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DETERMINING THE USE OF NOPAL MUCILAGE IN THE CONSTRUCTION IN COLONIAL TIMES (CASE OF CONVENT OF SAN DIEGO)

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Abstract. This research aims to determine the existence or not of organic components from the analysis in mortar fragments of the San Diego convent located in the historic center of the city of Quito – Ecuador. The investigation of the nine (9) samples of mortars were taken from the building that corresponds to the colonial era. The samples are: adobe, floor mortar, and plasters. These fragments correspond to different construction periods ranging from: 1597 to 1700. The present investigation determined that in the mortars analyzed there is the presence of the prickly pear mucilage. To perform an assessment mucilage patterns were obtained. For this two samples of the prickly pear cactus were taken. The first sample was obtained at room temperature, the same one that is light and sticky to the touch. The second one was extracted by means of cooking at a temperature between 90 to 100 ° C. This sample to the touch is much denser and more adherent. Likewise, the use of lime was added by comparing the action of quicklime with respect to the lime (drowned), which generates additional plasticity in the material. With these patterns the comparison of the model obtained from the old mortars was made; as a result, the patterns that coincide with each other are the spectra obtained by cooking with the one obtained from the old mortars. Therefore, this determines that the nopal mucilage was used in construction in the colonial era.

Keywords: mortars, analysis, mucilage, lime.

DETERMINACIÓN DEL USO DEL MUCILAGO DE NOPAL EN LA CONSTRUCCIÓN DE LA ÉPOCA COLONIAL (CASO CONVENTO DE SAN DIEGO)

Resumen. Esta investigación pretende determinar la existencia o no de componentes orgánicos a partir del análisis en fragmentos de morteros del convento de San Diego localizado en el centro histórico de la ciudad de Quito - Ecuador; se realizó la investigación de nueve (9) muestras de morteros tomadas de la edificación que corresponde a la época colonial, las muestras son: de adobe, mortero de pisos y enlucidos, estos fragmentos corresponden a diferentes periodos de construcción que van desde: 1597 a 1700; la presente investigación determinó que en los morteros analizados hay la presencia del mucílago de nopal. Para realizar una valoración se obtuvieron patrones del mucilago, para esto se tomaron dos muestras de la baba de nopal: la primera muestra fue obtenida a temperatura ambiente, la misma que al tacto es ligera y pegajosa, y la segunda muestra fue extraída por medio de cocción a una temperatura de entre 90 a 100 C°, esta al tacto es mucho más densa y adherente. Así mismo, el uso de la cal fue añadido comparando la acción de la cal viva, respecto a la cal apagada (ahogada) lo que genera plasticidad adicional en el material. Con estos patrones se realizó la comparación del patrón obtenido de los morteros antiguos, como resultado se obtuvo que los patrones que coinciden entre sí son los espectros obtenido por cocción con el obtenido de los morteros antiguos, lo que determina que se utilizó el mucilago de nopal en la construcción en la época colonial.

Palabras claves: morteros, análisis, mucilago, cal.

Introduction

Based on studies carried out in Mexico, where they maintain a tradition of the use of nopal in construction that dates back to pre-Hispanic times, it is assumed that it was used in the manufacture of adobe and lime mortars, due to the great advantages provided by this binder. natural, favoring so that these elements do not have a quick drying, avoiding in this way the breaking of the material and improving its mechanical properties. (Hernández, Coronado, López, & Horta, 2008).

The purpose of identifying the use or not of an organic binder is proposed in this research, in this case the nopal mucilago (*Opuntia ficus)* in existing heritage buildings in the historic center of the city of Quito - Ecuador, it is important to verify whether or not the nopal slime was used in the old mortars.

The use of nopal mucilage in traditional mortars is important since, in combination with lime, it increases its adhesive properties, improves mechanical characteristics and allows mortars to dry more effectively, in addition, it helps retain the moisture that traditional mortars need. to set correctly, and these improve their impermeability to water, particularities that will allow optimizing their use or application in the restoration and protection of heritage buildings.

For this research samples of the San Diego Convent were chosen, this building was considered to be one of the least intervened buildings that retains a high percentage of originality in its construction system and original materials with which they were used in its construction, in addition, there is a great particularity in this building, since it has five (5) well-defined construction periods ranging from the year 1597 to the year 1750, this will help us to identify if in each of the construction periods of the monument the same were used traditional techniques and materials for its construction; For the investigation and analysis of the mortars, the samples were taken, for which authorization had to be requested from the ecclesiastical authorities in charge of the convent, which allowed the collection of only two (2) samples for each construction period that has the building.

Construction periods:

Period 1: Main Cloister (1597-1609).

Period 2: Patio de la Pila Cloister (1700).

Period 3: Patio de la Pila Cloister, North Crossing (1714).

Period 4: Cloister of the Refectory (1731-1734).

Period 5: Novitiate Cloister (1750).

The building of San Diego, despite its years, preserves its majesty, presents a great solidity in its walls and stone columns from the seventeenth century. The different cloisters that make up the building have interior patios that are connected to each other through galleries where you can see the large arches on the ground floor and porticoes on the upper levels, the corridors in the upper galleries are illuminated by means of well-known architectural elements like flashlights. The walls on the ground floor are made up almost entirely of adobe covered by clay plasters and on the upper floor its structure is built in wood that in certain cases are tied with halter and wattle made up of reed and covered by a mud cake, its ceilings are made of reed tied with chilpe, zuro and clay. (Kennedy Troya & Ortiz Crespo, 2010)

Figure 1. Main facade of the convent of "San Diego" Quito - Ecuador.

Note: Own Source, 2019

The Nopal, are shrubby, creeping or erect plants, they acquire an average height of 3 to 5 m in height, in its growth it branches densely, it has a system rich in fine roots that are quite absorbent, it generally grows in arid areas with little rainfall. , the length of the roots depends on the hydric conditions of the land where it is grown, there are many industrial sectors that benefit from the exploitation of nopal, among them is the construction sector that use it as a binder and in the preparation of lime-based paints. (Sáenz, 2006)

In Ecuador it can be found throughout the Inter-Andean region, currently due to ignorance or loss of ancestral knowledge about the handling of materials and traditional construction techniques, its use is only edible from the fruit that the penca produces.

The chemical composition that certain authors cite is the following:

Table 1

Chemical composition of prickly pear

Chemical composition of slime	**Chemical composition of mucilage**
Water 91%, proteins 1.5%, lipids 0.2%, carbohydrates 4.5%, ash 1.3% rich in calcium (90%), vitamin C, carotenoids and fiber	Polysaccharides: galactose, arabinose, rhamnose, xylose and galacturonic acid.

