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Textile shelters for archaeological areas: a change in the preservation of Cultural Heritage

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Abstract

To overcome the limitations of traditional covering systems, a project for the creation of new shelters has to combine all current preservation requirements, (specifically; the compatibility and reversibility of new materials and protection from environmental aggression) along with new issues such as, flexibility, feasibility, low maintenance requirements, ease of disassembly and reusability.

The topic of this paper is the protection of archaeological sites, it will detail the authorsí research activity and a pilot project undertaken in Sardinia (Italy). Several technical aspects are analysed, highlighting solutions which could contribute to damage rather than serve to protect. The experimental set up and results sections describe the creation of two prototypes, produced in order to evaluate the technical performance of an alternative solution to the provisional shelter and several sets of solar irradiation measures taken in order to evaluate the behaviour of some innovative textile materials in comparison with traditional ones.

Keywords: membrane structures, fabrics, IRT, decay, solar irradiation, Sardinia, monitoring

1 The Conservation of Archaeological Sites in the Mediterranean Region

There exists a delicate balance between conserving ancient archaeological sites and making them accessible to increasing numbers of visitors. Nowadays, this is one of the greatest challenges faced by institutions involved in the preservation and promotion of local culture. This issue is particularly significant in countries which are home to a considerable number of cultural heritage sites. It is universally known that the history of the Mediterranean Basin represents a fundamental step in occidental history. This has created an extraordinary historical heritage with a consequent large number of archaeological sites which are in need of protection and promotion.

The protection of ruins in archaeological areas should be in conformity with various requirements, some of them have been discussed in the past and some of them have only recently been pinpointed thanks to a more technological approach: the contextuality of new shapes on ancient sites (requirement of design), the exploitation of the ìdidacticî function (requirement of display), the compatibility and removability of new materials within the ruins (preservation issue of reversibility/compatibility), protection from environmental aggression (due to: use; the landscape and the climate).

In the last few decades, the attention of scholars and professionals has been attracted, especially with regards to the final two issues. For example, research has been carried out on the effects of weathering on ruins, both protected and unprotected by shelters.

The Authors continue this trend with the present paper dealing with the protection of archaeological areas in Sardinia. The case study of the Su Monte area shows the application and results of a pilot project.

These sites generally have an elaborate building plan with consequent maintenance difficulties, requiring specific expertise and a scientific approach. Moreover, the geographical context in which the archaeological site is located imposes the need for an accurate assessment of the environmental impact due to the protection covering system. Furthermore, the changeable climatic conditions, both throughout the year and during a single 24 hour cycle, open up several issues related to the adequacy of current protection in the area.

According to the scientific literature, some causes of resultant damage are: rain (mechanical stress and chemical dissolution of binders), wind (mechanical stress and abrasion of surfaces), solar irradiation (thermal stress, different and opposite dilatation of materials), UV rays (damage of colours and pigments), fast evaporation/condensation cycles which caususes salt crystallisation and their spreading on the surfaces and within the materials, and more importantly a combination of all the above factors.

The uses of shelters in archaeological areas are numerous: starting from the excavation, when movable and small shelters protect workers and finds, to the restoration and display phases, during the application of strengthening and protective products, and finally, for protecting part of the restored finds from weathering. With this in mind, the project of the creation of new shelters has to combine the requirements for preservation and new issues for use, such as the flexibility, feasibility, ease of maintenance, ease of disassembly and reusability. The

research shows the priority of preservation, functional and technical aspects to the formal and design features.

Lightweight structures made using technical fabrics represent a possible alternative to the standard approach to the preservation of archaeological sites. Currently, the use of tensile structures for the protection of archaeological sites has not yet been thoroughly investigated. One application in this context can be found in the Caposoprano archaeological area in Gela (Sicily), where a modular saddle shaped series is employed to protect an ancient Greek military fortification. Another relevant example in which it is possible see an innovative reversible foundation system, is the wide span tensile structure designed for the Ħaġar Qim megalithic temple complex in Malta.

