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Characterization Study of A Putty for Restoration and Sculptural Modeling

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Abstract In Mexico, there are important elements within the built and sculptural heritage, characterized by a rich variety of cultures that left important vestiges. Due to the age of the various elements, it is necessary to carry out restoration processes that include the partial replacement of the components by others physically compatible. This same putty can be used to make sculptural models and the elaboration of pieces that allow making them known or preserving them. Recognizing the non-existence in the market of a product type dough or putty of drying in the open air that serves to model sculptural and architectural pieces, whose characteristics already provide dry appearance, color and texture type stone or mud, in this article, a putty was proposed, joining and mixing several organic and inorganic components, whose quality is that, when drying and hardening, you can manipulate and model the parts in less than twelve hours. This article presents the mixture and mechanical properties of the material obtained, such as compressive strength as well as permissible deformation.

Keywords Heritage, Building Materials, Putty for Sculptures

1. Introduction

Cultural heritage has intrinsic, historical, and artistic values that promote defining a sense of identity and belonging among individuals and people. The ancient inhabitants of Mesoamerica left a multicultural heritage in their architecture, sculpture, ceramics, painting, monuments, and other arts that are of great importance for their conservation.

On many occasions, it is not possible to have the original material that allows the restoration even if there are techniques for the analysis of them [1]. At present, some materials have been proposed to restore buildings that belong to the heritage of the cities [2], but it is difficult to define a universal material for the different nature of solids that exist as part of the heritage elements such as buildings, sculptures, among others [3]. At present, deterioration of cultural heritage has been observed mainly due to climate change [4], which leads to the need for the development of new materials that adapt to current needs, not only for restoration, but also for heritage modeling that allows conserving at least replicas of these.

Heritage conservation also requires heritage modeling as well as replication [5].

Since ancient time, man has made different types of crafts using clay or earth to make sculptural pieces, ceramics, jars, vessels, etc. There have been several materials that have been used throughout history and although they are different, others with similar physical characteristics can be found.

As explained by Monserrat Lastras Pérez, from the Polytechnic University of Valencia in his doctoral thesis

entitled "Research and analysis of filling putties for the integration of archaeological ceramic lagoons" initially puties based on wax, wood or gutta-percha were used, evolving to the greater use of plaster that is composed of plaster with the disadvantage of being hygroscopic, emphasizing that this paper this material is eliminated, in addition to other epoxidized resins. After 2015, there are several putties with inorganic loads mainly based on metal oxides whose coloration is white.

Currently, we have ancient elements that have been rescued both in excavations and other activities, or that have remained in shelter for a long time. However, in most cases, they are recovered with missing sections or have been degraded or cracked, being necessary a restoration that means the differentiated replacement of the parts in such a way that it is visualized as it was initially conceived.

This process can be done in layers in several days, if necessary to finish a work. Once dried, this product hardens in a few hours, acquiring a stony appearance, which can be manipulated and preserved for many years.

The objective of this work is to make replica pieces to scale sculptural and architectural works like those made by the pre-Hispanic world, which were made with stones or mud, to preserve the original pieces, using these replicas to expose and disseminate this ancient heritage. For this, a material that was developed in the facilities of the Faculty of Architecture, Design and Urbanism of the Autonomous University of Tamaulipas and that is described in the section of the method of this work is used.

2. Method

For this project, we developed a three-phase work plan: the first consisted of the creation of a manageable and moldable mass, whose appearance is stony; a second phase on physical and mechanical wheels, to check their strength and characteristics; and a third that consisted of the realization of sculptural pieces relying on mesh structures or wires for their interior core.

2.1. Phase 1

In phase 1, a mass was obtained that is mainly made up of various elements such as sandstone powder, coarse river sand, marble, corn starch, glues or polymers, glycerin, and water among others.

In this way, a putty with outdoor drying sands was obtained for modeling and restoration of sculptural pieces that can be used in the restoration of structures and that present great plasticity when manufactured, but that when dried acquires the shape that is conferred on it, as well as good mechanical resistance.

In addition, a moldable paste can be produced from the same mixture, which can then be produced from the same mixture of drying. It can withstand some deformation, returning to its original shape and applying to structures that undergo some dilation.

