COMPONENTS

This polymeric mortar made with *Albero* aggregates that we have named *PoliAlbero* is made of a aggregate very commonly found in the province of Sevillle, also named Alcalá limestone. The geological material is composed of a deposit of detritus and fossil limestone, very rich in mollusc shells, Briozoos y equinidus. These fossils are generally bad preserved, withdrawn during the retrogression of the oceans in that era.

This type of rock is of variable compaction, sometimes sandy and always very rough. Its is ochre or yellow coloured. Another of its characteristics is the abundant presence of quartz grain and the absence of clay. The geologic section above mentioned is extended over a length of 40 Km. and 5 Km. wide of average.

The *Albero* composition is quite homogeneous, but great differences depending on the size of the grain can be detected, as the chemical analysis shows in table I.

COMPONENTS	%
MgO	0,4 - 0,6
Al_2O_3	0,8 - 1,0
Fe_2O_3	1,7 - 2,3
SiO_2	12,6 - 13,6
CaO	45,4 - 47,0
Loss for calcination (1001C)	26,3 - 38,3

Table I: Crushed or sifted *Albero* chemical composition.

The granulation used is between the rates recommended by ASTM-33 and ACI, well known for conventional high-compactly cement mortars with a minimum quantity of conglomerate. Sizes are limited between 5 mm. maximum and 0.16 mm. minimum size.

The resin used for the polymeric mortar was a non-saturated polyester resin, chosen after analysing the resins available during the state of the art developed before the practical research. We concluded that this type of resin is the one that is most often used in building industry by experts and researchers, due to its very good rate price/quality. The same trademark and type of resin was always used: ortoftalmic resin, liquid form named ESTRATIL AL-100, composed of UP non-saturated polyester, in an estiren dissolution (30-33 % estiren). It is already accelerated to decrease the hardening time. The reticulation process, also named set or hardening process, is activated with the catalyst named MEK.PEROXIDE It is essentially metiletilcetone peroxide with a 33% of dimetil ftalate. This catalyst is added in weight proportion between 3 and 5% to polyester liquid resin. The catalyst activates the resin that starts the reticulation process at normal temperature up to harden. When using it must be mixture with the catalyst and immediately afterwards add the *Albero*. This mixture gives rise, after a copolymerization process under atmosphere temperature, to the material named *PoliAlbero.*

CHARACTERISTICS	VALUES
Liquid density	1,15 ± 0,04 g/cc a23 1C
Liquid viscosity	5-6 poises a 25ºC
Acid rate (UNE 53304)	23 - 25
Aspect	Uncoloured

Table II: Liquid ESTRATIL AL-100 resin characteristics.

CHARACTERISTICS		VALUES (average or peaks)
Mechanical Strength	Compression strength	70 - 120 N/mm^2
	Flexural strength	40 - 60 N/mm^2
	Tensile strength	20 - 30 N/mm^2
	Dilatation coefficient	20 ± 4 x 10^{-5} (30-80 ºC)
Density		1,18 -1,27 g/cc a 25 ºC

Table III: Reticulated ESTRATIL AL-100 resin characteristics.

The proportion aggregate/resin used for *PoliAlbero* research is 1:4. This means a 80% of *Albero* aggregate and a 20% of resin.

MOISTURE DEGREE OF THE AGGREGATES.

The influence of moisture degree in mechanical characteristics of the polymeric mortars has been

studied for a long time ago by different researchers. Ohama (1973) experimentally proved that moisture degree of the aggregates over 0,1% have a negative influence for the mechanical resistance of the polyester PM. He also studied wet conditions for curing and the duration of the process. Experimental tests carried out by Ohama (1973) showed that while temperature and duration of the curing process did have a significant influence in mechanical characteristics of the polymeric mortars moisture degree during curing and hardening process didn't. But it was also clearly noticed that wet aggregates had a very negative influence on the PM. Some other studies proved that the use of high moisture degree aggregates could cause reductions in the resistance of non saturated polymeric mortars up to a 80% compared to those PM prepared with aggregates with moisture degrees under 0,1%.

To study the influence of *Albero* moisture degree in polymeric mortars prepared with this aggregate, different *PoliAlbero* specimens were done and tested. They were prepared with different moisture degrees: from a 7%, which means the natural moisture degree of the aggregate, with a 4% and finally with a 0%. The aggregate was dried in an electric stove, measuring the moisture through following weights after five minutes drying periods. It was considered that null moisture was obtained when there was no weigh difference betweeen two following weights.

MEASUREMENTS AND TESTS

Tests referred to the different aspects studied of *PoliAlbero* are shown in Table IV under the RILEM PC Standards given in the RILEM Symposium held in Ostende (Belgium) July 1995 (RILEM TC-113, 1995).