Figure 1. Covering system in Caposoprano, Gela (Sicily). Picture by Canobbio.

Figure 2. Ħaġar Qim megalithic temple complex, Malta. Picture by Canobbio.

2 Su Monte Archaeological Area in Sardinia

The chosen case study is the ì Su Monteî archaeological ruins which are located near the Sorradile village, at the very heart of Sardinia. The area is on the south-eastern slope of Lago Omodeo, a large reservoir built in the 1930s for preventing drought inland.

The ruins are that of a ìnuragheî religious settlement (the main type of ancient megalithic edifice found in Sardinia), dating back to the end of 12 century BC. The complex is composed of an elliptic fence of 100m x 60m. Inside the fence there is a group of buildings, the main being a circular temple with a trapezoidal entrance hall. The building consists of two-three courses of trachyte blocks. On a not yet defined date, lightning struck the temple, causing its abandonment and extensive damage to the stone. Following excavation of the site the structures underwent restoration between 1998 and 2003 due to the fast spalling of the stone surface.

In 2006, the National Trust created a provisional shelter, and also provided the necessary maintenance of the site in order to prevent uncontrolled growth of vegetation. This site was also fenced off to prevent encroachment by wildlife. In 2007, the main building underwent restoration. The surface of the stones had been eroding due to: weathering, sharp thermal excursions during a 24 hour period, moisture, along with a huge very frequent Relative Humidity (RH) variation.

The location, the stone material and the restoration shelter provided an excellent opportunity to study the behaviour of ruins and a shelter exposed to the typical climate of an inland area in the Mediterranean Region.

3 Aims & Objectives

The first aim of this research is to improve understanding of the various aspects that should be considered when designing a flexible demountable shelter for finds protection in the Mediterranean Area.

The second aim of this project is evaluate the effectiveness of textile membranes for use as waterproof covers or shading. Currently, protection of finds is achieved by using solutions which involve traditional and local materials, such as the reed ceiling used in Su Monte. In this context, the new architectural fabrics can be integrated with the traditional building system, providing an alternative solution based on new technical innovation and materials.

4 Hypothesis and methodology

One of the most important aspects to consider is that an incorrect design can contribute to an increase in damage rather than protection. This can happen when the cover is opaque to infrared radiation, in this situation the radiation emitted by the ruins (due to solar irradiation/heating) remains trapped underneath the shelter, thereby increasing the surface temperature of the protected materials. Secondly, if the shape of the shelter prevents ventilation humid air can be caught underneath, during cooling water will then condense on the coolest surfaces, which could be the ruins, the supporting metallic structure, etc. Thirdly, it is not unusual that the shelterís orientation does not afford adequate protection from direct solar irradiation during the hottest hours of the day (according to the seasons, and the location of the ruins). Another significant source of damage is the collection of rainwater on the shelter in the situation where the collection and drainage of rainwater has not been considered properly and effectively. The water collected can damage the finds, falling down on them and also flowing through the ruins. Finally, in several solutions shelter brakes and anchorages often require invasive and massive concrete foundations nearby/across the ruins.

For these reasons, the study is based on functional aspects, considering the requirements related to temporary and seasonal use which lead to the development of a basic shelter ìkitî that can be adapted, modified and customised in order to meet the stated requirements. This can be achieved through an innovative building approach based on ìhyper-lightweightî frame structures and high performance technical fabrics often from other industrial sectors (such as extreme sports, the nautical industry, the aerospace industry, etc.).

The research is based on a multidisciplinary approach supported by the numerous competences available at The Building Environment Science & Technology (B.E.S.T.) Department at The Technical University of Milan (Politecnico di Milano) in partnership with the ìInnovative Textilesî Cluster which collect expertise in [illegible] and industrial

multidisciplinary approach in the design, the research group aims to understand the numerous aspects involved in the protection and preservation of cultural heritage.