2.1.1. Preparation of Putty

It is given to the proportion: sandstone powder from 10 to 30%, coarse river sand from 1 to 7%, corn starch from 25 to 45%, poly-vinyl acetate glues from 10 to 15%, fine marble from 1 to 10%, glycerin from 0.5 to 3.5%, water from 1 to 20%. It is worth mentioning that to achieve a greater texture and color depending on what is proposed to model or restore could vary the proportion.

In this sense, this product has been created for specific purposes to give similarity and appearance to sandstone and its color and texture variants, trying to recover the appearance, functionality, and aesthetic values of the pieces to be restored or modeled.

The consistency of this product is thick, it does not adhere to the hands easily and the application is manual, no specialized devices or tools are needed for its placement. It presents workability in a range of 6 to 12 continuous hours (this refers to the temporality of its manageability). The initial drying time comprises a range of 12 to 24 hours after which it can be worked mechanically.

This mass considerably decreases cracking with a high resistance, and low porosity. This is given to the proportion: sandstone powder of 10 to 30%, coarse river sand of 1 to 7%, corn starch of 25 to 45%, poly-vinyl acetate glues of 10 to 15%, fine marble of 1 to 10%, glycerin of 0.5 to 3.5%, the water of 1 to 20%. It is worth mentioning that to achieve a greater texture and color depending on what is proposed to model or restore could vary the proportion.

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Components and reagents for the creation of the outdoor drying mass with a sandstone appearance are shown in the following Figure 1.

Mixing of new elements and reagents (Figure 2).

Tests of malleability to the mass observing a deformation by compression without breaking (Figure 3).

2.2. Phase 2

14 mixtures with different ingredients and proportions were prepared, to achieve through physical and mechanical tests the characteristics sought in similarity in appearance and stone resistance. (See Table 1)