Note: Source: Rodriguez-Felix & Cantwell (1988)

Figure 2. Nopal plant
Note: Own source, 2019

Methods for obtaining patterns

In order to carry out the investigation of the mortar samples obtained from the building, the analysis of the samples of the nopal slime and slaked lime was first carried out in the laboratory.

To study the benefits of nopal, it was necessary to extract the mucilage from the stalk by using two methods, these being cooking and at room temperature, these two techniques were chosen because between the two they present differences in results between Yes, which allows us to establish different properties of the mucilage between each of the procedures, the established methods are:

- Method by cooking
- Soak or standby method

There is no standardization of the proportion for the extraction of the mucilage between water / nopal at room temperature and by cooking the nopales, however, for this research the ratio 2: 1 (water: nopal) will be considered; This emulsion is a thick substance that is obtained from the tuna pallet preserving its properties, for this purpose, the prickly pear trees were selected and collected, from which only certain stems were cut, leaving their main trunk so that in This will sprout new shoots.

Figure 3. Collection of the nopal plant.
Note: Own Source, 2019

For the use of the nopal, first each of the leaves was cleaned, proceeding to remove the thorns to prevent them from adhering to the skin, later it had to be cut into small pieces in the shape of squares of more or less 2 cm in length, this in order to facilitate and obtain a greater quantity of the mucilage from the nopal penca. (Abraján Villaseñor, 2008)

Nopal slime extraction

First method: at room temperature, the cut nopal was placed in a plastic container and then covered with clean water in a ratio of 1: 2, that is, 1 kg of nopal and 2 liters of water, then the container and daily this mixture was stirred in a circular way with a wooden stick, in this case the emulsion of the mucilage was obtained after 2 days. Next, the liquid containing the cactus slime was filtered by gravity using a fine mesh plastic strainer to separate the fibrous residues; By means of this method the nopales can be used for a second time to obtain more mucilage, in this case the process is repeated and the stalk is crushed with a wood to get more quantity of nopal emulsion, by means of this method the The mucilage that is obtained is of a light viscosity and a not very dense texture, but it maintains its adhesive characteristic.

Figure 4. Cutting the nopal leaves and obtaining the nopal at temperature

Note: Own Source. 2019

Second method: the cleaning and cutting process was repeated, the proportions of both nopal and water were maintained, then a cooking procedure was carried out at a temperature between 90-100 ° C for 120 minutes, to extract the greatest quantity of mucilago possible during the cooking period, the nopal was crushed so that it looses as much as possible all the slime that the stalk has, then it was left to rest so that the solids sediment and the liquid was cooled, thus obtaining the mucilage, to separate solid fiber fragments containing fluid filtered by gravity; With this process it was observed that an emulsion containing mucilage was obtained with a thicker and stickier consistency. (Leon, 2010).

Figure 5. Obtaining nopal through the cooking process.
Note: Own Source, 2019

Once the mucilage samples were acquired, both at room temperature and when cooked, they were placed in plastic containers and in the laboratory (INPC), where they were analyzed to obtain their patterns by using the *Infrared Spectroscopy* method.

To determine the chemical composition of the components that make up the different samples of the mortars, as well as the reference substances that they maintain for a possible application in them, this is intended to clarify through the use of the laboratory technique of infrared spectroscopy, and in the same way obtain as much analytical information as possible about its ingredients. To carry out the analyzes and proceed to obtain the patterns, different mortar samples were used, these correspond to different periods of construction of the San Diego convent.

Description and location of samples

Figure 6. Delimitation of the construction periods of the San Diego Convent with the sample points
Note: Own Source, 2019.

Table of location of the points that indicate the origin of the samples in the building of the mortars analyzed:

Table 1
Sample Location

Number	INPC code	Sample / Location	Observations
1	07-19-5	Arch Cemetery Mortar Restoration 2007	It was subjected to an ethyl acetate treatment after reading
2	07-19-6	Cemetery Wall Mortar	It was subjected to an ethyl acetate treatment after reading
3	07-19-7	Mampuesto Mix of the Enclosure (adobe)	It was subjected to an ethyl acetate treatment after reading
4	07-19-8	Pario de la Cruz mortar, east corridor	It was subjected to an ethyl acetate treatment after reading

5	07-19-9	Wattle mortar patio of the pile 2nd floor (east)	It was subjected to an ethyl acetate treatment after reading
6	07-19-10	Bahareque mortar patio of the pile 2nd floor (north)	It was subjected to an ethyl acetate treatment after reading
7	07-19-11	Modern repair mortar cladding	It was subjected to an ethyl acetate treatment after reading
8	07-19-12	Mortar to set the 2nd floor pastry floor	It was subjected to an ethyl acetate treatment after reading
9	07-19-13	Mortar Masonry theater access room 2nd Floor	It was subjected to an ethyl acetate treatment after reading

Note: Source: INPC Laboratory and Analysis Unit, 2020

Results

Organoleptic analysis of materials

To carry out the organoleptic analysis of the materials of both additives (nopal mucilage) and the binder (lime), the samples were provided:

- Nopal mucilago, obtained at room temperature and by cooking.
- Lime, quicklime sample and hydrated lime (slaked)

Nopal. - To know the physical state of the sample, two types of Mucilago samples were used: the nopal slime was obtained at room temperature (decomposition process) and the other sample was cooked at an average temperature of 80 ° C.

Physically these samples show differences. In the case of mucilage "cooked" at 80 ° C, it was observed that it is more viscous, and its sensory adhesion capacity is better compared to macerated mucilage, which is lighter in appearance. The mucilage has a main characteristic that is the viscosity, for our case, the same that is projected to be used in the application as an additive for use in construction and paints (Vargas-Rodríguez, et al., 2016)

Figure 7. Mucilage cooked at 80 ° C, and its effectiveness as an adhesive.
Note: Own Source, 2019

Lime.- binder that has its own natural adhesion and cohesion qualities to bind aggregates, and that notices a chemical reaction that hardens it, in this case it was provided:

- Quick lime powder.
- Slaked lime.

Quicklime is found in nature as limestone, this is obtained by processing it in ovens at high temperatures, in this action it is when it releases CO2 and the so-called "quicklime" is obtained, which is highly reactive in contact with water, resulting in a lumpy material.

Slaked lime [Ca (OH) 2], which is obtained as a result of having immersed quicklime in water for a period of time, the longer the slaking cycle, this will improve its purity, it is also known As "calcium hydroxide", as a result of this process it is presented as a fine paste with a purity of between 70 and 80%, qualities that determine its use in construction or in preparing canvases for painting. (Villalobos Ruiz, 2014)

Mud, its main components are feldspars, it is a mixture of sodium, potassium and calcium aluminosilicates, mainly with low quartz content (<12%), consistent with the mineralogical composition of the sedimentary soils of the inter-Andean valley.