The methodology can be divided into three steps. First, a frame of reference was identified, analysing all the problematic aspects involved. Subsequently, two materials were chosen for the waterproof and shading layers and two prototypes were constructed. Finally, several parameters such as temperature, humidity and solar irradiation were recorded, using different prototype configurations, over twenty-four hours and at different times of the year.

During the first step the frame of reference was created, examining aspects related to weathering exposure conditions, maintenance problems on the site and all restraints connected with the surroundings. In addition, other similar experiences were taken into account and climatic simulations were carried out in an attempt to predict the positive effects of different covering materials and arrangements.

Elisabetta Rosina, responsible for the experimental laboratory of The B.E.S.T. dept. (mobile unit), planned a preliminary monitoring of the site microclimate and surface temperature in 2007-2008 within a research plan promoted by Elena Romoli for the Sardinia Archaeological Register office. This preliminary study showed that for 20 days a year the air temperature is close to or below 0∞C with the lowest air temperature being -2∞C. The average values of air temperature and rain over a year are 8-10∞C (minimum) and 600-900 mm. The area is also characterised by an average RH of 60-65% in January and 45-50% in April, a total solar irradiation of 170 MJ/m^2 in January and 580 MJ/m^2 in August (daily average) with the prevailing wind from the NE, W and SW.

The results allowed for optimisation of the measuring plan. Standard methods were integrated with innovative application of IR thermography and psychrometry in order to define the critical areas and conservation requirements. The creation of a definitive shelter was investigated, taking into account different types, shapes, dimensions, structures, orientations and materials.

5 Experimental set up

The two prototypes enabled evaluation of the technical performance of alternative solutions to the provisional shelter. Through these physical models, protection performance was analysed, with solar radiation and rainfall taken into account.

Consequently, materials and building systems were chosen to meet several requirements such as time taken for assembly and disassembly, an easy mounting procedure, feasibility of use with non-specialised workers, and finally, a general use flexibility which allows the same module to be reused in different locations. For these reasons, architectural fabrics were chosen as the most suited material as they were able to meet all requirements, such as being lightweight, being easy to procure connection elements and being easy to use.

The prototypes were designed as simple tent structures using an existing supporting frame, made from scaffolding pipes, which support the reed ceiling. The design activity focused particular attention on a reduction in assembly costs sacrificing a correct tensioning procedure, using basic anchorage details and maximising results in terms of protection performance through a multilayer roofing system.

However, due to the mechanical resistance of the fabric, future developments should take into account tensile structures in order to provide protection and resistance from the wind.

The testing activity investigated two different configurations. Firstly an integration of existing traditional reed ceilings and a new false ceiling made using mesh fabrics (indicated by 2a, 2b and 3 in Figure 3 and Figure 4) which were also used as lateral shading. Secondly, a cover fabricated exclusively with coated fabrics and mesh fabrics (indicated by 1 and 4 in Figure 3 and Figure 4) was evaluated as a possible alternative shelter based on new material.

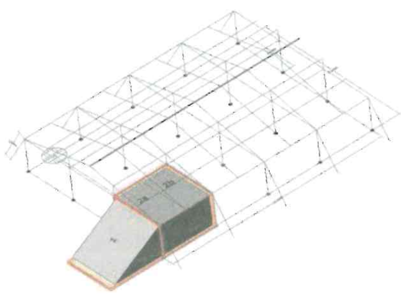

Figure 3. Shading layer mounting scheme.

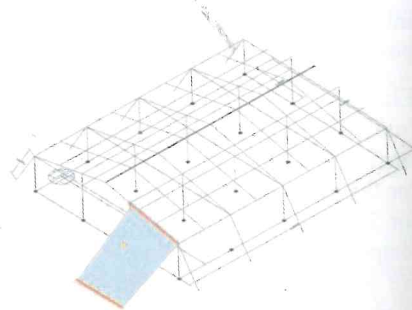

Figure 4. Waterproof layer mounting scheme.

