Pompeii Sustainable Preservation Project

Directed by Prof. Dr. Ralf Kilian

Summer School 2023

23/09/2023 – 06/10/2023

Activities report

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15.01.2024

Introduction

The third summer school of the Pompeii Sustainable Preservation Project took place in the archeological site of Pompeii from September 23 to October 6, 2023. Twelve participants, including young professionals and students in the field of Heritage Science (conservators, conservator-restorers, archaeologists and architects) coming from all over the world (Buthan, Marrocco, USA, Jordania, Switzerland, Italy, Germany, South Africa, Spain, Croatia, Greece, India), took part in this last campaign (fig. 1).

Figure 1 World map with participants' home countries marked by black dots

Like the previous campaigns in 2015 and 2018 (see https://rb.gy/cxk8nw), this year Summer School focused on different topics linked to the issues of the conservation of archaeological UNESCO World Heritage Sites with the example of Pompeii and more specifically of the Porta Nocera necropolis. The program of this edition was set with the objective of combining theory with practical implementation. As in previous editions of the summer school, the idea of bringing together participants from all over the world, with different experiences and approaches to heritage preservation, was to share knowledge and best practices and to develop professional links between an international group of young professionals with a view to future collaborations.

Program and topics

The Summer School 2023 program was designed, as the previous ones, to give participants an overview of the challenges involved in preserving and conserving an archaeological site as a whole. The topics covered were many and varied, drawing on a wide range of expertise given by external and internal experts, like the Fraunhofer collaborators, the functionaries of the Parco Archeologico di Pompei (PAP) or ICCROM staff professors.

During **week 1** participants were introduced to the context in which they would be working over the following days and weeks. The aim of this first week was to give them, through different lectures, general understanding of what is special in Pompeii and in the other sites around Vesuvius, how such sites are managed and what preservation challenges they face. The Summer School started with a general visit to the archeological site of Pompeii guided by Dr. Sara Lenzi (University of Pisa) to familiarize the participants with it. In-person and online courses started the second day with Valerie Magar (ICCROM) offering general lectures on values and significance of historic sites and on principles and trends in archeological **sites' management** worldwide, followed by a discussion between the participants and ICCROM experts, Dr. Alison Heritage and Dr. José Luis Pedersoli. **Sustainability** in site management was at the heart of the first week discussions. Dr. José Luis Pedersoli introduced us with an online lecture on what means *sustainability* in conservation practice and how can organizations and heritage professionals integrate sustainability in their daily work. He gave a second lecture on **risk management** and an introduction to the ABC method developed by ICCROM staff (including Dr. José Luis Pedersoli himself) and Dr. Stefan Michalski from the Canadian Conservation Institute – a step by step procedure for analyzing a single risk or to a comprehensive risk assessment of an entire heritage asset.

Prof. Monica Martelli Castaldi gave a talk on the **Herculaneum Conservation Project** for which she was one of the project leaders, giving an insight into the experience of taking care of an entire site moving from emergency to maintenance.

Another important topic of week one was **digital documentation**. Dr. Antonino Mazzaglia and Dr. Daniele Malfitana, researchers and Professors in classical archaeology from the CNR-ISPC and University of Catania, PSPP project partner institutions, offered lectures on quick digital documentation systems for archeological sites, showing many case studies, including laser scanning documentation of tombs from the Porta Nocera necropolis (collaborative project with the PSPP). Arch. Raffaele Martinelli, architecture officer of Regio IV, V of the PAP, gave a lecture on the digital documentation systems used at the archeological site of Pompeii, notably documentation using drones. Finally, week one was also an opportunity to exchange with the participants about their personal professional backgrounds and interests. Each of them shared his/her own experiences and the conservation issues he/she faces in his/her own country, leading to very interesting exchanges and linking between the whole international group.

The **second week** was mainly dedicated to **conservation issues** at the archeological site of Pompeii and more specifically at the Porta Nocera necropolis. Dr. Federica Bianco, a volcanologist from the Osservatorio Vesuviano, gave a lecture on the **volcanic activity** of Mt. Vesuvio, which overlooks Pompeii and other archaeological sites in the region - past eruptions and the threat it currently poses to the preservation of these sites.

Three different former Master students – Giuliano Barbieri (Hochschule für Angewandte Wissenschaft und Kunst Hildesheim), Marta Ebreo (Università degli Studi "Suor Orsola Benincasa" Napoli) and Léo Borgatta (Hochschule der Künste Bern) – gave a talk on their Master thesis in conservation-restoration, each of which was conducted on different tombs of the necropolis of Porta Nocera. **Moisture and soluble salts activity** were at heart of the discussions as these are considered to be the main factors of deterioration affecting the ruins of Pompeii and notably at the Porta Nocera necropolis (Kilian et al. 2023; Michette et al. 2018) but also many other heritage assets worldwide. Dr. Alison Heritage (ICCROM) came for a day to give a talk on moisture and soluble salt transport mechanisms and desalination methods. This day of theory was used to prepare the students for two days of practical work on salt analysis

Figure 2 Tour of ongoing excavation and restoration working sites with Dr. Vincenzo Calvanese

and the preparation and application of poultices to be held in the ICCROM laboratories in Rome during week four. This second week was also an opportunity to make several **site visits**. Dr. Pia Kastenmeier offered a visit to the archeological site of Herculaneum. Dr. Vincenzo Calvanese, Engineer Officer and head of the Technical Office at the PAP made us a tour of several ongoing excavation and restoration working sites. These visits were for the participants of the Summer School unique, as those working sites are for now close to the public (fig. 2). It was a privilege for the group of students to have access to these sites, and of great interest to them as they were able to have rich discussions with professionals directly working on the excavation and conservation of wall paintings and mosaics, who were kind enough to explain the materials and techniques they use. Following the visits, Dr. Vincenzo Calvanese offered us a lecture on the general management of the archeological site of Pompeii.

Week three started with an online lecture from Dr. Sarah Court (ICCROM) on identifying and working with **key stakeholders**. The aim of the lesson was to prepare participants to work with an external firm of landscape architects (Progetto Verde Scarl, Naples) contracted by the PAP

Figure 3 Participants presenting their conclusions on the redesign of the area of the necropolis where stone elements are today exhibited

with a new conservation and musealization project of the Porta Nocera necropolis. In fact, one day of the week was to be devoted to the project to redesign the area of the necropolis where statues and other stone elements that once belonged to various tombs are now exhibited (on the south side of Via Nocera). The idea of giving participants a real-life case study was to confront and possibly defend their project with that of the official architects commissioned by the PAP. The meeting between the architects and the participants, which took place on September 11, was very interesting, as the participants presented their project well and the architects were very receptive, leading to useful exchanges for both parties (fig. 3).

Risk assessment and **condition assessment** methods were predominant topics in week three. Originally, Dennis Mitschke (University of Bamberg) was to give a series of lectures on the **ABC risk assessment method** (introduced in week one by Dr. José Luis Pedersoli) and guide participants through the implementation of a survey of the necropolis using this method. Unfortunately, Dennis caught Covid and was not well enough to give his lectures. The participants were left to their own devices to study the method and to put it into practice on the necropolis. Participants with experience in risk assessment were able to guide others through the process and achieve good results.

