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MODIFICATION OF PORTLAND CEMENT MORTARS WITH CACTUS GUM

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Abstract. Portland cement-based mortars of the standard type used for modern constructions, were modified by adding liophilized cactus gum, extracted from an indigenous Mexican cactus. The results show an increase in compressive strength as high as 65 % with respect to standard mortars.

Key words: cactus gum, natural products, portland cement, gypsum, liophilization

1. Introduction

From ancient times, materials have been modified with all kinds of additives, aiming to improve their mechanical, physical and chemical properties. Mortars or other mixtures meant for building purposes have been particularly attractive for testing empirically a number of natural and synthetic additives. Today's construction technology relies on a number of commercial additives to control the water-cement ratio, to diminish porosity, to increase durability, etc. Besides the cost of those materials, what is especially important for the case of massive buildings, the environmental issues are generally of little concern in this area. Given the economical and social magnitude of the construction industry, it represents a very attractive field for Green Science and Technology, particularly for natural products which could be easily and rapidly produced at low cost and in such a way could improve some properties of building materials.

In this regard, the vast family of cactus represents a potential source of low-cost materials for the civil engineer. However, almost all the basic chemical research on cactus has been concerned with the extraction and identification of their alkaloids and other chemicals. From the green-technology standpoint, cactus pulp is used in the food industry [1], for water-oil separation [2] and recently, for producing environmental absorbents [3].

Mexico is the world center of the genetic diversity of prickly pear cactus. In this country, the use of this species is very extensive, starting with their use as fences for home gardens and agricultural patches, as protection for the soil from other vegetable species, as a medicinal plant, as raw material for the cosmetics industry to obtain fructose, pectine, dyes, etc., to, and finishing with their use as foodstuff, what perhaps is the most important from the cultural point of view. Early reports after the Spanish conquest of the Indians inhabitants reveal the use of cactus gum in building and civil engineering [4]. In fact, a number of organic materials are reported as additives and aggregates to improve properties such as plasticity, durability and strength in adobe, mortars and concrete [5-15]. However, the available literature is very scarce on the scientific details of these ancient technologies or the consequences of their modern application. Accordingly, the aim of this work is to explore the use of the gum extracted from the prickly pear cactus in lime-plaster-Portland cement-based mortars used in modern buildings and civil engineering, as a green alternative for some of the additives used routinely in a construction technology [7].

2. Experimental

Prickly pear Streptacantha, that belongs to the family Cactaceae and to the genus Opuntia, was utilized for the present study. The reason for choosing this particular species is their wide availability throughout the countryside and their low bromatological value.

· Gum extraction. There are at least three forms reported in the literature to extract mucilage (gum) from the leaves:

1. Mucilage diluted in water: 10.6 % of concentration. First, the leaves are cut and then peeled to extract the gum, allowing leaves to macerate in water for three days.

2. Concentrated gum.

3. Liophilized gum: at a pressure of 0.001 mbar and 223 K. The procedure is following:

i) 10 leaves of the cactus (which yield is 4.24 kg worth of powder cactus);

ii) the hearts of the cactus are crushed in a porcelain mortar;

iii) once the powder is liquefied, approximately 3.7 liters are obtained;

iiii) a series of sieves are utilized on the liquefied product.

· Sample preparation: mixtures were made with different amount of cactus gum, as summarized in Table 1. The mixtures were tested after 3, 7 and 28 days of aging, at standard room temperature (295 K) and relative humidity (40 %). The procedure for the mortars preparing was carried out according to the ASTM standards, by using commercial type I cement (Tolteca brand). The results so obtained correspond to the average of 5 identically tested samples.

Table 1

Compositions of materials prepared

Sample No. and material	Amount, g	Type of sand
1. Silica sand	270	Fine
2. Silica sand	460	Medium
3. Silica sand	270	Coarse
4. Portland cement	200	
5. Liophilized cactus gum	0.5, 1.0, 1.5 and 2.0	
Water (in all 5 cases)	121	

3. Results and Discussion

Table 2 summarizes the results of the compressive strength of different samples prepared with different amount of cactus gum, tested after 3 days of aging. So, it was concluded that the proper percentage of cactus gum was 0.5 g. since it yielded the best compressive strength/gum content relationship. Therefore, for the samples after 7 and 28 days, this was the gum content utilized. The results show that the best proportion, as far as the use of liophilized gum is concerned, is mixture No. 4 with cactus content of 1.5 g. The increase of the compressive strength is as high as 65 %.

Another extra bonus for the use of cactus gum for the modifying mortars and other construction materials is illustrated in Table 3. Indeed, one of the main parameters leading to the failure of actual buildings is the corrosion of their reinforcing steel structures, embedded in the mortar or concrete. The fundamental problem behind is the mixture pH. In the case of gypsum, a widely used construction material, either by itself or as an additive to mortars and concretes, the low pH (of around 9, typically), leads easily to corrosion. The use of cactus gum, especially, the lyophilized one, as shown in Table 3, leads to the pH control of the resulting composite, thus helping to reduce corrosion susceptibility.

Table 2

Average compressive strength of samples after 3 days of aging

Sample	Cactus gum content, g	Compressive strength, kg/cm^2
1	0.0	117.22
2	0.5	183.07
3	1.0	143.34
4	1.5	194.22
5	2.0	145.85

Table 3

Results of pH measurements

Material	Test temperature, K	pH
Liophilized cactus gum	299.1	4.64
Cactus gum as extracted	299.3	4.94
Gypsum + silica sand	299.7	9.67
Gypsum + silica sand + liophilized cactus gum	299.6	11.38

The above results are not simply due to a rheological role of the cactus gum, as the first thought could be, but they involve a complex chemistry of the polyelectrolites contained in the lyophilized gum, which not only react with the Portland cement constituents, but also catalyze the standard reactions. This issue is currently under study and will be reported separately.

4. Conclusions

The results demonstrate a positive increase of the compressive strength of mortars modified with cactus gum. The gum content and the liophilization procedure seem to be the key for obtaining of significant improvements in the mechanical performance, in terms of the Ultimate Strength achieved, of the mortars. Of course, some other mechanical parameters must be determined to fully explore the benefits of this additive. Nevertheless, one important advantage of the cactus gum use, at least from the practical standpoint, is the rheological behaviour of the resulting mixture, which is enormously enhanced and, thus, enables to think of the mortar almost as a kind of material for “sculpting” complicated shapes.

This is empirically evaluated by the easiness of application the mortar mixture to a wall. Comparing with a standard material, the modified mortar allows not only longer times before becoming a viscous mass, but also to shape the mixture at will. Finally, it must be mentioned that the great availability of the cactus employed in this study also opens the possibility of the massive use of this technology.

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МОДИФІКАЦІЯ ПОРТЛАНД-ЦЕМЕНТНИХ РОЗЧИНІВ КАКТУСОВОЮ СМОЛОЮ

Анотація. *Показано, що стандартні розчини на основі портланд-цементу, які використовуються у сучасному будівництві, модифіковані ліофільною кактусовою смолою, одержаною з місцевого мексиканського кактуса. Одержані результати свідчать про зростання міцності при стисканні на 65 %, порівняно із стандартними розчинами.*

Ключові слова*: кактусова смола, природні продукти, портланд-цемент, гіпс, ліофілізація.*