New and existing forms of protective shelter at Herculaneum: towards improving the continuous care of the site

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ABSTRACT
The Herculaneum Conservation Project has approached the conservation of a large-scale archaeological site (Herculaneum, Italy) suffering widespread forms of decay in two different ways: 1) with a site-wide campaign addressing conservation problems in areas most at risk and 2) with a case-study project for one urban block (Insula Orientalis I) exploring some of the complex conservation challenges in more detail. One of these challenges is how to approach the repair of existing roofing and how to design new forms of protective shelter for those spaces that have never been covered. Short-, mid- and long-term solutions for the repair and substitution of existing roofing are being tested as part of the site-wide campaign, while in the case-study area more enduring solutions (new mid- and long-term) for new shelters are being trialled.

INTRODUCTION
There continues to be great debate in the conservation world on the subject of roofing and protective shelters [1], a topic that is of great relevance to the archaeological site of Herculaneum where its vulnerable decorative surfaces, wood and metal features are exposed to the elements. The excavated areas of Herculaneum can be viewed from above, so protective roofing measures here have a greater visual impact than usual. In addition, unlike its sister site Pompeii, a considerable number of upper floors of the buildings of Herculaneum have survived semi-intact giving the ancient city a particular urban quality that needs preserving.

Along with drainage, roofing also represents a fundamental part of the urban infrastructure, which needs to be improved in order to slow down decay and reduce maintenance costs. Progress needs to be made in this area in parallel with general ordinary and extraordinary maintenance of the site in order to make the ancient city more manageable.

EXISTING FORMS OF PROTECTIVE SHELTER AT HERCULANEUM

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Maiuri’s approach to protective roofs
Unlike most archaeological sites that have undergone different site formation processes, the structures at Herculaneum are generally preserved to a considerable height thanks to the nature of the volcanic eruption of AD 79 and the preservation qualities of the volcanic material in which the city was buried [3–4]. During the 20th century excavations led by Amedeo Maiuri, it became evident that while the force of the pyroclastic...
flows and surges had swept away much of the city’s fabric it had also left entire portions of roof structures or floor plates intact (Figure 1). In areas of greater devastation, the survival of carbonised stumps of structural beams gave archaeologists additional information on where floor plates and roofs were attached to the walls [4–5].

Most of Maiuri’s reconstructions of floor plates and roofs during the excavation phase were motivated by the need for lateral structural reinforcement or by the need to protect the decorative features below. Indeed, the rooms that are covered today are nearly all decorated. However, there are also examples of reconstructions that were motivated by the need to show, even minimally, the original form of the space (for example, the corner of the peristyle of the Central Baths). Most of the roofs were made ad identicum using construction techniques and forms that imitated the original structure, an option Maiuri chose only when archaeological evidence was sufficient.

In these cases, the restoration construction methods he adopted were as similar as possible to the original Roman techniques, and when modern structural elements were used for reasons of cost or availability (for example, iron I-beams) the final result was carefully designed to appear identical to the original structure that had been found and documented [5–6]. If we consider the period in which most of Maiuri’s work was carried out (before, during and immediately after World War II) and the consequent shortage and difficulties in gathering these materials, the quality of his roofing construction methods was generally good, both in terms of building methods and of use of materials. His roofing approach reached an admirable equilibrium that, on the one hand, respected the archaeological evidence and, on the other, was effective in protecting the features below. Although a truly scientific attitude towards conservation issues was not yet established in the era in which Maiuri was most active, nevertheless his approach demonstrated an advanced sensibility to the need for site protection measures in the broadest sense. For example, the decorated floors that were not roofed were protected with layers of sand, removed during each dry season. Similarly, his restoration measures were followed by a systematic maintenance programme of the area, sustained by fixed teams of craftsmen.

Maiuri’s traditional roofing strategy not only allows the visitor today a visual ‘revisiting’ of what emerged during excavations, but also reinforces the legibility of the urban scale of the site. Moreover, reflecting on Maiuri’s legacy – understanding his construction methods and learning from their state of decay after a 60-year period – is a necessary point of departure for addressing the issue of roofing today, whether existing or new, temporary or permanent. Similarly, lessons need to be learnt from the fact that it is the gradual failure of the maintenance programmes that Maiuri set up that has triggered and aggravated the widespread decay of almost all the shelters of Herculaneum (be they light shelters, floor slabs or actual roofs) in the late 20th century [3].