Prof. Martelli Castaldi introduced the participants with two further condition assessment methods: the **Bird Eyes Overview (BEO)** and the **Organized Visual Observation (OVO)**. The BEO was **developed** by Monica Martelli Castaldi and was used in several projects including the Herculaneum Conservation Project (see Pesaresi & Martelli Castaldi, 2006), the conservation of wall paintings in the archeological site of Bagan in Myanmar (2014 – 2015) or during the preliminary campaign of the PSPP (2014). The BEO method aims to prepare large maps of the archaeological site as a whole, enabling users to see at a glance all the interconnections between potential deterioration factors (issues) and the state of conservation of the objects to be preserved. By assessing the level of deterioration of the various components of the objects, the BEO method should make it possible to define priorities as to where action should be taken first (emergencies) and to organize and follow the execution of the interventions. The OVO method was developed by conservator-restorer Corrado Pedelì (see Pedelì, 2014) and used in particular since 2015 for ICCROM courses in various Middle Eastern, Asian and European countries. This method aims to reorganize naked-eye condition assessment with a standard approach. Instead of using maps, the OVO method uses hierarchical diagrams, aiming, like the BEO method, to find correlation between weathering processes and deterioration of the original materials.

Preventive conservation measures for ruins were also discussed in week three, especially for horizontal surfaces. The conservation architect Dr. Paola Matilde Pesaresi (former Herculaneum Preservation Project, now director of Heritage Management, Diriyah Gate Development Authority, Saudia Arabia) offered a lecture on condition assessment of architectural heritage in archeological sites and on preventive conservation methods, including roof and *cocciopesto* protective systems. Dr. Pia Kastenmeier also gave a talk on the issues of protective covers in the archeological site of Pompeii.

Participants met part of the team who works for the maintenance of the archeological site of Pompeii under the supervision of the company Ales Arte Lavoro e Servizi S.p.A. Conservator – restorer Marta Ebbreo showed us areas of current work and the restoration materials and methods used to conduct treatments on original detached plaster. This meeting was a good opportunity for the group to share knowledge about restoration techniques and materials.

Finally, the group had the chance to have a look at the Parco Archeologico Pompei's archives thanks to Dr. Giuseppe Scarpati, Archeology Officer for Regio I and VIII of the PAP.

In **week four** the participants were asked to **survey the necropolis** using the map-based BEO method. The aim of the visual surveys was to identify the causes of deterioration of the structures and decorative renders of the tombs from the necropolis and to select tombs that require urgent treatments. The results of these surveys (see sections below) were a basis to define a **plan of work** for the weeks five and six. To facilitate the work within the short time available, the maps that were done in the first campaign in 2014 were given to the participants before they started their survey. The idea was to complete or improve the old maps according to the current state of the necropolis.

The fourth week also offered an opportunity to continue discussing preventive conservation with Dr. Alessandro Massari. Discussions focused on **water management** in the Porta Nocera necropolis. Water is a major issue for the conservation of the tombs. Located at one of the lowest points of the site, the Porta Nocera necropolis acts as a "water tank" where rainwater from the ancient city accumulates. We also discussed with PAP's art gardener, Dr. Maurizio Bartolini, and Arch. Paolo Mighetto the management of **vegetation** in the necropolis and how it can be used as a preventive tool to protect the tombs.

Two-days’ **workshop on soluble salt analyses and desalination methods** were planned at the ICCROM laboratories in Rome at the end of week four. Hosted by Dr. Alison Heritage, the aim of this workshop was to familiarize participants with different methods of soluble salt field-analysis (flame test, dissolution test, pH and MERCK strips detection tests, micro chemical tests). Participants were also able to try out different recipes of poultices for masonry/plaster desalination (fig. 4). During our visit to ICCROM headquarters we had the chance and privilege to see part of the **Mora sample collection**. This collection, the genesis of which was the life's work of the mural painting conservator-restorer couple Paolo Mora (1921-1998) and Laura Sbordoni Mora (1923-2015), comprises some 1.200 samples of materials (mostly wall paintings fragments but also ceramics, wallpaper, textiles, stone, plaster, stucco and glass) collected from some of the world's most famous heritage sites and monuments, in at least 35 countries.

Figure 4 Participants applying salt-reducing poultices in the courtyard of ICCROM headquarters.

Week five and **week six** were dedicated to **practical work**. The twelve participants were divided in two groups: one working under the supervision of Dr. Martin Michette (Oxford University) and archeologist Richard Grove on the implementation of a ground capillary water retention system using a **clay barrier system,** at the basement of the north facade of Tomb D-

N (Via Nucerina); the other working on **conservation treatments** to stabilize decorative stuccoes from the tombs of the necropolis.

The **final PSPP23 symposium** took place between Sunday October 1 and Monday October 2. Johanna Leissner of the Fraunhofer Sustainability Network Brussels, chair of the EU MOC group "Strengthening the resilience of cultural heritage to climate change", gave a talk on Sunday evening, at the Habita 79 Hotel in Pompeii, entitled "Cultural heritage in times of climate change - a European perspective". Monday, as second day of the Symposium, was devoted to a series of talks by various experts, including Dr. Alison Heritage (ICCROM), Prof. Dr. William Van Andringa (Ecole Pratique des Hautes Etudes, Paris), Prof. Dr. Ralf Kilian (Director of PSPP, Fraunhofer Institute IBP), Dr. Paolo Mighetto (PAP), Prof. Monica Martelli Castaldi. Participants were also able to present their findings to the public and professionals in attendance (fig. 5).

Figure 5 Ivan Martinovic presenting participants' results during the PSPP final symposium

Results of the PSPP's 2023 campaign

While the PSPP Summer School 2023 was more focused on theoretical learning, the time devoted to practical work gave some very good results that can be of interest for the future to be given to the conservation and re-musealization of the Porta Nocera necropolis. These results are given in the following sections.

Reimaging the musealization of the stone statues in the necropolis

Approximatively two days of work were given to the participants to build up a project for the re-musealization of stone statues and architectural features in the necropolis of Porta Nocera. Today, these stone elements are exhibited under a protective roof at the opposite of the so called Nocera Gate, one of the city gates leading into the ancient town of Pompeii.

To do this task, the participants were separated into three groups, every group working on a different topic:

- Condition assessment and conservation of the stone elements
- Musealization
- Architecture

The quick **condition assessment** done by the conservation group showed that if needed, the state of conservation of the stone elements allows them to **be handled and moved with caution** but only by or at least under the supervision of a conservator – restorer. There is no need for emergency treatments.

The group defined seven different types of deterioration phenomena, visible on the surface of the sculptures:

- Surface staining
- Scale formation
- Unsuitable previous restoration
- Biodeterioration
- Cracks
- Decohesion
- Detachment

The project of re-musealization of the stone elements would consider first to **remove** the sculptures and the fragments from where they are now. This idea is based on recent excavations carried on in the area of the modern city of Pompeii, a few meters behind the area where the stone elements are exhibited, where the archaeologists found the prolongation of the roman road that leads from the city gate to the southern *suburbium* (see fig. 6). The proposal would be

