Protecting Pompeii with Clay Barriers,

2017 Activities Report, PSPP

Ralf Kilian (Fraunhofer-Institute for Building Physics); Martin Michette (University of Oxford, School of Geography); Stefan Bichlmair (Fraunhofer-Institute for Building Physics); Sara Saba (Fraunhofer-Institute for Building Physics)

The effects of humidity are amongst the greatest challenges faced by conservators and cultural heritage managers in their efforts to preserve monuments at archaeological sites for future generations. This is apparent at the necropolis of Porta Nocera and Via Nucerina (Fondo Pacifico) in Pompeii (Fig. 1), which is situated in the lowest part of the archaeological site at the border between the ancient and modern cities, where there is visible evidence of consistent ground moisture intrusion. The state of conservation of the numerous funerary monuments at the Via Nucerina necropolis has declined steadily since their excavation in the early 1980s, in spite of the interventions by local authorities. Water ingress appears to be the primary deterioration mechanism.

Fig. 1: View of Via Nucerina in 2016 with Tomb D-N, under second protective roof from the left, top row.

Retrofitting impermeable moisture barriers generally requires chemical or mechanical intervention with historic fabric, which is often practically impossible or undesirable in the

context of conservation policy. Leaving the building unprotected can lead to rising damp, salt contamination and rapid deterioration. Clay barriers present a possible alternative. They consist entirely of natural soil materials and their installation is reversible. The technique is commonplace in some areas of environmental engineering, and has recently re-emerged in built heritage conservation (Egloffstein 2009), e.g. with churches in Bavaria or in Saxonia. Specialised mixtures, generally bentonite modified soils, as well as naturally occurring clayey soils have been employed; these can be compacted at the foot of below ground masonry without the need for further fixation. Installation involves excavating an area around the monument and compacting a 20-30 cm wide layer of suitable material at the foot of the foundations up to ground level. The rest of the excavated area is filled in. The barrier effect relies on various hydraulic mechanisms, which can differ depending on the soil or mixture being used (Michette et al 2017). The idea of the project is to test the effectiveness of this technique for the preservation of ancient monuments.

The archaeological site of Pompeii is particularly at risk from ground moisture due to saturation and seepage after heavy rainfall. Recent work has identified that local volcanic earth was used as a plaster, in part to protect walls against moisture, possibly even in the form of vertical barriers. There are suggestions that volcanic soils may be generally suitable for use as clay liners (Navia et al 2005). The project has therefore worked also to identify local soils from the Pompeii region for use in protecting the monuments of the archaeological site from ground moisture. Selected soils are subject to laboratory analysis to assess their suitability for use as an impermeable barrier and mixed or modified as necessary. The objective is to install a barrier at the Via Nucerina necropolis at the end of 2018 and undertake long-term monitoring of the effects in the following year. The wider aim of the project is to identify soil characteristics and components required to make clay barriers suitable for use in built heritage. This will expand the potential of naturally occurring soils as a long-term measure for sustainable, preventative conservation.

The Clay Barrier Project – An Interdisciplinary Approach to Preventative Conservation: the Interventions of 2017

The project is being carried out by several European research institutes within the context of a broader research initiative called the Pompeii Sustainable Preservation Project (PSPP). This latter project aims to help conserve the necropolis site of Porta Nocera (and Via Nucerina-Fondo Pacifico) with a holistic approach. The PSPP started working in these areas in 2014 and has conducted several restoration campaigns that can be described as emergency interventions to arrest the decay of the archaeological fabric.

Our research and conservation project on clay barriers started in January 2017 to the end of implementing a long-term conservation strategy. An initial survey campaign was conducted in March 2017 with an interdisciplinary team consisting of building physicists, conservators, archaeologists, geophysicists and geologists coming from all involved institutes, namely Oxford University, Fraunhofer IBP, TUM and the Italian IBAM-CNR in close collaboration with the experts of the Parco Archeologico Pompei. During two weeks the team collected an initial selection of potential barrier materials for laboratory testing, took non-destructive moisture readings from a number of monuments in the Via Nucerina necropolis, made a visual condition survey of the tomb selected for the long-term project (Tomb D-N, Fig.2) and conducted geo-physical investigations of the wider area. Further measurements and soil samples were taken in July, when our team also installed a weather-station to enable correlation with climatic conditions, and in September, whilst in August two conservators conducted emergency interventions on the monument to preserve the ancient plasters and decoration of the tomb. This emergency conservation intervention was requested by the Parco Archeologico Pompei as the necessary premise to the archaeological investigation around the funerary monument that Professor W. Van Andringa, University of Lille, conducted in September 2017. This preliminary archaeological excavation was also used to assess the risk of clay barrier installation and provide historical documentation. Before the excavated areas were re-filled, moisture and temperature sensors were installed at the interface between the foundations of the tomb and the surrounding soil.

Fig. 2: South Façade of the Tomb D-N at the Via Nucerina Necropolis, Pompeii with a protective roof dating in the 1980s. A characteristic horizon of salt damages to the plaster can be observed.

