Challenges in Conservation of Architectural Heritage

Edited by Ruben Paul Borg

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Civil Engineering Encounters

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Kamra tal-Periti
Chamber of Architects and Civil Engineers
Malta

Faculty for the Built Environment
University of Malta

Dipartimento di Ingegneria Strutturale
Università di Napoli "Federico II"

Università degli Studi di Ferrara

Dipartimento di Architettura,
Università degli Studi di Ferrara

TekneHub
Rete Alta Tecnologia Emilia-Romagna
Piattaforma Costruzioni

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The content of each paper is the responsibility of the respective author/s.

The papers published in this book, have been reviewed, and subsequently presented during Civil Engineering Encounters, on the 4th November 2011 at the Istituto Italiano di Cultura, Valletta, Malta and on the 3rd December 2011 at St Julians Malta.

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...it is again no question of expediency or feeling whether we shall preserve the buildings of past times or not. We have no right whatever to touch them. They are not ours. They belong partly to those who built them, and partly to all the generations of mankind who are to follow us.

John Ruskin (1880)
The Seven Lamps of Architecture

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Foreword

The Civil Engineering Encounters are a series of conferences organised by the *Kamra tal-Periti*, with the aim of bringing together international and local experts in engineering and professionals, and to address specific relevant themes in engineering.

In addressing conservation of the Architectural Heritage various disciplines and experts need to work together with the aim of preserving the Cultural Heritage. Engineering and materials science, together with management and conservation principles are all important in effectively addressing restoration, renovation and requalification of the Cultural Heritage. Whilst respecting the restoration tradition, innovative techniques and materials, new technology and construction processes present new solutions to address effectively the complexities of conservation of Cultural Heritage. Through an integrated design approach, professionals and technical experts must coordinate with stakeholders, authorities and production companies throughout the design process in order to achieve the best results through innovative technologies.

This publication includes the contributions of various experts from different disciplines, who are active in Conservation of Architectural Heritage.

The papers in this publication were reviewed and subsequently presented during two Civil Engineering Encounters Conferences organised by the Kamra Tal-Periti;

- “Engineering and the Protection of Cultural Heritage” at the Istituto Italiano di Cultura, Valletta [4th November 2011];
- “FOCUS Restoration, Renovation, Requalification”, at St Julians, Malta [3rd December 2011].

This publication is made possible thanks to the experts who have collaborated in these initiatives. The contributors include Professor Federico Mazzolani (Department of Structural Engineering, University of Naples “Federico II”), Professor Alex Torpiano (Faculty of the Built Environment, University of Malta), Professor Roberto Di Giulio (Department of Architecture, University of Ferrara), Professor Marcello Balzani (Teknehub, Universirty of Ferrara), Professor JoAnn Cassar, Dr. Reuben Grima and Claude Busuttil (Department of the Built Heritage, University of Malta), Ruben Paul Borg (Department of Civil & Structural Engineering, University of Malta), Hermann Bonnici, (International Institute for Baroque Studies, University of Malta), Katya Stroud and David Zahra (Heritage Malta), and Svetlana Sammut (aoM Partnership).

This book is published by the *Kamra tal-Periti* (Chamber of Architects and Civil Engineers, Malta) with the collaboration of the Faculty for the Built Environment, University of Malta, Malta; the Department of Structural Engineering, University of Naples “Federico II”, Naples, Italy; the Department of Architecture, University of Ferrara, Italy; TekneHub, University of Ferrara, Italy (European Construction Platform of the High Technology Network of the Emilia-Romagna Region) and Tecnopolo of the University of Ferrara.

This collection of papers presents not only examples of practical interventions but also scientific research carried out in different disciplines, from engineering to material science, archaeology to management; all have a common goal, in adequately and effectively addressing the Challenges of Conservation of the Architectural Heritage.

Ruben Paul Borg

Introduction

Vincent Cassar
President, Kamra Tal-Periti

It gives me great pleasure to be able to write these few words as an introduction to this publication by the *Kamra tal-Periti*. This is yet another milestone in the history and activities of the *Kamra* and in making proceedings of conferences which are held as part of its Civil Engineering Encounters programme, available in print format to all interested parties.

The concept of conservation of our historical architectural context has over the last years assumed a major and more active dimension. No longer do we satisfy ourselves with just looking at and admiring such architectural gems, or unfortunately, as has happened on occasions in the past, have the urge to knock them down and replace them by new modern constructions. On the other hand we feel the urge to preserve them in order to be able to admire them in their original beauty.

The Conferences address themes in conservation; engineering and the protection of cultural heritage; and restoration, renovation and requalification. In fact Beyond Restoration, Towards Renovation and Requalification, explains even more the concepts that should lie behind what we commonly refer to as a restoration project.

As the papers presented in this book effectively demonstrate, the concept of architectural restoration is a complex but highly interesting issue. This process presents many complexities, which can be solved through the use of innovative techniques, new technology and construction processes. At the same time it is important to keep in mind and respect traditional methods of restoration, which methods are based on long years of practice and knowledge. It is important also to involve stakeholders from the very start of a restoration project in order that the best solutions are identified and applied.

May I first of all thank Prof. Federico M. Mazzolani of the University of Naples "Federcio II", Prof. Roberto Di Giulio, Head of Department of Architecture of the University of Ferrara and Prof. Marcello Balzani, Director & Scientific Coordinator of TekneHub, University of Ferrara who have supported and contributed in these conferences in Malta. May I also thank Perit Ruben Paul Borg, Council member of the *Kamra tal-Periti* who was instrumental in the organization and coordination of these Conferences and in assembling and editing the publication. My thanks also go to Professor Alex Torpiano, the Head of the Department of Civil and Structural Engineering and Dean at the Faculty for the Built Environment at the University of Malta, who always comes forward not only to support such events, but has also contributed actively in the publication.

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My thanks go to the Universities and Institutions who have collaborated with the *Kamra tal-Periti* in these events and in this book, and to Nicola Ravagli from Fassa Bortolo for the support.

The Protective Shelters at Ħaġar Qim and Mnajdra: Impacts, dilemmas and values

Reuben Grima
Department of the Built Heritage, Faculty for the Built Environment, University of Malta

Katya Stroud
Heritage Malta

Alex Torpiano
Faculty for the Built Environment, University of Malta

ABSTRACT: Engineering technology has opened up many new possibilities for the protection of cultural heritage, which have brought with them the attendant dilemmas on the risks and impacts posed by those possibilities themselves. The case of the protective shelters over Ħaġar Qim and Mnajdra, completed in 2009,is examined here in order to explore some of the dilemmas that were faced from inception to completion, the values that informed the decisions that were taken, and some reflections two years after their completion. Apart from the benefits for the material conservation of the monuments, it is argued that their symbolic and aesthetic values may have been reinterpreted rather than degraded by the intervention.

1 CONTEXT

The Megalithic Temples of Malta are generally considered to be of outstanding importance for world prehistory because they are the oldest freestanding stone monuments to achieve such architectural sophistication, and are for this reason inscribed on the UNESCO World Heritage List. The material and structural characteristics of the temples, and the deterioration processes that led to the decision to shelter the temples of Ħagar Qim and Mnajdra, have been discussed in detail elsewhere (Cassar*et al.* 2010), and will be dealt with only briefly here. Following an extensive collapse that took place at Mnajdra during a severe rainstorm in April 1994, and another collapse that took place at Ħaġar Qim in November 1998, the need for a long-term conservation strategy for the Megalithic Temples was brought to the fore. An international meeting of experts convened in Malta in 1999 to discuss the issue recommended the creation of an interdisciplinary committee for the conservation of these sites. The Scientific Committee for the Conservation of the Megalithic Temples was instituted shortly after, and the first task it undertook was to identify the different agents and processes that were contributing to the deterioration of these sites. Rain, sun, wind and salts were identified as the principal agents causing deterioration. The combined action of these agents subjected the sites to repetitive and frequent wetting-drying and heating-cooling cycles, which in turn cause severe material deterioration, as well as progressive loss of the internal earth fill of the megalithic structures, compromising their structural stability.

These processes are believed to have accelerated when the excavation of Ħaġar Qim in 1839 and Mnajdra in 1840 increased their exposure to the elements. After more than a century and a half of such exposure, these processes have cumulatively resulted in significant and widespread losses of material and of structural stability.

2 RATIONALE OF SHELTERING

In August 2000, the Scientific Committee made recommendations for the installation of protective shelters, as part of a broader strategy for the long-term conservation of these sites. In simple terms, a two-pronged approach was proposed. Under the first prong, appropriate methodologies were to be researched, tested, and developed in order to implement micro-interventions addressing specific deterioration problems. The sheer complexity and extent of this task, however, made it immediately evident that it was a long-term project. The second prong was conceived for this reason. In order to slow down the rate of loss, even during implementation of the first prong of the strategy, a preventive measure was considered necessary. The Scientific Committee recommended sheltering as a measure that could be implemented in a relatively short space of time, yet provide literally umbrella protection for the entire site, while being relatively easy to reverse, in contrast to direct interventions on the megalithic remains themselves. For a more detailed discussion of the deterioration processes and the effect of sheltering, readers are referred to the paper cited above (Cassar et al. 2010), and the earlier work cited therein. For the present discussion, however, the key consideration is that the advice from the appropriate conservation specialists was that sheltering would create a much more favourable micro-environment for the conservation of the megalithic structures, and significantly slow down the rate of deterioration.

The proposal to shelter in itself raised a number of concerns about the impacts of such an intervention, particularly those on the aesthetic and contextual values of the site. In the discussion that follows, the benefits of the shelter for the material conservation of the megalithic structures will be taken as read, in order to focus on the debate on values and impacts that informed the decisions taken in implementing the project.

Figure 1.The collapse that occurred at Mnajdra in 1994.

3 DESIGN CONSIDERATIONS

The design process was launched in November 2003 with an international design competition under the auspices of the International Union of Architects. A number of key principles were established in the design requirements in the initial design brief, and were respected throughout the design and implementation process. These included a number of constraints and measures to minimise the impacts of the shelters on the site and its context. The structures were to be as simple and lightweight as possible, and were to be completely reversible, except for the foundations where strictly necessary. Foundations were to have the least possible permanent impact on the ground. Sightlines along the various axes of the prehistoric structures were not to be interrupted, and a number of possible astronomical alignments with the prehistoric structures were likewise safeguarded. While screening from sun and rain were primary design requirements, the shelters were also required to be sufficiently well-ventilated to avoid the risk of a greenhouse effect.

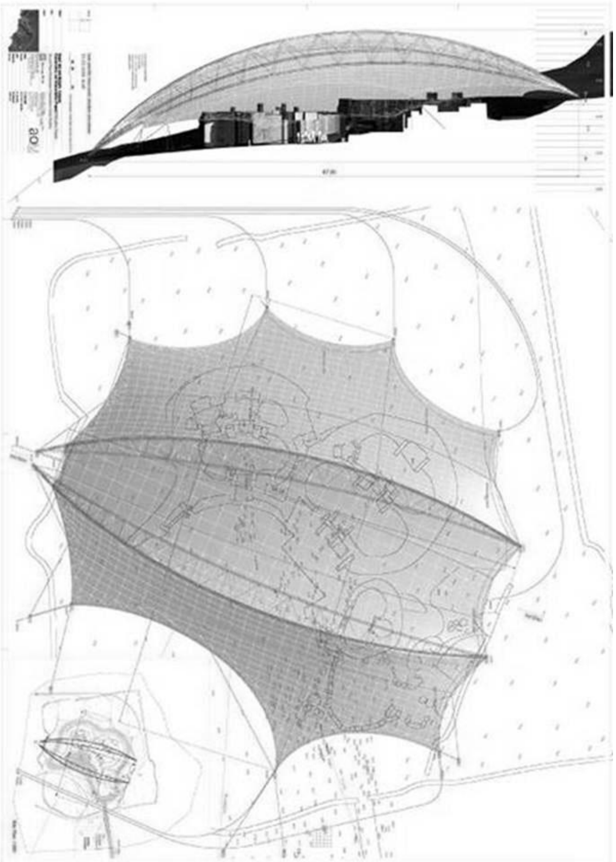

Figure 2.Plan and section of the shelter for Mnajdra.

The design selected from over forty submissions from around the world was that by the Swiss architect Walter Hunziker. During the development of the design submitted for the competition into the detailed tender document, the original, single-arch design for the tensile membrane structures was developed into a two-arch structure, to permit the lowering of the overall height of the shelters by several metres. At tender stage, it was also specified that the membrane, while screening most of the sun's rays, was to allow around 15% light transmission in order for the site to remain readable to visitors. Following the award of the contract, the design of the foundations went through a number of iterations between the contractor and the client and client's consultants, as well as national and international regulators, in order to minimise their visual and physical impacts to the least possible. A fuller discussion of these design considerations and iterations is given elsewhere (Cassar*et al.* 2010).