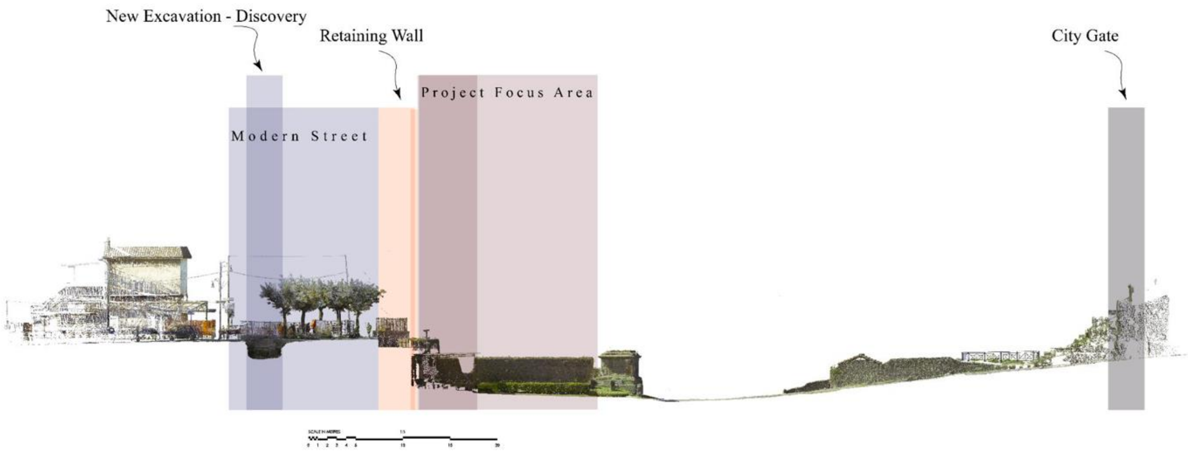


Figure 6 Cross-section of the Porta Nocera necropolis and modern Pompeii. Key areas are highlighted

to get clear the area from the stone features and the shelter that protects them today, to show visitors the remains of the **ancient street** leading to the roman city. In order to reinforce for the visitors this archeological discovery, one suggestion could be to fix a transparent panel to the retaining wall that today separates the necropolis from the modern city, drawing (or eventually projecting) the ancient road on the panel. In front of the panel a signpost would be placed giving directions to nearby Roman towns (fig. 7). For this project to be feasible, an in-depth condition assessment of the retaining wall should be done to evaluate the possibility of attaching such a panel on it.

In addition, the participants considered the possibility of distributing **spotlights** on either side of the ancient streets to **illuminate the tombs** at night. Visible from the modern street overlooking the necropolis, it is easy to imagine the beauty of the view of the illuminate necropolis. Should this idea be adopted, an important point for the participants is the **sustainability** of such infrastructure. As it has already been done in other places in the Parc of Pompeii, solar panels could be used to power the spotlights.

Finally, the project suggests increasing the number of **information panels**. There is today a lack of information on the necropolis, which certainly makes it difficult for the visitors to understand how important this area was for the Romans.

Figure 7 3D model of one of the participants' suggestions for redesigning the area where the stone elements are now exhibited.

Map-based surveys of the Porta Nocera necropolis using the BEO method

Using maps produced by Prof. Monica Martelli Castaldi in 2014 and later in 2018 by the participants of the former summer schools, this year's participants re-surveyed the western area of the necropolis.

The new maps produced this year focused on the following topics:

- Water management
- Vegetation and biodeterioration
- Structural integrity

- Decorative Surfaces

Water management

The necropolis of Porta Nocera is located at one of the lowest points of the archeological site of Pompeii. It acts as a “water tank” where rainwater that comes from the ancient city accumulates. The rainwater flows mainly from three accesses which connect higher points of the ancient city with the necropolis, located to the East, West and North. The paths of water and the areas where the water accumulates in the necropolis were well documented by the PSPP in 2014. The situation did not ameliorate since then. There is a clear **emergency** to find solutions to **keep water away** from the tombs’ structures as **water and the soluble salts** it contains are considered by the PSPP to be the main **factor of deterioration**. Also documented on maps in 2014 and re-surveyed this year, there are modern water collection systems located at different points of the necropolis which seem to be abandoned since years. Furthermore, water pipes placed in the retaining wall separating the modern city from the necropolis, conduct water from the modern street (via Plinio) directly on the top of the tombs located close to the wall. This is something that has to be taking care of in priority.

For the general water management system of the necropolis the participants propose s**tormwater basins**. These engineered structures are designed to manage stormwater to runoff effectively, to prevent flooding, erosion and water pollution. In alternative they proposed retention ponds to store temporarily excess water during heavy rainfall events and gradual release of water to prevent flooting

Vegetation and biodeterioration

Maps of the distribution of the vegetation (cause) in the necropolis and biodeterioration (consequence) visible on the decorative surfaces and masonry of the tombs, were produced in order to observe causalities by superimposing them. By comparing the maps, clear correlations between the significant presence of vegetation in the necropolis and mechanical deterioration (e.g. pressures in plaster and tomb structure due to plant growth) or physico-chemical deterioration (microbiological growth on tomb surfaces) can be observed. This year's survey focused also on what can be done immediately to slow down deterioration processes (fig. 8). The participants propose to:

- Cut back/ remove certain bushes or trees
- Apply biocide and remove small plants from the tombs’ surfaces
- Repair the protective layers of *cocciopesto*

- Completely redo the protective layers of *cocciopesto* when they are too damaged

Figure 8 Map of immediate interventions concerning vegetation and biodeterioration developed by the participants

Structural integrity

The map-based survey of the structural integrity of the tombs in the necropolis is a key document, as it provides rapid information on the (often precarious) state of conservation of the tomb structures (see fig. 8). Carried out this year by architects experienced in the field of heritage conservation, the study classifies the state of conservation of tomb structures into five categories:

- Collapsed
- Collapsing
- Very unstable
- Unstable
- Medium unstable

According to this list, none of the tombs in the necropolis is considered structurally sound.
Two tombs (P XXIV 2 30 and PXXIV 3 25) are already considered "collapsed". There are also six tombs (P XXIV 2 36, PXXIV 2 30, PXXIV 2 28, PXXIV 2 4, PXXIV 1 17/19, PXXIV 1 23) with " collapsing " status. These tombs are a **real danger** to visitors walking around them, as they could collapse at any moment. They need **urgent structural intervention** (!)
For each of these tombs, a map-based survey has been produced outlining the studies and additional work to be carried out (see fig. 9).

