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An Experimental Study to Evaluate the Additives Used to Improving the Properties of Completing Mortars of Archaeological Stone Statues with an Application on Rams Road in Luxor- Egypt

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Abstract

This research aims to evaluate the used additives in improving the properties of completing mortars of archaeological stone statues with an application on Rams road in Luxor, Egypt. Stone samples were taken from these statues, analyzed by X-ray diffraction and examined by Polarizing and scanning electron microscope, soil and groundwater samples were taken to determine their components. The stone was found to be Nubian sandstone, the soil type was found to be sandy soil, and the soil contained halite due to the presence of groundwater at the site, which has a high salinity. An experimental study has been done to evaluate additives to improve the properties of the completion mortar, the materials are: Addibond 65, primal AC33, polyvinyl acetate (PVAc) , clay and fired bricks powder . The physical and mechanical properties were measured to choose the best mortar. The mortar A (Lime + Sand+ White cement + Limestone powder + addibond 65) (1:3 :1:1 : 15%) is the best one which had achieved the best values in physical and mechanical properties before and after artificial aging.

Keywords

Experimental study; Rams road; Completion processes; Mortar; Addibond 65; Primal AC 33.

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دراسة تجريبية لتقييم المواد المضافة المستخدمة في تحسين خصائص مونة استكمال التماثيل الحجرية الأثرية تطبيقا على طريق الكباش بالأقصر – مصر

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الملخص

يهدف هذا البحث إلى تقييم المواد المضافة المستخدمة في تحسين خصائص مونة استكمال التماثيل الحجرية الأثرية تطبيقا على طريق الكباش بالأقصر – مصر ؛ حيث تم أخذ عينات من هذه التماثيل وتحليلها بواسطة حيود الأشعة السينية والفحص بواسطة الميكروسكوب المستقطب والميكروسكوب الإلكتروني الماسح ، أيضا تم أخذ عينات من التربة والمياه الأرضية لتحديد مكوناتها ، ومن خلال الدراسة تبين أن نوع الحجر هو الحجر الرملي النوبي ، وأن نوع التربة هي التربة الرملية والتي احتوت على ملح الهاليت بنسبة كبيرة بسبب وجود المياه الأرضية ذات الملوحة العالية بالموقع ، أيضا تم عمل دراسة تجريبية لتقييم المواد المضافة لتحسين خصائص المونة ، والمواد المضافة هي الإديبوند ٦٥ ، البريمال AC 33 ، البولي فينيل أسيتات ، ومسحوق الطين والطوب الآجر، تم قياس الخواص الفيزيائية والميكانيكية لاختيار أفضل مونة يمكن تطبيقها بالموقع الأثري ، وقد تبين أن المونة A والتي تتكون من (الجير + الرمل + الأسمنت الأبيض + مسحوق الحجر الجيري + الإديبوند ٦٥) (بنسبة ١ : ٣ : ١ : ١ : ١٥%) هي الأفضل من بين المونات ، حيث حققت أفضل النتائج في قياس الخواص الفيزيائية والميكانيكية قبل وبعد التقادم الصناعي.

الكلمات الدالة

دراسة تجريبية؛ طريق الكباش؛ عمليات الاستكمال؛ مونة؛ الأديبوند ٦٥؛ البريمال AC 33.

Introduction

The Sphinx road (Rams road) is one of the largest ancient sacred roads built by the ancient civilization to connect the two largest sacred regions east of mainland Luxor [1].

The idea of discovering this sacred path began during the revolution on July 23, 1952 AD. At that time, president Gamal Abdel Nasser issued a decision number (441) that considered the route of Rams road as his one of public facilities. This road disappeared over the centuries, especially since in Roman times, the landmarks of the road disappeared under a layer of silt and soil, upon which many buildings were built: houses and places of worship, mosques and churches.

The road was dedicated to religious festivals and processions and was used for religious holidays, especially the Opet festival, which celebrates the marriage anniversary of the god (Amun) and his wife, the goddess (Mutt). The Luxor Temple was celebrated in the month of Baba (Coptic calendar month). The road from Karnak temple to Luxor Temple is about 2,700 meters long and has more than 1,200 statues on both sides. The actual road discovery and restoration project began on December 25, 2009. The path of the Rams is the road that connects the Luxor and Karnak temples. A wide street surrounded by sphinx statues started from the beach. They are seen in the Karnak temple, where they are in the form of a sphinx with a ram's head, but here the ram symbolizes the god Amun, presumably to protect the temple and emphasize its axis. The ancient Egyptians called this path "Wat-nTr",, which means 'God's Way', and the Ram's Path in Karnak Temple was known as “Ta-Mate-Arhant”, also translated as 'rams' [2] - Figure(1).

Figure 1. Road from Karnak Temple to Luxor Temple (according to satellite imagery - Report of the Supreme Council of Antiquities - Upper Egypt Antiquities Authority).

1. Weeks, K.R., (2005). The Illustrated Guide to Luxor – Tombs, Temples and museums, Stars s.p.a, Vercelli, Italy, 169.
2. Boraik, M., (2013). The sphinxes avenue excavations (In Arabic), second report chapters de Karnak, Supreme Council of Antiquities, 14, 13-32.

1. Description of the statues:

The seated lion sandstone with a ram's head under its head is a statue of king Ramesses holding the sign of the key of life (ankh) in both hands and is about one meter long. The statue stands on a sandstone pedestal measuring 3.85 meters long, 1.40 meters wide and 0.95 meters high, the statue is 1.50 meters high. At the top of the base is a cornice, below which is a stick - Figure (2-3).

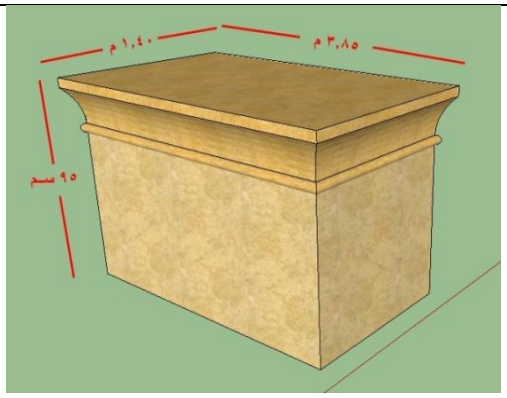


Figure 2. Dimensions of the base on which the rams are placed (Drawing: Author).