Fig. 3: excavation in and around tomb D-N, Prof. W. Van Andringa (September 2017).

Initial results and findings

Results of the 2014-15 climate monitoring show that there is a clear influence from ground moisture that is also being transported through the walls and then evaporates at the surfaces while transporting soluble salts in liquid state. Figure 4 shows a comparison of absolute humidity at the top of the tomb (grey) with the position in the niche in an old tin (green). The overall moisture content near the ground is considerably higher than that of the ambient air on top of the tomb.

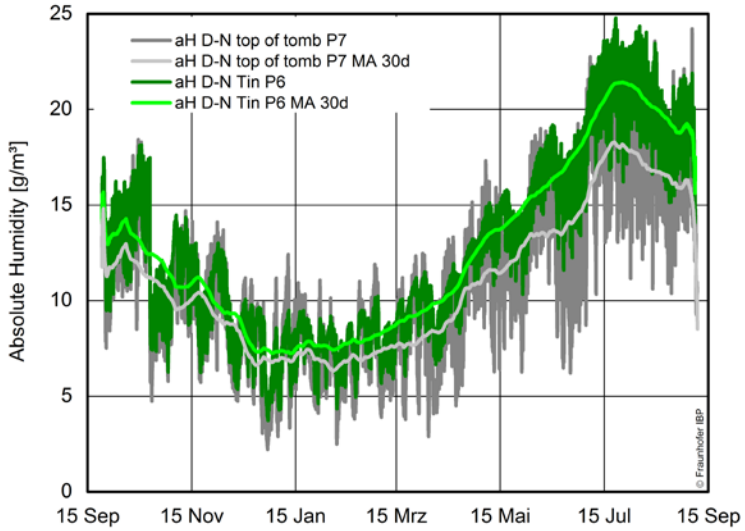

Fig. 4: Comparison of absolute humidity at the top of the tomb (grey) with the position in the niche in an old tin (green).

Looking at climate fluctuations behind the protective glazing (Fig. 5) we can see much larger amplitudes, going up to daily fluctuations of 80 % RH and more than 35 °C difference during 24 hours. This will lead to considerable stress at the surfaces as well as to vaporization of moisture and crystallization and re-crystallization of salts near the surfaces that will contribute to a continuous decay of the valuable ancient surfaces of Tomb D-N.

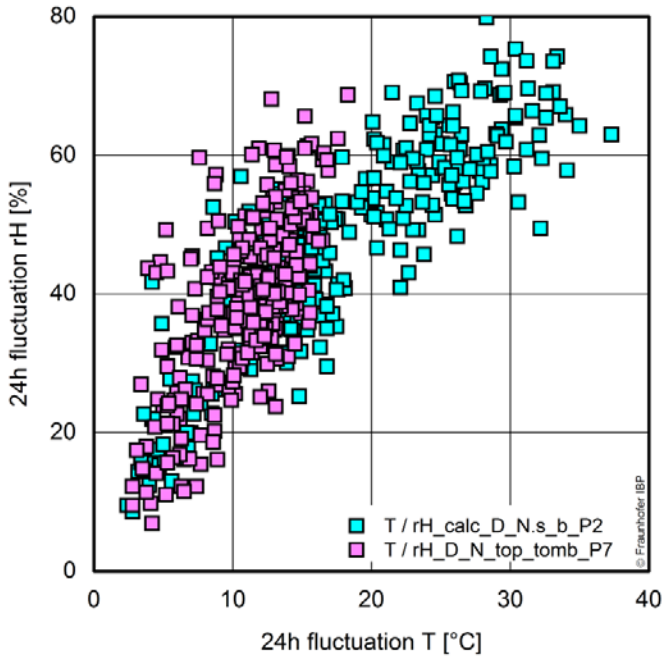

Fig. 5: Comparison of climate fluctuations of T and RH during 24 hours in a shaded area on top of the tomb (pink) and behind the protective glass on the south façade (light blue).

The moisture survey was carried out using a MOIST350B on all sheltered tombs along via Nucerina. The MOIST350B (hf sensor GmbH; Leipzig, DE) is a rigorous non-destructive moisture measurement device that uses microwave fields as a surrogate for moisture contents. The survey was carried out by dividing the elevations of the tombs into sensible regions. In the case of homogeneous materiality this took the form of a grid, noticeably heterogeneous regions (e.g. discoloured plaster or exposed stone) were individually measured. Approximately 30 surface and 30 sub-surface readings were taken per region. The readings and their evaluation show that moisture at both surface and sub-surface level is concentrated in lower parts of the masonry, particularly at the north-western and southern edges. Findings at other tombs were similar. This supports the observation made during the condition survey and suggests that rising damp was an active mechanism during the field-trip period.

Initial measurements in March were unable to take readings from behind the glass panels on the south and east sides of the tomb. Further measurements, however, could be taken in September 2017 following removal of the panels and partial excavation of the monument.