Floor slabs and pitched roofs
Mapping the presence of roofing on-site and analysing various aspects of it (quantity, construction technique, degree of decay, absence, etc.) [2] revealed that the actual ‘roofs’ that remain in Herculaneum today are limited in number. Reference is often made to a ‘roof’ when describing what is actually a floor slab acting as a shelter dividing a ground floor from the ruined shell of an upper floor – a very common situation in this ancient city. Research on the existing roofing has in fact confirmed that floor slabs form the great majority of protective coverings, with an overall surface area of...
2,529 m²; while actual roofs, either *ad idem* reconstructions or modern roofs, protect an area of only 860 m². These findings are interesting in themselves but also prompt considerations on various themes concerning both conservation and the site’s legibility.

In conservation terms the floor slabs, by their nature, are less resilient than pitched roofing; indeed, they were never intended to act as real roofs and have several technical shortcomings (see below). On the other hand, protecting rooms by reconstructing their floor slabs is one of the more successful forms of shelter on this archaeological site, as this approach is based on solid archaeological evidence and does not introduce unfamiliar elements into the ancient cityscape.

Instead, pitched roofs are easier to maintain and generally more resistant if built well. They also contribute to the particular urban character of the ancient city. The choice of construction techniques (in particular, the surface treatment of pitched roofs) has a critical impact on a visitor’s first view of the site. It is surprising that, despite their limited number, the strategic distribution of pitched roofs strengthens the impression of an intact cityscape for the visitor.

**Defining the problems**

**Covered and uncovered areas at Herculaneum**

Our site-wide survey showed that, within the excavated site of Herculaneum, there are 269 covered rooms making a total area of about 3,600 m², of which 440 m² of rooms are covered by a floor slab and a pitched roof because they form part of multi-storey structures (excluding subterranean levels).

This simple calculation in reality can be taken much further. For example, a comparison between areas that were presumably covered before the volcanic eruption (block by block) and the areas covered today shows that only about 14% of the areas originally covered were reconstructed during 20th century restoration work. A total area of 28,539 m² of the ancient city has been excavated, of which about 5,200 m² were originally exposed (18%) and approximately 23,400 m² were originally covered. This means that there must be an area of about 20,000 m² of originally covered interiors that today are exposed.

Surveying these uncovered areas, it is possible to identify which are decorated or contain materials that are highly sensitive to decay (carbonised wood, metals, etc.). It can be calculated that of the 28,539 m² of excavated area (excluding the roads), 11,000 m² are rooms characterised by decorative features and that of these 5,200 m² are covered, while the remaining 5,800 m² are out in the open air (Figure 2).

In order to evaluate the feasibility and importance of creating new roofing in Herculaneum, our analysis of the exposed rooms was given further details following consultation with archaeologist and conservator-restorer colleagues. Those uncovered areas that have decoration of particular value (documentary, historic, archaeological, artistic or being unique), and those where decay is rapid and decorative features are on the verge of being lost completely were identified.

Even though this research still resulted in the identification of 2,600 m² that needed protection, only 400 m² of these were deemed potentially coverable (with permanent or temporary solutions) as part of the site-wide emergency campaign, i.e. with a relatively simple planning stage [2]. This final selection was identified on the basis that these areas did not require extensive reconstruction, large-span structures or elaborate design analysis (to avoid an adverse impact on the formal aesthetic equilibrium of the existing buildings). Some of these areas have already been protected with new roofs (primarily temporary solutions but some...
permanent in the case of direct substitution), while other interventions are in the process of being planned and will be erected during 2008–2009. The information gathered during the trials of shelters in the Insula Orientalis I case study project (see below) was pivotal in allowing the site-wide campaign planning process to shift from analysis to the actual implementation of solutions so swiftly.

The remaining rooms that need protection (roughly 2,200m²) will require more in-depth conservation proposals in the future. This is because without the support of archaeological evidence the options to be evaluated for modern additions need to be calibrated in a sustainable way with the general character of the site and its long-term maintenance needs. For these rooms where the erection of new roofing is not feasible, either in the short term or ever, but extensive floor decorations are present, the benefits of reburial (temporary or permanent, and potentially seasonal) are being carefully considered. This approach will also benefit those rooms where well-planned roofing solutions are feasible but are on hold pending the results of on-going experiments in the case study project (see below) and other long-term projects run directly by the local heritage authority, the Soprintendenza Archeologica di Pompei.