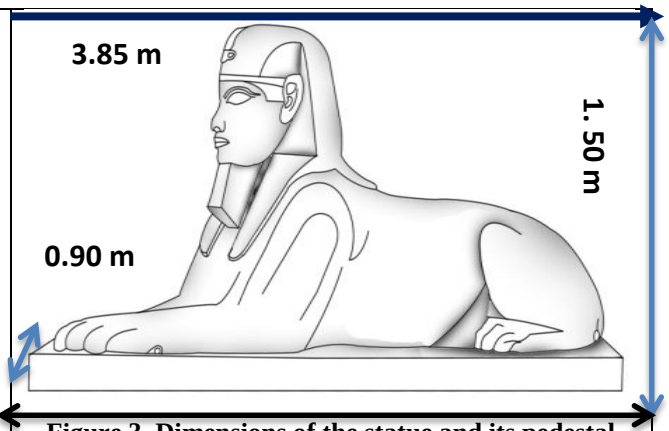


Figure 3. Dimensions of the statue and its pedestal (Drawing: Author).

The statues and pedestals show some phenomena of deterioration, the most significant being:

A. Some floors fell under the statues pedestals.

B. Cracks exist on many parts of the statues bodies and on the pedestal at various locations with various shapes.

C. Some parts of the statue's body are separated but still in place.

D. Several parts of the base are missing and incomplete, including those replaced by old mortars.

E. Old completion processes of some pedestals and statues bodies.

F. Some of the statues have completely separated upper parts.

G. Presence of intentional damage at bases and statues bodies as well as the pavement.

H. Most of the rams heads and statues of the gods are lost.

I. There are many plants and weeds along the road.

J. Extensive groundwater exists at several locations along the road.

K. The disappearance of many pedestals and statues, especially in the sanctuary behind and under the church.

L. There are many scattered parts that are not in place - Figure (4, 5).

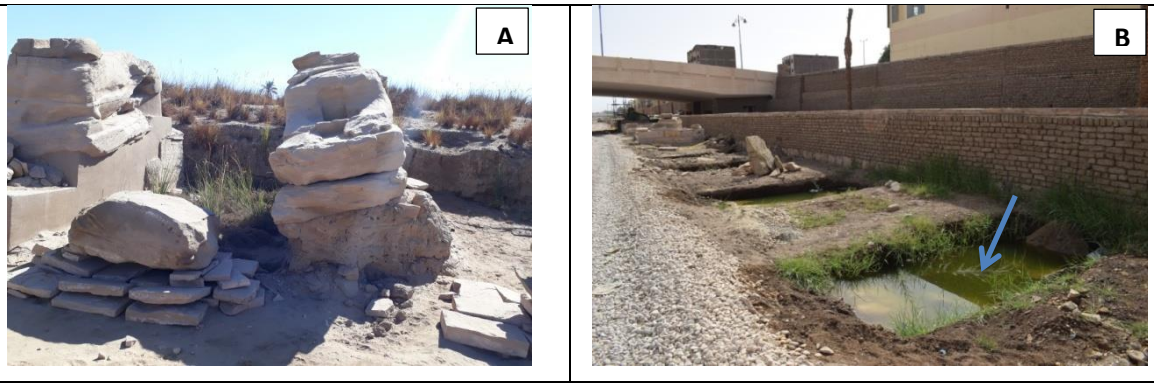


Figure 4. (A) Loss of some parts of statues pedestals (B) Groundwater presence in the site where the sample was taken as arrow refers.

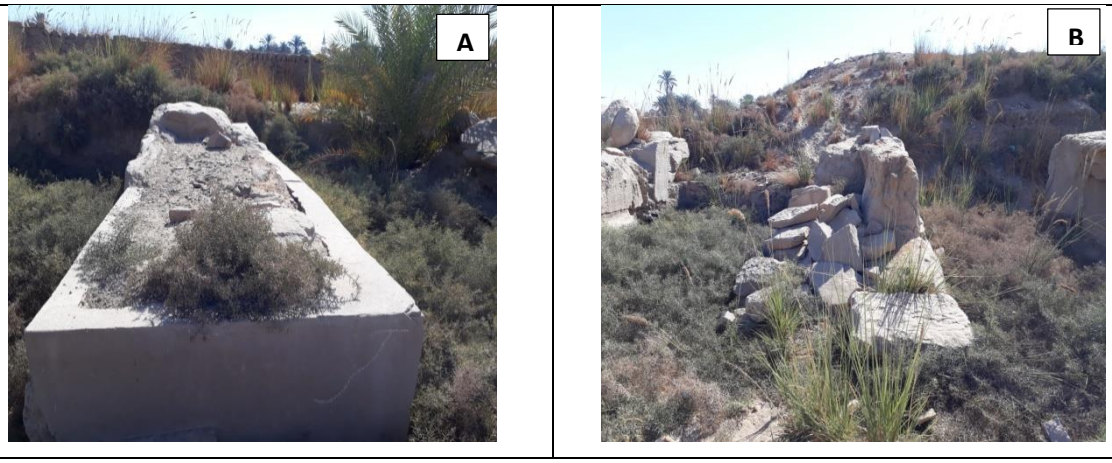


Figure 5. (A) Some statues bodies are lost (B) Some road bases have been destroyed and there are many weeds.

2. Previous restoration processes on the statues:

Some of sandstones that make up the bases have been very carefully cleaned using soft brushes and fine scalpels to remove dust, dirt and clay calcifications in order to preserve it. A 1:1 solution of ethyl alcohol with water was then used to remove dust residues and clay deposits that were difficult to remove mechanically.

The weak sections of sandstone bases and the rams' bodies were consolidated with a 3% solution of Paraloid B-72 in acetone. After that, parts of the pedestals were rebuilt in their original places, and the missing parts were completed with new sandstone, then some parts separated from the bodies of the statues were assembled to each other using stainless steel bars with Araldite 1306 to stick these parts in their original places. The cracks and small gaps in the statues' bodies were filled using lining mortar, then the statues were lifted and fixed on their bases using a suitable lifting machine.