Materials analysis by infrared spectroscopy

The laboratory uses the specific test procedure PEE-LAB-INPC-04 for Analysis by Infrared Spectroscopy FTIR-ATR1. This technique uses radiation in the infrared range and through signals in the form of peaks, which allow us to identify certain functional groups or molecular interactions, and in this way determine the substances to be investigated.

In some cases, due to the interest in certain functional groups, it is necessary to extract them from the matrix that contains them, for this the principle of elutropic series (solubility series) applied in liquid chromatography is used.

Analysis of standard or reference substances

The reference substances obtained were mucilage obtained from nopal and lime. These substances, as indicated on the labels, were subjected to different physical and chemical treatments in order to improve certain mechanical properties, adhesiveness and cohesion.

The samples in aqueous medium cannot be measured with the FTIR-ART equipment, because the water interferes with the signals of the samples. In order to carry out the readings without interference, the excess liquid of these substances is evaporated, and they are immediately placed on the ATR glass in order to obtain a suitable spectrum.

In order to adapt the samples to the protocols used in the laboratory, a code was provided for each one of them. This information is presented below in the following table.

Table 3
Reference Substances

INPC code	Sample	Observations
07-19-1	Mucilago extracted from nopal in water, heated to 90-100 ° C	It was subjected to an evaporation treatment for its reading
07-19-2	Mucilage extracted from nopal in water, by macerating for 7 days	It was subjected to an evaporation treatment for its reading
07-19-3	Lime slaked for 18 months	It was subjected to an evaporation treatment for its reading
07-19-4	Quicklime	No treatment

Notes: Source Laboratory and Analysis Unit INPC, 2020

Mucilage

The measurements made were made with the FTIR-ATR equipment, whose results are presented in Transmittance vs. wave number. The signals indicated in figure 9 are the product of molecular interactions (spectral vibrations), which the mucilage presents against an infrared beam. These data indicate that there are small variations between mucilage obtained at 80 ° C (cooked) and mucilage at room temperature. It can be seen that cooked mucilage has a larger signal around 1000 cm-1 compared to uncooked mucilage.

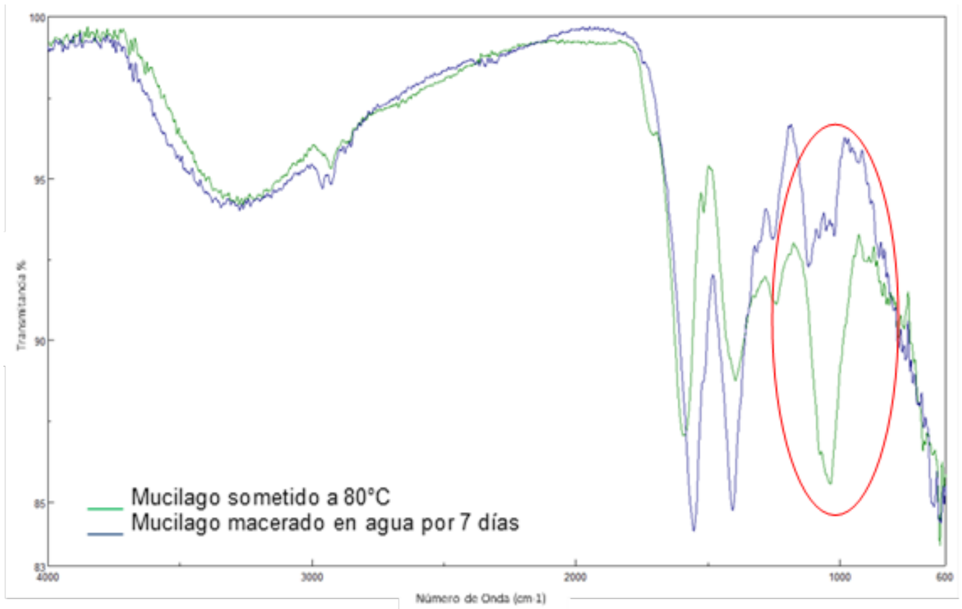

Figure 8. Spectra of mucilages obtained by FTIR-ATR.
Note: Source: INPC Laboratory and Analysis Unit, 2020

In order to interpret the previous result, the peaks found in the spectrum of mucilage cooked at 80 ° C are described.

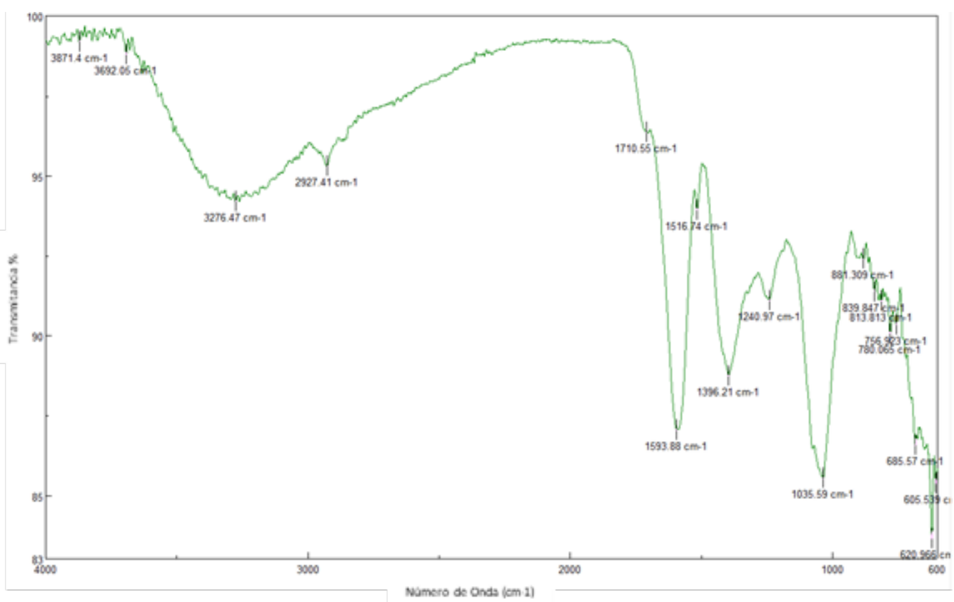

Figure 9. Mucilage spectrum subjected to 80 ° C (cooked) obtained by FTIR-ATR..
Note: Source: INPC Laboratory and Analysis Unit, 2020

Also, the mucilage is subjected to the previous procedure at room temperature macerated for 7 days.