Moreover, a team from the Italian IBAM-CNR conducted a geophysical investigation around the monument in order to understand the archaeological context and, eventually, detect the presence of structures that are still buried underground and that could prevent the installation of the clay barrier. Thanks to the survey we now know where the barrier can be safely installed.

Fig. 6: 3 D Model of Tomb D-N, Via Nucerina created by the IBAM-CNR Team.

In 2017 another goal of the project was to search for suitable barrier materials. The following materials were identified, collected and eventually transported back to Munich for laboratory testing that are underway. Preliminary testing consisting of a visual assessment, gravimetric determination of moisture content (MC) and an HCl drop test to indicate alkaline components was also undertaken.

- Martino Clay (MAR): A plastic, grey clay with little to no coarse granulate. Some organic matter. Taken from near Salerno (15.03.17).
- Majano Clay (MAJ): Slightly plastic, red-brown sandy clay. Moderate organic matter. Taken from near Sorrento (16.03.17).
- Trasaella Clay (TRA): Very slightly plastic, brown soil with some sand and coarse granulate. Much organic matter. Taken from near Sorrento (16.03.17).

- Red Pozzolana (RPO): Coarse, red-brown sand with little very coarse granulate. Taken from near Terzignio (16.03.17). Sediment from volcanic eruption.
- Black Pozzolana (BPO): Coarse, dark grey sand with some very coarse granulate. Taken in Terzignio (16.03.17).
- Fango (FAN): Plastic, light grey clay with very uniform fine granulate. Taken from near Terzignio (16.03.17).
- Botarro Sand (BOT): Black sand with very little fine granulate. Some white or grey grains. Taken in Botarro (14.03.17).
- Pumice Pozzolana mix (PPM): Red-brown soil with little fine and much coarse to very coarse granulate. Gravel grading predominantly pumice. Taken in Terzignio (16.03.17).

Materials were selected based on (Michette et al 2017):

- Suspected clay content: Potential for high compaction density. Potential for cation exchange with alkaline materials and formation of stable matrix. Potential for swelling and flocculation filling pore space.
- Suspected pozzolanic reaction potential.
- Abundance and availability.

Whilst some of the selected materials may be suitable for use as barriers with little or no modification (e.g. MAR), other were selected with the sole intent of providing potential mixing materials to induce geo-chemical reactions (e.g. RPO, BPO).

Outlook and Next Steps

Environmental monitoring will continue for the entire 2018 before installation of the clay barrier in order to deliver a detailed picture of ground moisture regimes. Besides the clay barrier, a new roof to better protect the monument from rain and sunlight will be erected in the Fall of 2018. The Technical University of Munich has developed a new type of protective roof (Fig. 7). A first version of this prototype has been installed on another funerary monument in Via Nucerina (Tomb H) last August 2017. This roof is modular, built according to resist seismic movement and with low-maintenance materials. Before installation at Tomb D-N, the design will be studied and developed further. Particularly the effect of areas subject to fluctuating sunlight will be considered in light of recent research highlighting associated risks to salt weathering (Cabello-Briones 2017). The project was indeed proposed

for a site which is already sheltered in order to minimise the parameters of influence when assessing the impact of a clay barrier.

Fig.7: Prototype of the new covering roof developed by Fonti and Emmerling, TUM and installed on Tomb H of Via Nucerina in August 2017.

The work of the project will therefore continue in 2018 and 2019 thus prolonging this research initiative for one year. The new timeline, already discussed with the donor, is necessary because the team had to collect more information than it was initially thought, since in Pompeii comparable data were lacking, before implementing its main intervention, namely the installation of the clay barrier. This, in turn, needs to be also monitored for a longer period of time (about a year – 2019) to establish its effects on the conservation state of the funerary monument.

During the upcoming PSPP Conservation Summer School (September – October 2018) the topic of the protective roof will be also central to the discussion and first results of the project will be presented during the second and closing workshop.

Bibliography cited

Cabello Briones C. (2017), Effects of Open Shelters on the Preservation of Limestone Remains at Archaeological Sites, Oxford University Dissertation, Supervisor: Prof. H. Viles

Egloffstein P., Egloffstein T. (2009) Einsatz und Grenzen von Tonabdichtungen an Gebauden. Feuchteschutz am Baudenkmal IFS-Tagung; IFS-Bericht, Institut für Steinkonservierung eV.,: 23–36

Michette M., Lorenz R. and Ziegert C. (2017) Clay barriers for protecting historic buildings from ground moisture intrusion. *Heritage Science*, 5(31): 1-11.

Navia R., Hafner G., Raber G., Lorber K.E., Schoffmann E., Vortisch W. (2005), The use of volcanic soil as mineral landfill liner - I. Physicochemical characterization and comparison with zeolites. WASTE Manag Res. 1 OLIVERS YARD, 55 CITY ROAD, LONDON EC1Y 1SP, ENGLAND: SAGE PUBLICATIONS LTD; 23(3): 249–59