Use of prickly pear juice for the improvement of characteristics of mortars and concrete

Research · August 2015

DOI: 10.13140/RG.2.1.3483.5680

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USE OF PRICKLY PEAR JUICE FOR THE IMPROVEMENT OF CHARACTERISTICS OF MORTARS AND CONCRETE

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The Prickly pear is a plant existing in different parts of the world, mainly in warm and hot dry climate. It belongs to the cactus group, with very similar characteristics. Its use has been very wide by the humankind for security in fences or soil protection from erosion, but it has also generated other benefits, such as feeding for people as well as livestock, medicinal and cosmetic use, refuge for insect colonies (cochineals) for purple colorant production, and other uses in building as it has waterproofing effects on façade walls [1,2].

There are some traces of the use of prickly pear juice long ago for building maintenance in America, Africa and India [3,4,7]. Other organic products used with the same purpose were of animal origin (excrements, fats and proteins, whey, casein, egg whites, blood or urine) as well as plant origin (latex from the rubber plant, extract from the banana plant leaves or carobs, sugars and glucose, flours, plant oils, starches, gums, cactus, waxes or resins) [5,6]. Sometimes, plant fibres were added to avoid cracking. The objective of all these admixtures was to improve impermeability of the component used over the facade, adobe blocks, lime mortars or even paintings. The achievement of this improvement was due to the introduction of biopolymers that helped to reduce porosity, avoid water penetration and, therefore, increase durability of these elements that, in the large majority of cases, were weak to atmospheric impacts. One analysis of the prickly pear juice developed by Chandra [6] detected the presence of fructose, glucose, saccharide, maltose and raffinose in traces. All of them are biopolymers and proteins with different composition and types.

In the case of prickly pear juice (known as nopal mucilage in America), its use is in different ways, adding it to the adobe mass, surface mortars, or like a painting too. Its effectiveness depends on the application and penetration depth, as it is shown by Martínez-Camacho et al [3]. As it can be observed, for a correct surface priming (in the case of painting), a first treatment is applied with the basis of alcohol for the juice to be able to penetrate properly in the open pores. Otherwise, the effect is much weaker.

Present studies about the use of prickly pear have been focused on two main fields:

- Heritage building restoration
- The use in new mortars and concrete

USE OF PRICKLY PEAR JUICE IN HERITAGE BUILDING RESTORATION

The main objective for the use of prickly pear juice in all these cases was the improvement of impermeability, improving durability as well. Additionally, it introduced other improvements, such as more elastic mortars reducing cracking.

The restoration works for this heritage architecture suggest the use of the same materials (or natural native materials that are less aggressive over the building) for the maintenance of the building in the same way as the original one as much as possible.

The normal use was inside adobe mass and soil blocks and in coating elements, lime-mortar linings or directly as a waterproof layer [1,3,4,7]. Besides, it is interesting to highlight the study developed by Pérez Castellanos about the use for mural painting restoration, analyzing the proportions of load and binder, where the juice acts as a binder [11].

A very important aspect is the identification of these products in the different construction elements. Several studies have been carried out for this identification in general [4,5], in wall elements (adobe [3] or even stone [9]) and coatings (lime mortars [7,8]). This way, the effect of its application is analyzed and the possibility of restoration with the same product as well.

USE OF PRICKLY PEAR JUICE IN NEW MORTARS AND CONCRETE

Nowadays, the prickly pear juice is still being used for facade waterproofing in some regions of America, especially in Mexico, in rural areas where natural resources are used for building. This use is developed like an addition in adobe and compressed soil blocks [16], used as a binder, and in lime mortars for coating [2]. Mattone [20] describes the "bahareque" technique, in which plant fibres and prickly pear juice are mixed to make a mortar for construction elements and walls with reduced thickness.

Chandra et al [6] thought for the first time about the possibility to use this juice for new mortars and concrete, with portland cement. According to this first study, this product can increase impermeability of the resulting product, and prolong setting and hardening time as well, what produces a delay in initial strength. After that, other similar studies are developed that confirmed these results [12] and, in addition, surprising results are obtained about the improvement of other characteristics, such as compressive and flexural strength [2,16,18,19], and the performance as corrosion inhibition for steel in reinforced concrete [12, 13,14,15,17,18]. Furthermore, there is the possibility to obtain fibres from this plant, which can be added as plant fibres inside mortar and concrete mass [20,21].