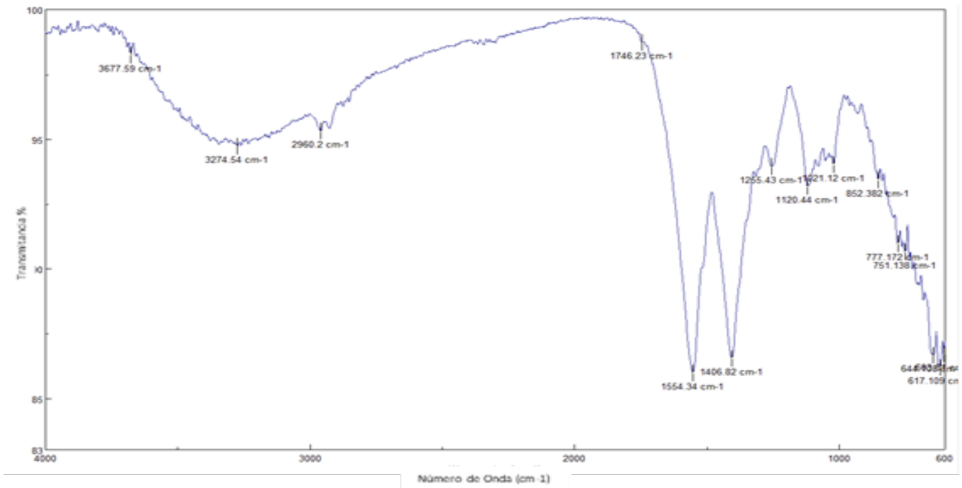

Figure 10. Spectra of mucilage macerated in water for 7 days obtained by FTIR-ATR.
Note: Source: INPC Laboratory and Analysis Unit, 2020

The FTIR-ATR spectrum of various types of mucilages are characterized by having a reading of values2 ranging from 1000 cm-1 to 2000 cm-1, it identifies the largest number of chemical groups that provide information that can be used to differentiate the different types of mucilages. According to bibliographic sources, the presence of these functional groups can be explained in the following way.

The presented spectra present signals or stretching bands in OH alcohol groups (3100-3600 cm-1), they appear due to the formation of hydrogen bonds of these functional groups, these vibrations, together with the signals of CH, CH2, CH3 (methyl, methylene and methine group) which are stretch bands (3000–2800 cm -1).

The strongest signals occur in the common fingerprint region of polysaccharides or carbohydrate units (1300–1050 cm − 1). As well as the 1200-1800 cm-1 region of the carboxyl group state.

However, the region between 1000-2000 cm-1 identifies the greatest amount of chemical groups, which provides information that can be used to differentiate the different types of mucilages.

Between the wave numbers of 1200 to 900 cm-1 there are monosaccharide and polysaccharide type sugars, at 1750 cm-1 aldehydes typical of sugars are present, at 1100 cm-1 there are esters associated with these same sugars that are part of the mucilages. These sugars are called arabinose, rhamnose, galactose and xylose (Aguilar Reynosa & Rodríguez, 2010). These sugars guarantee adhesiveness and cohesion together with other elements that make up the mortar.

Quick lime and slaked lime

These substances were subjected to a drying treatment to eliminate excess water that interferes with the analysis. The readings below are adjusted to determine spectral similarities and differences between these two materials. Concordances can be observed in three peaks of the patterns, these are located approximately at 3600 cm-1, 1400cm-1 and 800 cm-1, which are presented in the following figure.

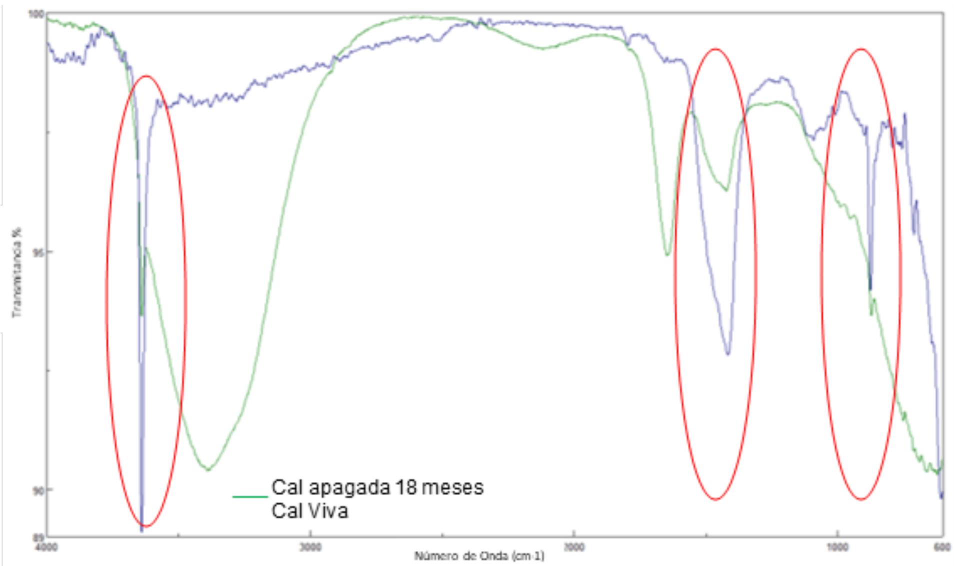

Figure 11. Spectra of lime types obtained by FTIR-ATR.

Note: Source: INPC Laboratory and Analysis Unit, 2020

To identify the different anomalies or changes in the spectral readings, the quicklime and slaked lime are read separately, being able to obtain the wave number values individually, which allows us to obtain an adequate identification of them.

The infrared spectrum of slaked lime is presented below

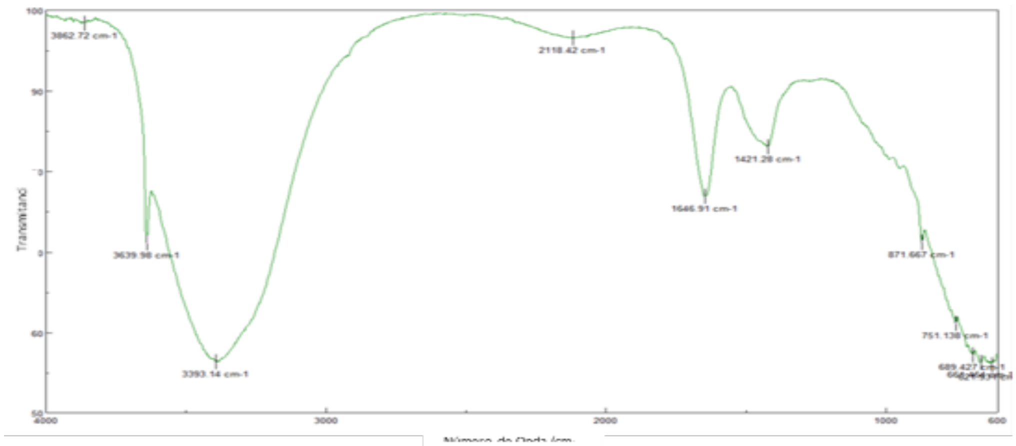

Figure 12. Spectrum of slaked lime obtained by FTIR-ATR
Note: Source: INPC Laboratory and Analysis Unit, 2020

Likewise, quicklime has the following wave number values, as indicated in the following graph.