4 DESIGN CONSIDERATIONS

When the case was made for the benefits of sheltering for the material conservation of the megalithic monuments, a fundamental question that needed to be addressed was whether the visual intrusions that the shelters would create, and the radical changes in the way the sheltered sites were seen and experienced, were indeed justified by the gains for the material conservation of the site. The definition of the design requirements and the subsequent refinement of the shelter designs, outlined above, helped ensure that the visual and physical impacts would be kept to the least possible that one could hope to achieve. They could not, however, alter the fact that the shelters would fundamentally change the appearance of the monuments for as long as they stood. How did one go about deciding whether such a change was justified, or indeed desirable? The remainder of this paper focuses on this question, first, by discussing how the effects of sheltering on the various values of the sites were weighed at the time of the decision to shelter, and second, by making some retrospective reflections, two years after completion of the shelters.

5 SOME TRENDS & PRINCIPLES IN CURRENT CONSERVATION PRACTICE

The foundation texts of current conservation practices are the charters and declarations that have codified, articulated and re-interpreted fundamental guiding principles for best practice in conservation over the past century. Anyone hoping to find clear and unequivocal answers in these documents to the basic questions of whether and when it is advisable to shelter a site, and under which conditions, is likely to be disappointed. This is largely due to the fact that the primary aim of conservation charters is to distil and define generalised underlying principles, which may then be applied to the practical realities of as wide as possible a range of specific scenarios.

A further trend in recent decades has been the progressive acknowledgement that perceptions of value in cultural heritage resources may vary considerably from one cultural tradition to another, and that consequently the specifics of what may be defined as good conservation practice may also vary from one cultural context to the next. Perhaps the most significant watershed in this process was the (1994) Nara Document on Authenticity, where the euro-centric bias in some earlier conservation principles, particularly on the safeguarding of authenticity, was recognized and addressed. One result of this development was that conservation charters became even more wary of prescribing specific solutions. The need to recognize the specific traditions, materials and circumstances when applying conservation principles had itself became a fundamental principle.

Table 1. Some trends in conservation thinking and practices

	from…	…to
SOLUTIONS	Universally applicable	Culture-specific, site-specific
PERSPECTIVES	Euro-centric	Multicultural
VALUES	Immutable	Subject to re-interpretation

A key distinction that is fundamental to the debate on sheltering is that between the conservation of intact buildings which still function as complete structures, and ruins which do not. This distinction is clearly recognized in the 1964 International Charter for the Conservation and Restoration of Monuments and Sites (the Venice Charter), which still provides the baseline for conservation practice on built monuments. Article 15 of the charter is dedicated to excavations. It lays down the general principle that ‘Ruins must be maintained and measures necessary for the permanent conservation and protection of architectural features and of objects discovered must be taken.’

The main focus of the charter is however aimed at restoration and consolidation interventions on the monument itself, and it provides no further guidance on how to approach the question of sheltering.

The same train of thought is also pursued in the 1990 ICOMOS Charter for the Protection and Management of the Archaeological Heritage which asserts the principle that '…the archaeological heritage should not be exposed by excavation or left exposed after excavation if provision for its proper maintenance and management after excavation cannot be guaranteed…'. The scenario that this principle is more commonly applied to is that of an excavation in progress, where it informs decisions on how large an area to excavate, and how to backfill it for protection after the excavation campaign. As a principle, however, it nevertheless has relevance to the debate on sheltering.

The 2003 ICOMOS Charter for the Analysis, Conservation and Structural Restoration of Architectural Heritage provides more detailed principles and guidelines. It recognises, for instance, that on archaeological sites, the'…structural responses to a rediscovered building may be completely different from those to an exposed building…'. The charter does not, however, make any specific reference to the concept of sheltering. Turning now to a charter that focuses on regulating visitor-related interventions, we may note that the 1999 ICOMOS Charter on Managing Tourism at Places of Heritage Significance provides guidelines on the provision of visitor facilities, but stops short of discussing the impact on the visitor experience of a conservation measure such as sheltering.

In a parallel tradition, a succession of documents has sought to safeguard the landscape setting of historical and archaeological monuments. The UNESCO (1962) Recommendation concerning the Safeguarding of Beauty and Character of Landscapes and Sites laid the foundations for the safeguarding of the context and setting of a monument. From 1978 onwards, the Operational Guidelines of the UNESCO (1972) World Heritage Convention stipulated that the setting of sites must meet the test of authenticity for them to be inscribed on the World Heritage List. The (2005) Vienna Memorandum articulated these principles in greater detail in the context of historic urban landscapes, while the ICOMOS (2005) Xi'An Declaration on the Conservation of the Setting of Heritage Structures, Sites and Areas laid out broader guidelines for the safeguarding and management of such settings. New intrusions in the views and vistas of such settings are identified as a primary cause for concern in both of the latter two documents.

6 WEIGHING THE IMPACTS

Against the backdrop that has just been outlined, the decision whether to shelter was evidently caught between a rock and a hard place. On the one hand, some of the most important values of the megalithic monuments were intrinsic to the original fabric and structure of the megalithic monuments, which were deteriorating at an alarming rate, and which the shelters would be instrumental in protecting. On the other hand, the shelters would have a severe (however reversible) visual impact on the monuments and their setting, and on their symbolic and aesthetic value. This Hobson's choice scenario, where it appeared that one set of values or another had to be sacrificed to safeguard the other, was uncharted territory in terms of the principles and guidance provided by the charters. The pragmatic line of reasoning that was developed in order to resolve this dilemma was to define an order of priority between the two sets of values, not with the purpose of dismissing or diminishing from any of these values, but to permit cogent and well-informed decision-taking to fulfil the present generation's responsibilities towards future generations. The extraordinary importance of the Maltese megalithic monuments, and the basis for their outstanding universal value and their inscription on the UNESCO World Heritage List, evidently lay in the remarkable and unprecedented architectural solutions that made these the oldest stone monuments of such architectural sophistication, anywhere in the world. The only witness to this remarkable achievement lay in the surviving fragments of the original material and structure. Their progressive deterioration by the elements was threatening these fundamental values. In this scenario, safeguarding the relationship of the monuments to their setting, and of its symbolic value, would have little meaning if the monuments themselves were progressively lost as a result.

Table 2. The debate on values prior to shelter implementation

Protecting: TYPOLOGICAL STRUCTURAL CONSTRUCTION FUNCTIONAL ARCHITECTURAL HISTORICAL VALUES *(basis of WH OUV)*	*Temporarily sacrificing:* AESTHETIC LANDSCAPE SYMBOLIC VALUES
(based on checklist of values in Gomez-Robles 2010)	

Prioritising values and weighing them against each other in this manner, it was decided that it was more important to do everything possible to retard the damage being caused by the elements to safeguard the core values of the monuments, even at the expense of a colossal visual intrusion in the immediate setting of the monuments, which would persist for as long as the shelters were left in place. This pragmatic reasoning, which formed an important part of the rationale of the decision to shelter, finds parallels in a set of guidelines and principles written for a very different context, namely heritage sites in China (Agnew & Demas 2004). This document is worth citing here, notwithstanding its very different geographical scope, because it is one of the very few documents which give practical guidelines on whether and when to shelter an archaeological site:

> 11.4 Construction of protective buildings or shelters is an exceptional conservation measure for aboveground sites when no alternative is available. This solution is most appropriate in the case of excavated archaeological sites that have been approved to remain exposed (Agnew & Demas 2004, 84).

The scenario contemplated in the guideline cited above closely resembles that faced at Ħaġar Qim and Mnajdra. The same document then continues by defining a number of principles which must be observed when sheltering, all of which were fully addressed at Ħaġar Qim and Mnajdra:

> 11.4.1 The primary consideration in the design and construction of such a building or shelter is its protective function.
>
> 11.4.2 Protective buildings or shelters must not adversely affect the historic condition of a site and their construction should be reversible.
>
> 11.4.3 The function of a protective building or shelter should not be compromised by blindly attempting to replicate an ancient style(Agnew & Demas 2004, 84).

7 CONSERVATION & INTERPRETATION

When the decision to implement the shelters had been taken, an important element in the preparations for implementation became the communication of the rationale of the intervention to the general public, for whom these monuments were iconic sites, not only in terms of their archaeological value, but also in terms of their value as symbols of national identity. The approach that was taken to public information and engagement from the early days of the implementation of the project presaged a charter that was still being drafted at the time.

The 2008 ICOMOS Charter for the Interpretation and Presentation of Cultural Heritage Sites maps out seven key principles of best practice for the integrated conservation and management of cultural heritage sites. It underscores the principle that '…the choice of what to preserve, how to preserve it, and how it is to be presented to the public are all elements of site interpretation', and sets out to'…define the basic principles of interpretation and presentation as essential components of heritage conservation efforts and as a means of enhancing public appreciation and understanding of cultural heritage sites'(ICOMOS 2008, preamble). Although the Ħaġar Qim project was already at an advanced stage of implementation when this charter was ratified, the project is a good example of several of the principles that this charter articulates so clearly for the first time. Most notably, the charter repeatedly emphasises the inseparability of interpretation form conservation. For example, under Principle 5 'Sustainability', Point 4 states:

> Interpretation and presentation should be an integral part of the conservation process, enhancing thepublic's awareness of specific conservation problems encountered at the site and explaining the efforts being taken to protect the site's physical integrity and authenticity.

Figure 3.The visitor centre at Ħaġar Qim. A section of the permanent exhibitionis dedicated to explaining conservation issues.

Figure 4.The spring equinox in March 2009, when the shelter over Mnajdra was nearing completion.

Even before the charter was ratified, the Ħaġar Qim project had become a case study in public engagement in the conservation issues surrounding the site. The installation of the shelters constituted an unprecedented change in the appearance of two very iconic monuments, and it was evident from the outset that the rationale of such an intervention needed to be carefully explained to the public. The site curators and consultants made repeated use of all the available media, from the press and the web to radio and television, locally and internationally, to engage the public in the conservation process, by explaining the dynamics of the deterioration process, and the role of the shelters in the broader conservation strategy. Throughout the implementation of the project, the public continued to be updated regularly on progress of works, setbacks encountered, and precautions being taken to safeguard the site.

The sheltering project also included the creation of site interpretation facilities for visitors. A section of the interpretation in the new visitor centre was expressly dedicated to explaining the conservation issues. A section of the permanent exhibition in the centre graphically communicates the mechanisms of deterioration and the degradation that the monuments have suffered as a result. The rationale of the shelters, and the process of installation, is explained in an accompanying audio-visual presentation, giving every visitor the opportunity to understand the fundamentals of the conservation issues even before visiting the sites themselves.

Public perceptions of the project went through an interesting evolution. At the outset, opinions were divided between those who supported the project because they believed that the material conservation of the monuments was the paramount consideration, and those who objected to the project because of its aesthetic impact, which was frequently described as a sacrilege of such a cherished place.

When the supporting arches were installed over Ħaġar Qim in December 2008, the sudden change to the skyline triggered the launch of a Facebook group called 'Doesn't Ħagar Qim deserve better?' (http://www.facebook.com/group.php?gid=43478911374. Accessed 13/11/2011). Criticism of the project peaked in the first quarter of 2009, following the two incidents when a membrane panel was damaged during its installation. Notwithstanding all the efforts to inform the public about the need for and nature of the project, much criticism was based on misconceptions and misinformation. A common complaint was that the shelters were going to obstruct the astronomical alignments with the rising position of the sun on the first day of each season. In fact, the design brief stipulated that these alignments be respected, and the shelters have actually made these phenomena more visible by reducing random light spilling in, making the contrast between areas lit up by the sun and those in shade more dramatic, and a little closer to what it would have looked like before the buildings fell into ruin.

Upon completion of the shelters in June 2009, the sites were fully re-opened to the public. A palpable shift in public perceptions started taking place when visitors started entering the monuments in their newly sheltered setting. The effect of the completed shelters on the way the monuments were experienced had been impossible to predict, and it was only at this point in time that opinions on the final result could start forming. As this began to happen, a number of pleasant surprises were registered. Visitor feedback began to indicate that many members of the public who had been bemused, or in some cases even dismayed, by the shelters from a distance completely revised this opinion after visiting. Independently of nationality, level of specialist knowledge, or familiarity with the site, the response of the overwhelming majority of visitors has been very positive.

One of the most frequent comments is that the shelters have restored a sense of entering a monumental enclosed building. The quality of the diffused light below the shelters has also attracted much favourable comment, as it permits a reading of subtle gradations in stone colour and texture that were previously washed out by the harsh sunlight. Likewise, the improved acoustics have had another unexpected effect on visitors, leading them to speak in lowered voices and inspiring a sense of awe on entering a hallowed place. Another side-effect of the shelters has been the significant improvement in visitor comfort. Protection from extremes of sun and rain has encouraged visitors to prolong their visit, and permits visits to proceed unhindered by weather conditions.

Some of these new gains in the way the monuments are encountered and experienced had not been planned or intended, but were simply very happy, and very welcome, accidents. During the two years that have elapsed since the completion of the shelters, however, the largely unintended benefits they have brought about in the readability of the site have led to some rethinking about the impact of the shelters on the symbolic and aesthetic values of the site, which will be discussed next.