TESTS OR MESUREMENTS		STANDARDS
Mechanical Strength	Compression strength	UNE 83821/92. DIN
	Flexural strength	DIN 53452. UNE
	Flexural-Tensile strength	UNE 82821

Table IV: Test Standards

EXPERIMENTAL TESTS RESULTS

Experimental tests results are average values of the values obtained from series of three or six specimens and are indicated among with the standard deviation values.

TESTS ON PRISMATIC SPECIMENS 4 x 4 x 16 cm.						
Characteristic values	Flexural-Tensile strength (Mpa)			Compression (Mpa)		
Albero moisture degree	0%	4%	7%	0%	4%	7%
Average	14,0	11,3	7,2	69,6	42,5	27,6
Number of specimens	6	6	6	6	6	6
Deviation	0,55	0,4	0,3	2,0	1,5	1,0

Table V: Flexural-Tensile and Compression strength tests result for prismatic specimens.

TESTS ON CYLINDRICAL SPECIMENS Φ5 x 10 cm.						
Characteristic values	Strain %			Compression (Mpa)		
Albero moisture degree	0%	4%	7%	0%	4%	7%
Average	3,11	3,31	3,41	39,8	23,5	15,3
Number of specimens	6	6	6	6	6	6
Deviation	0,15	0,15	0,15	0,7	0,45	0,3

Table VI: Compression strength tests result for cylindrical specimens.

TESTS ON SLABS SPECIMENS 15 x 15 x 1 cm.			
Characteristic values	Flexural strength (Mpa)		
Albero moisture degree	0%	4%	7%
Average	24,3	16,1	14,3
Number of specimens	6	6	6
Deviation	0,7	0,5	0,4

Table VII: Flexural strength tests result for slab specimens.

TEST RESULTS ANALYSIS

Comparative studies between *Albero* PM (1:4 proportion) test results for the different moisture degrees have been done. This comparative study is shown in Figures 1 to 4. These results lead us to the above listed conclusions:

The influence of the moisture degree of *Albero* used as an aggregate for a polymeric mortar is very important for the mechanical strength. So important that when the aggregate has a 4% moisture degree, compression strength decreases up to a 40% with respect to the PM prepared with a 0% aggregates moisture degree. Further more it will be reduced up to a 60% when the aggregate has a 7% moisture degree. For Flexural-Tensile strength reductions are 19% and 49% respectively. Flexural strength decreases 34% and 41% respectively.

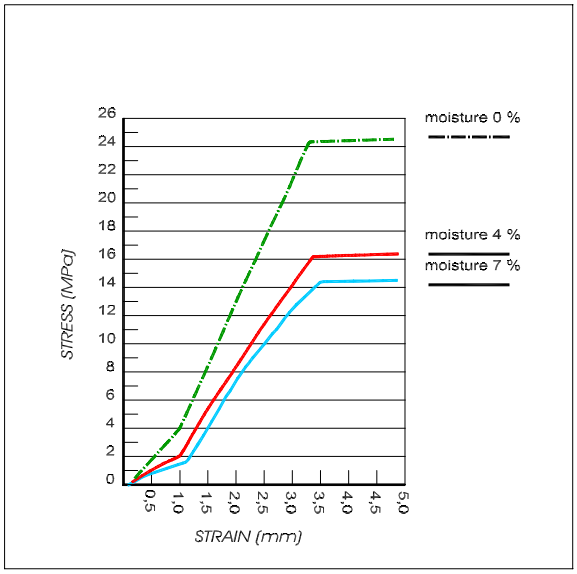

Figure 1: *PoliAlbero* stress/strain curve, according to different moisture degrees of according to *Albero.*

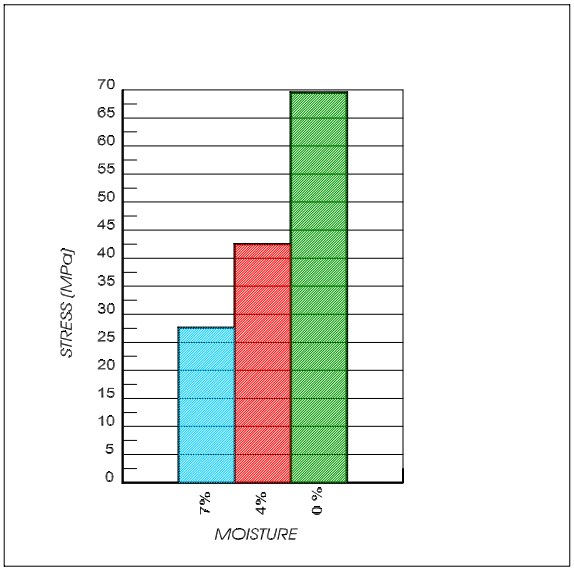

Figure 2: *PoliAlbero* compression tests for prismatic specimens 4x4x16 cm.

different moisture degrees of *Albero*.