EXTRACTION OF PRICKLY PEAR JUICE

There are different techniques for the extraction of this juice. The most common one consists of peeling and cutting in small layers of this plant leaves, and they are introduced in water for 2 days. This way, the extract is dissolved in water obtaining a thick and sticky solution. This product is introduced in the mass together with the water [6]. Some authors requires only one day for the production of this solution [9], while others need 3 days [2].

Another process is developed from a water/prickly pear leaf relation of 2, heating this mix to 60±5ºC during 3 hours, with manual stirring every 10 minutes and then poured and filtered. The conservation of the resulting product is carried out by refrigeration [10].

Another author dehydrates the resulting product and obtains a more concentrated one [2]. Besides, it is also studied the introduction of prickly pear dust as an addition proportionally to the cement content [9, 13, 14]. Thus, prickly pear leaves are dried and ground to obtain this dust.

Finally, it is also interesting the freeze-dried rubber obtained from prickly pear leaves developed by Hernández-Zaragoza [2]. 10 cactus leaves (4.24 Kg of cactus dust) are ground and liquefied to 0.001 mBar pressure and 223 K temperature. With this process, about 3.7 litres of product are obtained.

When the addition is made as prickly pear juice, the proportion is established respect to the mixing water content, substituting part of it. In that way, it is tested different proportions up to the whole substitution of the mixing water. When the addition is dust, it is added proportionally to the cement content. Thus, the studied proportions are not over 5%, and they are carried out as an addition, not substitution.

TESTS MADE AND RESULTS OBTAINED

In addition to the study of the different characteristics obtained, it is also compared the different ways of this juice obtaining, despite the fact that it is not developed in the same way nor for the same purpose. Besides, these results are compared to other products with different origins, such as aloe vera, marine algae, etc.

Chandra et al [6], as the oldest and perhaps the most complete study, analyses firstly the characteristics of prickly pear juice in mortars and concrete about fresh mass density, consistency, flexural and compressive strength, water content, absorption (capilarity), absorption in its application as a painting, freeze-thaw cycles and X-ray difraction analysis. The results show a delay in the cement grain hydration, therefore an increase of setting time, and a delay of initial strength as well, which gets to the same level at 28 days. Moreover, the prickly pear reduces porosity and capillarity, increasing impermeability and water resistance. These results are confirmed by different authors, even in some cases comparing this product to the effects obtained with super-plasticisers and its good performance for self-compacting concrete [10].

It is interesting to highlight the comparison made by Ventola et al [9], between the prickly pear juice and dust. According to this study, the increase of mechanical strength is bigger with dust addition, as well as setting time. On the other hand, absorption is less with prickly pear juice, and therefore, impermeability is better.

In these tests, it can be observed that the pH of the mixture is reduced, but in different tests it is noticed that steel reinforcing is better protected from corrosion [2]. Several later tests are developed and they confirm the idea that this addition acts as a corrosion inhibitor in reinforced concrete.

STUDY PROPOSALS

It is important to remark that these studies are mainly referred to Mexico. Notwithstanding, the prickly pear is a plant grown in a large part of South Europe. In Spain, for example, it is considered as a native plant, although its origin is from America [1].

It is interesting to know the possibilities that can be obtained with different processes for obtaining prickly pear juice, among them the capacity of solubility and density of this juice, the accuracy in the process to obtain it, shelf life and conditions, etc. All of them are necessary for an industrial production of an innovative product based on this product.

It is interesting to improve the knowledge and results about the improvements that can be introduced in new mortars and concrete, with statistical studies that confirm the best proportions and improvements. In addition, the comparison of this product with other super-plasticiser admixtures can help obtain similar results with a reduced environmental impact.

As it can be observed, the application in mortars and concrete is evidently advantageous, but durability of this product in concrete mixtures is not studied along time and in different exposure conditions. Besides, impermeability can be at risk due to deterioration. The durability of this product is then affecting the concrete durability too. Therefore, the study of durability is a prior question for the success of this product in new concrete mixes.

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