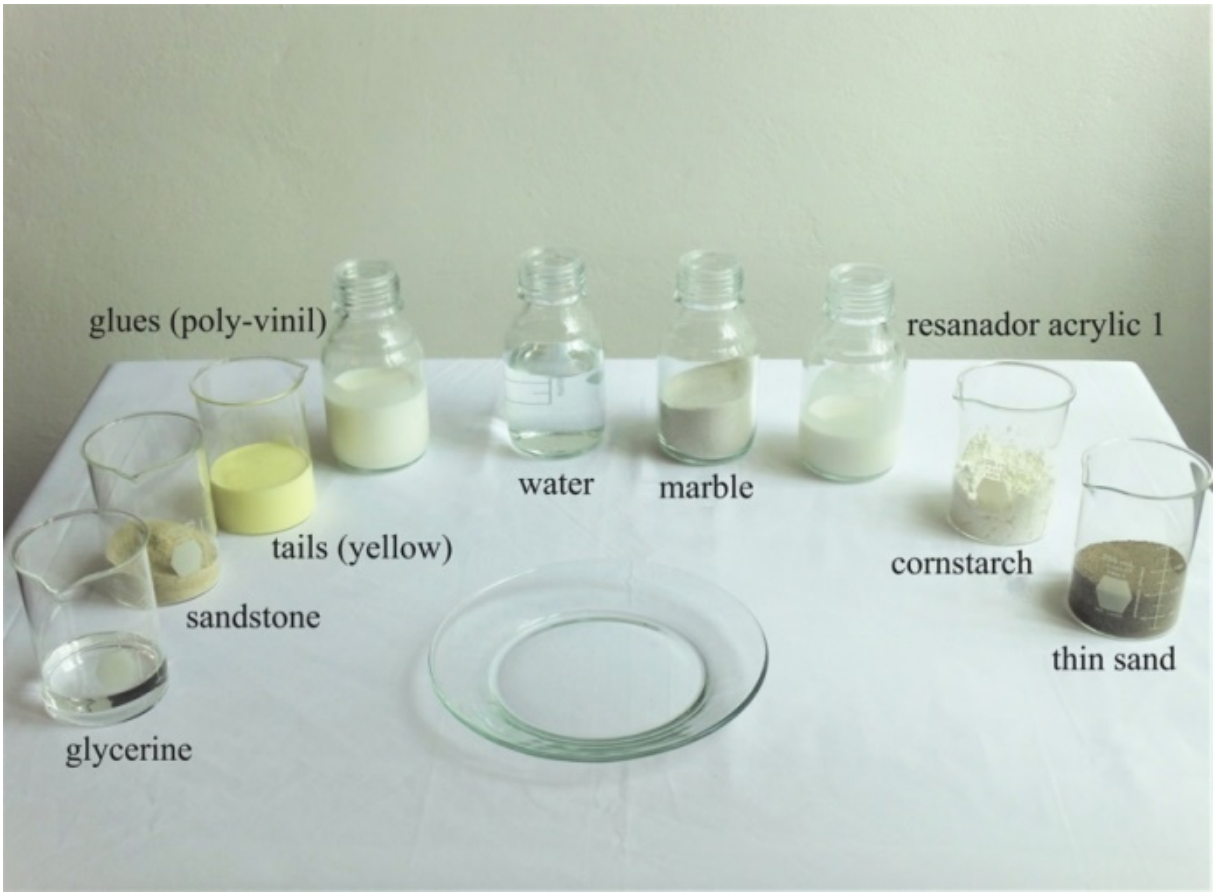


Figure 1. Main components used in the elaboration of the sandstone finishing mass

Figure 2. Manual mixing of constituent elements of the mass

Figure 3. Mass showed the malleability property

Table 1. Registration of experimental mixtures of the dough

	MIX 1	MIX 2	MIX 3	MIX 4	MIX 5	MIX 6	MIX 7	MIX 8	MIX 9	MIX 10	MIX 11	MIX 12	MIX 13	MIX 14
1. Marble	15	20	20	20	25	0	0	20	0	14	18	3	0	10
2. Sandstone	13	15	0	0	0	25	10	0	20	17	12	10	22	5
3. Cornstarch	18	25	25	20	8	30	35	20	43	40	40	38	40	35
4. Thin sand	0	0	15	10	0	0	15	10	0	0	0	0	0	0
5. Arena thick	0	0	0	10	15	8	5	10	6	5	2	2	4	4
6. Glycerine	3	2	2	0	1	0.5	2	0	4	1	1	1	3	0
7. Lanolin	3	2	2	0	0	1	2	0	0	0	0	1	0	0
8. Glues (poly-vinyl)	30	30	30	30	15	20	0	0	0	0	0	0	0	0
9. Tails (yellow)	0	0	0	0	0	0	20	10	0	15	19	20	16	15
10. Alcohol	11	0	0	0	0	0	0	0	0	0	0	0	0	0
11. Salt	2	1	1	2	1	0.5	0.5	2	0	0	0	0	0	0
12. Water	5	5	5	8	12	15	8.5	8	6	8	8	8	9	8
13. Resanador acrylic 1	0	0	0	0	23	0	0	0	0	0	0	0	0	0
14. Resanador acrylic 2	0	0	0	0	0	0	12	0	7	0	0	0	0	3
15. Lime	0	0	0	0	0	0	0	0	0	00	0	0	6	0

2.3. Laboratory Tests Carried Out

2.3.1. Flexural Strength

This test, also known as a rupture module, consists of the arching or flexion of 3 points to a specimen until it fractures to obtain the highest stress it can withstand in this way.

The compressive strength is calculated as follows:

$$\sigma = \frac{3FL}{2bd}2 \quad (1)$$

Where: F, L, b, and d, are the force in the center of the specimen, length of the support section, width and thickness, respectively.

The procedure is as follows: In a hydraulic press, a rectangular specimen is placed and employing 3 rollers (2 support and 1 to apply the force) the corresponding force is applied to perform the test. The experiment is stopped until the specimen breaks or fails, the applied force is indicated on the hydraulic equipment, and in that way the stresses to which it was subjected can be calculated.

2.3.2. Compressive Strength

It is an experiment in which the pressure that tends to cause a reduction in the volume of the object to which it is applied is determined; in a didactic way, if we assume that the object that perceives this effect is found by planes perpendicular to the pressure exerted, the planes will approach each other.

Compressive strength is calculated using the following equation:

$$R = \frac{F}{A} \quad (2)$$

Where: R, F, and A, are the compressive strength, strength, and cross-sectional area of BTC, respectively.