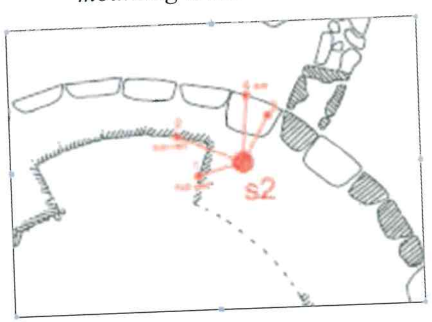

Figure 5 Diagram of the positioning of the surface temperature probes S2 1 and S2 2

Figure 6 Interior of the main room, positioning of the surface temperature probes S2 1-4

The composite textile membranes chosen, produced with equivalent characteristics by several manufacturers, belong to Ferrari Textile production. In particular, Stamisol FT381 3128, classified Bs2d0 according to EN 13501-1 (practically non-flammable, the total smoke production as well as the ratio of increase in smoke ... droplets/particles occurred), was selected for the

according to DIN 4102-1 (flame resistant building materials) was chosen for the waterproof layer.

		SOLAR TRANSMISSION	SOLAR REFLECTANCE	SOLAR ABSORPTION	SOLAR FACTOR	Euroclass
	Name	Ts	Rs	As	g	EN 13501-1
PVC-Polyester layer	Precontraint 1002T2 back PVDF	6%	78%	16%	12%	B1 (din 4102-1)
Shading layer	Stamisol FT381 3128	29%	38%	33%	21%	Bs2d0

Table 1. The properties of each membrane. Data by Ferrari.

Once the prototypes were completed in July 2009, several sets of solar irradiation readings were taken across the traditional shelter, (consisting of a reed ceiling and an insulating layer, the traditional shelter and an additional horizontal shading layer, the PVC-Polyester layer, the shading layer, the addition of PVC-Polyester and shading layers) in order to evaluate the behaviour of the innovative textile materials compared to the traditional ones.

A photoradiometer (HD 2302.0, Torran inc.) served to measure solar irradiation (direct and diffused). The authors performed measurements (Figure 7) under the shelter and outside, close to the shelter edge and inside the room.

Measurements were performed at dawn, at noon and at sunset, in order to compare the effects of the shelter and its additional layers at different irradiation intensities. Moreover, IR Thermography was taken during each collection period in order to measure the surface temperatures of the walls while the textile sides were shadowing the sides.

6 Results

The results of the experimental activity showed that the irradiation coming through the overlapped PVC-Polyester and shading layers was small (16-17 W/m^2) almost the same as the amount of irradiation passing through the reed ceiling shelter (17-19 W/m^2). The addition of a horizontal shading layer underneath the reed shelter reduced the irradiation to 7-8 W/m^2. The irradiation passing through the shading layer was 102 W/m^2, whereas the irradiation passing through the PVC-Polyester layer was 40 W/m^2.The use of overlapped PVC-Polyester and shading layers thus yielded the same results as those for the traditional shelter. The addition of a shading layer to the traditional shelter increased filtration of solar radiation.

From a thermal imbalance point of view the stone surfaces showed a variable thermal stress according to the plane (horizontal/vertical), the elevation, the location (close/far from the shelter edge) and the orientation. Solar irradiation was identified as the major cause of heating in any season therefore the highest values depended on the intensity of the irradiation. The lowest surface temperatures during the night (and before dawn) from September to May were very close to dew point. Relative humidity was always close to 90% in those hours.

RH is generally high in Su Monte because of its proximity to a large lake (Lake Omodeo). In any season, but especially from autumn to spring, RH sharply decreases/increases (gradient 30-40%) just after dawn and sunset; due to heating of the rocks in the early hours of the morning. The water evaporates very quickly, causing salt efflorescence on/in the surfaces. At sunset the air temperature sharply decreases and condensation occurs, starting from the colder surfaces (the metallic structure of the shelter, the coldest stone). Condensation implies liquid water on the surface it was in fact observed that on the horizontal surface the liquid water remained for a longer time. Therefore, on these surfaces the presence of the water caused the crystallised salts to dissolve and consequently the absorption of the salt solution into the surface.