Conservation challenges raised by Maiuri’s ad identicum forms of shelter

Amedeo Maiuri’s decision to reconstruct most of the roofs and floor slabs at Herculaneum ad identicum (a decision that was then followed by the excavators who came after him in the north-west corner of the site in the 1960s [7]) was part of his programme to create a museum-city [2–3] with permanent staff. As permanent staff were laid off and the system of site maintenance, which had been guaranteeing the daily care of the site, broke down, the conservation problems tied to this domestic-scale reconstruction became evident in the space of only a few years [3].

These reconstructions were only carried out for individual rooms and not for entire building units. Often the rooms were only partially covered and, as mentioned above, covered by floor slabs adapted for use as roofing. In addition, the presence of ancient walls and the remains of original carbonised wooden elements inevitably impeded the use of more comprehensive waterproofing techniques that would have guaranteed a longer lifespan. Failure of rainwater drainage systems (gutters, downpipes, drains) aggravated the state of individual roofs, often causing a chain reaction on surrounding roofing (water that has accumulated over a room will either penetrate the structure of the roof itself or will collect on adjacent structures). Increasing difficulties in managing rainwater [8], widespread and serious decay and the inaccessibility of the upper levels inhibiting maintenance are the consequences of these various factors.

Substantially, the domestic-scale reconstruction for re-roofing Herculaneum, implemented by Maiuri and his successors, even if well designed and executed, had the primary shortcoming typical of traditional vernacular architecture: the need for constant maintenance, usually guaranteed by the owners but, in the case of a site, by a fixed staff [3].

Forms of decay common to floor slabs

As already mentioned, floor slabs reused as roofs have suffered most damage from rainwater ingress due to their very shallow inclination, the difficulty of installing downpipes and the need for constant maintenance. Water infiltration can lead to damp patches, the rotting of floorboards, decay and warping of beams and boards, the detachment of the waterproof layer, and partial or total collapse. As the upper screed of floor slabs (above the beams and boards) does not have to bear any dead or live load (the weight of additional structures, visitors or furniture) it could be lightweight (made of a paste of lapilli, earth and some lime). It was then covered by a waterproof layer (usually asphalt, protected by a second thin screed of lime/cement and gravel). The major point of potential weakness has proved to be where the floor slab meets the wall, even if the waterproof layer was doubled and, often, extended into the wall to stop infiltration at this delicate point.

However, the mortar protection alone has proved to be insufficient. After a certain amount of exposure to the elements in the absence of a maintenance programme, the mortar crumbles and the waterproof layer exposed to the sun comes away. Water then penetrates between the wall and the floor slab under the impermeable layer. This then causes the earthen screed to swell, causing rot and the warping of the beams and floorboards below, exposed as they are not only to direct water damage but also to the deformations of the screed layer above.
Forms of decay common to pitched roofing

Pitched roofs suffer significantly less from water penetration, thanks to the rapid drainage of rainwater down the slope of the outer covering. As a result, they undergo less structural damage to their wooden elements. The resilience of the upper covering is largely based on the resistance of the tiles since in Herculaneum’s case there are rarely other layers between the outside and the inside of the roof. The quality of the tiling is crucial for the survival of ad identicum roofs: if thin or of poor quality they allow capillary penetration and the beams suffer from damp. Even if the timber is treated, with wet/dry cycles they decay quickly. In the most serious cases, the poorer quality tiles have such little resistance that they begin to flake, with consequent danger for visitors.

The assortment of different tiles that resulted from continual repairs means that even roof covering in a good condition regularly shows localised signs of deterioration, with the risk of tiles breaking and falling, and partial or total collapse due to the rafters and purlins gradually decaying.

The protection of beams (or lack of it) is directly linked to the level of decay triggered by water infiltration between the tiles. Generally, only the valley rafters (where two pitches meet) are separated from the roof’s covering, by a sheet layer of either lead or aluminium. The purlins, and often even the wall plates, do not have any protection. In the case of compluviate roofs (four slopes descending inward to a central opening), the valley rafters and central ring beam (built of reinforced concrete in the early 20th century restorations due to the difficulty in obtaining and transporting large enough solid wooden beams) are generally those most affected by humidity. When parts or all of the drainage system are blocked, water seeps through the tiles and begins to decay the load-bearing valley beams underneath where they meet the compluviate ring beam. For this reason, signs of decay in the reinforced concrete beams are widely visible in Herculaneum, with the surface lifting and the reinforcement rusting, which in turn triggers further structural cracking.

Resolving the problems

Repairing existing forms of protective roofs

The urgent problems raised by the widespread decay of existing roofing led us to address their repair and substitution within the site-wide emergency campaign [2] resulting in a lean planning process applied on a large scale and omitting those areas that required more in-depth research.