Figure 5.A view of Mnajdra after completion of shelter.

8 RE-INTERPRETING AESTHETIC & SYMBOLIC VALUES

At the time of the decision to shelter Ħaġar Qim and Mnajdra, part of the rationale was that, although the intervention would have a negative visual impact on the symbolic and aesthetic values of the monuments, this was justified because it was absolutely necessary as part of a strategy to preserve the very fabric of the monuments themselves. Following installation of the shelters, however, the actual effects of sheltering on how the sites were experienced in practice, and the response of the public to this experience, shed fresh light on the discussion. The overwhelmingly positive feedback of visitors to this new way of experiencing the monuments began to suggest that, contrary to most expectations, a number of gains had in fact been registered in the readability of the monument. Even more surprisingly, a consistent strand in the feedback from the public was the appreciation of the aesthetic and symbolic qualities of this new experience.

This emerging reality has led us to reconsider the question of the impact of sheltering on the aesthetic and symbolic values of Ħaġar Qim and Mnajdra. The original concerns about the visual impact of the shelters were closely bound to the underlying idea that the intervention would intrude on the primordial and unchanging relationship between the sites and their setting, which not only had immense archaeological value but had also acquired immense symbolic value as a touchstone of Maltese identity.

Symbolic and aesthetic values, however, are the values most likely to be reworked and transformed by successive generations (Gomez-Robles 2010, 154). On closer examination, the history of Ħaġar Qim and Mnajdra reveals a succession of such reworkings over the centuries. For the purpose of the present discussion, two of these transformations will be picked out.

Figure 6.View of Ħaġar Qim by Jean Houel (Houel 1787, Plate CCLX).

8.1 *The Romantic vision*

A formative and influential chapter in the history of the relationship between people and ruins was their discovery by the Romantic movement. Between the latter decades of the eighteenth century and the early decades of the nineteenth century, antiquities across Europe were widely adopted as sources of inspiration for poets and artists. Ancient ruins were particularly prized, their hauntingly incomplete nature conjuring poetic visions of lost worlds. The more craggily ruinous and overgrown they became as nature took its course, the more treasured they were for the epiphanies they could inspire.

The spread of this new way of thinking about archaeological sites through the Mediterranean region was inextricably bound with the Grand Tour. Of the many travellers' accounts that have come down to us, one of the most monumental was that created by the erudite artist and polymath Jean Houel (1787). The fact that the oldest known representation of Ħaġar Qim is that created and published by Houel is not simply a stroke of good fortune, it is itself significant as a record of what was considered worth representing. In Houel's drawing, some of the taller megaliths rise from the largely buried remains, which form a part of the surrounding agricultural landscape. The artist is shown listening to the narratives of the local inhabitants, while the donkeys that carried him there graze in the background. The drawing, and many that were to follow it, epitomises the romantic vision of the sites as timeless and mysterious testaments to a lost world, at one with the natural landscape.

8.2 *Monumentalising the monumental*

A new, and very different, paradigm in the way archaeological sites and monuments were perceived was to emerge during the second half of the nineteenth century. This was the search for monumental markers of past societies, to be pressed into service as part of the colonising project of every European power with imperialist ambitions, and in the nationalist reactions that imperialism was to provoke. Monuments now needed to be 'unjungled', excavated, measured, recorded, expropriated and fenced off (Andersen 1991). This new paradigm was being consciously articulated and put into practice in Malta by the early 1880s (Grima 2011). At Ħaġar Qim, the story of the successive interventions to clear, consolidate and reconstruct the monument (Stroud 2003) has revealed a symptomatic concern with making it appear even more monumental. The removal of the appear even more monumental. The removal of the earth deposits that surrounded (and protected) the site, and particularly the reconstruction of the main façade during the early twentieth century, speak volumes of the new ways of perceiving and using the monument. The same paradigm continues to exercise influence to our times. The construction of a rectangular stone and steel enclosure around Ħaġar Qim in the late 1960s (removed in the late 1990s) in a sense completed the colonial project for the site.

Figure 7.Façade of Ħaġar Qim, showing reconstructions conducted during the first half of the 20th century (After Stroud 2003).

8.3 *Sustainable stewardship*

Each of these successive paradigms created new aesthetic and symbolic values for the monuments, and each took a toll on the sites' existing values, whether by destruction through neglect, or whether through deliberate disturbance or exposure to the elements. Against this backdrop, the sheltering of Ħaġar Qim and Mnajdra , and its impact on their aesthetic and symbolic values, may be read in a new light. Rather than being an unprecedented intrusion in a timeless and primordial setting, it is the latest chapter in a long history of flux and transformations. Not unlike the paradigms that preceded it, it too has had a cost, in this case on some of the aesthetic and symbolic values that had been invented for the site in the framework of the preceding paradigms. Yet the sheltering itself has arguably created new aesthetic and symbolic values, which are based on the concept of sustainable enjoyment and responsible stewardship of the site in the name of future generations. This, perhaps, is the more suitable paradigm for our times.

9 LIMITATIONS & FUTURE RESEARCH

The observations on public opinion and responses made here are mostly based on informal conversations with visitors and letters and comments in the press and online. A structured survey of visitor attitudes, and how they may change before, during and after a visit, is highly desirable, and would permit a deeper understanding of the themes explored here.

Figure 8.Façade of Ħaġar Qim, following completion of the shelter.

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The Seismic & Volcanic Vulnerability of Architectural Heritage: The Vesuvian Villas

Ruben Paul Borg
Department of Civil & Structural Engineering, Faculty for the Built Environment, University of Malta.

Federico M. Mazzolani
Department of Structural Engineering, University of Naples "Federico II", Naples, Italy.

ABSTRACT: The assessment of vulnerability of the urban area in the Vesuvian Area, was carried out within the framework of EU COST Action C26 'Urban Habitat Constructions under Catastrophic Events'. A data collection exercise was conducted through an in situ survey for the volcanic vulnerability assessment on different construction typologies, such as historic, residential and school buildings, and monumental villas, located in selected areas exposed to volcanic hazard. During this activity, the building identification was performed through a visual investigation, supported by an *ad hoc* form, related to the building vulnerability to seismic and volcanic actions. This paper refers to the data collection activity concerning 9 Vesuvian Villas, and the seismic and volcanic vulnerability assessment of these monumental structures.

1 INTRODUCTION

Vesuvius, or more precisely Somma-Vesuvius, is an explosive volcanic complex, located about 15km away from Naples, Italy. The area is densely populated and a possible Plinian eruption implies disastrous consequence. In Europe, the Vesuvius area is considered to be the area with the highest volcanic risk.

The Vesuvius Case Study was introduced within the research activities of the European Project COST Action C26 'Urban habitat constructions under catastrophic events' with particular reference to the activities concerning Risk Assessment for Catastrophic Scenarios in Urban Area. The main purpose was to examine the effects of a probable Vesuvian eruption on the urban area and Architectural Heritage. The research activity was first focused on the qualitative and quantitative definition of the actions on construction as a result of an explosive eruption (Mazzolani et al., 2008; Mazzolani et al., 2009a); and, following that, on the volcanic vulnerability assessment through a specific methodology (Mazzolani et al., 2009b).

In particular, with respect to the volcanic vulnerability assessment, typical constructions in the area were assessed, through a detailed in situ survey activity, which was carried out with the contribution of the PLINVS Centre (Hydrological, Volcanic and Seismic Engineering Centre). Out of 18 towns which surround the Vesuvius crater the town of Torre del Greco was selected for the study. Torre del Greco is the most populated town in the Vesuvian area with 90,600 inhabitants. The majority of the study areas considered, were located in Torre del Greco, including an important portion of the historic centre with, a decentralized residential area, 4 km away from the vent, and a number of schools distributed on the whole city territory. The areas and buildings selected are representative of the Vesuvian urban environment in terms of exposure, comprising both ordinary buildings and strategic constructions.

The identification of the construction types was performed through a visual examination, together with the compilation of an *ad hoc* form, taking into account the factors which affect the building vulnerability to volcanic effects. The data collected was then used in the application of the specific methodology for the assessment of the volcanic vulnerability, which has been developed by the PLINIVS Centre within the EXPLORIS European project; acronym for "EXPLOsive eruption RISk and decision Support for EU populations threatened by volcanoes" (Mazzolani et al. 2010).

In addition 9 monumental buildings in different Vesuvian cities, that is Torre del Greco, Ercolano, Portici and San Giorgio a Cremano, were also included in the investigation. These consist of Historic Villas, and represent a sample of an important portion of the Vesuvian cultural-architectural heritage, the 122 Golden Mile Villas (Vesuvian Villas).

This paper in particular refers to the data collection methodology and the seismic and volcanic vulnerability assessment of the Vesuvian Villas.

2 THE GOLDEN MILE VILLAS

2.1 *Location of the Villas*

The villas considered in the investigation are also know as the Golden Mile Villas, and are located along the Golden Mile, forming part of the Royal Calabria road between Portici and Torre Annunziata. The 122 villas constitute an important part of the cultural and artistic heritage of the Vesuvian area. The Villas are located in the various towns along the Golden mile as indicated in Figure 1. The list of Villas located in each respective town is presented in tables 1-6.

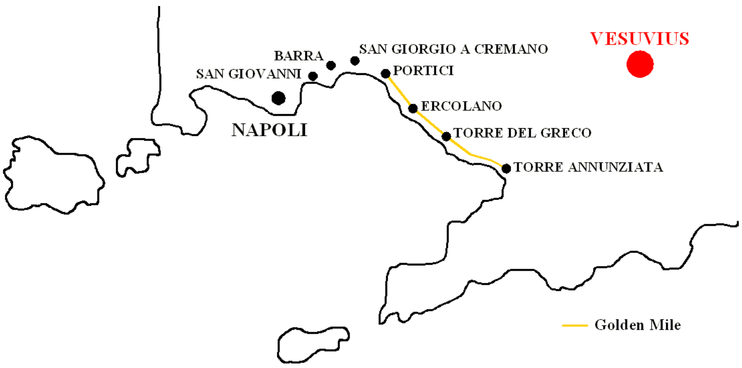


Figure 1. The location of the Golden Mile Villas in the Vesuvian Area.

2.2 *Historical background*

In 1738 Queen Maria Amalia of Saxony married the King of Naples, Carlo of Borbone. She persuaded her husband to build a Royal Villa in Portici. From then on all Neapolitan aristocrats built their summer holiday villas along the coastal area at the foot of Vesuvius. Therefore during the course of the eighteenth century many villas were built and others were restored, transforming the area, into the so called "Golden Mile", rich in architectural and historical heritage.

Table 1. The 19 villas located in Torre del Greco

Villa Cardinale	Villa Macrina	Villa Prota
Villa Vallelonga	Villa Solimena	Villa Maria
Palazzo Chicchella	Villa Mennella	Villa Ercole
Villa San Gennariello	Palazzo Petrella	Villa Fienga
Palazzo del Salvatore	Villa Caramiello	Villa Guerra
Masseria Donna Chiara	Villa Bruno Prota	Villa Ginestre
Villa delle Ginestre		

Table 2. The 22 villas located in Ercolano

Villa Favorita	Villa Aprile
Palazzo Correale	Villa Arena
Palazzo Tarascone	Villa Lucia
Palazzo Capracotta	Villa Passaro
Villa Giulio de la Ville	Villa Durante
Villa Tosti di Valminuta	Villa Ruggiero
Villa Vargas Macchucca	Villa Consiglio
Villa Principe di Migliano	Villa Campolieto
Villa De Bisogno Casaluce	Villa De Liguroro
Villa Signorini (Via Roma)	Villa Mannes Rossi
Villa Signorini (Corso Resina)	Palazzo Municipale

Table 3. The 31 villas located in Portici

Palazzo di Fiore	Villa Zelo
Villa Ragozzino	Villa Nava
Palazzo Amoretti	Villa Gallo
Palazzo Evidente	Villa Meola
Collegio Landriani	Villa Starita
Palazzo Moscabruno	Villa Emilia
Palazzo Lauro Lancellotti	Villa Menna
Palazzo Ruffo di Bagnara	Villa Aversa
Palazzo Serra di Cassano	Villa Maltese
Esedra (ex Villa Buono)	Villa Sorvillo
Palazzo, Corso Garibaldi n.28	Palazzo Valle
Palazzo, Corso Garibaldi n.40	Palazzo Reale
Palazzo, Corso Garibaldi n.100	Villa Mascolo
Rudere in C.so Garibaldi n.316	Villa d'Amore
Palazzo Capuano (ora Villa Materi)	Villa d'Elboeuf
Palazzo, Corso Garibaldi n.101/111	

Table 4. The 30 villas located in San Giorgio a Cremano

Villa Bruno	Villa Jesu
Villa Marulli	Villa Righi
Villa Carsana	Villa Leone
Villa Borrelli	Villa Menale
Villa Olimpia	Villa Lignola
Villa Bonocore	Villa Cerbone
Villa Carafa Percuoco	Villa Tanucci
Villa Tufarelli di Sotto	Villa Cosenza
Villa Giarrusso e Maria	Villa Sinicopri
Villa Giulia o De Marchi	Villa Pizzicato
Villa Galante, via Buozzi	Villa Vannuchi
Villa Galante, via Pessina	Villa Marullier
Villa Caracciolo di Forino	Villa Salvetella
Villa Avallone ora Tufarelli	Villa Ummarino
Villa Pignatelli di Montecalvo	Villa Zampaglione

Table 5. The 9 villas located in Barra

Palazzo Bisignano	Villa Amalia
Villa Nasti ora Letizia	Villa Salvetti
Villa Spinelli di Scalea	Villa Filomena
Villa Pignatelli di Monteleone	Villa Sant'Anna
Villa Giuli o De Gregorio di Sant'Elia	

Table 6. The 11 villas located in San Giovanni a Teduccio

I Villa Volpicelli	Villa Vittoria	Villa Papa
II Villa Volpicelli	Villa Cristina	Villa Vignola
Palazzo Procacciani	Villa Faraone	Villa Paudice
Villa Raiola Scarinzi	Villa Percuoco	

2.3 *The Architectural styles of the Vesuvian villas*

The predominant architectural styles present in the Golden Mile villas are Baroque and Rococò. Baroque elements are evident in the villas of the first half of the eighteenth century, whereas in the second half of the century a Rococò style predominates.