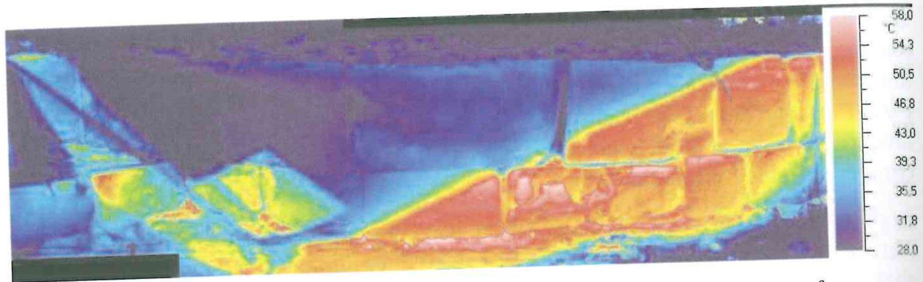

Figure 7 Infrared Thermograms composite, see the hesting effects of the poor shadowing of the shelter on the western side at noon on July 29th, 2009.

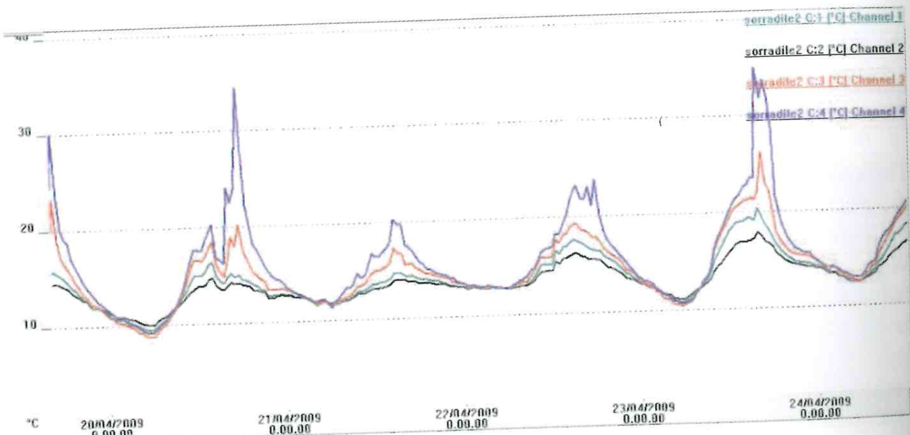

Figure 8 Graphic of the surface temperature measurements of probes S2 1-4 during the days April 20-24 2009. See the high temperature imbalance between noon and sunset as measured by probe S2-4, which is set on the exterior, western vertical side.

Rising damp occurred in some small areas, this is a serious risk to the conservation of structures, because the evaporation of water implies the crystallisation of salts (already set in the lower part of the northern elevation).