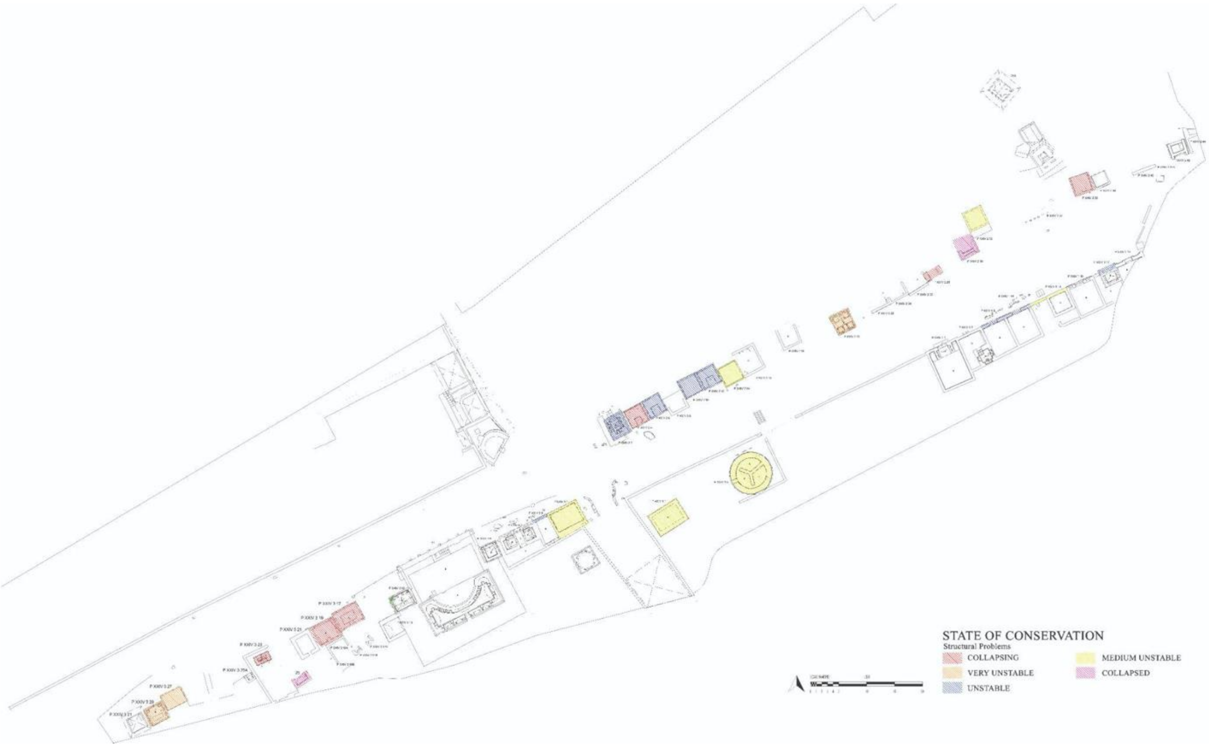


Figure 9 Map of the state of conservation of the tombs' structures developed by the participants

Decorative surfaces

A map-based survey of the condition assessment of the decorative surfaces was done in order to select tombs which need **emergency treatments**. In total, **eleven tombs** were identified as priority tombs (see fig. 10 and 11).

As a complement to the maps, the participants proposed the creation of a catalog for each tomb, which should contain information on the original technology of the tomb, a condition glossary, maps of the state of conservation and the conservation – restoration treatments carried out. This information has been documented in previous campaigns, but as separate

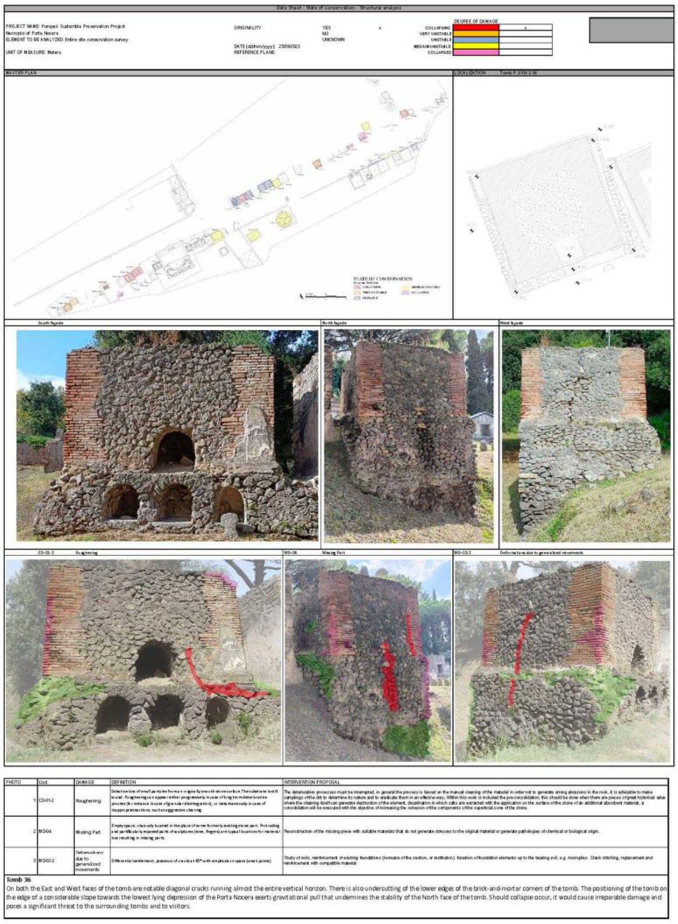


Figure 10 Catalog of suggested interventions for structural problems developed by the participants

documents. The idea here would be to bring all this information together in a single catalog for each of the tombs (same as for structural problems).

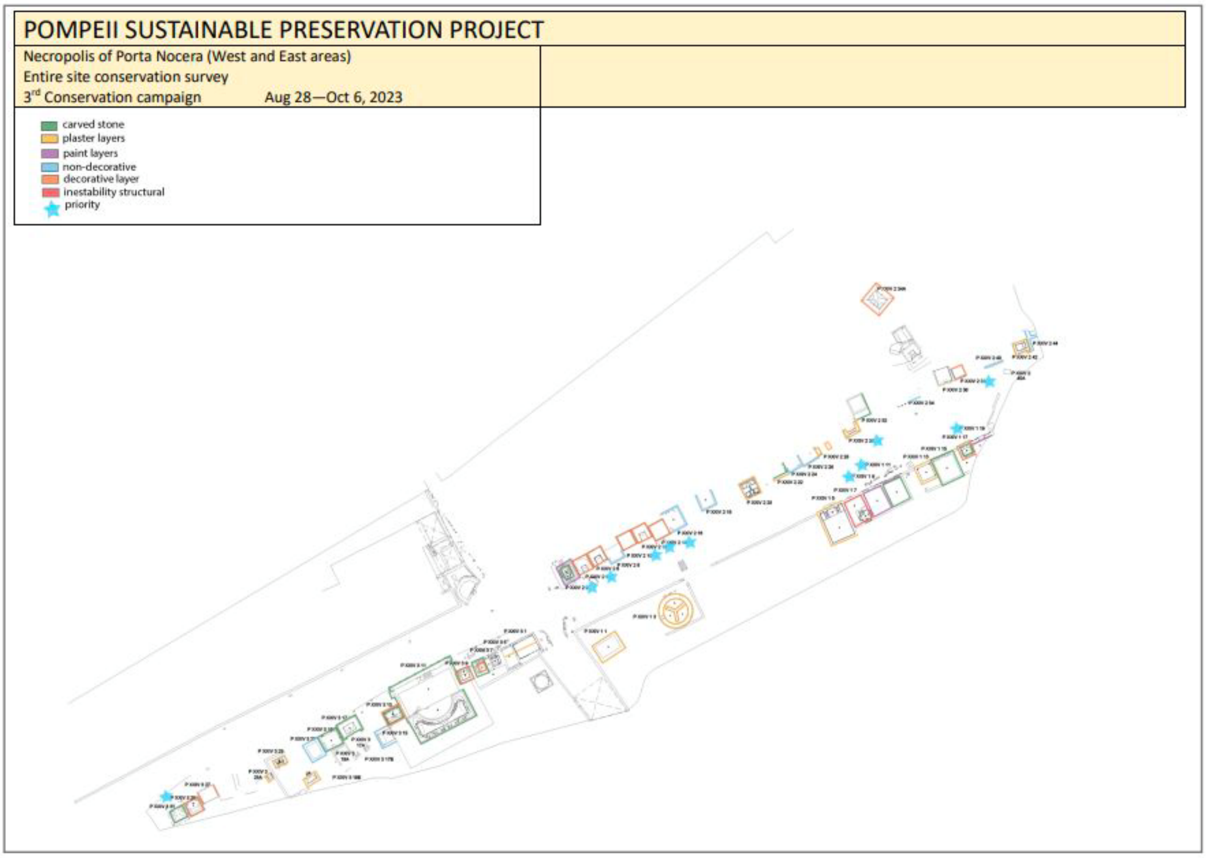


Figure 11 Map of entire site conservation survey concerning decorative surfaces developed by the participants. Priority surfaces (i.e surfaces that need emergency treatments) are highlighted with stars