3. Treatment and restoration processes (Completion and reconstruction):

This stage is one of the most critical stages in developing a treatment and restoration plan. Archaeological materials have artistic, historical and cultural value, even without decorations, inscriptions or writing, but because they show scientific value. The purpose of restoration is to

discover and protect these values in accordance with legal provisions and the recommendations of international conventions on the protection of antiquities, and the restoration process is considered a highly specialized operation, and this all shows that the restoration work of antiquities is procedures related to the material of the antiquity that should be well understood and the method of its design and analysis of those elements.

Through the field survey of the rams' statues, it was found that there was a large loss in the pedestals and bodies of the statues, which necessitates the presence of completion operations for the missing parts with stone and mortar, there were many destroyed statues. In particular, the stones on the pedestals of the statues which need to be replaced with another intact parts of the same type of the sandstone, there were some statues that suffer from subsidence of the soil below due to the groundwater effect, which requires dismantling and reconstruction of these statues, with the presence of international regulated standards in this regard.

- Criteria for reconstruction and completion of the archaeological landmarks:

1- The reconstruction and completion processes of the archaeological landmarks become necessary in order to lead to a more comprehensive understanding of the archaeological and historical values of the archaeological landmarks[3], provided that there are sources and documents that can be relied upon in restoring the original image[4].

2-The reconstruction, completion of the lost parts using new materials, provided that they are homogeneous in design, color, texture and all other visual appearances, and this must be done according to confirmed historical images or elements [5].

3- The reconstruction's process must be accompanied by putting in place all controls to preserve any underground foundations or elements [6] .

4- Reconstruction of the missing parts must be done in a way that does not harm the integrity and general appearance of the original existing elements.

5- Items of sculpture, painting or decoration which form an integral part of a monument may only be removed from it if this is the sole means of

3. Woolfitt, C., (2012). Preventive Conservation of Ruins: Reconstruction, Reburial and Enclosure, in: Sullivan, Sh., and MacKay, R. (eds), Archaeological sites: Conservation and Management, The Getty Conservation Institute, 503.

4. El-Banna, El S.M., (2002). Historic cities preservation, restoration and maintenance (In Arabic), First edition , Zahraa Al Sharq Library , Egypt, 248.

5. Moustafa, B.M., (2000). A study of the impact of the planning environment on the architectural implications of archaeological buildings and the methods of their restoration and maintenance in application of the Bazara Agency,(In Arabic) , Master thesis, Restoration Department , Faculty of Archaeology , Cairo University.

6. Salman, A.F., (2010). The principles of restoring archaeological monuments in accordance with international conventions, (In Arabic) , Shadirwan Magazine, Syria, 1,6.

ensuring their preservation (Article 8- Venice Charter 1964) [7].

6- Replacements of missing parts must integrate harmoniously with the whole, but at the same time must be distinguishable from the original so that restoration does not falsify the artistic or historic evidence (Article 12 - Venice Charter 1964)[8].

Materials and Methods:

One of the statues which needed for the restoration processes as a result of soil problems , where samples of soil and sandstone were taken from the base to identify their components, damage causes and develop a restoration plan to preserve this important cultural heritage.

Samples were subjected to analyze by x-ray diffraction (XRD) – (Model : Philips Analytical X- Ray B.V - Housing and Building Research Center – Dokki – Giza – Egypt), examined with polarizing microscope (PLM) – (Model : 40X-1000X AmScope - Petrography Laboratory – Faculty of Science – Cairo university – Giza- Egypt) and scanning electron microscope (SEM) – (Model: XTM.1999-2007-Housing and Building Research Center – Dokki – Giza – Egypt). Also, a sample of the ground water was taken on the rams road to identify its components.

- An Experimental study to evaluate the materials used in improving the completion mortars:

The stage of preparing and choosing the mortar used in the completion processes, as well as the operations of linking the stone blocks, whether in the bases, the body or the pavement, is of the greatest importance, as it is used in a large and essential manner due to the poor condition in which the rams are located and the severe loss in many of them, which requires completion operations in a large way.

The mortar used in the completion processes consists of (lime + sand + white cement + stone powder), the materials used to improve the properties of the mortar are Addibond 65, Primal AC 33 and polyvinyl acetate (PVAc).

A. Addibond 65:

A multi-purpose adhesive based on butadiene-styrene latex, produced locally by Chemicals for Modern Building Company (CMB). It is added to mortar to improve its properties in general, and increases its adhesion strength to various building materials and increases resistance to water permeability in particular. It also increases flexibility and reduces shrinkage, which helps to avoid cracks which occurs after drying and increases the mortar's resistance to stresses, especially compressive, tensile and bending stresses. It also increases workability and reduces the mixing

7. ICOMOS (1964). International charter for the conservation and restoration of monuments and sites , the Venice charter.
8. ICOMOS, 1964 (Venice charter).

ratio, which helps in ease of implementation[9].

B. Primal AC 33:

The chemical composition is a copolymer of ethylacrylate–methylmethacrylate[10], produced by Rohm and Haas Company. It is a white emulsion in color tending to a very light scarlet. It is diluted with water to the ratio required for operation, it is characterized by stability against light, it changes color or loses its transparency with high humidity and temperature, it dries after applying in about (40 minutes) and it is a reversible material [11].

C. Polyvinyl Acetate (PVAc):

PVA is a water-soluble synthetic polymer made by dissolving polyvinyl acetate (PVAc) in an alcohol such as methanol and treating it with an alkaline catalyst such as sodium hydroxide[12]. It is used as an adhesive and added to the mortars to improve their properties[13] ; it is produced by C.T.S s.r.l Company.

- Preparation of the mortar samples:

Five types of mortars have been prepared with different compositions and proportions to test their physical and mechanical properties and to choose the effect of different polymers on their properties in order to choose the best and most suitable one for use in restoration processes as follows:

1- The mortar samples were prepared in the form of cubes with a size of (5 cm x 5 cm x 5 cm) and waiting until they are completely dry.