The Vesuvian villas include typical elements of these architectural styles: all villas enjoy important views and are open to the natural beauty, of Vesuvius or the sea, in contrast to the elevation on the street. In all the villas, different architectural styles are evident. In some cases, the villas have an elliptical court with sculptures as in Villa Bruno, Palazzo Bisignano, Villa Pignatelli di Montecalvo, Villa Ruggiero, Villa del Cardinale, Villa Bruno Prota. Other villas are linked to the sea, with terraces and gardens reaching the coast, as in Villa Leone, Villa Vannucchi, Villa Lauro Lancellotti.

In all the villas there is a clear contrast between the rational plan, characterized by axis of symmetry and the free interpretation of ornamental elements. A predominant feature in most of these villas is the main axis connecting the hall of the building to the internal park, following the sequence portal–hall–courtyard–garden. The typical typologies of the Vesuvian villas are three: in the first, the building is surrounded by the garden, and the only contact with the street is a portal; in the second, the garden is on a side of the villa, and in the third, the building overlooks the street. The important views and panorama are visible from the interior spaces, which are rich in decoration and stuccos.

It must be pointed out that an important aspect of the architecture of the Vesuvian villas is the context and the relationship with the natural features of the surrounding environment.

2.4 *The Architects of the Vesuvian Villas*

Information on the architects of the villas is, only partially, available from historical documents, but a significant number of important architects were engaged in their design. The list of architects includes Solimena who painted frescoes in a villa in Barra; San Felice, whose work can be found in Villa d'Elboeuf in Portici; Villa Granito of Bel Monte-Signorini in Ercolano; Palazzo Tarascone in Ercolano; Villa Durant; Villa Pignatelli of Montecalvo in San Giorgio a Cremano, Villa Pignatelli of Montecalvo in Barra.

The works of other important architects such as Vaccaro, Vanvitelli, Fuga are found respectively in Villa Meola and Villa Signorini in Ercolano, in Villa Campolieto in Ercolano and Villa Pignatelli of Monteleone in Barra; and in Villa Favorita in Ercolano.

Other less famous architects worked on the Vesuvian villa including Schiantarelli, Saluzzi, Gioffredo, Giustiniani, Pollio, Tagliacozzi, Astarita, Canevari, Anaclerio and Cuomo. (Cardarelli et al)

3 THE DATA COLLECTION METHODOLOGY

3.1 *Aims of the Investigation*

The investigation and the data collection activity have been inspired by two main targets. The first target is the assessment of the seismic and volcanic vulnerability of the Vesuvian Villas examined. The second target is the identification of appropriate damage mitigation techniques for such important buildings, which must be protected for posterity from possible exceptional actions, due to their important heritage status.

3.2 *The Survey forms*

The methodology was based on data collected during detailed field investigations through in-situ survey activities in the area of study. The aim of the investigations was to collect the data and parameters influencing the volcanic vulnerability for each construction. The data collection activity was carried out through visual investigations, with the use of two different forms, developed by the PLINIVS Centre (COST Action C26 report, 2009; Mazzolani et al., 2010):

- An *ad hoc* form for the identification of volcanic vulnerability elements, with an additional form for recording the valuable artistic elements in monumental buildings.
- The MEDEA schedule for data collection of possible damage mechanisms, the seismic damage and the vulnerability elements;

The *ad hoc* form for volcanic vulnerability includes different sections, and is summarized in Table 7. The survey form is based on the following sections:

1 The IDENTIFICATION section is intended to locate the building with reference to the geographical parameters given by the Campania Region.

2 The GENERAL INFORMATION section refers to the type (ordinary building, warehouse, electrical station, etc.), destination (residence, hospital, school, etc.), use (fully used, partially used, not used and abandoned) and exposure (ordinary, strategic, exposed to special risk) of the construction.

3 The CONDITION section refers to age and state of conservation of the structure (poor, mediocre, good and excellent) and typology of the finishes (economic, ordinary, luxury).

4 The DESCRIPTIVE CHARACTERISTICS section refers to the number of total storeys starting from the lowest ground level, the number of floors above the ground, including the penthouse, the number of residential apartments, the presence of occupied or not basement, the height of the first storey, minimum and maximum heights up to the roof, the presence of barriers with height >2m, the orientation (angle between the longest or the main façade and the North) and the position in the block (Figure 2).

5 The STRUCTURAL CHARACTERISTICS section refers to the principal typology (reinforced concrete, masonry, wood, steel and mixed), primary vertical structures (sack masonry with or without reinforcements, hewn stones masonry, masonry or tuff blocks, RC frames with weak or resistant cladding, etc.), primary horizontal structures (timber floor, floor with steel beams, concrete-tile structures, vaults, etc.), geometry of the roofing (plane, single pitched, multi pitched and vaults), thickness of the walls and the curtain walls and typology of the curtain walls (tuff blocks or squared stones, concrete blocks, etc).

6 The OPENINGS section refers to the percentage of openings on the façade, the number of small, typical and large windows, their material (timber, PVC, aluminium or timber-aluminium, light steel and steel of security anti-intrusion type), their protection and their conditions (perfect, efficient, poor, bad or lack of windows).

7 The INTERVENTIONS section refers to the age and type of repairs (extraordinary maintenance, upgrading and retrofitting).

8 The REGULARITY section refers to the regularity and distribution of curtain walls in plan and along the height, the type of the structure (single or two-directional frames, single or two-directional walls and walls with frames), soft floor (pilotis on a part of the ground floor, totally open ground floor and intermediate soft storey) and possible presence of stocky beams or columns.

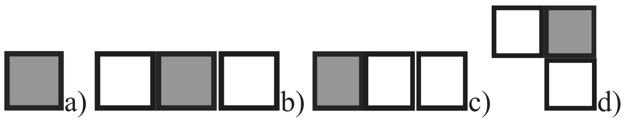


Figure 2. Position in the urban block: a) isolated, b) internal, c) external, d) internal corner.

Table 7. PLINIVS Centre survey form for the assessment of the volcanic vulnerability.

SECTION	DATUM
IDENTIFICATION	progressive number of the block number of the building in the block
GENERAL INFORMATION	type destination use exposure
CONDITION	age state of conservation of the structure typology of the finishes
DESCRIPTIVE CHARACTERISTICS	number of storeys number of apartments basement occupied basement height of first storey minimum height maximum height fence orientation position
STRUCTURAL CHARACTERISTICS	principal typology primary vertical structures primary horizontal structures geometry of the roofing structure of the roofing thickness of the walls thickness of the curtain walls typology of the curtain walls
OPENINGS	percentage of openings on the façade number of small windows number of typical windows number of large windows material of small windows material of typical windows material of large windows protection of small windows protection of typical windows protection of large windows conditions of the windows
INTERVENTIONS	type of repairs age of repairs
REGULARITY	regularity in plan regularity along the height distribution of curtain walls in plan distribution of curtain walls along the height distribution of the structure arcade (soft floor) squat element

These parameters define each construction in terms of geometry, typology and importance and mainly measure the volcanic vulnerability of the construction itself. In particular, these parameters can be divided into two groups.

The first group provides information on the main vertical and horizontal structures, the regularity in plan and in elevation, the age and conservation of the construction, the number of storeys. These aspects are associated with the evaluation of the seismic vulnerability of buildings. The second group is specific to the building behaviour under the effect of an explosive eruption, referring to the roof structure typology, and the openings. The information on the type of the roof structure is associated with the collapse due to ash-fall deposits during an eruption. The information on openings, including opening shape, the size and the protection of the openings, is associated with the pyroclastic flows.

The form in Table 7. is generally suitable for the collection of data related to the volcanic vulnerability assessment of ordinary constructions. However in the case of the survey activity related to the historic monuments (Vesuvian Villas), updates to the form were necessary. These updates were necessary since the monumental buildings are of great importance and more detailed information is required.

In view of this, the updates indicated in Table 8, were proposed, with reference to the survey form for the cultural heritage damage in Model B of the DPCM2006. The following sections are included:

1. The LOCATION section refers to the location of the building with reference to the site characteristics (flat land, peak, filling or inclined soil, depression), the urban context (urban centre, urban periphery, industrial or commercial area, historical centre), the surrounding infrastructures (pedestrian or vehicle access, access for heavy facilities, neighbourhood parking) and the presence of other risks (landslide, inundation, industrial or natural threats).
2. The DESCRIPTIVE CHARACTERISTICS section refers to the type of artistic heritage, such as frescoes, mosaics, mouldings, tapestries, altars, statues, books, prints, paintings on different bases, furniture, furnishing and archaeological finds.
3. The STRUCTURAL CHARACTERISTICS section refers to the state of general conservation of vertical and horizontal structures and roofs, the presence of steel or RC tie beams, internal elements (arcades, lodges, internal court yards) and material and constructive discontinuities.
4. The INTERVENTIONS section identifies the possible type of structural interventions, like extraordinary maintenance, upgrading, retrofitting, enlargement etc.
5. The REGULARITY section indicated the plan layout, which can be rectangular, extended rectangular, L- shaped, C- shaped or with court yards.

Table 8. Survey form integration for the monumental building.

SECTION	DATUM
Location	Site characteristics Urban context Infrastructures Presence of risks
Descriptive characteristics	Type of artistic heritage
Structural characteristics	State of general conservation of vertical structures State of general conservation of horizontal structures State of general conservation of roofs Presence of steel or RC tie Internal elements Material and constructive discontinuities
Interventions	Type of interventions
Regularity	Plan layout

The MEDEA (Manuale di Esercitazioni sul Danno ed Agibilità) tool is designed to support earthquake damage assessment in Italy (MEDEA). The scope of the damage assessment tool is to carry out an evaluation of damages, in particular with respect to masonry and reinforced concrete structures. The tool is intended to assess the damages in structures, and associated mechanisms. Therefore a range of alternative damage mechanisms are identified and defined and the damages can be linked to the related mechanisms (Papa F. et al, 2004).

The MEDEA form includes various sections including the following; a section on the identification of the building; a section on vulnerability parameters for the structure; and a matrix for the mechanisms and structural damage.

In the case of masonry buildings, the matrix refers to the global and local mechanisms, and to the structural damage with respect to vertical and horizontal structures.

In the first part of the MEDEA form the seismic vulnerability elements, are recorded, as shown in Table 9.

Table 9. Vulnerability elements according to MEDEA form

1. Absence of connection between orthogonal walls and/or tie-beams or stringcourse at different levels
2. Presence of stringcourses in breccia on masonries with double facings
3. Any floors badly connected with the walls
4. Masonry of low-quality, reduced resistant area along one or both directions
5. High percentage of openings
6. Foundations inadequate to resist the vertical load increment due to the earthquake
7. Different consistencies of the foundation soils, presence of landslide or liquefaction
8. Presence of added buildings with different stiffness and/or with localized connections
9. Variation of the structural system at upper levels
10. Presence of a raising and/or a stiff and badly connected roof structure
11. Presence of staggered levels
12. Excessive distance between bracing walls
13. Pushing structure and/or absence of connection between the wall and the roof
14. Presence of lintel with reduced bending stiffness or with inadequate support length
15. Presence of lowered arches or inadequate support of lintel
16. Local reduction of the masonry section (presence of flues, niches, etc.)
17. Local discontinuities (filling of old openings, bad realization of masonry sewing, etc.)
18. Presence of ridge beam of considerable sizes
19. Presence of openings in the proximity of the roof ridge

In the second part, the damage to vertical structures or to horizontal structures is recorded. Each damage is related to global (GB) or local mechanisms (LM), as listed in Table 10.