Before starting this planning process, various trials were undertaken to check the possibility of carrying out interventions on different levels – short- (1- to 5-year lifespan), mid- (5- to 20-year lifespan) and long-term (30+ year lifespan) – and their costs/benefits. In the period 2005–2006, some roofs were repaired or substituted that were considered typical of situations across the site in terms of structural decay, the presence of decorative features, the difficulty of access and maintenance challenges. Care was taken to ensure that none of them exhibited additional problems such as the requirement of more intensive planning (e.g. detailed measured surveys, scientific analysis, etc.) and the more in-depth approach being piloted in the case study project (see below).

In many cases, the solutions that were eventually adopted proved to be different to what initially...
had been envisaged, and the operational decision-making process proved to be extremely useful for establishing case studies that covered a good sample of common and widespread conditions. The roofs and floor slabs used in these trial interventions were:

- **Samnite House, atrium**: repair of the *ad identicum* (compluviate) roof (Figures 3–5)
- **House of the Cloth; House of the Beautiful Courtyard, room 4a**: repair to the reinforced concrete floor slab

Experience gained from on-site trials

Ad identicum wooden floor slabs: repairs to floor plates contributed to a greater understanding of the decay mechanisms and of different solutions to the general problems of draining rainwater from floor slabs and flat roofing. If not maintained regularly and carefully (in particular, where the floor meets the perimeter wall), the floor slabs built with a wooden structure begin to show an exponential growth of decay that makes them useless and dangerous in a very short time span (about five years).
‘roofing’, in this case it is reasonable to plan works having only viewed the situation from below prior to intervening. On the other hand, deterioration of structural elements does not often allow simple repairs but leads to the need to find special solutions, such as the substitution of elements or the reconstruction of entire sections. Sometimes it has been necessary to accept compromises within the site-wide campaign as a result of the numerous factors to be taken into consideration [2] and the inevitable learning curve as work proceeds. For example, the repairs to the peristyle of the Palaestra taught us important lessons in pushing further with definitive measures wherever possible (we did not in this case and later regretted it) [9].

New temporary roofs: in those areas where the roofs or floor slabs are in danger of imminent collapse, or it has already happened, their substitution with short-term roofing has been carried out. This has also been tested even in areas that have never previously been covered. These new roofs, even though clearly provisional, have only been inserted over small spans and are distributed over large complex areas so that they do not cause any significant changes to the overall appearance of the area.

The criteria for future programming of the repair and substitution of existing roofing

In general, the decision as to which intervention was most suitable was arrived at not only by understanding the nature and level of the damage (through decay mapping) but also by calculating the factors that allow maximum survival and minimum maintenance with the smallest financial commitment possible. Where the potential cost of a repair was extremely close to that of complete reconstruction (often it is the expense of scaffolding that is the deciding factor in the overall cost of an intervention on a roof), the longer-term solution was carried out. A provisional, shorter-term solution was normally chosen if a definitive project had been planned by the Soprintendenza Archeologica di Pompei for the same area within the next five years.

The experience gained from these tests has led to the planning of a new batch of works exclusively aimed at roofing repairs across the site. From an economic and administrative point of view, this work has been divided by typology (for example, repair of *ad identicum* floor slabs, modern floor slabs, pitched roofs, etc.), and applied on a large scale (about 55 rooms).
This simple commissioning approach is compatible with existing heritage authority procedures (its management is made inflexible by legal and bureaucratic procedures [3]) and, if planned well, can survive on limited internal technical support during works (important given that Soprintendenza technical personnel can be in charge of numerous work sites at a variety of archaeological sites at any one time).

Fixed prices per square metre for a type of work to be carried out have been indicated, but leaving margins for possible unforeseen events. This has let us reach an average cost for each of the various forms of decay to be treated. With the typology-based approach, materials are used in larger quantities and gain more advantageous market prices than the small quantities used in mixed tenders and, similarly, quality control of supplies need only be carried out once, at the start of work when all materials are delivered. The risks connected to the problematic pre-qualification of the tendering companies are mitigated (by law, the best price offered is still a crucial factor in the choice of building company) due to the simplicity and uniformity of interventions.