2- The cubes were dried in an oven at a temperature of 105ºC for 24 hours to ensure dryness and stable weight. Then, after preparing the mortar samples, tests are carried out on them to determine the physical and mechanical properties and to study the effect of the different weathering cycles on them, Table (1), Figure (6).

9.Taha, Sh., Ali, M., Habashy , A., and Saad, M.,(2023). Experimental Study to Evaluate of The Mortars Used to Complete and Reinforce the Layers of Preparation of Detached Mural Paintings from Yakan House Historic Cairo (1769:1849 AD) , JARCH, 23, 26, 1030.

10. Fragata, A., Candeias , C., Ribeiro, J., Braga, C., Fontes, L., Velosa, A., and Rocha, F. , (2021). Archaeological and Chemical Investigation on Mortars and Bricks from a Necropolis in Braga, Northwest of Portugal, materials, 14,1-17.

11. Cocca, M., D'Arienzo , L., D' Orazio , L., Gentile, G., and Martuscelli , E.,(2004). Polyacrylates for conservation : chemico - physical properties and durability of different commercial products , polymer testing , 23, 334.

12. KulKarni ,V.S., and Shaw, Ch.,(2016). Use of Polymers and Thickeners in Semisolid and Liquid Formulations, in Essential Chemistry for Formulators of Semisolid and Liquid Dosages, Academic press, 43-69.

13. SICKELS, B.L.,(1981). Organics vs. synthetics: their use as additives in mortars in Mortars , Cements and Grouts used in the conservation of Historic Buildings , Symposium 3-6-11, Rome,32.

Figure 6. The mortars samples after processing and complete drying.

Table 1. The proportions of each used mortar sample and the additives to improve its properties

ymbol	Mortars compositions	Proportions
A	Lime + Sand+ White cement + Limestone powder + Addibond 65.	1:3 :1:1 : 15%
B	Lime + Sand+ White cement + Limestone powder + Primal AC 33.	1: 3 :1 :1 :2
C	Lime + Sand+ White cement + Limestone powder + Polyvinyl Acetate (PVAc).	1: 3 :1 :1 :2
D	Lime + Sand+ White cement + Limestone powder.	2:1:3:2
E	Lime + Sand+ Limestone powder + Clay + Fired bricks powder.	1:1:2:3:2

Note: The dry mixture is added, and then limewater and the additives are added to it.

Results and Discussion

A. Polarizing Microscope examination (PLM):

Through the polarizing microscope examination (PLM) of a sandstone sample taken from one of the deteriorated statues which is located in the third sector of the four sectors of the Rams Road, it is found to be a Nubian sandstone composed mainly of quartz grains bound together by iron oxides, quartz, and minor amounts of calcite. The grains of quartz range from fine to medium-coarse, and upon inspection, quartz grains are mostly semi-coarse, as they are susceptible to mechanical deformation and appear as several very fine cracks representing the stresses exerted on the stone, Figure (7).

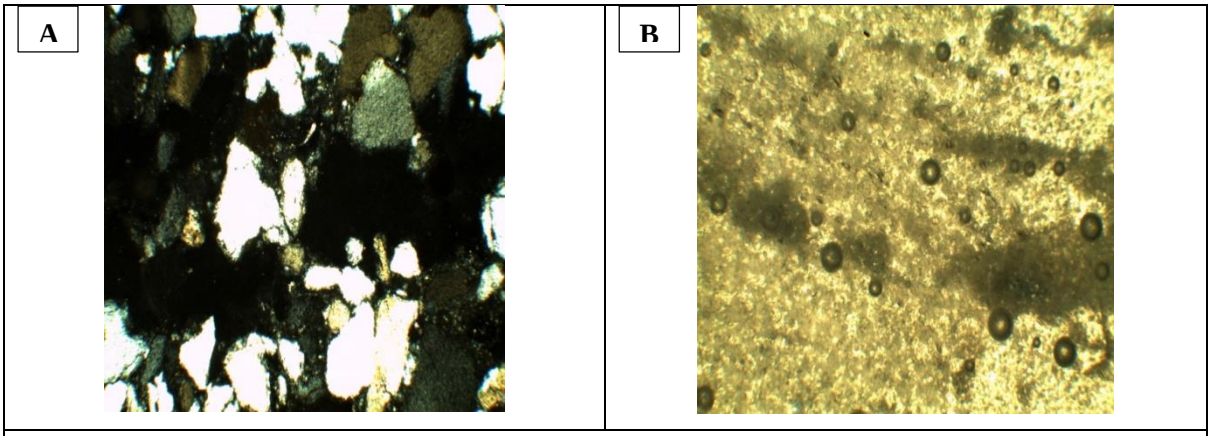


Figure 7. (A-B) Examination of a sandstone sample using a polarizing microscope (PLM) (×100).

B. Scanning electron microscope examination (SEM):

Examination of sandstone samples by scanning electron microscope (SEM) revealed grain erosion, cracks, voids, and a weak internal texture of the samples surface, Figure (8).

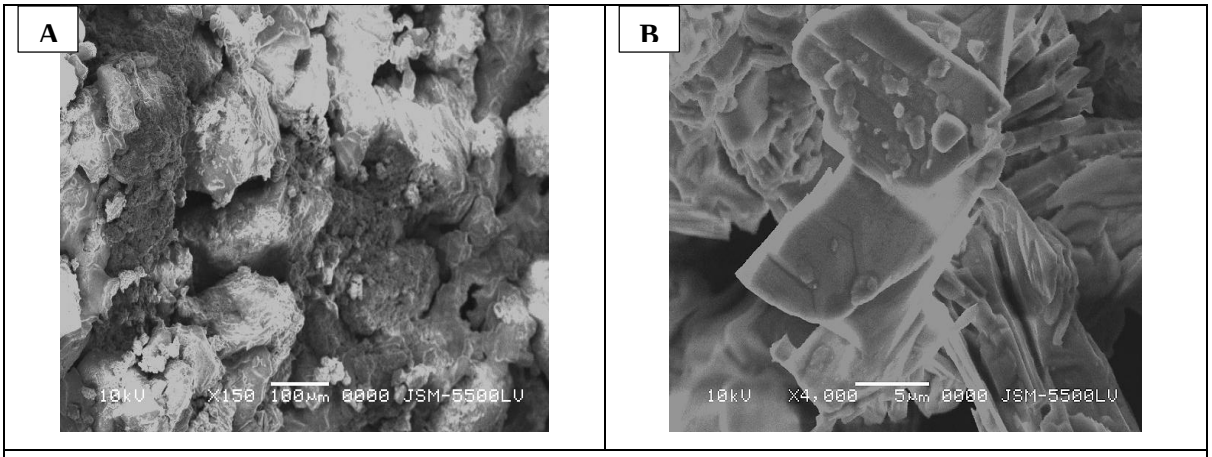


Figure 8. Examination of a sandstone sample using scanning electron microscope (SEM), (A) magnification power X 150, (B) magnification power X 4000, it shows many gaps and crystals break.