Table 10. Damage Mechanisms according to MEDEA form

M1	Storey shear mechanism (GB)
M2	Shear mechanism for upper storeys (GB)
M3	Whole wall overturning (GB)
M4	Partial wall overturning (GB)
M5	Vertical instability of the wall (GB)
M6	Wall bending rupture (GB)
M7	Horizontal sliding failure (GB)
M8	Foundation subsidence (GB)
M9	Irregularity between adjacent structures (GB)
M10	Detached floor and roof beam (GB)
M11	Lintel or masonry arch failure (LM)
M12	Material irregularity, local weakness (LM)
M13	Roof gable wall overturning (LM)
M14	Corner overturning in the upper part (LM)
M15	Overturning of the wall supporting the roof (LM)
M16	Vault and arch overturning (LM)

In MEDEA, in the case of masonry structures, the global mechanisms have been subdivided as follows:

In plane mechanisms: these mechanisms occur when the classical diagonal X cracks appear as a consequence of the formation of diagonal compressive forces in the walls of the masonry box, excited by in-plane actions in both directions. These mechanisms are due to the poor tensile strength of the masonry.
Out of plane mechanisms: these damage mechanisms appear through an out of plane movement of one or more walls of the masonry box, due to failure of the connection between the walls of the facade and the orthogonal ones, as a result of the seismic action. This is possibly enhanced through the thrust of floors and roofs.
Other mechanisms: this category includes those mechanisms that could not directly be recognized as in plane or out of plane mechanisms, but which involve the building as a whole, generating the total collapse of the structure (i.e. detached floor and roof beam, irregularity between adjacent structures, etc.).

In the case of masonry structures, the local mechanisms are classified as follows:

Local dislocation: these mechanisms are those, for example, that arise for arch or architrave failure, or in part of the structure characterized by different irregularities, often connected to significant stiffness variations (i.e. inappropriate retrofitting such as reinforced concrete interventions in masonry structures, etc.). The phenomenon generally determines the crumbling and the expulsion of the material in the areas adjacent of the element involved.
Elements causing horizontal thrust: these mechanisms are determined by the action of single elements that produce horizontal thrust on the supporting structures; good examples are the thrusting elements of a roof or the vaults, the thrust action of which is not sufficiently balanced.

Therefore, with reference to the classification outlined above, 16 different collapse mechanisms have been identified for masonry structures, which are related to the seismic damages.

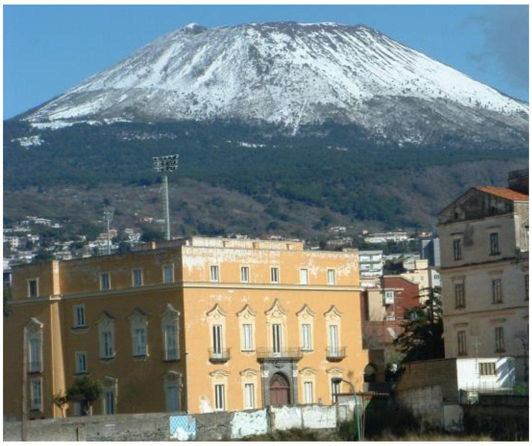
3.3 *The Vesuvian Villas investigated*

The survey activity has been conducted in relation to 9 Vesuvian villas:

- in *Ercolano*: Palazzo dei mosaici in Villa Favorita's park on sea (PVF), Villa Campolieto (VC), Villa Ruggiero (VR), Villa Aprile (VA) (Figure 3);
- in *Torre del Greco*: Villa Macrina (VMA), Villa delle Ginestre (VG) (Figure 4),
- in *Portici*: Villa Mascolo (VMO) (Figura 5) ;
- in *S. Giorgio a Cremano* : Villa Bruno (VB) e Villa Vannucchi (VV) (Figura 6)

Almost all villas are actually in use, excluding villa Mascolo, that will be transformed into a museum. The characteristics of the villas vary, and such variations include the use of the building, including public office, accommodation facilities, and building with different uses, such as Villa Vannucchi and Villa Bruno.

a



b

c

d

Figure 3. The Villas assessed in Ercolano: a) Palazzo dei mosaici, b) Villa Ruggiero, c) Villa Aprile, d) Villa Campolieto.

a

b

Figure 4. The Villas assessed in Torre del Greco: a) Villa Macrina, b) Villa delle Ginestre.

Figure 5. Villa Mascolo in Portici.

a b

Figure 6. a) Villa Vannucchi; b) Villa Bruno in S Giorgio a Cremano.

The type of construction is often not identifiable. The state of conservation is good for all the villas that have been subject to recent rehabilitation, except villa Campolieto, which is in a mediocre condition. The typologies of finishes range from ordinary to luxury.

With regards the structural characteristics all villas are constructed in sack masonry; the exception is Villa Vannucchi which includes reinforcements. In all villas the primary horizontal structures are constituted of a combination of vaults without tie beams and plane timber or steel floors. The roof structures are structures without significant thrust in Villa Vannucchi, Villa Mascolo, Villa Ruggiero and Villa delle Ginestre. The structure includes vaults in Villa Campolieto, Villa Bruno and Villa Macrina. However in the remaining villas one encounters a structure with thrust, made out of wood with two pitch, without ridge pole and tie beam. In view of the complexities of these villas both in plan and also in elevation, it is hardly ever possible to define them as regular.

The percentage of the openings varies from one façade to another, but in average, for half of the villas the value is in the range 10% – 25%; and for the remaining half between 25% - 50%. The number of openings varies substantially, in relation to the villas, whereas the material of the openings (wood) is the same for all. In general the openings are in a good state of conservation and their protection is efficient.

The number of storeys ranges from 2, in Villa delle Ginestre and in Palazzo dei Mosaici, to 6 in Villa Campolieto. The number of storeys is 4-5 for the other villas. The height of the storeys ranges from 4 m in Villa Macrina to 10 m in Villa Campolieto; and the maximum and minimum heights up to the eaves varies from 4 m in Villa Macrina to 24 m in Villa Campolieto. A fence is present only in the case of half of the villas, that is Villa Campolieto, Villa of Ginestre, Villa Bruno and Villa Ruggiero. All Villas are isolated from the surrounding buildings, excluding Villa Campolieto that is enclosed in two opposite blocks and Villa Vannucchi and Villa Aprile that are free on three sides. The villas are located in the urban centre or the periphery, except Villa delle Ginestre, situated in an agricultural area. In the case of almost all villas, the topography consists of flat land or inclined terrain. In all the villas there are both pedestrian and vehicle access, and also neighbouring open spaces. The cultural and artistic heritage present in the villas varies in type and extent: frescoes; mosaics, moldings, tapestries, altars, books, paintings, furniture and paper & parchment artefacts (Figure 7).

a b

Figure 7. Artistic heritage in Vesuvian Villas: a) Villa Vannucchi Stucco, b) Villa Campolieto fresco

Table 11. Vulnerability elements of the 9 Vesuvian villas

V.E.	PVF	VMA	VA	VMO	VG	VC	VB	VR	VV
1	●	●	●	□	●	●	□	●	●
2	□	□	—	□	□	□	□	□	□
3	—	●	—	□	□	□	□	□	□
4	●	●	●	□	●	●	●	●	□
5	●	●	●	□	□	●	●	●	●
6	□	□	—	□	□	□	□	□	●
7	□	□	—	□	□	□	□	□	□
8	●	●	●	□	□	□	●	●	□
9	□	●	□	□	□	□	□	●	□
10	□	□	□	□	□	□	□	●	□
11	□	□	●	●	□	●	●	●	□
12	●	□	●	□	□	●	●	●	●
13	□	—	●	□	●	●	—	□	□
14	●	—	●	□	□	●	●	□	□
15	—	—	—	□	□	□	□	□	□
16	●	□	●	□	□	□	□	□	□
17	□	□	●	●	□	□	□	□	●
18	□	●	□	□	□	□	□	□	□
19	●	●	●	□	□	●	□	□	□

● Yes; □ No; — Unknown

The form described above was completed for each villa. In addition for each villa, the vulnerability elements to seismic action as reported in Table 9 and as defined in the MEDEA form, were recorded. These are summarised in Table 11.

As evident, from Table 11, most of examined villas include more than one vulnerability element. In particular the following vulnerability elements could be identified; a good connection to bearing walls is not present, the masonry quality is low, there is a high percentage of openings on the facades, an excessive distance between bracing walls and staggered levels, lintel have reduced bending stiffness or with inadequate support length, and openings are located in the proximity of the roof edge. All these situations are considered to be vulnerability elements because they prevent a "box" behaviour of the structure in case of an earthquake, with the probable consequence of global or partial mechanism.

On the basis of the vulnerability and the points above, the second part of the MEDEA form was compiled. In this regard, it is necessary to point out that in the form, only the possible collapse mechanisms, have been reported. These were not necessarily based on the crack pattern, even because almost all the villas investigated had been recently repaired. The probable mechanisms recorded in the investigation are reported in Table 12.

Is important to notice that the global or local mechanisms identified in Table 12 are possible mechanisms, and consistent with the structural characteristics of the villas.

Table 12. Damage Mechanisms of the 9 Vesuvian villas

D.M.	PVF	VMA	VA	VMO	VG	VC	VB	VR	VV
M1	●	●	●	●	●	●	●	—	●
M2	—	●	●	—	—	—	—	—	—
M3	●	●	●	—	●	●	●	—	—
M4	●	●	●	—	●	●	●	—	—
M5	—	—	—	—	—	—	—	—	—
M6	—	—	—	—	—	—	●	—	—
M7	●	—	—	—	—	—	—	—	●
M8	—	—	—	—	—	—	—	—	●
M9	●	●	●	●	●	—	●	●	—
M10	●	●	—	—	—	—	—	●	—
M11	●	●	●	●	●	●	●	—	—
M12	●	—	●	●	—	—	—	—	—
M13	—	—	—	—	—	—	●	—	—
M14	—	—	—	—	—	—	●	—	—
M15	—	●	●	—	●	●	●	—	—
M16	●	●	●	●	●	●	●	●	—

● Possible; — Improbable

4 CONCLUSIONS

The Vesuvian area represents a zone of high hazard with regards to seismic and volcanic events. The volcano, Vesuvius, is associated to an explosive event, meaning that the catastrophic events related with its possible eruption should be very violent. This situation of high risk has induced the European project COST Action C26 'Urban habitat constructions under catastrophic events' to introduce the 'Vesuvius case' within its research activities. With the intent to evaluate the seismic and volcanic vulnerability assessment on different constructive typologies located in this area, an intensive survey activity has been carried out. In particular this paper illustrates the survey activity on 9 historical and monumental Vesuvian Villas, located in the, so called Golden Mile. The examined villas built during the eighteenth century, by the Neapolitan aristocrats, form a small but representative part of a rich architectural heritage.

The collected data was assessed through specific methodologies which have been developed by the PLINIVS Centre (Mazzolani et al., 2010). The investigation emphasizes a complex situation. The characteristics of the villas vary considerably, including their use and other aspects as structural characteristics. It is difficult to identify a unique type of construction: each villa represents a unique case. However some dominant characteristics are present. All villas are constructed in sack masonry; the horizontal structures include a combination of vaults and plane floors; they are not regular in plan or elevation; the percentage of openings in the façade are on average for half of the villas in the range of 10%-25% . The number and the height of the storeys is different for each villa. Almost all villas are isolated from the other buildings.

Each villa presents more than one seismic vulnerability element, and the most recurrent vulnerability elements are; the absence of good connections to bearing walls, an excessive distance between bracing walls and staggered levels, lintel with reduced bending stiffness. With regards the possible global or local collapse mechanism, the most recurrent in the examined villas are: a storey shear mechanism (M1), the whole or partial wall overturning (M3), irregularity between adjacent structures (M9), detached floor and roof beams (M10), the lintel or masonry arch failure (M11), the overturning of the wall supporting the roof (M15), and the vault and arch overturning (M16).

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Protection of Historic Buildings

Federico M. Mazzolani
Department of Structural Engineering, University of Naples "Federico II", Naples, Italy

1 INTRODUCTION

The Mediterranean and Balkan area is greatly exposed to seismic hazard. Consequently, its cultural heritage is strongly susceptible to undergo severe damage or even collapse due to earthquake. The constructions mostly exposed to seismic risk are the historical and monumental ones, since in many cases they are not endowed with basic anti-seismic features and/or no seismic retrofit has been applied to them. If the latest earthquakes occurred in this area are considered (Friuli-Italy, 1976; Vrancia-Romania, 1977; Campania and Basilicata-Italy, 1980; Spitak-Armenia, 1988; Banat-Romania, 1991; Erzincam-Turkey, 1992; Dniar-Turkey, 1995; Umbria-Italy, 1997; Adana-Turkey, 1998; Iznit and Duzce-Turkey, 1999; Athens-Greece, 1999; Afyon-Turkey, 2002; Bingol-Turkey, 2003; Bourmedes-Algeria, 2003; Al Hoceima-Morocco, 2004, L'Aquila-Italy, 2009 to mention the most important, only), the extremely unsatisfactory degree of seismic protection is clearly apparent. Degradation in material quality, lack of appropriate maintenance and, above all, absence of elementary anti-seismic provisions are the clear reasons of the very large number of the collapses, particularly in old masonry structures, occurred during earthquakes.