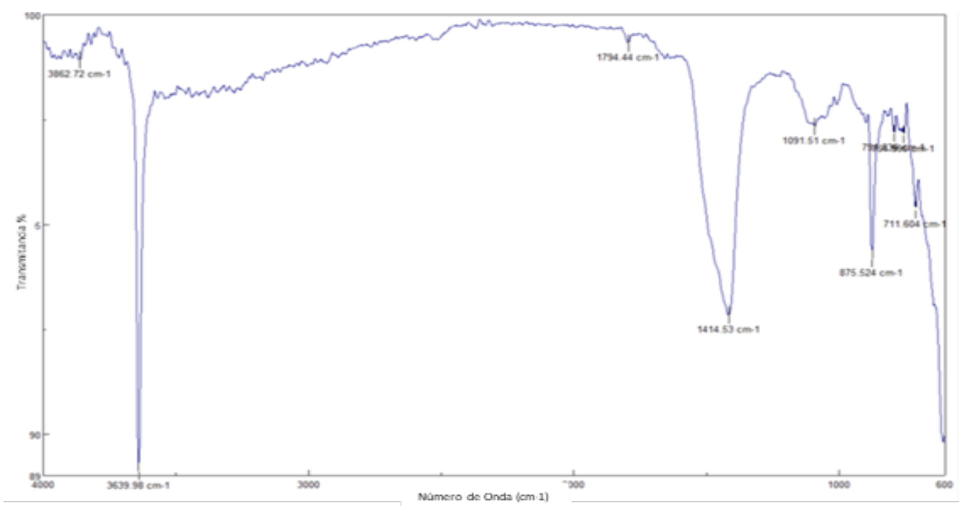

Figure 13. Spectrum of quicklime obtained by FTIR-ATR
Source: INPC Laboratory and Analysis Unit, 2020

Mortar Samples

As the samples are in solid state, it was necessary to extract the substances of an organic nature. For this, the protocol for handling organic samples in soil recommends extracting the samples with ethyl acetate, due to its intermediate elution strength (0.58 in the Snyder3 series), very commonly used in chromatographic separations. For this reason, the solvent should only drag the possible related organic substances found in the samples and read them after their evaporation. For the analysis by FTIR-ATR, the spectral region between 1800 to 600 cm-1 corresponding to the fingerprint area of the spectra was used. Not all the infrared spectral area measured provides us with information to compare. That is why, the measurement area of the spectra is restricted and, in a more didactic way, they will be separated in scales of the graphs in transmittance vs wave number.

On the basis of the FTIR-ATR spectroscopy analysis, the different spectra were compared with the reference substances (cooked mucilage4 and slaked lime), prepared exclusively to determine their possible production technology. Through the "Knowitall" software, we can compare and superimpose these spectra digitally.

Almost all the samples show the same peaks as the nopal reference at 80 ° C. There were only two samples that were unrelated, these were: modern repair mortar for the enclosure, mortar for laying the 2nd floor pastry floor. This information is presented in the following graph.

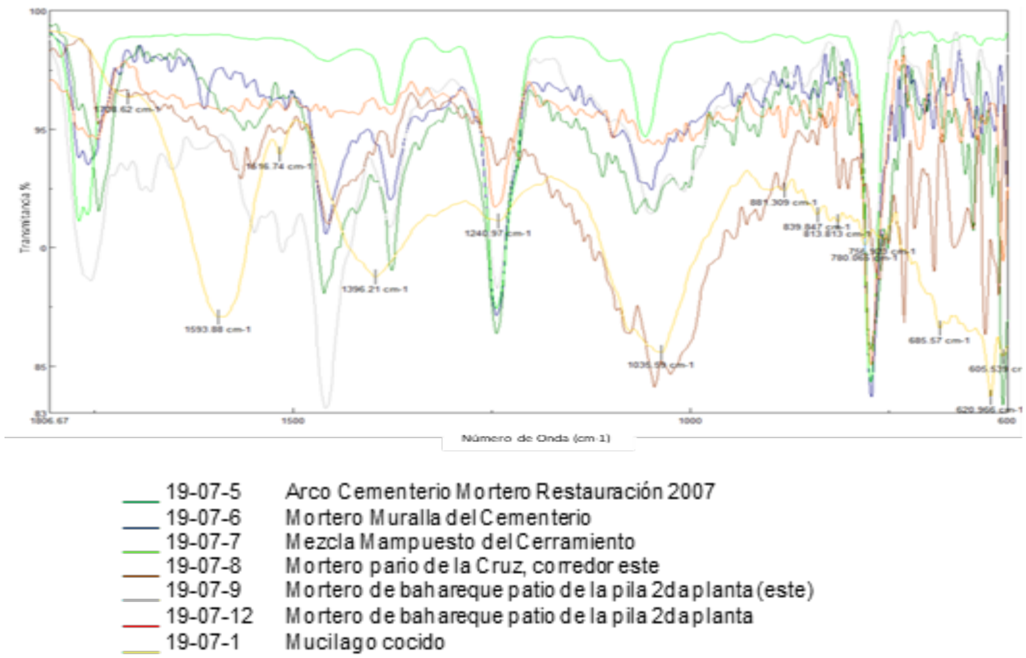

Figure. 14. Spectra the samples vs the cooked mucilage

Note: Source: INPC Laboratory and Analysis Unit, 2020

The information that matches the spectra of nopal with the samples is detailed below. In this case, it was determined that the spectra corresponding to the sample areas: bahareque mortar patio of the 2nd floor pile (north) and mortar masonry, access room to the 2nd floor theater, had bands in 1455.99 cm-1 that are Alcohols (CO), 1375.96 cm-1 (CO) corresponding to esters and 1102.12 cm-1 (HO-COO) which are carboxylic acids. Despite having an organic nature, in themselves they do not define, like the rest of the spectra, a possible addition of binding materials such as mucilage.

A more detailed way to identify the spectra is to compare each of the samples against the reference substances, such as mucilage and slaked lime. We will divide the spectral ranges into groups and we will also differentiate the organic components and the lime.

Spectral range from 1520 - 1500 cm-1

The mucilages have a remarkable characteristic in different spectral bands, to begin with, the peaks shared by the samples and the mucilage can be observed at wave numbers 1593.88 cm-1 (NH) that correspond to amino, 1516.74 cm-1 (CO) corresponding to alcohols.