C. Elemental analysis by EDX (Energy Dispersive X-Ray Analysis):

The Elemental analysis of the sandstone 's sample by EDX unit (attached to scanning electron microscope) showed the presence of the following elements : Si (66.50%) , Al (10.75%) , Ca (6.00%) , K (4.43%), Fe (4.13%) , Mg (2.76%) , and Na (2.65%) , the elements represented the components of Nubian sandstone (quartz, calcite and clay minerals), Figure (9) - Table (2).

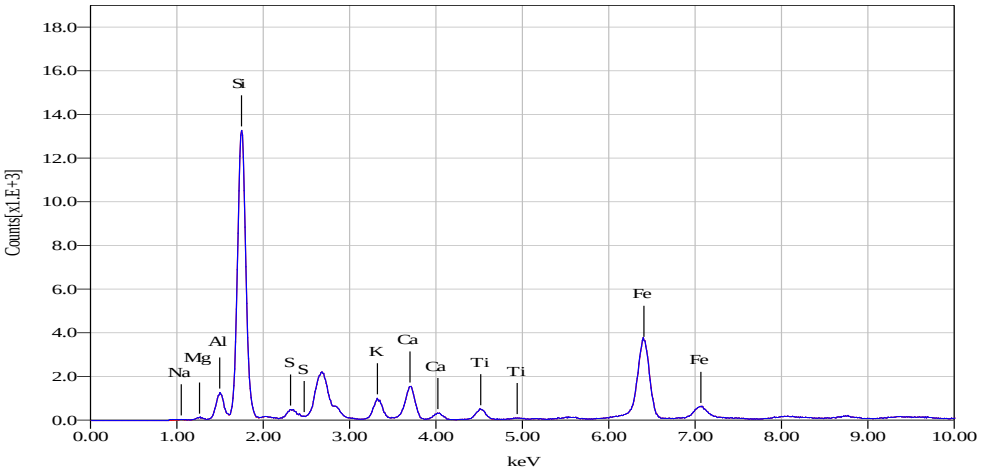


Figure 9. The elemental analysis by EDX of a sandstone sample.

Table 2. The Elements of the sandstone's sample (EDX analysis).

Element	Weight %
Na	2.6583
Mg	2.7634
A l	10.7577
Si	66.5013
S	1.5857
K	4.4371
Ca	6.0013
Ti	1.1650
Fe	4.1303

D. X-Ray Diffraction analysis (XRD):

XRD analysis of sandstone samples showed that they consisted mainly of quartz, gypsum, dolomite and anhydrite, in addition to magnetite, magnesite and ferroxite. This shows the displacement of the binding material of the quartz grains that make up the sandstone. Deposition on a surface in the form of a dark solid layer by the impact of groundwater [14] .

The chemical analysis results of the soil sample showed that it is a sandy soil; it consists of quartz, halite and calcite, in addition to orthoclase, gypsum, and dolomite, which indicates the presence of halite in a high percentage in the soil due to the ground water existence, Figure (10).

14. El-Sayed, SSM., and Maky, A.Y., (2022). Archaeometric investigation to evaluate Acrylic, silicon materials and nano-additives as consolidation material to sandstone monuments of the sphinxes avenue (Luxor, Egypt), Scientific Culture, 8,1,51-62.

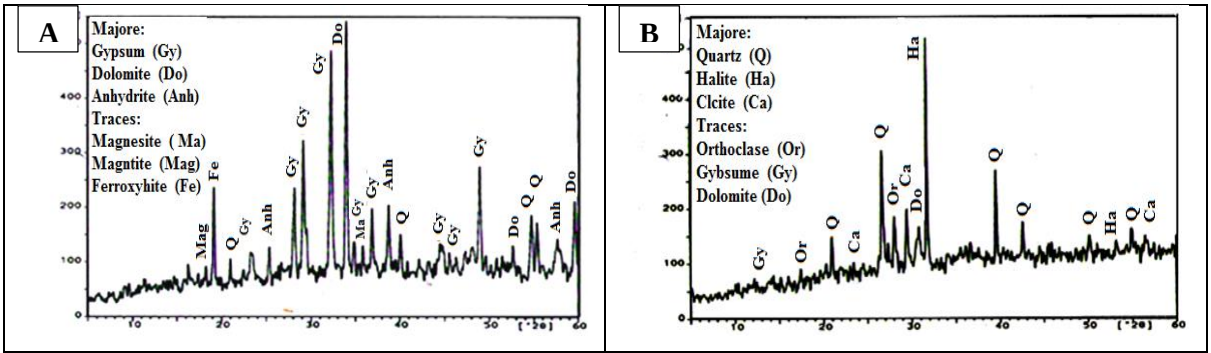


Figure 10. X- Ray Diffraction (XRD) analysis (A) a sandstone sample, (B) a soil sample (under a statue).

E. Groundwater chemical analysis:

It is clear from the chemical analysis of the water sample that this sample is characterized by a higher salinity than normal due to the high percentage of dissolved ions in it, which are calcium, potassium, magnesium, chloride and sodium. This explains the presence of a high percentage of crystallized salts in the soil and on surfaces of the lower courses up to a height of about one meter in Rams statues, because this water is one of the most important sources of salts at the site, Table (3).

Table 3. Results of chemical analysis of groundwater's sample.