The procedure is as follows: In a hydraulic press, a uniform portion of sand is placed and on it the BTC to which the test will be applied is placed. The hydraulic equipment applies uniform pressure on the partition until the maximum permissible stress translates into a break or failure; the applied force is indicated on the same hydraulic equipment and depending on the perpendicular area of the block, the resistance of the material is calculated.

2.4. Phase 3

For the realization of the sculptural samples of experimental type, the following procedure was carried out:

- Choice of sculpture for its replica, documented with photographs and archaeological and historical records, in some cases indirect observation in the museum where the original work is exhibited.
- Proportion study to choose an appropriate scale for its management.
- The work begins by building a steel or wood structure that will be the internal skeleton or soul of the sculptural replica that supports and solidity.
- Then the putty is prepared in advance and placed in layers on the skeleton covering the entire surface of approximately 1/2 cm thick. It is allowed to dry for 12 hours before applying the successive layers that are necessary depending on the base sample.
- The details and highlights are modeled manually and using spatulas until the closest resemblance to the original is achieved. The following figure shows this process step by step (Figure 4).

3. Results and Discussion

We made an outdoor drying mass with a sandstone appearance for modeling and restoration of sculptures and architectural pieces according to the mixture of the following components: sandstone powder 15%, coarse river sand 5%, corn starch 35%, poly-vinyl acetate glues 15%, fine marble 10%, glycerin 2%, water 18%. Homogenization was achieved by manual mixing for eight minutes until all the elements were fully integrated, taking care that there was no formation of lumps.

The mixture obtained in this example was placed in a prism whose height was twice the width of the base; in 24 hours it was unmolded and waited for complete drying of 25 days, then proceeded to determine its mechanical resistance to compression using a digital press that supplied a load to the prism determining a mechanical resistance to the understanding of 24kg / cm^2.

Figure 4. Process of obtaining a sculptural piece

The sample showed no cracking during the 28 days. A replica made and monitored for 3 months did not present cracking or modifications on its surface.

As a second example, according to the description above, the application of the mass obtained according to example one is detailed, the following proportion was used: sandstone 15%, coarse river sand 5%, corn starch 35%, poly-vinyl acetate glues 15%, fine marble 5%, glycerin 2%, water 18%.

This mass obtained was applied in a work of sculpture of small size of about 35cm approximately, as a scale replica of a pre-Hispanic sculptural work of about 80cm approximately of the original size.

The procedure that was followed was to make a hard structure of stainless-steel wire forming a rigid structure or skeleton that was anchored to a rigid base of cedarwood.

A quantity of dough is prepared to give it a first layer on the manufactured structure. This dough was prepared with the conditions described in this example number two, manually joining and kneading all the ingredients in a glass container until a uniform and flexible mass was achieved to be used.

The prepared mass is applied by opening the wire skeleton with a first layer of flexible sandstone mass of a thickness not exceeding 1 cm to avoid detachments and letting it dry for approximately 24 hours.

Subsequently, a second layer no larger than 1 cm thick is applied, modeling manually in the first 12 hours, letting it rest for about 24 hours until the next application of another layer.

As the last step, the following missing layers are added, modeling until reaching the desired volume and shape.

It is carved and polished using hand tools such as spatulas, blades, burins, etc. Once dried after 24 hours, it can be modeled and carved with hand and electric tools such as small drills. Finally, it is left to dry at room temperature for a week to achieve its final resistance.

In general, the following advantages stand out:

- Natural drying in ambient air (24 hours). There is no need for ceramic firing.
- Fresh touch, not sticky.
- It works with ease, admitting the addiction of pasta during its handling.
- It can be painted with plastic paints, varnished, sanded, laminated, rolled and cut.
- It is presented as a flexible wet clay paste to model by joining the ingredients with water and kneading.
- To prevent it from drying, it can be stored in airtight bags for a few hours.
- It has a sandstone appearance finish to which different shades and textures can be given.
- With this mass it is possible to model geometric, irregular, warped shapes, etc.

This is achieved with the improvement and addition of new materials and reagents in their chemical composition. One of the objectives is to provide a product whose usefulness is mainly found is the restoration and replacement of missing as well as this mass can be used for modeling sculptural and architectural pieces of movable and immovable property of the ancient heritage as well as scale replicas.