In the planning phase of this batch of roofing repair works, the results of the mapping of decay demonstrated that about half of the roofs and floor slabs on site were in a serious or very serious condition (about 1,500m² of a total of 3,600m² were given a gravity of decay score of 3 or 4, on a scale of 0–4). Most of these roofs covered spaces with decorative features and, furthermore, about 400m² were in areas open to the public. The mapping process allowed us to prioritise interventions according to an elaborate range of factors foreseen within this initial systematic analysis [2]. The roofing and floor slabs to be repaired in this next phase were identified thanks to a further screening that took into account the funding available and the need of the Soprintendenza to complete work in areas that could then potentially be reopened to the public.

Strategies to avoid the mistakes of the past
Future planning was based on the study of the current condition of the site’s roofing and the results of the trial interventions. The aim was not only to make the interventions last longer, but also to consider during the planning phase the inevitable difficulties of maintaining structures in such a large archaeological site, located 20m below the modern access levels, and evolve commissioning models reapplicable in the future by the heritage authority. The objectives can be summarised as follows:

- to work with other conservation specialists and suppliers to improve the quality and performance of materials and techniques and to optimise supervision mechanisms
- to define the right standards for identifying ‘minimal’ requirements
- to reduce water penetration in floor slabs in particular, with technical solutions that are long-lasting and easily maintained
- to make the ad identicum roofs more resistant, with the addition of protective materials to the beams that are necessarily exposed, since they have direct contact with the tiles
- to make provisional roofing aesthetically acceptable (consolidating not undermining those values for which the site has been recognised as important), easily maintained and reversible
- to improve contractual procedures so that supervision can be reduced during the works (in line with the limited technical staff the heritage authority has available)
- to work with the experts for humidity and water to ensure water drainage infrastructure functions effectively
- to pre-plan with the conservator-restorers the necessary protection for the decorative features
- to work with the structural engineers so that measures on support structures (walls, beams, etc.) are compatible with the lifespan of the overall intervention: short- (1- to 5-year lifespan), mid- (5- to 20-year lifespan) and long-term (30+ -year lifespan)
- to facilitate future maintenance by providing access to roofing and improving access routes to work sites.

The benefits of a site-wide approach to improving existing roofing
This approach to repairing existing roofing at Herculaneum fits well in the framework of the site-wide campaign which addresses numerous types of decay of archaeological structures and shortcomings in the infrastructure of the ancient city [2]. Operating within a site-wide strategy (evaluating the distribution of resources in context) has allowed us to justify an increase in the number of mid- or long-term
interventions. This shift in approach has delivered objective criteria to defend the adoption of more enduring measures over temporary propping for existing roofing, but with sufficient elasticity that they can even be applied to public tenders. Given the chain effect of roofing decay (its impact on adjacent and lower structures, and decorative features [10]), this site-wide approach is an important step forward. However, it does have the same limits of any large-scale operation and would not be possible without the parallel investment in research and in-depth experimental work (see below) that can inform decision-making over time, helping to readjust the direction of the project and to improve intervention techniques.

Returning to a stable status quo by eliminating emergencies is certainly the first step towards stabilising Herculaneum’s highly decayed roofing structures. Two major challenges remain: the fine tuning of a simple maintenance regime, which is ‘light’, sustainable and efficient [2], and the development of strategies for new long-term shelters, particularly for large-span spaces which have an inevitable impact on the urban character of the site (see below).

EXPERIMENTAL SHELTERS FOR THE PROTECTION OF EXPOSED ROOMS
GIONATA RIZZI

As already emphasised, shelters are crucial at Herculaneum for the conservation of its archaeological fabric and, particularly, its decorative features. Indeed, the many spaces that remained exposed after Maiuri’s campaigns (see above) were often rich with wall paintings, mosaics, stuccos and marble cladding conceived and created to be indoors. As decay in recent years has shown, they can barely be conserved in an open-air environment [2–3].

Yet, if everyone seems to recognise the need for protection of more areas than those that were given a roof in the past, problems arise as soon as one attempts to develop a consistent approach to increase the number of sheltered areas. In the first place: protective shelters (new structures detached from the original fabric) or roofs (a reconstruction of the ancient form)? The question is not merely theoretical since, in Herculaneum, one has to deal with original Roman remains as much as with the past restorations that have shaped the present appearance of the site: hence the difficulty of deciding between the policy of reconstructions adopted by Maiuri [4–5] and a new approach using modern structures in a site that until now has had none.

In making this decision, three major aspects needed to be considered:

- the excavated area is one district of an ancient town made up primarily of remarkably intact residential buildings: its urban value is certainly among its most important qualities and can be deemed unique to this site
- the first view that a visitor has when entering Herculaneum is from above, allowing the morphology of the urban fabric to be immediately appreciated (the relationships between streets and built areas and between originally open and originally roofed spaces)
- in Herculaneum modern shelters can hardly have supports that are independent of the original walls since both inside and outside they would have to rest on archaeological remains (mosaics, marble, etc. inside; stone paving slabs and curbs outside).