The extreme seismic vulnerability of the historical constructions is confirmed by this evidence and, consequently, urgent strategies for the seismic protection of the cultural heritage are strongly required. Considering the construction as a system, the objective is improving its global performance, rather than providing solutions to specific structural or architectural problems, requiring the set-up of new techno-logical systems. Moreover, the new intervention methods must be not only reliable and durable, but also, if required, easy to monitor and remove, the latter aspect corresponding to the widely shared policy of safeguarding existing buildings from inappropriate restoration interventions, with particular reference to historical and monumental constructions. At the same time, modern constructional systems have provided good seismic performances, strongly limiting damage and completely avoiding collapse. Consequently, a slow but continuous increasing in the sensitivity to the use of more advanced technologies in the earthquake protection policy has started. The excellent performances of innovative materials have been acknowledged and the potential advantages of using special techniques for seismic resistant structures has been recognized, in a step by step process. Although initially referred to new buildings, this trend represents an important study field in seismic rehabilitation of existing buildings, with particular interest for historical constructions, which deserve delicate restoration operations (Mazzolani 2005, 2006a,b, 2007a,b, 2008a,b, 2009).

2 THE PROHITECH RESEARCH PROJECT

The problem of the protection of historical buildings has been deeply examined in the EC funded PROHITECH research project on *"Earthquake Protection of Historical Buildings by Reversible Mixed Technologies"* (2004-2009), which has been focused on historical buildings, namely those dating back from the ancient age up to the mid of the 20th Century, mainly belonging to the Euro-Mediterranean area, whose cultural heritage is strongly susceptible to undergo severe damage or even collapse due to earthquake. The main objective of the project has consisted in the development of sustainable methodologies for the use of Reversible Mixed Technologies (RMTs) in the seismic protection of the existing constructions. RMTs exploit the peculiarities of innovative materials and special devices, allowing ease of removal when necessary. This proves to be an important feature since the cultural importance of historical constructions limits, in many cases, the possibility to upgrade them from the seismic point of view, due to the fear of using intervention techniques which could have detrimental effects on their cultural value.

The scientific activity of PROHITECH project has been subdivided into four parts, aimed at producing four main deliverables, developed in four years starting from 1 October 2004. The workplan has been based on twelve scientific workpackages, plus three management workpackages. A number of sixteen scientific workpackage deliverables has been produced. Sixteen academic institutions, coming from twelve Countries mostly belonging to the South European and Mediterranean area, have been involved in the research programme (Fig. 1).

Figure 1. The partner countries in the PROHITECH project.

The partner countries have been: Algeria (AL), Belgium (B), Egypt (EG), Macedonia (MK), Greece (GR), Israel (ISR), Italy (I), Morocco (M), Portugal (P), Romania (RO), Slovenia (SL), Turkey (TR). The partner institutions and the relative responsible persons are indicated in the following:

1 I-UNINA: University of Naples "Federico II"-Engineering Faculty, (F.M. Mazzolani, project General Coordinator);
2 B: University of Liège (J. Jaspart);
3 MK: University of Skopje (K. Gramatikov);
4 GR: Technical University of Athens (I. Vayas);
5 NA-ARC: University of Naples "Federico II"-Architecture Faculty (R. Landolfo);
6 P: Technical University of Lisbon (L. Calado);
7 RO-PUT: "Politehnica" University of Timisoara (D. Dubina);
8 RO-TUB: Technical University of Bucharest (D. Lungu);
9 SL: University of Ljubljana (D. Beg);
10 TR: Boğaziçi University of Istanbul (G. Altay Askar);
11 ISR: Technion Israel Institute of Technology, Haifa (A.V. Rutenberg);

12 EG: Engineering Centre for Archeology and Environment, Faculty of Engineering, Cairo University (M. El Zahabi);
13 M: Moroccan National Scientific and Technical Research Centre, Rabat (A. Iben Brahim);
14 SUN: Second University of Naples (A. Mandara);
15 AL: University of Science and Technology "H. Boumedien" of Algier, Civil Engineering Faculty (M. Chemrouk);
16 UNICH: University of Chieti/Pescara - Architecture Faculty (G. De Matteis, project Technical Coordinator).

3 THE RESEARCH WORKPLAN

3.1 *General*

The main objective of the PROHITECH research project has been the development of suitable methodologies for the use of reversible mixed technologies in the seismic protection of existing constructions, with particular emphasis to buildings of historical and artistic interest. This would primarily involve saving human lives and reducing both economic and cultural losses due to earthquakes. The main subject of the research has been represented by relevant buildings erected from the ancient age to the first half of the 20th Century, all of which can be considered as belonging to the cultural heritage of the involved countries. Such buildings cover a wide and diversified range of structural categories needing to be fitted with adequate anti-seismic provisions.

The above objectives have been pursued through the creation of twelve scientific workpackages dealing with sixteen deliverables, which have been aimed at the production of four main deliverables, representing the final output of the four parts which the research plan has been subdivided into. The interconnections among the WPs and the four parts, leading to the achievement of the project goals, is shown in Figure 2, while the workplan of the project is illustrated in Figure 3.

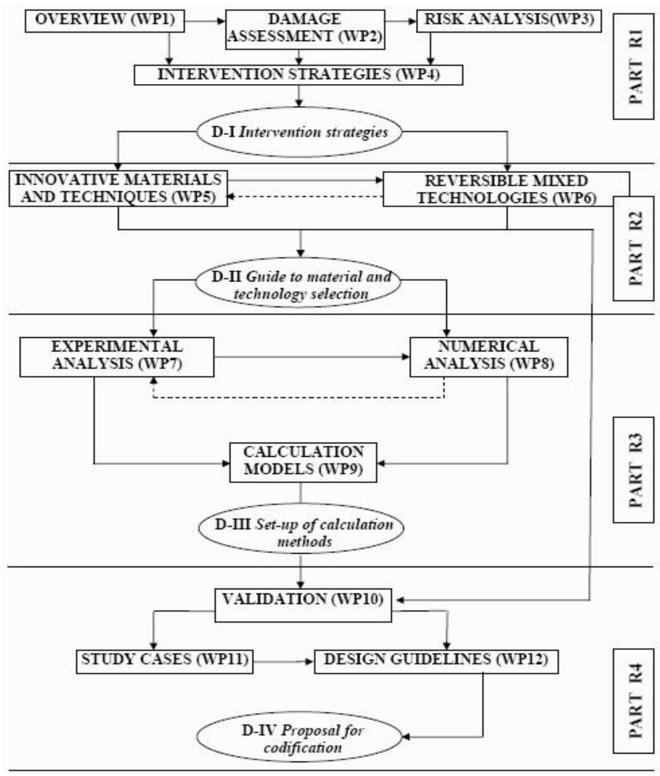


Figure 2. Interconnection among workpackages, deliverables and main deliverables.

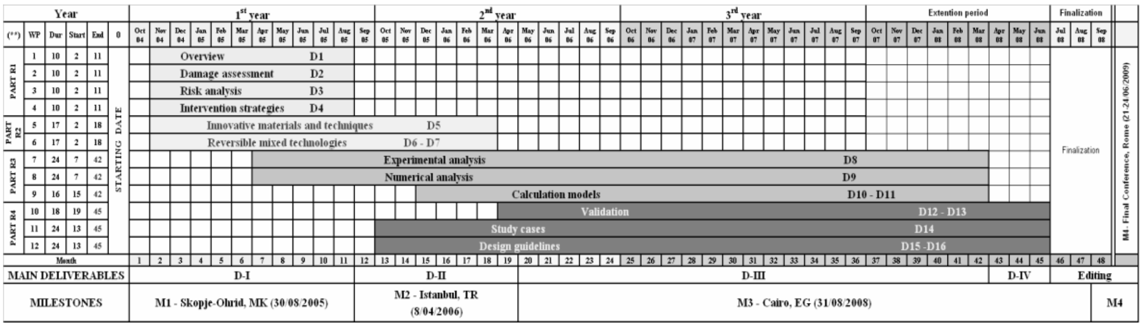


Figure 3. The workplan of the PROHITECH project.

The workpackages (WPi) are listed in Figure 3, grouped into the four parts, together with the project deliverables (Di) and the main deliverables (D-I, D-II, D-III and D-IV).

3.2 *Part R1-Intervention strategies*

The activities concerning the part R1 have been developed and concluded during the first year. In particular, within the Workpackages from 1 to 4, four project deliverables (D1-to-D4) have been produced. Moreover, the First Main Deliverable D-I has been completed, as listed hereafter.

WP 1 – Overview of existing techniques
D1 Overview of traditional technological systems adopted for seismic rehabilitation of historical buildings in European and Mediterranean Countries.
WP 2 – Damage assessment
D2 Assessment of earthquake-induced structural damage in historical buildings of the Mediterranean area.
WP 3 – Risk analysis
D3 Assessment of seismic risk maps and evaluation of seismic vulnerability of historical building heritage in the Mediterranean area.
WP4 – Intervention strategies
D4 Definition of methodologies for seismic up-grading of constructions based on both strengthening of structural elements and control of the seismic response.
The first main deliverable D-I deals with Assessment of intervention strategies for the seismic protection of historical building heritage in the Mediterranean basin (Volume I).

3.3 *Part R2-Selection of materials and technologies*

The activities concerning the part R2 of PROHITECH project have been developed during the first two years and they have been concluded in the second year. In particular, within the Workpackages 5 and 6, three project deliverables (D5-to-D7) have been produced. Moreover, the Second Main Deliverable D-II has been completed.

WP 5 – Innovative materials and techniques for seismic protection
D5 Identification of innovative materials and special devices to be used for reversible mixed technologies in structural rehabilitation.
WP 6 – Set-up of advanced reversible mixed technologies for seismic protection
D6 Development of reinforcement procedures for structural elements based on the use of reversible mixed technologies;
D7 Set-up of seismic protection systems based on the dissipation of seismic input energy.
The second main deliverable D-II deals with Reversible mixed technologies for seismic protection: guide to material and technology selection (Volume II).
It is worth noticing that deliverables D6 and D7 are arranged as a unique volume.

3.4 *Part R3-Experimental and numerical research*

The activities related to Part R3 have been developed starting from the first year of the project, up to its end. In particular, within the Workpackages 7, 8 and 9, four project deliverables (D8-to-D11) have been produced. The Third Main Deliverable D-III is based on a synthetic editing of the above project deliverables.

WP 7 – Experimental analysis
D8 Experimental assessment of the behaviour of true-scale structural elements strengthened with innovative reversible mixed technologies.
WP 8 – Numerical analysis
D9 Calibration of numerical procedures for the analysis of strengthened structural elements on the basis of experimental results.
WP 9 – Development of calculation models
D10 Set-up of analytical models for special materials and special devices for the seismic structural control.
D11 Development of simplified models for the global seismic analysis of historical constructions.
The third main deliverable D-III deals with Reversible mixed technologies for seismic protection: experimental and numerical activity versus calculation models.

Due to the large amount of work carried out in Part R3, and the related outputs, the Third Main Deliverable is arranged into three volumes, as follows:
Reversible mixed technologies for seismic protection: experimental activity (Volume III);
Reversible mixed technologies for seismic protection: numerical activity (Volume IV)
Reversible mixed technologies for seismic protection: calculation models (Volume V);

3.5 *Part R4-Set-up of codification rules*

The activities related to Part R4 have been developed starting from the second year of the project, up to its end. In particular, within the Workpackages 10, 11 and 12, five project deliverables (D12-to-D16) have been produced. Moreover, the Fourth Main Deliverable D-IV has been completed.

WP 10 – Validation of innovative solutions and procedures
D12 Validation criteria for restoration interventions.
D13 Validation of existing rehabilitation interventions.
WP 11 – Study cases
D14 Selection of study cases belonging to the historical building heritage of the Mediterranean area: analysis of feasibility of interventions based on the use of innovative reversible mixed technologies and relevant design of seismic retrofit.
WP 12 – Development of design guidelines
D15 Codification rules for the design of seismic protection interventions based on innovative reversible mixed technologies.
D16 Preparation of an operational manual for the practical implementation of proposed procedures.

The fourth main deliverable D-IV deals with *Proposal of codification on the use of reversible mixed technologies in the seismic protection of historical buildings*.
Due to the large amount of Part R4 outputs the Fourth Main Deliverable is arranged in one volume, as follows: *Seismic protection of historical buildings: design and applications (Volume VI)*. The six volumes are now in press.

4 EXPERIMENTAL ACTIVITY

4.1 *General*

The experimental analyses have maybe represented the actual core of the PROHITECH research project, they having provided a very important contribution in the development of Reversible Mixed Technologies to be applied for the seismic protection of historical buildings.

The work has been carried out with the main aim of assessing and setting-up new mixed techniques for the repair and strengthening of historical buildings and monuments belonging to the Cultural Heritage of the Mediterranean basin.

The experimental activity has been developed at five different levels, namely full scale tests, large scale models, sub-systems, devices, materials and elements.