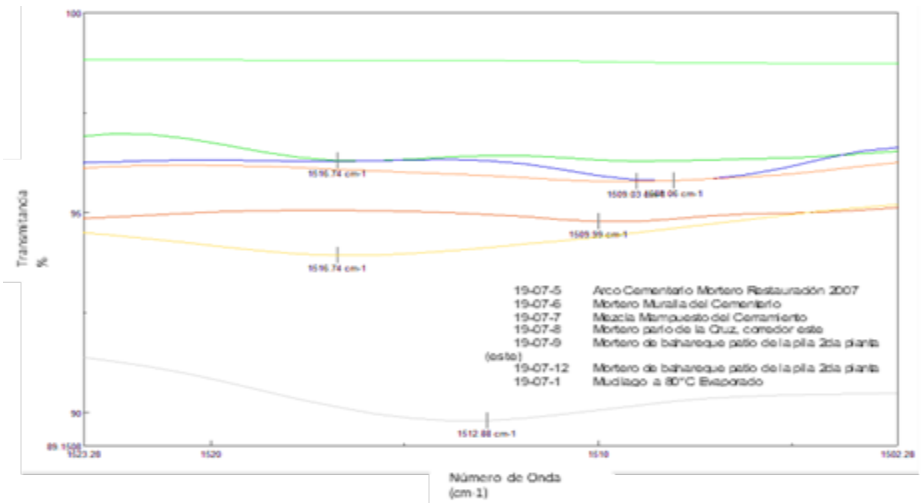

Figure. 15. Spectra of the samples vs the cooked mucilage range between 1520-1500 cm-1.

Note: Source: INPC Laboratory and Analysis Unit, 2020

Spectral range from 1450 - 1300 cm-1

To verify the existence of alcohols and esters, this range is chosen within the spectrum. What was identified was that there is another band that corresponds to a mucilage component located at 1396.21 cm-1 (C-O) and corresponds to an ester.

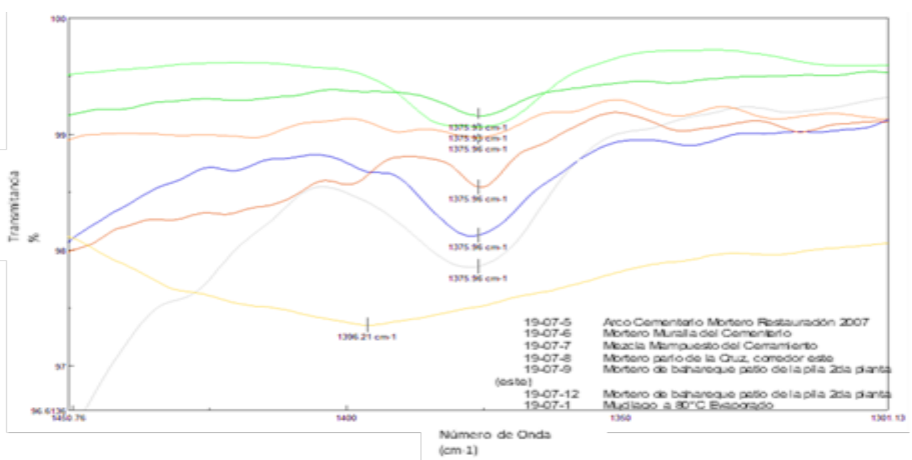

Figure. 16. Spectra of the samples vs the cooked mucilage range between 1450-1300 cm-1.
Note: Source: INPC Laboratory and Analysis Unit, 2020

Spectral range from 1300 - 1100 cm-1

Within this zone, the functional groups of carboxylic acids are found, in peaks around 1240.97 cm-1 (HO-COO).

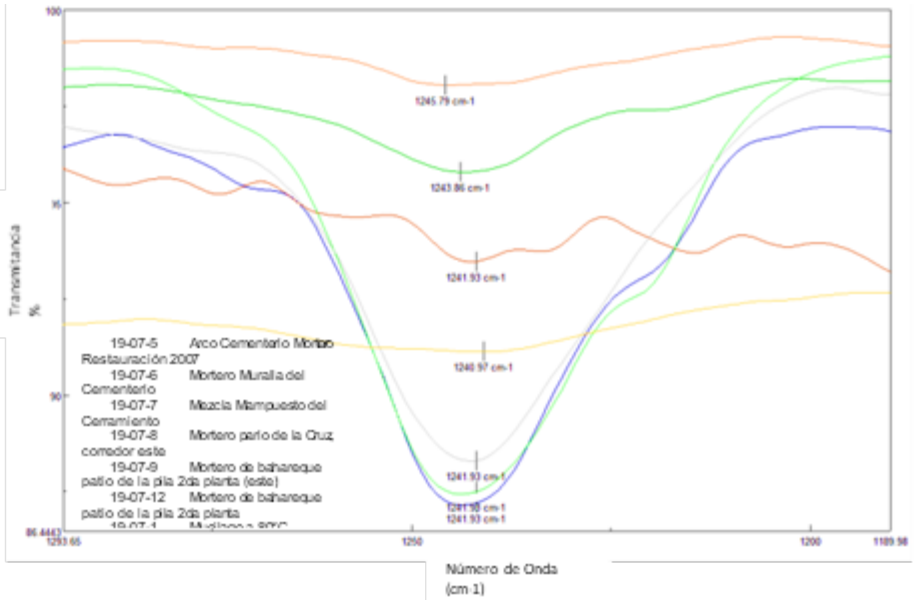

Figure. 17. Spectra of the samples vs the cooked mucilage range between 1300- 1100 cm-1.
Note: Source: INPC Laboratory and Analysis Unit, 2020

Spectral range from 1100 - 960 cm-1

This spectral zone is one of the most important since alcohol groups are manifested. In the peak located at 1035.59 cm-1 (C-O) they correspond to this group, located in the reference substances and in all the samples.