Parameters	Units
PH	8.3
Conducity at 25º C	7621.00Ms/ cm
T.D.S	5171.01mg/ L
Total Alkalinity as $CaCO_3$	115.16 mg/ L
Ammonia as N	2.00
Chloride – CT	645.03 mg/ L
Total Hardness as $CaCO_3$	2824.00 mg/ L
Calcium – Ca	646.12 mg/ L
Magnesium – Mg	291.55 mg/ L
Sodium – Na	456.32 mg/ L
Potassium – K	79.44 mg/L

F. Evaluation of the materials used in improving the completion mortars:

Tests were conducted to determine the physical properties such as density, porosity and water absorption of the mortars that were used in the experimental study to verify the importance of the materials used in improving the properties of the mortars , Table(4).

Table 4. Mortars physical properties results.

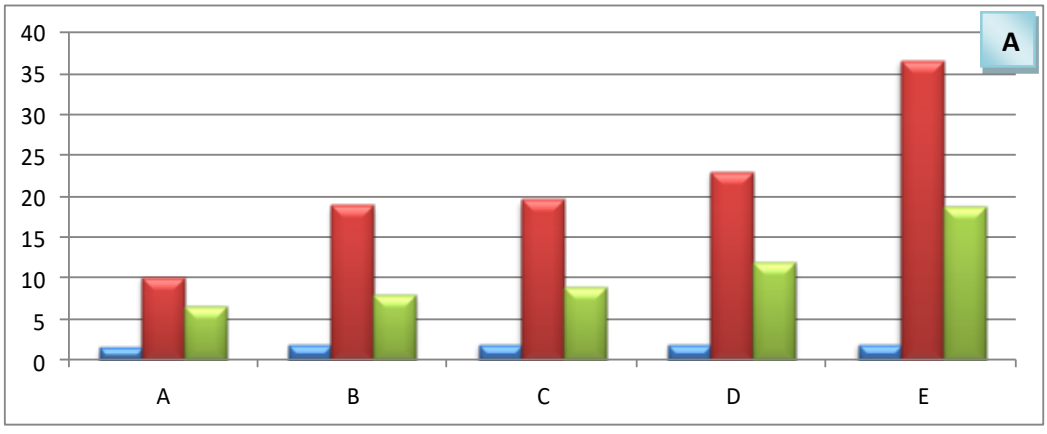
Water Absorption %	Porosity %	Density g/cm^3	Mortars symbol
6.59	10.21	1.56	**A**
7.91	18.88	1.93	**B**
9.01	19.58	1.94	**C**
11.85	23.08	1.95	**D**
18.76	36.63	1.96	**E**

The mechanical properties of the mortars were also determined, such as compressive strength of the different mortars, to show the extent of their strength and resistance to various environmental factors at the archaeological site, Table (5), Figure (11).

Table 5. Mortars mechanical properties results (compressive strength).

Compressive strength (Kg/ Cm^2)	Mortars symbol
105	**A**
103	**B**
94	**C**
85	**D**
75	**E**

It is clear from the previous results that Mortar (A) achieved the best results in resisting mechanical stress at a rate of (105) kg / cm^2, as well as giving an excellent result in its ability to bind and adhere to sandstone, followed by Mortar (B) with a rate of resistance to mechanical stress amounting to (103) kg / cm^2 and very good bonding and adhesion strength, then followed by mortar (C) with a rate of resistance to mechanical stress amounted to (94) kg / cm^2 and very good bonding and adhesion strength, followed by mortars (D, E) with a rate of resistance to mechanical stress amounting to (85,75) kg / cm^2 and good bonding and adhesion strength.



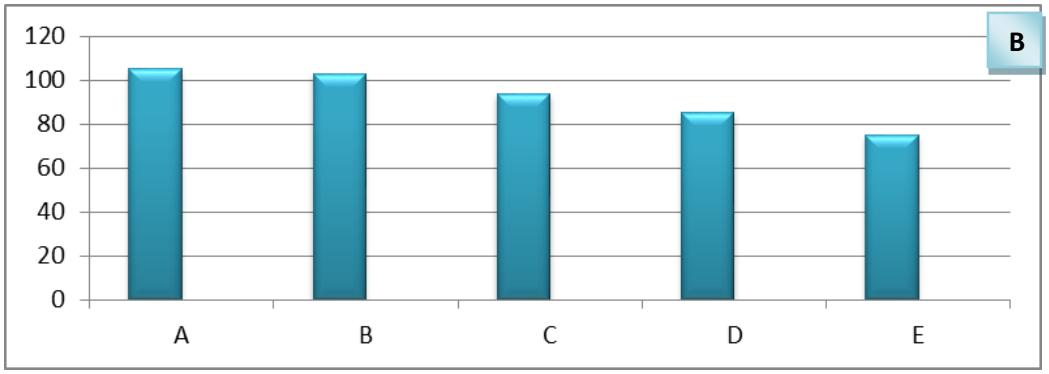


Figure 11. (A) Mortars physical properties results, (b) mortars mechanical properties results before artificial aging (Diagram: Author).

- Artificial aging of the mortars samples:

This test was carried out by the following steps:

1- First, drying the mortar samples in a drying oven for 24 hours at a temperature of 105°C, then recording their weights (ASTM C97).

2- Then, submerging the mortar samples in water and then placing them in a drying oven at a temperature of 70°C for 7 hours.

3-Putting the samples while they are dry in the drying oven at a temperature of 60° C for 11 hours.

4- Cooling the samples at room temperature for 20 hours. This process was repeated for ten consecutive cycles.

5- After that, the samples were immersed in a sodium chloride solution at a concentration of 30% for 5 hours, then the samples were dried in an oven at a temperature of 45 ° C for 9 hours, then the samples were left at room temperature for 12 hours. This process was repeated for ten successive cycles, the effect of salt weathering on treated mortar samples was also evaluated (EN 1015-21).

The physical and mechanical properties of the mortars were also determined after artificial aging processes as following in Table (6-7), Figure (12).

Table 6. Mortars physical properties results after artificial aging.

Water Absorption %	Porosity %	Density g/cm^3	Mortars symbol
7.69	11.50	1.46	**A**
8.21	19.90	1.70	**B**
10.11	20.50	1.74	**C**
12.95	25.10	1.75	**D**
19.96	38.00	1.73	**E**

Table 7. Mortars mechanical properties results (compressive strength) after artificial aging.