Conservation – restoration treatments on decorative surfaces

As Pesaresi and Martelli Castaldi (2006) point out, a long period of neglect can produce the same effects as a single disastrous event. The Porta Nocera necropolis has long suffered from a lack of maintenance, putting the decorative surfaces of the tombs at risk of total loss. In the two summer schools preceding this one (2015 and 2018), four weeks were dedicated to emergency interventions on the decorative surfaces of the tombs. This year, only the last two weeks out of a total of six were set aside for this kind of work. The **short time available** (a total of seven days) to implement conservation measures and the **urgent needs** of the decorative surfaces, whose loss of original material threatens to increase daily, placed the participants (and this was the objective) in an uncomfortable situation where decisions had to be taken quickly, finding consensus within the group. However, this is a frequent situation in the practice of conservation of archaeological sites. It most often occurs during excavations, when objects need to be secured immediately to prevent any loss of material. In such circumstances, the conservator-restorer has to intervene very quickly. This is what makes the specificity of archaeological site conservation comparing to “common practice” in other fields and this is probably one of the **main learnings** of the PSPP Summer schools, particularly for young professionals who have not yet had the opportunity to work in emergency situations.

Discussions ensued between members of the conservation group on how to proceed. After defining the types of treatment required and the materials available, Prof. Monica Martelli Castaldi confronted the participants with the question of how they would proceed in such an **emergency situation**. While some participants wished to proceed directly to emergency treatments, with the materials and techniques they are used to, the majority of the participants wanted to carry out **preliminary tests on restoration materials** in order to choose the most appropriate and compatible with the original materials. A workshop on materials testing was therefore organized. Under the supervision of conservator-restorer Léo Borgatta, the aim of this workshop was to use on-site material testing methods that would enable a rapid and definitive selection of restoration materials. The tests carried out are presented below.

On site tests on restoration materials

Material testing was implemented to select different types of restoration materials that meet suitable properties for the deterioration processes of the tombs’ decorative plaster:

- A consolidation product for pre-consolidation and consolidation of loose aggregates
- A grout for the backfilling of plaster layers detachments
- Two recipes of restoration mortar for fillings and edging repairs of *arriccio* and *intonaco* plaster layers

Consolidation products

Three lime-based consolidation products from the German manufacturer CaloSil that contain different ratio of nanolime particles were tested:

- CaLoSil IP25 (25g of nanolime particles per liter, diluted in isopropanol)
- CaLoSil E50 (50g of nanolime particles per liter, diluted in ethanol)
- CaLoSil Paste-like (120g of nanolime particles per liter, diluted in ethanol)

And one silica-based consolidation product:

- Nano Estel (colloidal liquid dispersion with nanosilica particles)

The consolidation products were tested for two main properties: penetration and consolidation strength.

Penetration tests are made using 100ml graduated syringes filled with washed sand from the original arriccio plaster layers. The syringes are put into graduated test tubes to collect potential rest of consolidation product. 20ml from each consolidation product is injected into the 100ml syringe. The penetration deepness of each product is recorded. From all the consolidation products, the CaloSil IP25 and Nano Estel showed the best penetration properties.

Consolidation tests are carried out using plastic lids in which washed sand from the original arriccio plaster layers is placed. Each consolidation product is injected into the sand until saturation. Once the consolidation products have dried completely, the lids are turned upside down. The number of loose particles, i.e., particles that are not consolidated, can be observed. Of all the nano-lime-based consolidation products, CaloSil Paste-like showed the best consolidation properties. Nano Estel also gave good results. Any change in colorimetry or surface appearance was also recorded. The sand sample into which Nano Estel was injected showed a very strong change in colorimetry. The sand changed color from light to dark grey. Also, the appearance of the sand turned glossy. Regarding CaloSil products, the higher the concentration of lime nanoparticles, the more the product tends to form a white veil on the surface of the sand. Apart of this, no real change in colorimetry was observed with CaloSil products.

Based on the results obtained, the choice fell on **CaloSil IP25** consolidants when the area of plaster to be consolidated did not require too much consolidation. For more de-cohesive areas, it was decided to use **CaloSil E50**, with the option of diluting it slightly to prevent the original surface from whitening too much.

Grouts

PLM-AL, *Ledan TB1* and *Calxnova Kalkinjektionsmörtel*, industrial **grouts** commonly used in conservation – restoration in Europe –- as well as a homemade grout developed by conservator – restorer Léo Borgatta were tested on site.

Industrial grouts were prepared according to their technical sheets.

The **homemade grout** was developed to meet long-term, short-term and site-specific performance criteria (see table 1 and 2). The grout is made of a **slaked lime binder** from the German manufacturer Calxnova. According to the technical sheet, this already made product is composed of 50% slaked lime, water and with the addition of 1% of an additive to improve workability ("verarbeitungsverbessernde Additive"). Aggregates in the mixture are fine quartz powder, hollow micro-spheres of perlite, roman pozzolana. Because of the high soluble salt content of the plasters, the grout was tested with a reduced water content with the addition of 50% ethanol.

Long-term performance criteria	Short-term performance criteria
- Minimal shrinkage after setting - Porosity, water vapor permeability and hygrothermal behavior similar to the original plasters - Mechanical strength similar or lower than that of the original plasters - Low dry density - Good adhesion	- Low wet density - Good injectability - Good flow - Low water content and release

Table 1 Long-term and short-term grouts performance criteria according to Pasian et al. (2020)

Site-specific performance criteria	
Thick and deformed delamination between stone (masonry) and coarse plaster or between layers of coarse plaster (arriccio)	Thin delamination between plaster layers
- Adhesion, especially for horizontal surfaces where the grout needs to bear the weight of the plasters - Low wet and dry density versus bulking properties to fill large voids - Good flow, especially for horizontal surfaces - Low water content for plasters highly contaminated with soluble salts	- Good injectability and flow - Low water content for plaster highly contaminated with soluble salts

Table 2 Site-specific performance criteria modified from Pasain et al. (2020)

The following performance criteria were tested on-site for each grout:

- Wet and dry density
- Flow
- Injectability
- Shrinkage

Wet and dry density

20ml grout was injected in a syringe and weighted (wet weight). 20 ml grout was injected in plastic cup and weighted 48 hours later (dry weight).

Results are given in the table below.

20 ml of grout	Wet weight (g)	Dry weight (g)
1. Ledan TB1	33 g	28 g
2. PLM-AL	29 g	18 g
3. Calxnova Kalkinjektionsmörtel	42 g	33 g
4. Homemade grout (100% water)	15 g	10 g
5. Homemade grout (1-1 water - ethanol)	15 g	10 g

Table 3 Results of wet and dry density for each grout tested

The self-made grout showed a very low wet and dry density compared to the other grouts tested.

Flow

10 ml grout was injected by the person, with the same pushing power, through a syringe and let flow on a plate of cellular concrete on which grooves have been carved. The length of the distance covered by the grout is measured. The **homogeneity, thickness and adhesion** of the grout to the plate were also observed. **Injectability** of the grouts was also assessed by the person in charge of carrying out the test.

As expected, all the industrial grouts showed good flow. They also demonstrated good homogeneity, thickness and adhesion to the plate. All three also showed good injectability performance. The homemade grout mixed with 100% water showed good flow, high homogeneity and thickness, as well as strong adhesion to the plate. The homemade grout mixed with a 1:1 ratio of water to ethanol did not give very good results. It showed poor injectability and poor flow, certainly due to the rapid evaporation of the alcohol.