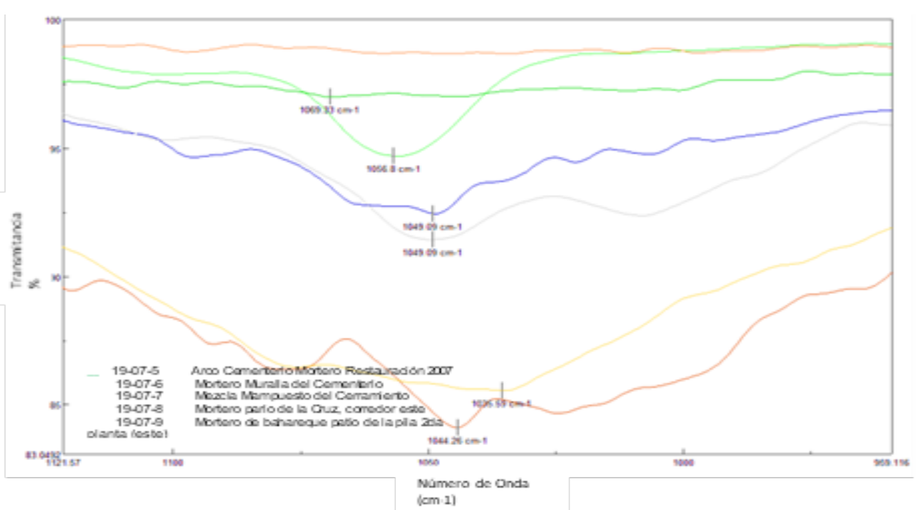

Figure. 18. Spectra of the samples vs the cooked mucilage range between 1100-960 cm-1.
Note: Source: INPC Laboratory and Analysis Unit, 2020

Spectral range from 960 - 600 cm-1

Finally, in peaks at 771 cm-1 (C-C) that correspond to branched carbons, 685.57 cm-1, and 621 cm-1 (C-C) that belong to linear carbons, compounds that are part of mucilages.

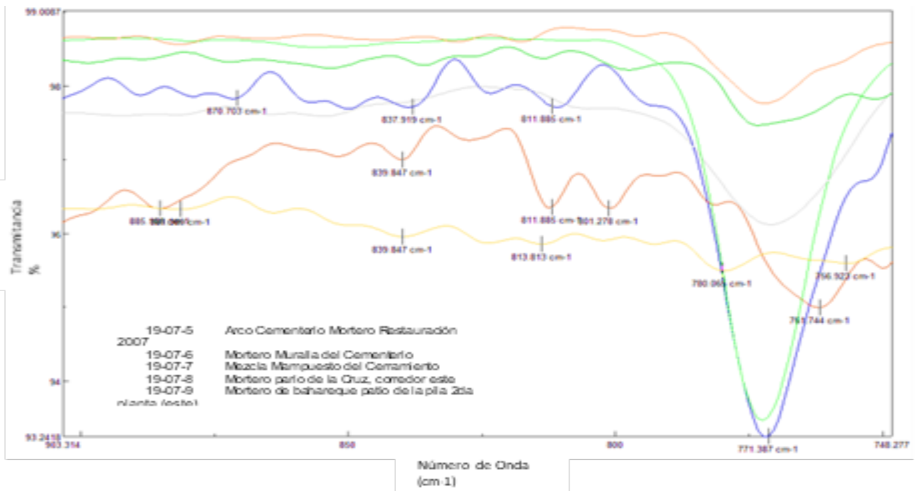

Figure. 19. Spectra of the samples vs the cooked mucilage range between 960 - 600 cm-1.
Note: Source: INPC Laboratory and Analysis Unit, 2020

For the analysis of the presence of lime, the slaked lime standards were also compared with the samples delivered to the laboratory. In all cases there is the presence of lime in the mortars. To illustrate, the standard of slaked lime will be shown for months, with the samples of the arch cemetery mortar restoration 2007, the mortar of the cemetery wall and the mortar of the enclosure, which are equivalent to the mortars of the oldest construction stage.

The samples that do not contain the main nopal peaks themselves have been compared with slaked lime, the results are shown below.

Spectral range from 3700 - 2760 cm-1

We can see that the peaks at 3640 cm-1 corresponding to a Ca-O-H bond, typical of hydrated lime, in addition to a peak at 3400 cm-1 typical of an O-H bond.

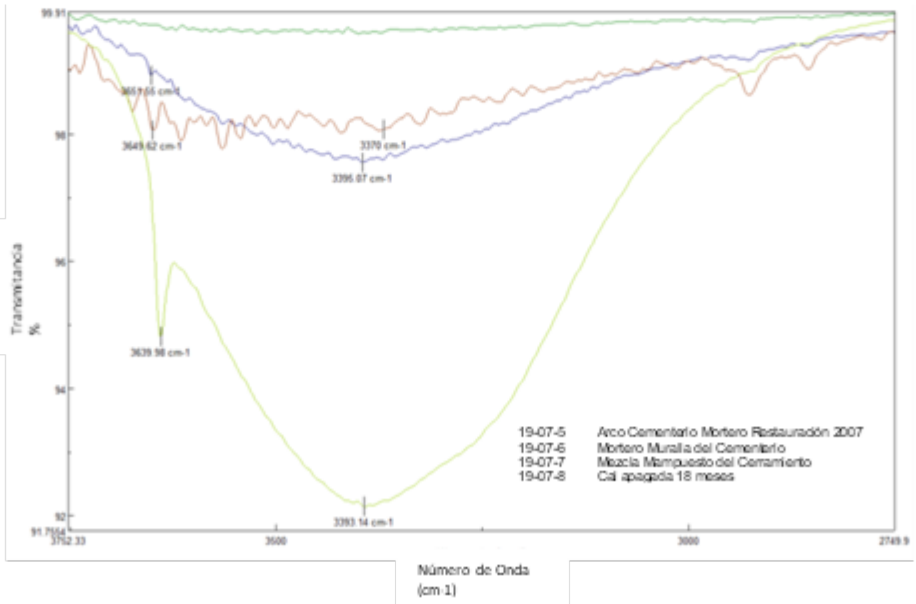

Figure. 20. Spectra of the samples vs slaked lime range between 3700 - 2760 cm-1.
Note: Source: INPC Laboratory and Analysis Unit, 2020

Spectral range from 1560 - 1270 cm-1

Within the same spectra, we can see that at 1647 cm-1 there is a Ca = O bond.

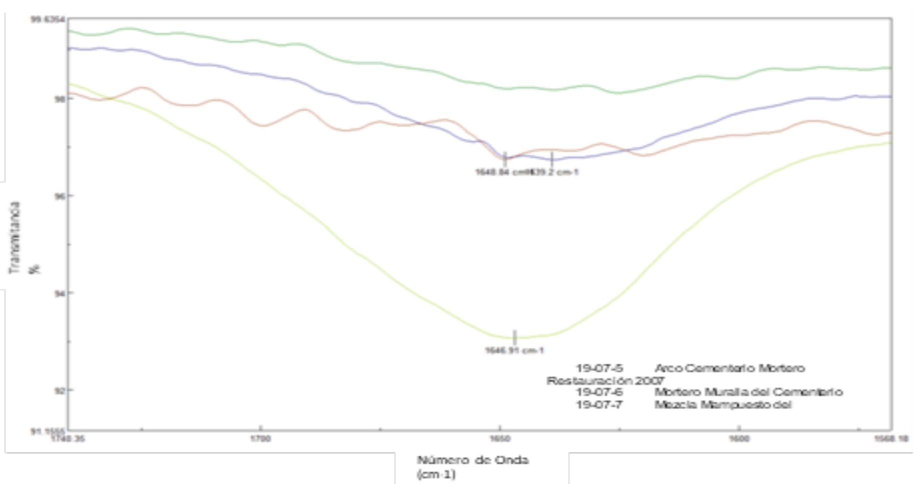

Figure. 21. Spectra of the samples vs slaked lime range between 1740 - 1560 cm-1.
Note: Source: INPC Laboratory and Analysis Unit, 2020