The complex design questions raised by long-term shelters at Herculaneum merited particular attention, creating conservation problems that could not be solved through the site-wide campaign alone. These were examined in depth using the case study of the Insula Orientalis I located in the south-east corner of the site (consisting of the House of the Gem, the House of M.P.P. Granianus and the multiple-storey House of the Telephus Relief).

Because it would have taken time to identify the most appropriate long-term solutions, preliminary measures had to be developed urgently to protect the more fragile areas of the urban block. Moreover, these preliminary measures themselves could potentially inform the debate on long-term strategies, and so they were designed as a set of experiments with these main objectives:

- to give immediate protection to the areas most at risk
- to develop prototypes of affordable, medium-term provisional shelters to cover large-span areas, which could be employed elsewhere on the site wherever lack of funds or other factors might hinder longer-term solutions
- to design them in a way that, with good maintenance, their lifespan could be increased to some extent according to needs
to provide those involved in the decision-making process with a better understanding of problems when designing permanent protective measures, both from the point of view of its visual impact and its conservation efficiency.

The design of these prototypes was influenced by other studies underway (the preliminary assessment of shortcomings in water collection and disposal systems prepared by the experts for humidity and water, and the initial stages of the mapping and analysis of decay carried out within the site-wide campaign) but, above all, by the following requirements:

- the shelters had to provide good protection from rainwater without restricting air movement and without inducing dramatic changes in the microclimate
- although provisional, the shelters had to be visually acceptable even if left in place for a period of five to seven years
- the shelters had to not hinder access to nor the study of the rooms they protected
- they had to be easy to build by a local, non-specialist workforce and to be made of small elements easy to transport to the site and to carry by hand (the excavated area of Herculaneum has no vehicular access)
- they had to be cost-effective
- their design had to involve as little reconstruction of walls as possible in order to support the new roof.

The contributions of the structural engineer and the expert for humidity and water were fundamental in developing the final proposal [14–15]. Interestingly, in meeting these requirements, the design had to abandon the first options considered (metal space frames, tenso-structures, etc.), and came gradually closer and closer to Roman construction methods. The more traditional building technologies, in this case, seemed to represent the simpler solution with the best balance of cost/benefit [11–13]. Furthermore, by developing specific shelters for each space (as Maiuri did – see above), these new additions could facilitate visitor understanding of the cityscape and of the domestic interiors.

In the Marble Room of the House of the Telephus Relief (Figure 8) [16] a pitched roof was built on a closely spaced grid of light trusses (constructed in situ) so as to avoid the need for a secondary structure of rafters (Figure 9). The trusses rest on a perimeter beam supported, in the absence of a perimeter wall, by load-bearing frames placed in correspondence with the original door and window frames (Figure 10). The roof exterior is covered in bituminous impermeable sheeting that is a self-adhesive rolled product very easy to position. This sheeting, containing an anti-UV silica protection, is attached to ‘Sterling’ OSB boards (composite wooden boards made from softwood strands compressed and glued together with exterior-grade, water-resistant resins), which are fixed directly to the multiple trusses. This roof is probably quite similar in shape to the original...
one but, to avoid unnecessary reconstruction of the load-bearing walls in this phase, it has not been built to its original height (Figures 11–12).

In the atrium of the House of the Gem [17] roofing was erected that followed the original Roman structural scheme (a compluviate roof) but positioned at the height of the existing masonry (i.e. much lower than the original roof would have been; Figures 13–14). To avoid the difficulty of delivering heavy structural elements to the site, up to five smaller wooden joists were bound together in bundles on site to form a more robust beam to span the entire atrium width, thereby effectively replacing what would have been the large, solid timber originally used by the Roman builders (Figures 15–16). The roof slopes are made up of ‘Sterling’ OSB boards (as above) covered by a bituminous impermeable felt supplied with an upper layer of copper sheeting. This option is slightly more expensive than the sheet product of the House of the Telephus Relief but has a longer lifespan and, as the copper ages, has a more acceptable aesthetic impact on the site. Adopting the same geometry and slope of the original compluviate roof (which is known exactly) but erecting it at a lower height facilitated the construction process and the gutter work for rainwater management.