Shrinkage

20ml grout were injected into pre-wetted 4cm diameter plastic tubes disposed on a cellular concrete plate. The grout samples were left to dry inside the deposit for 48 hours.

In terms of shrinkage, PLM-AL showed the best performance, as no cracks were visible. Surprisingly, many cracks formed in the Ledan TB1 sample. This could be due to poor mix preparation, where too much water was added. Calxnova Kalkinjektionsmörtel showed a few tiny cracks. The homemade grout mixed with 100% water gave slightly poorer results, with some larger cracks. The homemade grout with a 1:1 water/ethanol ratio showed the worst performance, with significant shrinkage. This is certainly due to the rapid evaporation of the alcohol.

Conclusion of grout tests

Grouts	Density	Flow	Shrinkage
1. Ledan TB1	-	+	-
2. PLM-AL	+/-	+	+
3. Calxnova Kalkinjektionsmörtel	-	+	+/-
4. Homemade grout (100% water)	+	+/-	+/-
5. Homemade grout (1-1 water – ethanol)	+	-	-

Table 4 Summary table of grouts performances

Of all the grouts tested for **thin to medium delamination** (< 5 mm), PLM-AL showed the best performance. Nevertheless, the grout's high hydraulic properties and potential soluble salts it may contain (according to data sheet) increased the risk of damaging the weakened original plaster due to mechanical and chemical incompatibility and was therefore excluded. The choice fell on **homemade grout** mixed with 100% water, which also performed well. It is a very light material with good workability, low resistance, good adhesion and good flow, making it highly compatible with the original plasters. A 1:1 water/ethanol mixture would have been preferable due to the presence of soluble salts in the plasters but showed too poor performances to be used on site. A grout that achieves the same performance as one mixed only with water, but with a reduced water content, should be therefore further investigated.

For **larger detachments** (< 5mm), the choice fell on the **foam mortar** developed by conservator-restorer Klaus Klarner. This mortar has been in use at the PSPP since the first restoration campaign in 2015 (see former reports) and has demonstrated its ability to stabilize plaster that has become largely detached from the masonry.

Edging repairs and plaster fillings

Different mortar recipes have been made for the edging repairs and plaster fillings. The reasons why the groups decided not to use the same recipes as during the last summer school, are that they were considered too complicated and contained too much hydraulic components, making them too strong for the original plasters. In fact, despite discussions and warnings about a difficult future application, the group who in 2018 dedicated some time to the tests for edging mortars, “got lost in a search of perfection” working on preparations with too precise quantities and with too many types of local and non-local sands. **Performance criteria** for the 2023 mortar recipes were low strength (weaker than original plaster), good workability and color/apparency to match with the original plasters.

Slaked lime (and not hydraulic lime) was the binder for all the mortar recipes. For **arriccio layers** regional volcanic sand, grey river sand as well as basalt sand were selected as aggregates.

The following recipes were tested:

1. 50% fine grey river sand – 50% coarse basalt sand
2. 85% fine grey river sand – 15% coarse basalt sand
3. 75% fine grey river sand – 25% coarse basalt sand
4. 50% fine grey river sand – 50% local volcanic sand
5. 67% fine grey river sand – 33% local volcanic sand

For all recipes, the particle size distribution is between 0 and 2 mm and the lime-aggregate ratio is 1:3.

Mortar recipe n.5 met all performance criteria. Nevertheless, the local volcanic sand that were planned to be used appeared to be too dirty for restoration purposes. This was confirmed by a sedimentation test that showed that the sand contained clay and slit particles up to 9%, which, according to European Standard BS EN 13139:2002, should not exceed 3% by volume.

It was therefore decided to **avoid the use of the volcanic sand** that could have been detrimental for the conservation of the original plasters. The ratio between fine grey river sand and basalt aggregates was adapted during the work, depending on the color to be achieved in order to match the color of the original plaster and the need of a finer or coarser mortar.

Regarding recipes for **intonaco plaster layers**, the best results have been obtained by mixing 50% fine yellow river sand (< 1 mm) with 50% coarser yellow river sand (1-2 mm) and adding a maximum of 5% (so as not to increase the hydraulicity of the mortar) of yellow pozzolan if necessary, to obtain a warmer, more yellowish color of the mortar.

Tombs selected for conservation interventions

The condition assessment survey of the decorative surfaces, done by the participants, allowed to select several tombs where emergency interventions are needed (see fig. 11). **The tomb P XXIV 1 3** was chosen in priority to conduct emergency treatments. While this tomb was not considered the most priority one to intervene, it was selected for two other reasons, related to the short time available for the practical work. First, the large surface of plaster still in place gave the possibility for the whole group of participants to work together on the same object, where more experienced participants could help the others if needed. Second, the tomb is separated by an enclosure wall from the ancient street, the normal path used by tourists to visit the necropolis. So, the tomb's discreet location allowed the participants to work without disturb by and to the visitors.

Emergency treatment had to be carried out on the north wall of **tomb DN** (east side of the necropolis), where the preventive clay barrier system was to be implemented. Excavating the earth to reach the base of the tomb, to be able to install the clay barrier, loosened the lower part of the decorative plaster still present on the surface. With the plaster detached from the masonry in some places, it was necessary to intervene in emergency to avoid any loss of original material during the implementation of the clay barrier.

Finally, some emergency interventions were carried out on the decorative plasters of the south wall of **tomb P XXIV 2 10.** This facade was considered as an emergency case, especially because the surface of the *intonaco* (finishing plaster layer) shows extensive scaling deterioration that had to be treated urgently in order not to lose more details of the original decorative surface.

Conservation – restoration interventions: step of works

A detailed written and graphic report has been produced for each area treated. The aim of this section is to present the general methodology adopted to treat the **delamination** of the plasters and the work steps followed.

First measure to be undertaken before every operation is to **secure loose original materials** that could fall off while doing other treatments. In order to do that, the **facing** method was used. This method consists of applying a piece of Japanese paper to the unstable plaster area using a fixative, in this case an organic resin, **carboxymethylcellulose** (fig. 12) The role of the Japanese paper is to form a bridge to secure the moving part of the original plaster by being fixed to areas where the material surfaces are stable (usually the masonry surrounding the unstable plaster area). This temporary treatment is reversible as the carboxymethylcellulose is easily soluble in water. As it is an organic-based material, the fixative should be removed quickly, as soon as the area is definitely stabilized to avoid any microbiological growth. A discussion was held on this topic, leaving the participants free to use the method or to try the work without previous facing. It was evaluated and discussed that, if possible, it is better to avoid facing, especially in archaeological sites, as the adhesive used to apply the Japanese paper will be absorbed by the surface, remaining inside the porosity of the mortar and altering its physical properties.

When the area is temporarily secured, **conservation measures** can be undertaken:

- Every plant that grew in the plaster delamination is killed using a biocide. We used *Biotin* from the CTS
- When possible, the voids of the detachments are cleaned mechanically to get rid of earth or any loose particles
- Any gaps created by the detachment of the plaster layers that might be an open path for the grout are closed temporarily using cotton
- The voids created by the detachment have to be pre-wetted using a syringe filled with a solution of 1/1 water to ethanol
- The voids are grouted using the homemade grout described above (fig. 13). Wide detachments are grouted with the foam mortar.
- After the setting of the grout – generally waiting for at least a day – the edges of the delaminated plasters are closed using mortar recipe for *arriccio* or *intonaco* plaster layers (fig. 14). In certain cases, the loose plaster aggregates around the edges have to be consolidated, using CalsoSil IP25 or CaloSil 50 prior to the application of the edging repair mortar. This is in order to have a good connection between the restoration mortar and the original one. Consolidants can be also used for pre-consolidation of loose particles inside the void before grouting if necessary.