4.2 *Full scale tests*

The full scale experimental tests have been referred to the following constructions: a reinforced concrete building located in the Bagnoli area in Naples, Italy (Fig. 4); the Mustafa Pasha Mosque in Skopje, Macedonia (Fig. 5); the Gothic Cathedral in Fossanova, Italy (Fig. 6); the Byzantine St. Nikola Church in Psacha, Kriva Palanka, Macedonia (Fig. 7); the Beylerbeyi Palace in Istanbul, Turkey (Fig.8).

Figure 4. The real reinforced concrete building in Bagnoli, cyclically tested until collapse and then repaired by means of different techniques.

Figure 5. Mustafa Pasha Mosque in Skopje, Macedonia.

Figure 6. The Gothic Cathedral in Fossanova, Italy

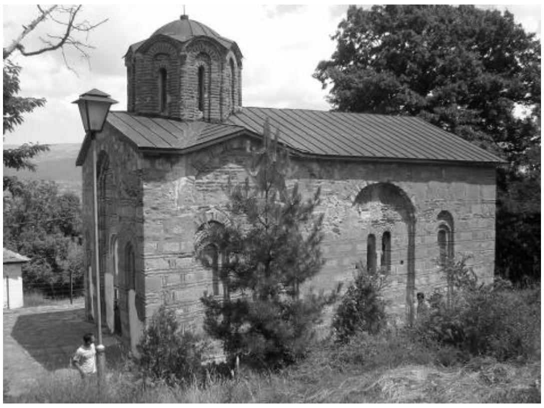


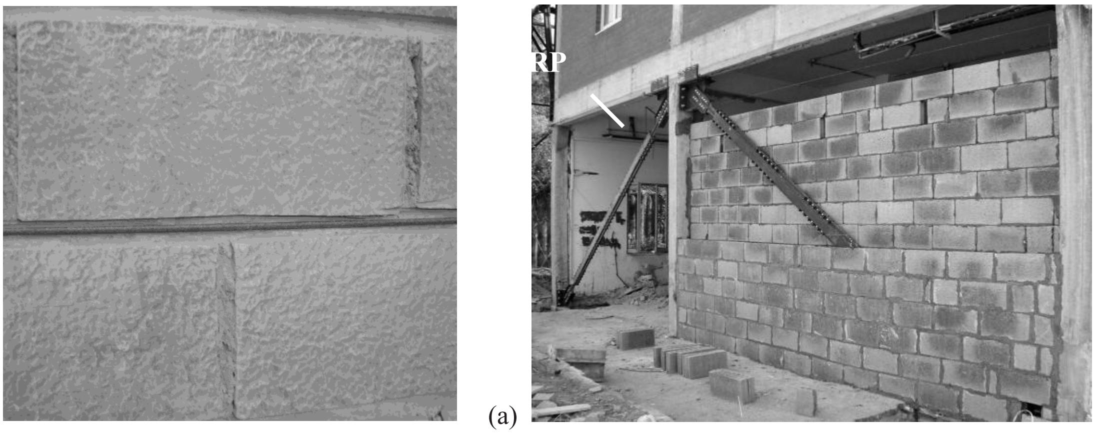
Figure 7. St. Nikola Church in Psacha, Kriva Palanka, Macedonia.

Figure 8. The Beylerbeyi Palace in Istanbul (Turkey).

The experimental studies on the Bagnoli R.C. building have been extremely exhaustive and detailed, since this building is not an “ad hoc” built model but it is a “real” construction, actually representative of a large part of the building stock present in many Countries during the 20th Century, it representing a unique occasion of knowledge of wide interest. After preliminary tests on the materials, aimed at characterizing them from the mechanical point of view, the dynamic identification of the structure has been carried out (Mazzolani et al., 2005). Inelastic cyclic tests under lateral loading conditions, with the possibility to alternately push and pull the construction up to reach pre-fixed horizontal displacement values, have been carried out. The experimental tests have been carried out in three phases. In the first phase, the original structure has been strongly damaged by applying a seismic input corresponding to a return period of more than three thousand years (Fig. 9).

Figure 9. Damage in the real R.C. building after the test on the original structure without reinforcement.

In the second phase, it has been repaired by means of FRP bars placed in the mortar joints of the external walls (Fig. 10a) and damaged again (Della Corte et al., 2008). In the third phase, an intervention by means of buckling restrained braces (BRBs) has been carried out (Fig. 10b), with subsequent further tests, during which three different configurations of BRB have been selected according to an optimization process (D’Aniello et al., 2007).



(a) (b)

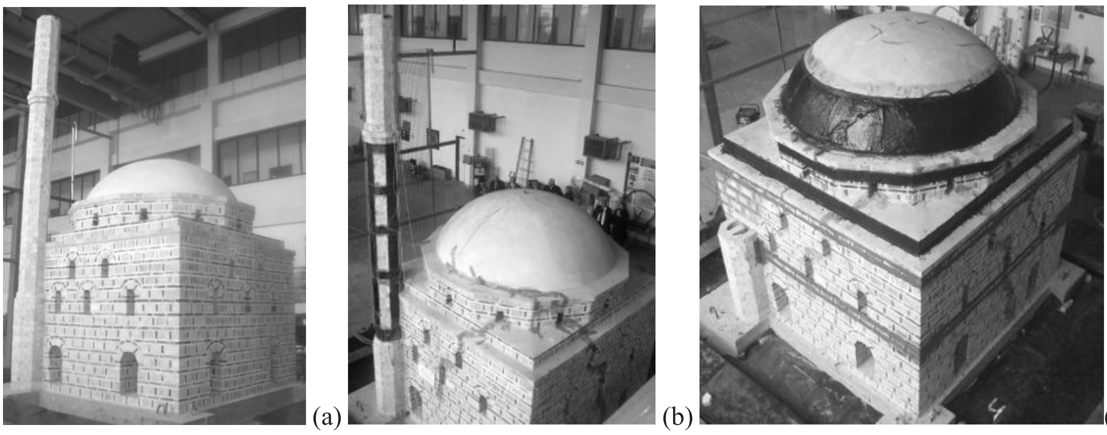
Figure 10. consolidation interventions in the R.C. building (a) by means of FRP bars; (b) by means of BRBs.

The full scale experimental activity on the other above mentioned buildings, say the Mustafa Pasha mosque (Fig.5), the Gothic Cathedral in Fossanova (Fig.6), the St. Nikola Church in Psacha, Kriva Palanka (Fig.7) and the Beylerbeyi Palace in Istanbul (Fig.8), have been based on non-destructive tests, mainly focused on the characterization of the structural materials and on the dynamic identification of the constructions. Ambient vibration tests have been systematically done.

4.3 *Large scale tests*

The programme of large scale tests has included experiments on the following models: Mustafa Pasha Mosque; Fossanova Gothic Cathedral; Greek Temple; St. Nikola Byzantine Church in Psacha.

The 1:6 scale model of the Mustafa Pasha Mosque has been realized at the IZIIZ Laboratory in Skopje (Fig. 11a). The main objective of the experimental investigation has been the study on the effectiveness of the proposed reversible intervention, based on the use of C-FRP elements.



(a) (b) (c)

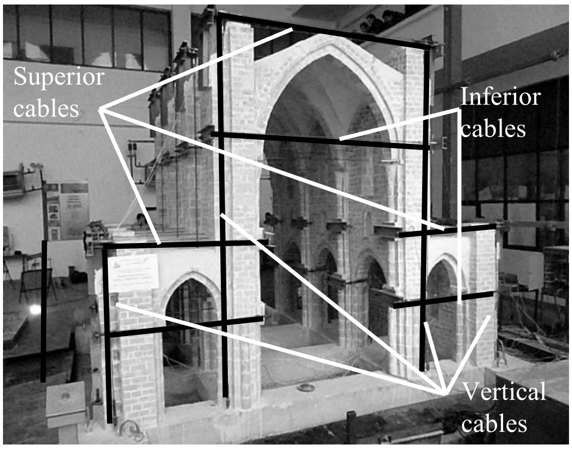
Figure 11. The 1:6 scale model of the Mustafa Pasha Mosque: (a) before the tests; (b) after the minaret consolidation; (c) after the walls consolidation by means of C-FRP wraps and rods.

The experimental campaign on the Mustafa Pasha Mosque model has been carried out in three main phases (Krstevska et al. 2007; Landolfo et al. 2008). During the first phase, the model has been subjected to low intensity seismic inputs, in order to damage only the minaret. In the second phase, after the consolidation of the minaret by C-FRP elements (Fig. 11b), larger seismic inputs, corresponding to the Petrovac earthquake (Montenegro, 1979) have been applied, in order to assess the effectiveness of the intervention on the minaret and to severely damage the mosque, whose dome has been seriously cracked.

In the third phase, in which the minaret has been removed due to safety requirements, the mosque model has been consolidated (Fig. 11c) and has been subjected to larger seismic inputs. The adopted intervention technique has proved to be very effective, so that it has been selected by local Authorities for the consolidation of the real mosque, currently ongoing (Mazzolani et al., 2009).

The 1:5.5 scale model of the Fossanova Gothic Cathedral has been tested at the IZIIS Laboratory (Fig. 12a).


(a)



(b)

Figure 12. The 1:5.5 scale model of the Fossanova Gothic Cathedral: (a) before the tests; (b) the consolidation intervention by means of horizontal and vertical ties.

Shaking table tests have been carried out on the Fossanova model both before and after the consolidation, carried out by means of FRP cables. After the test on the original construction, which has induced damage, the model has been repaired and post-tensioned FRP cables, both horizontal and vertical, have been applied (Fig. 12b). The consolidated model has been subjected to two tests, in which the vertical cables were always active: a first test, with only the superior horizontal cables active; a second test, with all the horizontal cables active. The used intervention has increased the seismic resistance of the structure of about three times.

With regard to the tests on the large scale models of a Greek temple (scale 1:3 with respect to the columns of Parthenon), several experiments have been conducted on the shaking table of the Earthquake Engineering Laboratory of the National Technical University of Athens (NTUA), namely experiments on three freestanding columns in a row (Fig. 13a), experiments on three columns in a row with architraves (Fig. 13b) and experiments on columns in corner (Fig. 13c). Shaking table tests both before and after the consolidation by means of metallic clamps have been carried out. The protection systems used have proved to be effective in the seismic protection of the Greek temples.

At last, the 1:3.5 scale model of the St. Nikola Byzantine Church (Fig. 14) has been tested on shaking table at the IZIIS Laboratory. A first test on the base isolated model, by means of the ALSC floating-sliding system, has been carried out. The protection system has performed adequately, it preventing any damage to the model. A second test, in which the seismic isolation has been removed, has led to severely damage the construction.

 (a)  (b)  (c)

Figure 13. The 1:3 scale models of Greek temple columns in three configurations: in a row without (a) and with (b) architrave; (c) with columns in corner.

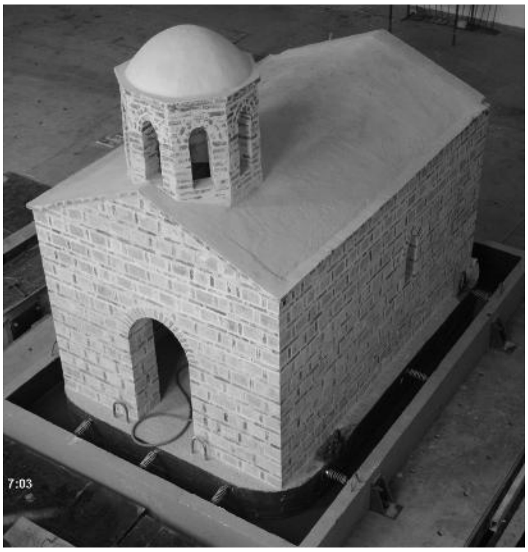


Figure 14. The 1:3.5 scale model of the St. Nikola Church.

4.4 *Sub-systems*

A large number of experimental tests on sub-systems has been carried out, they being mainly related to the application of RMTs to masonry, timber, reinforced concrete and iron structures.

With regard to masonry panels, two main groups of experiments have been carried out. The first group, at the “Politehnica” University of Timisoara (Romania), has dealt with the behaviour of masonry panels consolidated by means of metal (steel or aluminium) sheeting plates or steel wire mesh, applied at the external faces of the panel. In this case, the connection of the metal sheet plates to the masonry wall can be realised in two ways, namely by means of chemical anchors or pre-stressed ties; the wire mesh is glued to the masonry wall by using epoxy resin. The second group, at the University of Naples “Federico II” (Italy), has dealt with the behaviour of masonry walls strengthened by FRP bars, located in the mortar joints. These tests have been aimed at investigating the behaviour of such masonry walls in three conditions, namely in absence of the retrofitting system, in presence on the FRP bars at one side of the wall only, and in presence of the FRP bars placed at both sides of the masonry wall. In addition the experimental activity on timber sub-systems has been developed in two main groups of tests.