Compressive strength (Kg/ Cm^2)	Mortars symbol
95	**A**
90	**B**
85	**C**
75	**D**
63	**E**

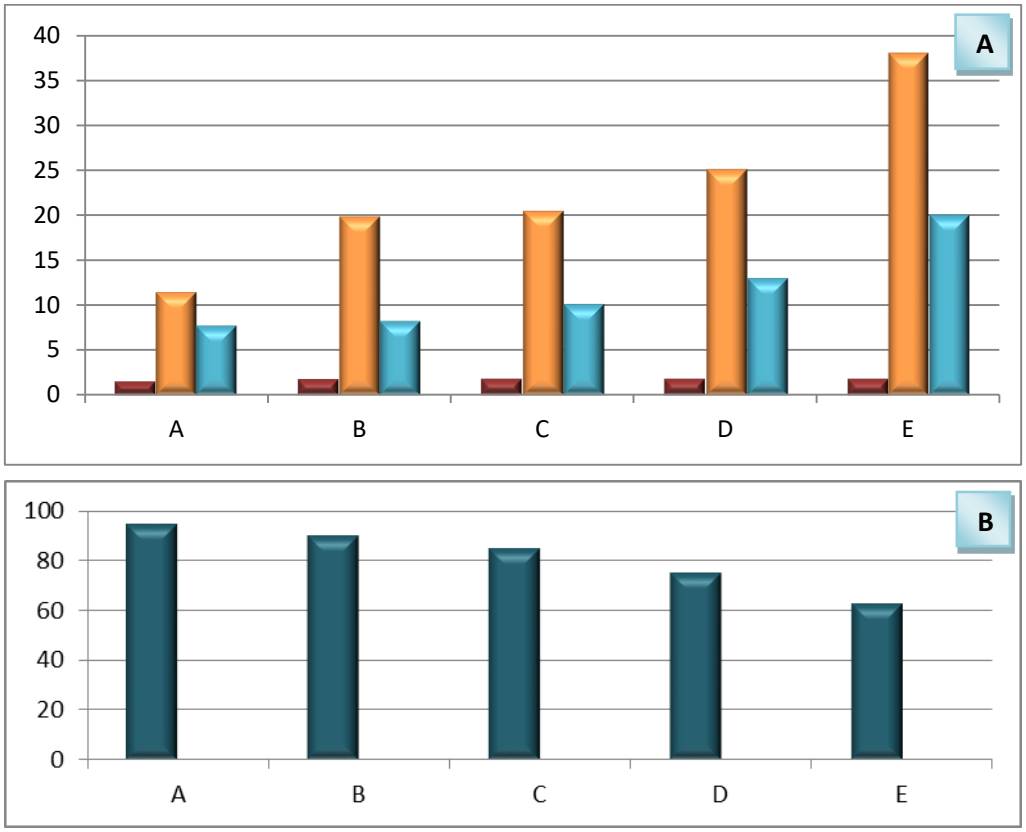


Figure 12. (A) Mortars physical properties results, (B) mortars mechanical properties results after artificial aging (Diagram: Author).

By measuring the physical properties such as density, porosity, water absorption and measuring the mechanical properties (compressive strength) of the mortar samples before and after artificial aging, it was found that the mortar containing Addibond 65, which is symbolized by the symbol A, is the best mortar, followed by the mortar B containing primal AC 33, then mortar C containing polyvinyl acetate (PVAc) compared to the original mortar, which is mortar D and mortar E containing clay and fired bricks powder . Thus, Addibond 65 is one of the effective materials in improving the properties of completion mortars; it is an isolation material, followed by Primal AC 33 and then Polyvinyl Acetate (PVAc).

G. The Restoration processes of the chosen statue (Reconstruction and completion):

The process of reconstructing a selected statue involves several steps as following:

A- The original location of the base to be rebuilt is determined and the original dimensions are determined (width 120 cm, length 330 cm, height 118 cm).

B- Drill a 50 cm deep hole in the original location of the base and increase the sides of the original dimensions by 10 cm.

3- Fill 20 cm of the hole with gravel and sand (replacement).

4-25 cm of the hole is filled with reinforced concrete made of sand, gravel and cement.

5- Lay the distilled burlap over the concrete and apply bitumen over it to isolate and protect it from ground water, Figure (13).

6- The stone blocks used to rebuild the base should be prepared considering the fact that they are made of the same type of stone (Nubian sandstone) and the dimensions of each block used to build the base, the dimensions and sizes of the stone blocks that were in the foundation in the past, the orientation of all blocks and their placement on each layer of the foundation.

7- The foundation layer with a length of more than 5 cm on each side is laid according to the stone pavement facing it, taking into account the height of its mass.

8- The selected mortar from the experimental study which is consisting of (lime + sand+ white cement + stone powder + Addibond 65) is used and mixed with lime water in proportions (1:3:1:1:15%) , Figure (14).

9- Then the remaining blocks (1st, 2nd, and 3rd) are completed and connected with the previous mortar, filling the gaps and joints with the same mortar.

10- A composition called Al-Dahara is used. It consists of (silt, primal and colored oxides) dissolved in distilled water. Modern stones are painted with this to obtain a color similar to ancient bases.

11- The body of the restored statue, which is sandstone, is lifted to the pedestal by silk ropes and appropriate lifting machinery is used to prevent the body from being damaged by the force of the load. It is installed on the base.

12- The body is fixed to the base with the same mortar that is used to connect the base courses together, Figure (15).