Areas of plaster delamination highly affected by **soluble salts** are not fully filled with grout. Only few local **connection spots** are done, in order to avoid at maximum, the issue of giving new path for soluble salts to migrate to the surface.

Figure 12 Application of a facing to temporary secure plaster using Japanese paper and carboxymethylcellulose

Figure 13 Grouting of the voids caused by the detachment of plaster layer (intonaco)

Figure 14 Application of restoration mortar to close open edges caused by the detachment of plaster layer

Implementation of a preventive conservation method using clay barrier on tomb DN (report from Dr. Martin Michette)

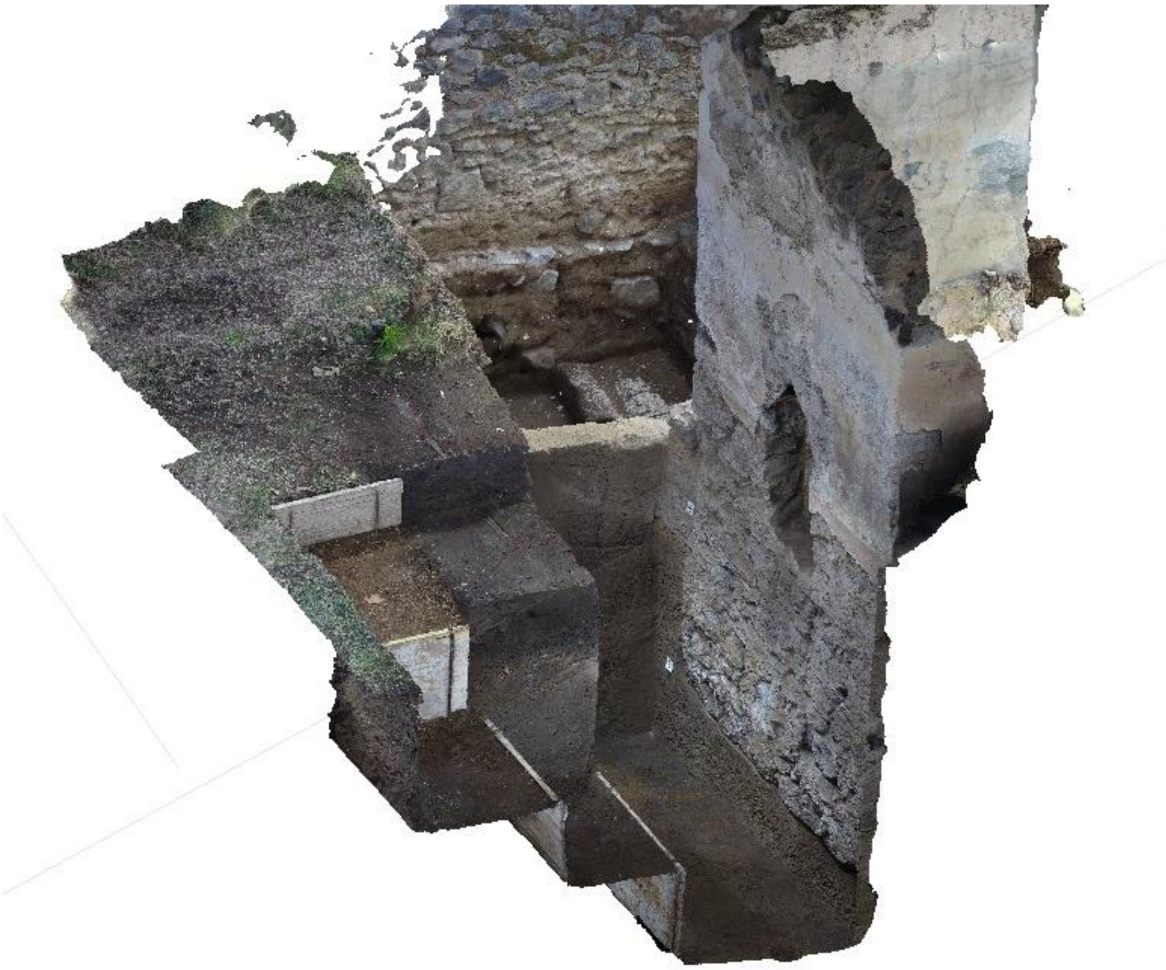


Figure 15 The north side of Tomb D-N showing the exposed subterranean surface which was partially covered by the barrier installation (photogrammetry prior to installation)

Summary

- A clay barrier made from a mixture of 2 locally available geomaterials was installed along part of the north facing side of a funerary monument in Pompeii, covering approximately the bottom 1 m.
- The barrier was made from unprocessed materials, which were prepared, tested, and mixed on site.
- An initial attempt to prefabricate bricks to construct the barrier was terminated due to concerns over the joints.
- The remaining barrier was constructed using the standard method of compacting loose material directly into a removeable formwork.

- Moisture sensors were installed in front of the barrier (i.e. moist side) and behind the barrier (i.e dry side) at three heights.

Introduction

This is a report on the partial installation of a clay barrier along one side of Tomb D-N of the Via Nucerina, Pompeii. The barrier was prepared and installed during a workshop from 25 September to 5 October 2023 as part of the PSPP Summer School 2023. The aim of the workshop was to explore the general feasibility of installing clay barriers made from unprocessed geomaterials in an archaeological context.

The workshop was led by Martin Michette and Richard Grove, with supervision from Pia Kastenmeier. Four participants of the Summer School were engaged with the project over its whole duration, the rest of the group rotated daily or half-daily. Also instrumental to the workshop was the excavation of Tomb D-N by William van Andringa, his team and two workmen of the excavation firm Vitiello.

Preamble

The workshop built upon the findings of two site surveys in 2017 and two orientation workshops at the Fraunhofer IBP in Holzkirchen in 2021 and 2022.

In March 2017 an initial site visit and survey was made. This included a non-destructive moisture survey of Tomb D-N to establish ongoing ground moisture intrusion and 'rising damp' as active decay mechanism. An initial identification of suitable local materials for producing clay barrier was also made.

In September 2017, following an excavation by William van Andringa, moisture sensors were installed on subterranean surface of Tomb D-N. An ongoing identification of suitable materials and collection for analysis was made. These were analysed at the Technical University Munich and a decision was made to produce the barrier from a mixture of a volcanic black sand from Vesuvius and a calcareous clay from near Salerno.

In October 2021 and November 2022, two orientation workshops were held at the Fraunhofer IBP in Holzkirchen. These explored the practical aspects of the barrier installation, including the mixing of the materials and the best way of compacting the mixture. Due to concerns about potential vibrations, the decision was made to produce pre-compacted bricks rather than compacting the barrier at the monument.

Preparing the material

Prior to the workshop (mid-September), the parts of Tomb D-N which had been excavated in 2017 were re-excavated under the supervision of Pia Kastenmeier. Further excavation by the team of William van Andringa completely exposed the northern 'foundation' of Tomb D-N, an area of approximately 2 x 2 meters. The objective of the clay barrier workshop during the Summer School was to cover as much of this exposed area as possible with a 150 mm deep clay barrier.

Approximately 5 tones each of the black sand and the calcareous clay were delivered on 25 September. The black sand was tested for sulphates to give an approximation of salt content, with negligible results. The material was kept under sheets of black plastic to minimize moisture loss.