Figure 10. New roof over the Marble Room of the House of the Telephus Relief, supported by wooden frames placed in the original door and window spaces, 2006. Reproduced with permission from Gionata Rizzi/HCP.

Figure 11. Roof over the Marble Room of the House of the Telephus Relief during construction viewed from the south, 2006. Reproduced with permission from Jane Thompson/HCP.

Figure 12. The Insula Orientalis I viewed from the south in 2007, one year after completion of the experimental roofs over the two rooms: in the foreground the pitched roof covers the Marble Room of the House of the Telephus Relief, the sloping roof to the left is from the Maiuri period, and just behind it can be seen the new roof covering the atrium of the House of the Gem. Reproduced with permission from Jane Thompson/HCP.
The other areas of the three houses in the case study area that deserved immediate protective measures were actually single rooms of modest span, one in the House of the Gem and one in the House of M.P.P. Granianus. These were originally covered by an entire second storey which had been partially swept away by the AD 79 eruption. Since floor plates are often used to act as flat roofing to shelter archaeological remains throughout the site (see above), it was decided that permanent (rather than medium-term) solutions should be tried out in these two cases. The missing floor slabs were reconstructed with a view to them acting as long-term roofing, so as to test different construction techniques and to monitor their performance through the seasons (especially for the battuto, the highly compacted mortar mix of the upper surface). Thus the most effective and long-lasting options can be applied elsewhere in the site.

Two types of flat roofing have been tested: one with a wooden structure similar to the original Roman form for cases where the underside is visible (rooms 2, 20, 22, 23 of the House of the Gem; Figure 17) [18]; and the second, in zinc-coated steel, for those cases where it is desirable to hide the new structure with a ceiling (room 10 of the House of M.P.P. Granianus; Figure 18) [19]. In both instances, the original beam holes were used in order to reconstruct the floor at exactly the original level. To put the new beams into position without dismantling the original masonry, beams made of two separate elements were employed so that each portion could easily be inserted into the original socket before being joined together. The floor was then covered by a lightweight,
sloped screed for rainwater drainage, duly waterproofed and topped by 5–8cm of *cocciopesto* (lime mortar mixed with brick fragments and beaten according to ancient Roman techniques). To avoid water penetration, the joint between perimeter walls and the screed was sealed with a long-life waterproof sealant specified by the expert for humidity and water (with replacement requirements gathered in maintenance schedules).

This type of protection has some major advantages in that it does not entail any modification of the existing volume and, seen from above, appears as a flat surface that recalls the original floor. Monitoring the performance of the two solutions in unison with the conservator-restorers, the research scientists, the expert for humidity and water and the structural engineer will provide information on their relative needs for future maintenance.

**CONCLUSIONS**

The large-scale and complex urban character of Herculaneum required a two-pronged approach to roofing issues: urgent measures for temporary roofing and for the repair and substitution of existing roofs.
across the site; and new shelters in the case study area to protect the most precious rooms in the medium term and to address the more problematic issues raised by new, large, long-term shelters in general.

The site-wide campaign [2], both in its ‘emergency’ phase and in its later ‘continuous care’ phase, is benefiting from major capital investment in replacing missing urban infrastructure and repairing standing structures (improving site access, rainwater collection and disposal, and structural repairs of masonry and roofing). These measures needed to be implemented rapidly across the entire site and, where possible, to deliver lasting solutions. However, more time and more in-depth design analysis and experimentation (including studying whole houses/urban blocks in an integrated way) were needed before employing solutions that would have a high impact on the urban aspect of the site.

Addressing the issue of protective shelters with both the broad, site-wide approach and with in-depth studies has proved effective in defining the diverse range of conservation problems and in ensuring that the lessons learnt (through the successes and failures of this two-pronged experimentation) deliver approaches to the long-term protection of this large site which are suited to the site and the heritage authority’s needs. This approach is yielding a large body of experience and knowledge which will gradually form the foundation for future routine maintenance and conservation work at Herculaneum. This material may also provide a useful departure point for those undertaking similar work in Pompeii and other large archaeological sites that face similar problems of widespread decay.