To check their strength and durability, several cubes were made with different constitutions according to the proposed experimental mixture register, for which a representative element is shown in Figure 5.

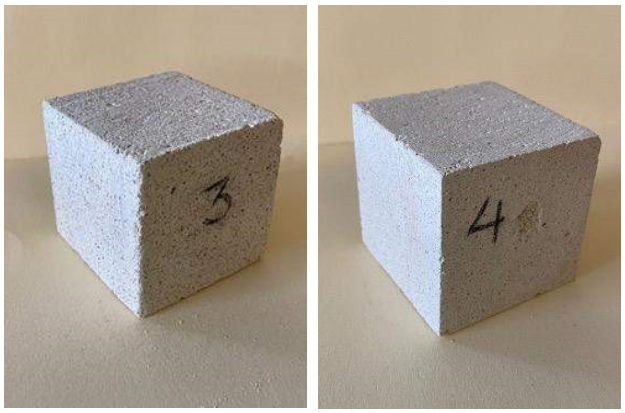
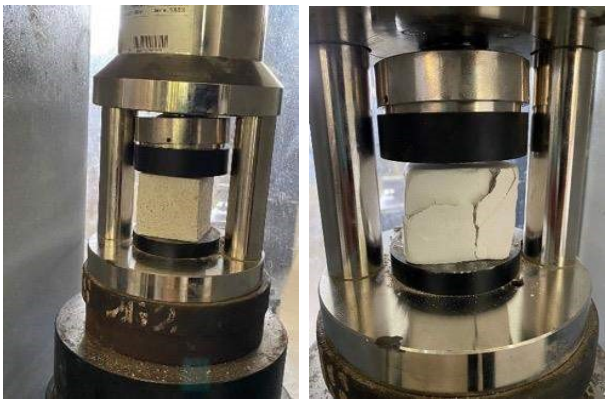


Figure 5. Specimens for the analysis of mechanical tests

For physical and resistance tests, the cubes were placed in a Compressive Strength Test machine, or servicing fractures in some cases, as shown in Figure 6. It is important to note that even after the stress test and the failure presented in the solid, it does not completely crumble.



(a) (b)

Figure 6. Representative sample a) before and b) after the compression test

Resulting in certain favorable pieces without fractures in its surface and constitution, at the end of the tests, part 3 obtained greater compressive strength. Qualitatively the observations are presented in Table 2. In addition, Figure 7 presents representative images of the failures presented. The quantitative results are shown in Table 3.

Table 2. Linear retraction results

No.	Retraction (% V/V)	Cracked	Adhesion
2	1.5	No	Loud
4	1.4	No	Loud
3	1.3	No	Loud
5	0.9	No	Casualty
8	0.8	No	Casualty
9	0.1	deformed	Loud
10	1.2	No	Loud
11	0.1	deformed	Casualty
13	1.2	No	Loud

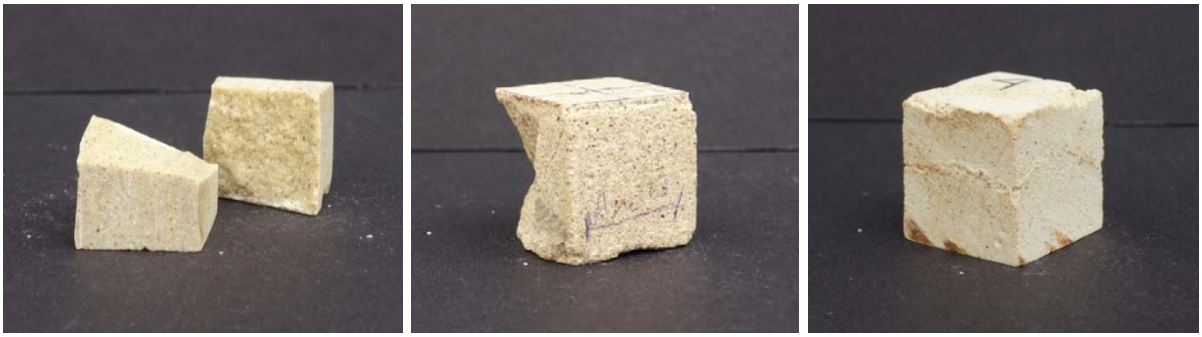


Figure 7. Photographs of the sample example observing various properties such as a) breakage, b) fragmentation but without detachments of small pieces c) failure without breakage

Table 3. Results of compressive and flexural resistance (error<2.5%)

No.	Compressive Strength (kg/cm^2)	Flexural Strength (kg/cm^2)
2	24.3	3.1
3	63.5	6.9
4	52.3	6.1
5	25.14	3.8
8	54.7	6.1
10	31.5	3.9
13	13.5	1.6

To check and measure their resistance to the outdoor, they underwent in triplicate an accelerated aging machine for a month, which is shown in Figure 8.