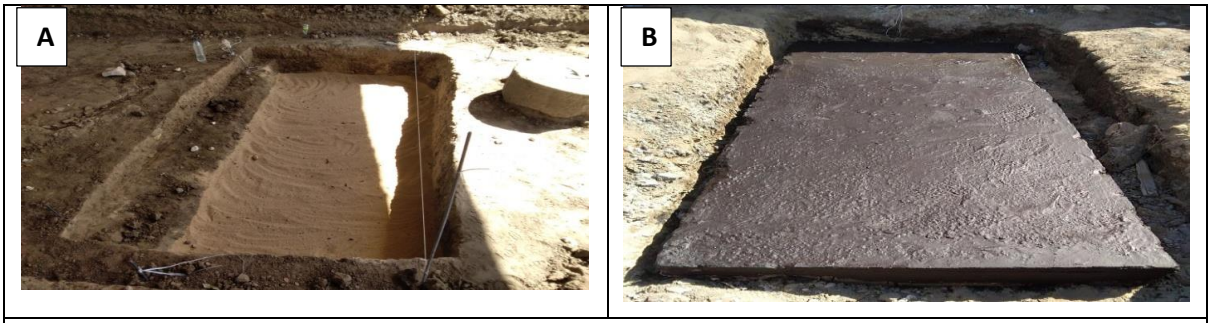


Figure 13. The shape, depth and dimensions of the hole in which to build the foundation and place the replacement sand and fine gravel.

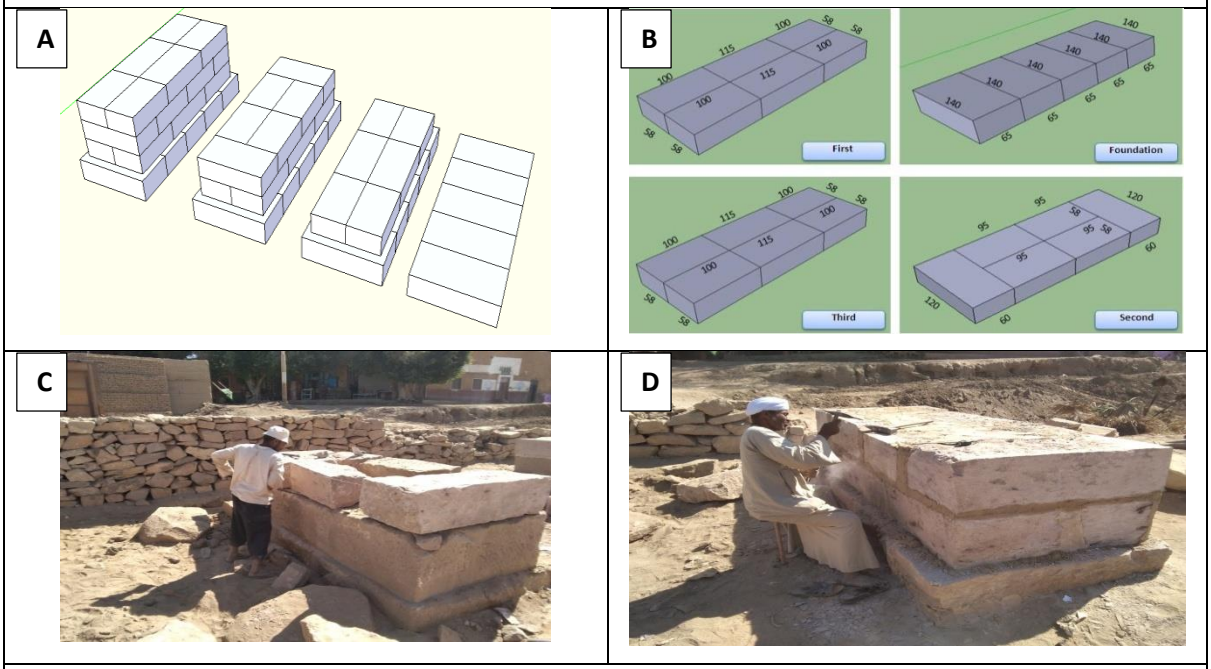


Figure14. Shows the statue's base building method and its dimensions (Drawing and Photo: Author).

Figure 15. Shows the process of raising and fixing one of the statues' bodies on the base after reconstruction processes.

- Completion processes:

Many statues have suffered significant loss of the statue body. One of these statues underwent the following restoration processes.

A- For this, a mechanical and chemical cleaning procedure is carried out, using a poultice made of ethyl alcohol and water in a 1:1 ratio and covered with polyethylene to remove dirt and calcifications, Figure (16).

B- The body was consolidated with Wacker (OH) 100 + nano silica 3% using a brush[15] , Figure (17).

C- Making a sketch of the main body of the statue to identify the missing parts to be completed and attach other parts to know the position of each part of the main body.

D- Missing parts are completed with a mortar, so the assembly and finishing process takes place directly on the base [16], Figure (18).

E - Use a mortar which was chosen in the experimental study consisting of (lime + sand + white cement + stone powder + Addibond 65) and mix with lime water in a ratio (1:3:1:1:15%) considering completion conditions , differentiation and homogeneity , Figure (19-20).

F-Separated parts were assembled by an adhesive (Araldite 1092)[17].

Figure 16. The cleaning process of the statue's base.

Figure 17. The consolidation with Wacker (OH) 100 + nano silica 3%.

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Figure 18. The completion of the missing parts in the base with a mortar.

Figure 19. The installation of the statue's body on the base.

Figure 20. The completion processes of the chosen statue (A) During (B) After.

Conclusion

The Sphinx or Rams Road has previously suffered from deterioration and damage to many statues, which number is more than 1, 200, as a result of the presence of groundwater , the presence of a residential block in addition to deliberate vandalism and theft.

The Egyptian government has paid attention to this road by exposing and restoring many statues along the road extending from Luxor temple to Karnak temple. Luxor witnessed a global celebration of the opening of Rams Road on November 25, 2021 with the support of the political leadership and in the presence of his excellency president / Abdel Fattah Al-Sisi.

The statues of the road have undergone many restoration processes, such as: mechanical and chemical cleaning processes, consolidation, reconstruction, assembly and completion of the missing parts[18].

Two statues were selected, one of which underwent reconstructions for the base and body, and the other underwent cleaning, consolidation and reconstruction processes, then assembly and completion for the body.

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Experimental studies were conducted on a number of mortars to evaluate the additives used to improve their properties. It was found that Addibond 65 is the best additive to improve the properties of the completion mortar, followed by Primal AC 33 and then Polyvinyl Acetate (PVAc). These materials are available, easy to use, economical, and do not negatively affect the monuments[19].

The researchers recommend the need for a periodic maintenance of the road to detect any deterioration phenomena of statues and intervention immediately to treat them for this road of major local and international importance [20].

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