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REFERENCES


9. The repair of the peristyle roof of the Palaestra required the substitution of some of the wooden rafters of the roof. The remaining rafters, though bowed, still fulfilled their static role, but the structural engineer’s calculations could not guarantee their performance in supporting the roof in compliance with all legally required criteria (e.g. in the case of earthquake activity). The alternative was to reconstruct the roof structure completely, adding modern elements that would meet the minimum legal requirements. However, a complete reconstruction would have led to a radical rethinking of some of Maiuri’s approaches and would have required an in-depth study not envisaged by the site-wide campaign (e.g. reusing the original rafter holes would require removing remains of the original in situ carbonised wood). In deciding to carry out a mid-term intervention – not replacing the tiles (thereby reducing the dead load on weak rafters) but to substitute them with a sandwich of panels and waterproofing – we maintained current structural standards, respected the fixed cost criteria, and bought time to develop a long-term roofing strategy.

10. The House of the Tuscan Colonnade, room 7 (2006): the ad identicum floor slab was highly compromized by decay and the only choice was to substitute the beams and completely reconstruct the floor slab (cost approx €500.00/m²). The specific problem was found to have been caused by the increased amount of water the downpipe had to eliminate, given that the drainage system of the late 20th century roof of the adjacent College of the Augustales had been designed in such a way as to channel the water onto this house’s floor slab. The infiltration had ruined the floor slab’s beams (especially where they met the perimeter walls). This was seen to correspond to a failure in the waterproofing, a direct result of a lack of maintenance. The temporary shoring carried out before the Herculaneum Conservation Project’s works had only focused on the rotten area around the downpipe, since the wider problem of the beams was invisible, thereby leaving a high risk of collapse.


15. Water and humidity have proved to be one of the greatest causes of decay at Herculaneum, and many other heritage sites. For discussion of these issues, see Massari, G. and Massari, I. Damp Buildings: Old and New. ICCROM, Rome (1994).

16. Area 175m², total construction cost €35,143.00 excluding professional fees = €291.00/m². Clearly these costs will be further reduced in the future if the solutions are applied more widely and bulk orders of supplies and subcontractor services can be obtained.

17. Area 135m², total cost €23,310.00 = €173.00/m². The cost per square metre of the House of the Telephus Relief is higher because of the need for new wall elements and roofing and the exceptional three-storey scaffolding built on the ancient shoreline. The scaffolding was also used by the conservator-restorers to work on the plaster and carbonised wood features of the facades, thereby optimising value for money.

18. Area 16.6m², approximately €450.00/m². Cost per square metre will be heavily reduced if applied...
widely in the future and larger orders of materials are possible.

19. Area 20m² = approximately €650.00/m². Cost per square metre will be heavily reduced if applied widely in the future and larger orders of materials are possible.

Des formes nouvelles et existantes de toits de protection à Herculanum: vers l’amélioration des traitements continus sur le site

Paola Pesaresi et Gionata Rizzi

RÉSUMÉ
Le Projet de Conservation Herculanum a envisagé la conservation d’un site à grandes dimensions (Herculano, Italie) souffrant de nombreuses formes d’altération de deux modes différents : 1) à travers une campagne sur tout le site pour affronter les zones en péril, et 2) au moyen d’un projet d’étude de cas pour un bloc urbain (Insula Orientalis I), afin d’explorer en profondeur certains des complexes défis de conservation que le site pose. Parmi ces défis, nous retrouvons les questions posées par la réparation des toitures existantes sur le site, et par la création de nouvelles formes de toitures de protection pour des espaces qui n’ont jamais été couverts. Des solutions à court, moyen et long-terme pour la réparation et la substitution de toitures existantes sont en train d’être testées dans une campagne qui couvre tout le site, tandis que des stratégies à moyen et long terme sont expérimentées dans l’aire de l’étude de cas.

Formas nuevas y existentes de coberturas de protección en Herculano: hacia la mejoría del cuidado continuo en el sitio

Paola Pesaresi y Gionata Rizzi

RESUMEN
El Proyecto de Conservación Herculano abordó la conservación de un sitio arqueológico de grandes dimensiones (Herculano, Italia), con amplios problemas de degradación, de dos modos diferentes: 1) a través de una campaña que abarca todo el sitio para enfrentar las áreas de mayor riesgo, y 2) a través de un proyecto de estudio de caso de un bloque urbano (Insula Orientalis I), para explorar en mayor profundidad algunos de los complejos desafíos de conservación que el sitio plantea. Uno de esos desafíos se encuentra en cómo abordar la reparación de cubiertas existentes en el sitio, y cómo diseñar nuevas formas de cubiertas de protección para espacios que nunca han sido cubiertos. Las soluciones a corto, mediano y largo plazo para la reparación y sustitución de cubiertas existentes se están probando en una campaña que cubre todo el sitio, mientras que las estrategias para cubiertas de mediano y largo plazo se están experimentando dentro del área del estudio de caso.