M... it was noticed that the gradient of the soil caused surface water to flow

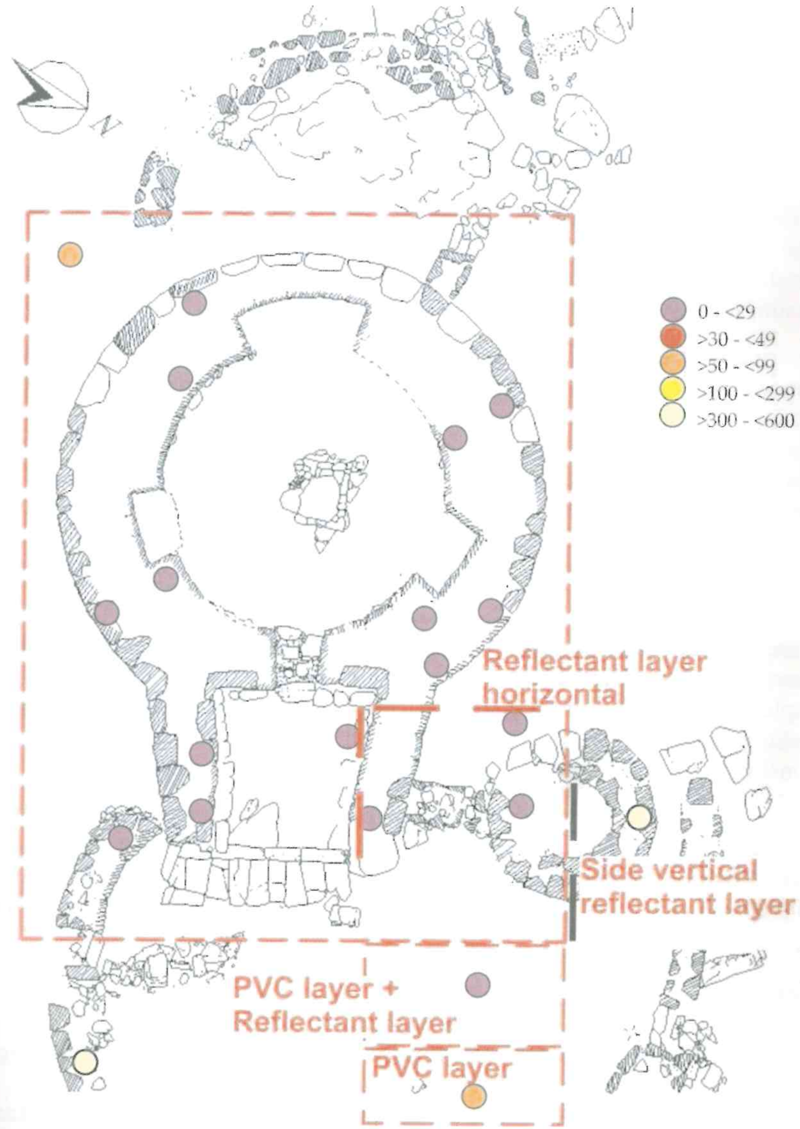

Figure 9 Measurements of the irradiation after setting the textile shelter and sides in addition to the reed ceiling. The diagram shows the location of the horizontal shading layer underneath the roof, the location of the exterior PVC and shading layers, the vertical shading layer as vertical side. The coloured circles show the location of measurements of irradiation. The colours show the power of measured irradiation on the spot (W/m²)

The material has to support mechanical stress due to its weight: in the case of a wet structure the resistance decreases, especially to constrain the tractive effort frequent cycles of wet/dry cause stress underneath the surface, where the water remains trapped. During the experimental activity this was indeed observed and this lead to damage such as flaking, cracks and exfoliation.

7 Conclusions and future works

The research showed that the performances of the PVC-Polyester layer meets several of the requirements relating to the protection of archaeological finds. Both materials, also when not combined in a double layer solution, showed interesting behaviour from the point of view of solar irradiation.

Comparing the costs and the advantages of protection by fabric shelters, the research concludes that fabric shelters are highly competitive and a valid alternative to traditional ones, guaranteeing the same protection from solar irradiation. Furthermore, these types of structures offer several advantages such as higher flexibility, lower visual impact, modularity, suitability to any orientation of the shelter (horizontal, vertical, etc), reusability, lighter supporting structures, feasible stockage on site, easy transportation, low maintenance requirements, fast installation/dismantling and finally, higher durability in general, compared to traditional types.

The use of textile shelters is not only limited to the covering of findings after their display; the textile shelters meet many other needs of archaeological sites, for example the protection of workers and findings during the excavation phase, the periodic protection of fragile and corruptible findings during the wet season, the seasonal protection from the fading of frescoes and mosaics, etc.

In future research, testing campaigns will be carried out in order to prevent side effects related to ageing of the fabric and following alterations in absorption and reflection properties. Moreover, it is expected that the data obtained will also be able to help develop a pilot project to investigate architectural and engineering aspects.

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