Rango espectral desde 1560 – 1270 cm^{-1}

In the analysis there is also another peak at 1420 cm-1 that corresponds to Ca-O

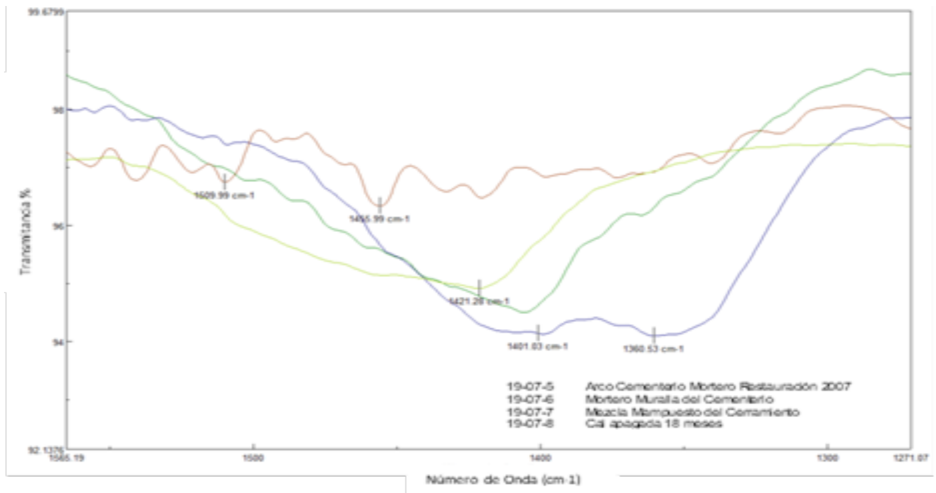

Figure. 22. Spectra of the samples vs slaked lime range between 1560 - 1270 cm-1.
Note: Source: INPC Laboratory and Analysis Unit, 2020

Spectral range from 880 - 600 cm-1

Finally, there are not so well defined peaks, whose bands are at 870 cm-1, 750 cm-1 and between 680 to 620 cm-1, whose bonds could correspond to Ca-O bonds.

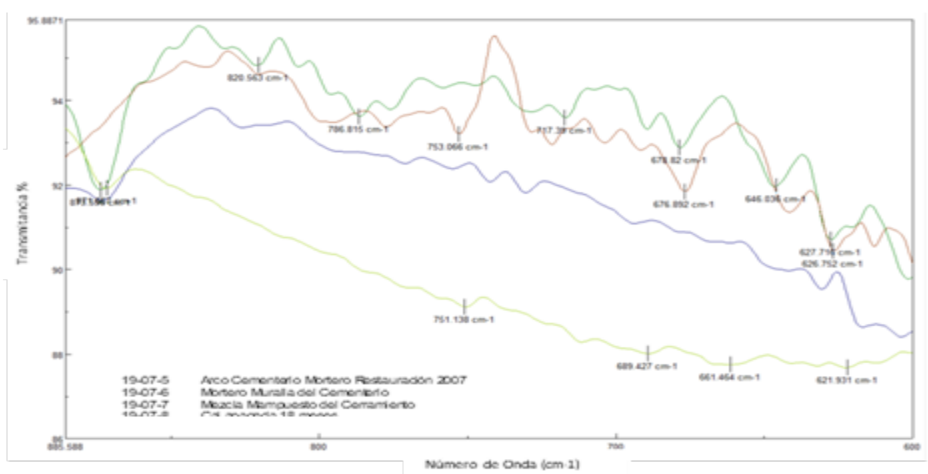

Figure. 23. Spectra of the samples vs slaked lime range between 880 - 600 cm-1.
Note: Source: INPC Laboratory and Analysis Unit, 2020

Summary of results and discussion

In summary, the 1455.99 cm-1 bands correspond to alcohol (CO), 1375.96 cm-1 (CO) ester and 1102.12 cm-1 (HO-COO) carboxylic acid present in the samples Patio bahareque mortar of the 2nd floor pile (north) and Mortar Masonry, access room to the 2nd Floor theater. The bands shared by the samples and the mucilage are: 1593.88 cm-1 (NH) Amino, 1516.74 cm-1 (CO) Alcohol, 1396.21 cm-1 (CO) ester, 1240.97 cm-1 (HO-COO) ac. Carboxylic, 1035.59 cm-1 (C-O) Alcohol, 771 cm-1 (C-C) branched carbons, 685.57 cm-1, and 621 cm-1 (C-C) linear carbons.

From the results set forth above, the functional groups found correspond to organic materials of natural origin, associated with nopal due to the similarities found to the measured pattern. This nopal compared was the one that was previously at boiling temperatures, dissolving these sugars and leaving them in solution. Once this mixture is obtained, it is easier to spread together with straws and clay, to obtain an optimal mortar in a suitable proportion.

The combination used in the mortar, in an appropriate proportion, manages to improve thanks to the properties of sugar, certain mechanical properties, adhesiveness and cohesion.

P Based on the foregoing, it can be ensured that the analyzed mortar samples contained organic matter similar to prickly pear under heating, these samples correspond to: arch cemetery mortar restoration 2007 (07-19-05), cemetery wall mortar (07-19 -06), mixture of masonry of the enclosure (07-19-07), east corridor patio mortar (07-19-08), adobe mortar patio de la pila 2nd floor (east) (07-19-09) , wattle and daub mortar 2nd floor pile patio (07-19-10).

Conclusions

It can be assured that the analyzed mortar samples contained organic matter similar to nopal, these samples correspond: to the arch of the cemetery mortar used in the restoration of 2007, mortar from the cemetery wall, mixture of the enclosure masonry, mortar from the cross, from the east corridor, wattle and daub mortar from the patio of the 2nd floor pile (east), bahareque mortar from the patio of the 2nd floor pile.

The spectral analysis of the previous mortar samples and the pattern of cooked mucilage coincide in a high percentage, which is why we can assert that they share the same chemical behavior.

Through the organoleptic analysis it was possible to appreciate the overall behavior of mucilage and lime in an unknown proportion, it provides better plasticity, adhesiveness and maintains the humidity of the mortar, which is why they persist until today, with a minimum degree of deterioration .

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