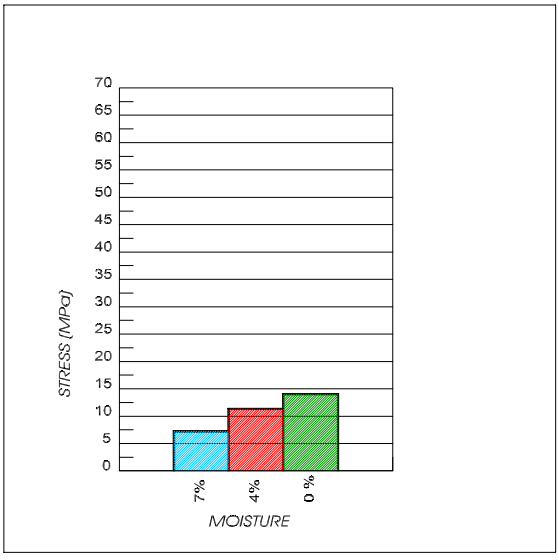

Figure 3: *PoliAlbero* compression tests, for cylindrical specimens Φ5 x10 cm. according to different moisture degrees of

Albero.

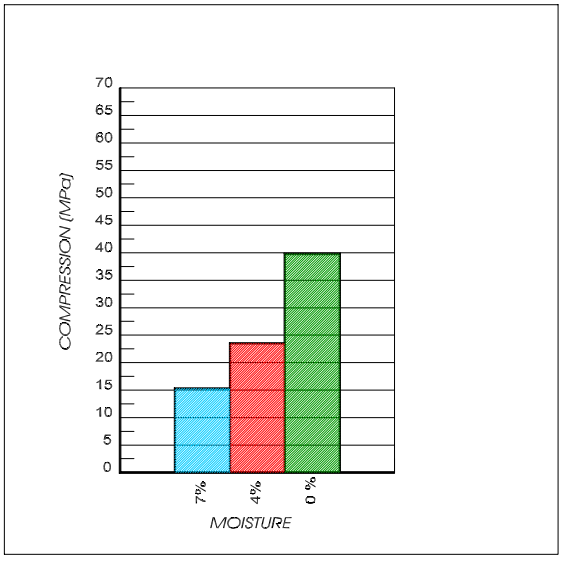

Figure 4: *PoliAlbero* Flexural-Tensile strength tests for prismatic specimens 4x4x16 cm. according to different moisture
degrees of *Albero*.

REFERENCES

1. Fowler, D. W., "Aplications of Polymer Concrete". *Jornada sobre aplicaciones de polímeros en el hormigón.* Bilbao, Dic. 1996.

2. I. G. M., "Memoria explicativa y mapa geológico, CARMONA". Instituto Geológico y Minero. Madrid. Hoja n1 985 del Mapa Topográfico Nacional.

3. Materiales Compuestos, "Actas I Congreso Nacional de Materiales Compuestos." Sevilla, 1995.

4. Moshchanskii, N.A. y Paturoev, V. V. Editores, "Structural chemically stable polymer concretes". I.P.S.T., Jerusalem, 1971.

5. Ohama, Y., "Mix proportions and properties of polyester resins concrete." Paper SP-40-13.ACI. SP-40, pp 283-284. ACI Committee 503. Detroit, USA 1973.

6. Olivares, M., Laffarga, J., Galán, C., Martineau, Ph., "A new polymeric mortar made of Albero." 8th. European Conference on Composite Materials science, technologies and applications (ECCM'98). Naples, 1998.

7. Ramírez, J. L. y Urreta, J., "Hormigones poliméricos. Tipos y Propiedades. Investigación y Desarrollo." *Jornada sobre Hormigones Estructurales Especiales*. Bilbao, Mayo, 1995.

8. ACI: Committee 548, "Polymer in concrete. Advances and applications." SP-116, 1989.

9. Barrios Sevilla, J., "Preparación y estudio de un cemento PAS a partir de Albero de Alcalá de Guadaira (Sevilla)." Tesis doctoral inédita. Universidad de Sevilla, 1.975.

10. Czarnecki, L., "The Status of Polymer Concrete". Concrete International, July. 1985.

11. Dikeou, J.T. y col., "Concrete-polymer materials", third topical report, BNL 50275 (t-603) & USBR REC-ERC- 71B6. Jan, 1971.

12. *I.C.C.: International Congresses and Conferences: "*Proceedings of the International Congress of Polymers in Concrete": 1st (ICPC-1, London,1975), 2nd (ICPC-2. Austin, 1978), 3th (ICPC-3, Koriyama, 1981), 4th (ICPC-4, Darmstadt, 1984), 5th (ICPC-5, Brighton, 1987), 6th (ICPC-6, Shangai,1990), 7th (ICPC-7, Moscow, 1992), 8th (ICPC-8, Ostende,1995).

13. González Vila, V., Artículo de la Enciclopedia de Andalucía. Tomo 2, Cementos. 1980.

14. Prieto Carrasco, I. y Alastrue Castillo, E., "Informe geológico-minero sobre las posibilidades de utilización de las calizas en la Loma de Los Alcores." Inédito- Sevilla, Junio, 1963.