26 and 27 September were spent optimizing a production line for producing bricks. Samples of both materials were tested for moisture content, with the black sand measuring fairly consistent at 8-10% and the clay showing a wider range of 6-10%. This can be explained by the unprocessed consistency of the clay, which included larger lumps of clay as well as looser fine material. When processed, the clay becomes consistently fine grained. When homogeneous, it is likely to have a consistent moisture content.

To achieve a mixture with the correct proportions of clay in a good consistency, it was necessary to break down the unprocessed clay into smaller pieces. Several different techniques were used across the workshop including grinding and pounding with stones and pounding and crushing with mallets.

Eventually the following method for processing the clay was adopted. Using sieves and buckets, the raw material was divided into three parts. The finest material was left unprocessed, the medium grain (approx. 1 mm to 1 cm) was pounded using stones, and the coarse grain (lumps larger than approx. 1 cm) were first crushed using mallets and then pounded using stones. Care was taken to keep all parts of one batch together so as not to affect the overall grain size distribution of material being used in a mixture. This was the initial, and most time-consuming process in the production line.

The mixture was produced from approximately 2 parts clay and 1 part sand. These proportions were based on the previous tests conducted at the TUM. Rather than attempting calculations, water was added during mixing until it became moist but not wet. The ball drop test was used to establish if the mixture had the right consistency. Again, this was based on the laboratory protocols.

Formwork was constructed from OSB panels to produce bricks of 15 x 15 x 30 cm. The mixture was compacted into the formwork in several layers using mallets. Overall, 15 bricks were produced before we switched approach (see below). The bricks had an average density of 2.07 g/cm^3, ranging from 1.92 to 2.22 g/cm^3.

Installing the barrier

On 28 and 29 September, the barrier was initially constructed by building a wall of bricks. A slightly wetter mixture was used as a mortar and some additional compaction was performed with mallets to bind bricks together. A small gap of 2-3 cm was left between the barrier and the monument. This was backfilled with black sand after each course to accommodate the uneven surface of the monument.

After 2-3 courses of bricks, it became clear that the method was not working due to the joints. The barrier was also becoming uneven due to slightly different brick sizes.

From 2 to 5 October, we therefore switched back to the standard method for installing clay barriers. The mixture was produced as above, but then transported loose to the monument and filled into a removeable formwork made from OSB panels. It was then compacted into layers using a tamper.

This method produced a homogenous barrier with an even surface. The bricks still proved useful for building up the ends of the barrier. The formwork was removed after every few courses and the gap between the barrier and the monument was still backfilled with sand.

One formwork panel between the barrier and the monument was impossible to remove. It was decided that if and when the barrier is re-excavated, its condition will give an indication of how much moisture intruded through the barrier.

In total, the barrier was built up to approximately the bottom 1 m of the exposed north side. The excavation was successively infilled as the barrier was built up, to provide lateral support. The remaining approximately 1 m of the north side, which was not protected by the barrier, was infilled using the previously excavated material.

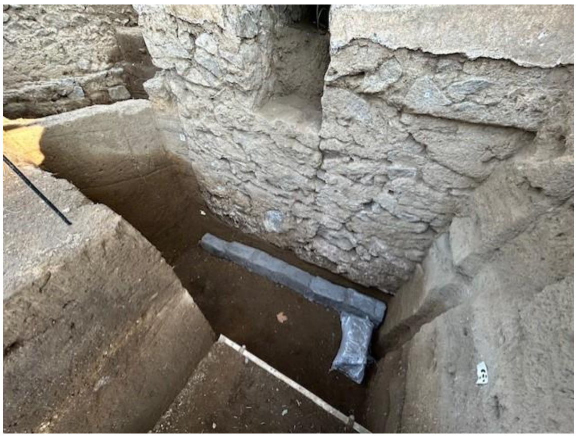
Moisture sensors

Six moisture sensors which had previously been used to monitor ground moisture at various different heights and aspects around Tomb D-N were reinstalled to monitor the effect of the barrier.

Three sets of two sensors were installed at different heights, with one outside the barrier to measure ground moisture, and one behind the barrier to measure the effect of the barrier in mitigating the ground moisture.

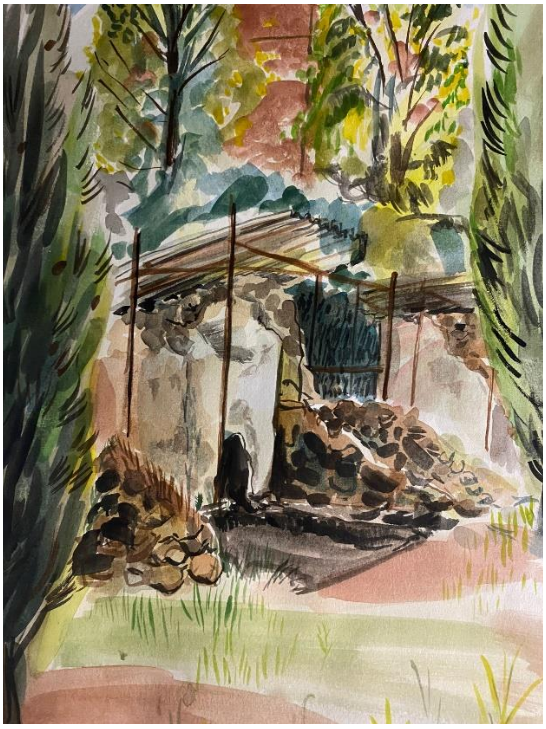
The sensors were reconnected to the Fraunhofer datalogger, along with a new battery. A record was made of the sensor locations.

Images







Conclusion

This year's Summer School activities were a great opportunity for participants, the Fraunhofer team and the PAP to learn from each other.

Not only did the quantity and quality of the various presentations enable participants to leave with a good overview of the complexity of the various activities and players involved in the conservation of archaeological sites, but the six weeks also provided an opportunity for exchanges between experts and young professionals in the field.

The opportunity to learn about the materials to be used is just one of the contributions PSPP has made in recent years, showing participants what is used in Italy but also what can be found in other countries, and how mortar recipes can be developed on site with local materials. This is even more important for participants who have limited resources and difficulties to obtain restoration products in their own countries.

In this course, great emphasis is placed on the particularities of working "in a state of emergency", as is often the case when an object emerges from excavation, but also during natural disasters or the risks or damage caused to heritage in ongoing conflicts.

The decisions that conservators are forced to make in these situations may be far removed from common practice, but the right decisions must be made to save the object, the surface or the monument. PSPP is a small boot camp in which these matters can be discussed and even tested, which is a special opportunity.

The network of friendships and professional relationships forged between participants during their short stay in Pompeii will endure into the future, as we have seen with the two previous summer schools, enabling professionals to stay in touch and continue exchanging views on the vast and perpetually evolving field of cultural heritage conservation for years to come.

Acknowledgement

The authors of this report would like to thank the Director, Dr. Gabriel Zuchtriegel, and PAP staff members who contributed to the success of this Summer School: Dr. Paolo Mighetto, Dr. Vincenzo Calvanese, Arch. Raffaele Martinelli and Dr. Giuseppe Scarpati as well as all external speakers. Special thanks go to Generale CC Giovanni Capasso and his staff for their hospitality in the Casina Pacifico, which we occasionally used as a lesson room. We would also like to thank PSPP partner ICCROM and Dr. Alison Heritage for hosting us for two days in their laboratories in Rome.

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