This machine has the purpose of reproducing the damage caused by sunlight, rain, and dew. In a few days or weeks, QUV equipment can reproduce the damage that occurs over months or years outdoors. To simulate outdoor weathering, the accelerated QUV equipment exposes materials to alternating cycles of UV light, controlled condensation, and high temperatures. It simulates the effects of natural sunlight and artificial irradiance using special fluorescent UV lamps and simulates dew and rain with condensed moisture and/or water spray.

The treated samples show that after the aging tests, the proposed putty (photo left) does not present significant changes or fractures to the camera exposure for 40 days and which is shown in Figure 9.

Figure 8. Accelerated aging chamber used in the test

Figure 9. a) solid image from putty and b) rock image

Figure 10. Interface of the two components. The union of a selected putty plate with a rock presents a homogeneous union without separations, after the exposure of the accelerated aging chamber

The results are shown in Figure 9 and Figure 10, highlighting that the mass does not suffer damage in a month. Therefore, it could withstand an outdoor environment for years. This equates to minimum durability of 15 years under normal pressure and ambient temperature conditions.

3.1. Observations of the Mixture Developed for Sculptural Pieces and Architectural Restoration

The components of putties for modeling over time have been very varied. They were usually elaborated by the same master sculptors or art restorers in their workshops with formulas that were like a secret.

In this sense, this product has been created for specific purposes such as recovering the appearance, functionality, and aesthetic values of restoration of a piece, as well as the creation of a new putty with a sandy and stone-like characteristic.

Unlike other commercial putties, this one has the advantages found in Table 4.

Table 4. Characteristics of the mixture for use in sculptures and buildings

Consistency	Liquid	☐	Thick	■		
Application	Manual	☐	Pouring	■	Spatulas	■
Can be modeled	No Yes	☐		■		
Working time	More than 12 hours					
Drying time	24 hours					
Color and texture variation	High	☐	Medium	☐	Low	■
Contraction	High	☐	Medium	☐	Low	■
Cracking	High	☐	Medium	☐	Low	■
Dry hardness	High	■	Medium	☐	Low	☐
Porosity	High	☐	Medium	☐	Low	■
Polishing leveling	High	■	Medium	☐	Low	☐
Aging	Fast	☐	Slow	☐	Slow	■
Waist	Easy	■	Medium	☐	Laborious	☐
Adhesion	High	■	Medium	☐	Low	☐
Reversibility for post-drying work	Good	☐	Bad	☐		
Safety for human beings	High	☐	Medium	☐	Low	■
Compressive strength	High	■	Medium	☐	Low	☐
Flexibility first 12 hours	High	■	Medium	☐	Low	☐
Contraction	High	☐	Medium	☐	Low	■
Physical-chemical stability over time	High	■	Medium	☐	Low	☐
Preparation	Easy	☐	Medium	☐	Expensive	■
Isotropy, temperature and humidity	Good	■	Zero	☐	Average	☐

4. Conclusions

A mass was obtained from the previously developed putty called: "Putty with outdoor drying sands for modeling and restoration of sculptural pieces", adding new elements whose specific purposes have been selected in this new mass such as the sandstone finish.

With the mass obtained, several models of replicas of representative lump sculptures were made, several models of bulk replicas representative of the sculptural heritage of the Olmec and Huastec culture were made with satisfactory results in which the sandstone type finish is appreciated. They have great firmness and resistance to wear.

From the mechanical tests it is found that the solid obtained from 24 to 63kg/cm^2 and are compatible with rock-based materials and solids.

With this study it was found that with this product you can restore and model sculptural and architectural pieces with a stone finish with great durability, so it can be applied.

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