The first group has been related to the tests carried out on timber composite beams and floors, at the University of Naples “Federico II” (Italy) and at the Istituto Superiòr Tecnico of Lisbon (Portugal), both systems being based on an innovative technological system useful for connecting timber elements and concrete slabs (Fig. 15) (Calado et al., 2008). Such systems have been applied as a consolidation intervention in the Diplomatic Hall of the Royal Palace in Naples (Faggiano et al., 2005) which is shown in Figure 16.

The second group of tests has been carried out at the Boğaziçi University of Istanbul and it has been related to the study of the behaviour of timber frames equipped by means of metal shear panels (Fig. 17).

Experimental tests on reinforced concrete columns retrofitted by means of three techniques, namely r.c. jacketing, the FRP jacketing, and steel jacketing, have been carried out at the Technical University of Bucharest (Romania). Tests on iron elements retrofitted by means of FRPs have been developed both at the University of Liège (Belgium) and at the University of Naples – Architecture Faculty (Italy).

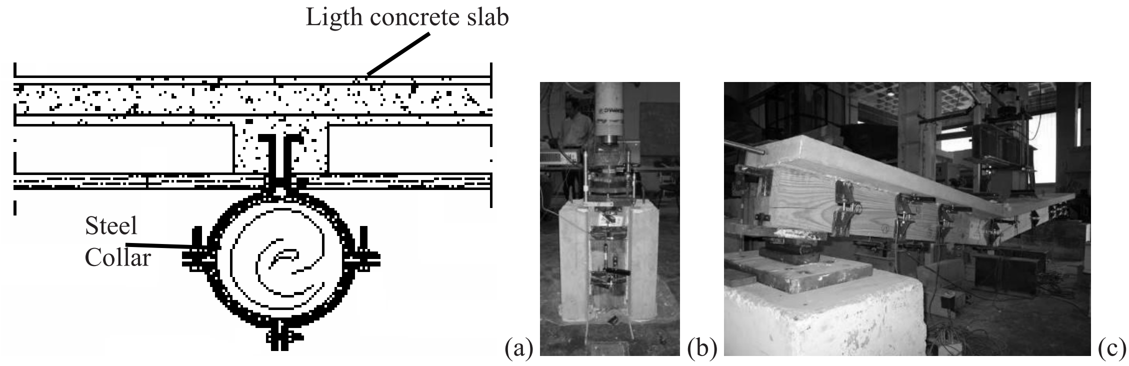


Figure 15. Timber-steel-concrete connections: (a) cross-section with steel collars around circular wooden beams; (b) push-out test on concrete slab-wooden beam connection specimen; (c) test on composite beam with rectangular cross-section.

Figure 16. Consolidation intervention on the wooden floor structure in the Diplomatic Hall of the Royal Palace of Naples.

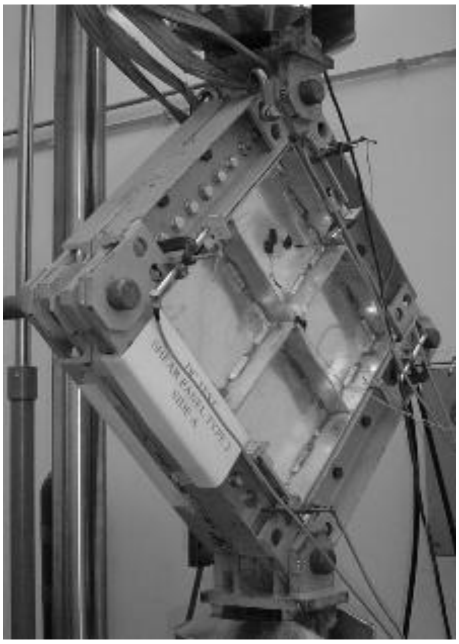
4.5 *Tests on devices*

The experimental investigation of the innovative devices has been aimed at characterizing the cyclic performances of the Reversible Mixed Technologies developed within the project, in order to optimize their use in the seismic protection of historical and monumental buildings.

Figure 17. Test specimen of metal shear panels for consolidating timber structures.

A wide campaign on the cyclic behaviour of pure aluminium shear panels has been carried out at the University of Naples "Federico II" (Italy) and at the University of Chieti-Pescara "G. D'Annunzio" (Italy) (De Matteis et al., 2007, 2008). The experimental tests have been carried out on both full bay and bracing type pure aluminium shear panels (Fig. 18). In particular, four full bay and four bracing type specimens have been considered. For both groups of experiments, the main differences among the tested systems are related to the presence of adequate stiffening ribs on the panels and to the connection (bolted or welded) between the ribs and the panels.

(a)

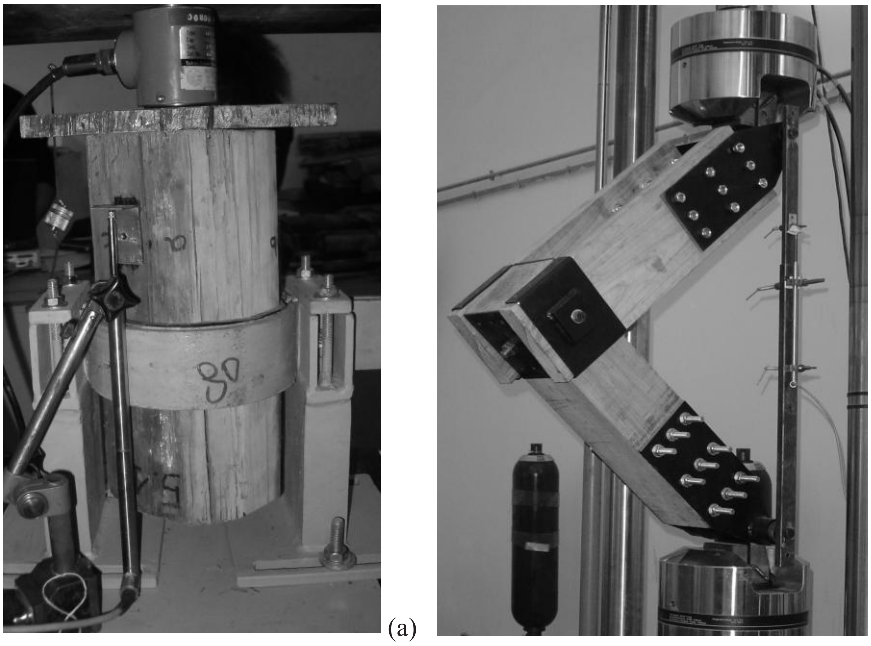


(b)

Figure 18. Pure aluminium shear panels: (a) full bay type; (b) bracing type.

The basic innovative devices used for the realization of composite timber-steel-concrete elements, have been subjected to extensive experimental investigations (Figs. 19a,) at the University of Naples "Federico II" (Italy) and at the Istituto Superiòr Tecnico of Lisbon (Portugal).

A special dissipative beam-to-column node has been conceived at the University of Naples "Federico II" (Italy), and it has been subjected to experimental investigations devoted to evaluate the node capability to dissipate the input seismic energy by a torque mechanism in metal elements placed in the nodal area (Fig. 19b).



(a) (b)

Figure 19. Devices tested in Naples: (a) timber-steel connectors; (b) torque dissipative node for timber frames.

For the connection of marble elements, special steel anchors in marble have been studied at the Technical University of Athens (Greece), by performing pull-out tests on threaded reinforcement bars which were installed in drilled holes and connected to the marble by means of a suitable cementitius material. Moreover, special metallic devices for the connection of marble architraves have been tested at the University of Ljubljana (Slovenia), in order to assess the effectiveness of such innovative system in linking marble blocks each other.

Further experiments on devices are referred to iron connections (University of Liège, Belgium, together with University of Naples-Architecture Faculty, Italy), to magneto-rheological devices at the Second University of Naples (Aversa, Italy), and to DC90 dampers at the University of Ljubljana (Slovenia).

4.6 *Tests on materials and elements*

The tests on materials and elements have represented the basis for all the experimental analyses carried out at different scales, as previously described. Simple elements and materials have been characterized from the mechanical point of view, so allowing the correct interpretation of the experimental results coming from the tests at larger scales.

Experimental campaigns have been performed, in particular, on elements made of: adobe (Rabat, Morocco), bricks with mortar (Skopje, Macedonia), stone (Rabat, Morocco and Algiers, Algeria), marble and limestone (Ljubljana, Slovenia and Athens, Greece), iron (Liège, Belgium and Naples, Italy), aluminium (Naples, Italy), timber (Istanbul, Turkey and Naples, Italy), concrete (Bucharest, Romania).

5 NUMERICAL ACTIVITY

5.1 *General*

The numerical analyses have represented the counterpart of the experimental tests described in the above section, since most of them have been focused on models of the experimented test specimens. Consequently, also for the numerical analyses, the activity has been developed at five levels, from full scale building to materials and elements. The clear aim of this activity has been the set up of reliable numerical investigation tools, useful for both studying aspects difficult to catch in the experimental tests and providing the basis for the set up of calculation models adequate for historical buildings retrofitted by Reversible Mixed Techniques.

5.2 *Full scale model*

The whole Bagnoli r.c. building, already described in the section on full scale experimental tests, has been modelled by means of the non-linear finite element program SAP2000 at the University of Naples "Federico II" (D'Aniello et al., 2008). In the numerical model the presence of the innovative BRB retrofitting system has been taken into account, and the numerical results, from the static non-linear analysis of the building, have well matched the experimental ones.

5.3 *Large scale models*

Pre- and post-experimental numerical analyses, devoted to support the development of advanced analytical models, have been performed for the large scale models interested also by the experimental tests. The Mustafa Pasha Mosque has been modelled in cooperation between the University of Naples "Federico II"-Architecture Faculty and the University of Skopje "Sts. Cyril and Methodius" (Landolfo et al., 2007) (Fig. 20a). The Gothic Cathedral of Fossanova has been modelled at the University of Chieti-Pescara "G. d'Annunzio" (Fig. 20b).

The model of the St. Nikola Church in V. Psacha has been set up at the University of Skopje "Sts. Cyril and Methodius" (Fig. 21a) and the Greek Temple has been modelled at the National Technical University of Athens (Fig. 21b).

5.4 *Models of sub-systems*

Numerical models aimed at investigating the behaviour of sub-systems endowed with RMTs have been set up. Several retrofitted sub-systems have been considered in the study, namely: masonry walls and metal panels (Fig. 22a, b) ("Politehnica" University of Timisoara – Romania and University of Chieti-Pescara "G. d'Annunzio" – Italy) (Campitiello et al., 2007), masonry walls and FRPs (University of Naples "Federico II" – Italy), timber frames and metal shear panels (Boğaziçi University of Istanbul – Turkey and University of Chieti-Pescara "G. d'Annunzio" – Italy), timber composite floors (Fig. 22c) (University of Naples "Federico II" – Italy and Istituto Superiòr Tecnico of Lisbon – Portugal), iron elements and FRPs (University of Liège – Belgium).

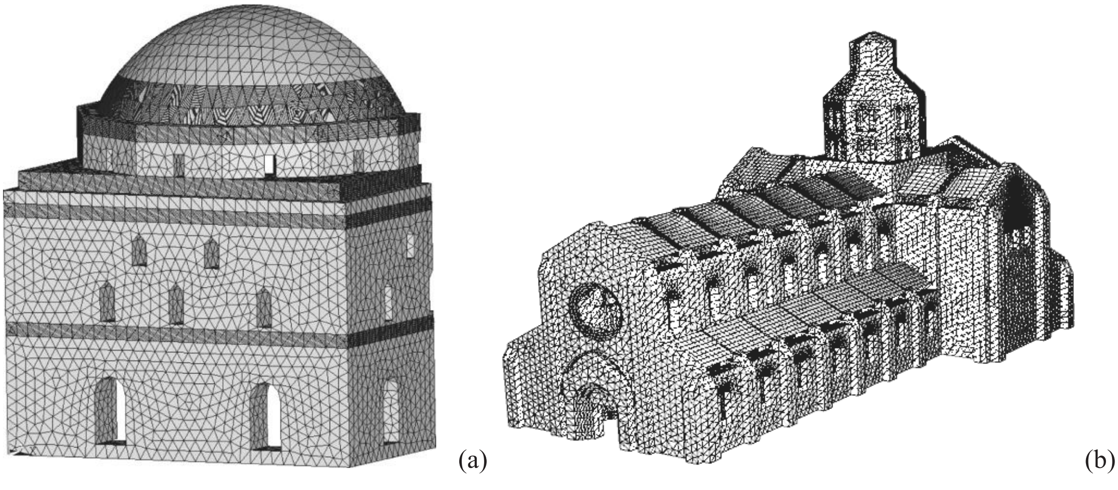


Figure 20. FEM models: (a) Mustafa Pasha Mosque; (b) Fossanova Gothic Cathedral.

In all cases, pre- and post-experimental analyses have been carried out. The pre-experimental analyses have been used for setting up the models and carrying out preliminary studies. The post-experimental analyses have been developed in five phases, namely: the numerical simulation of the original specimens, the modelling of the strengthening devices, the simulation of the strengthened specimens, the comparison with the experimental results, and the calibration of numerical procedures for the analysis of the strengthened structural systems.

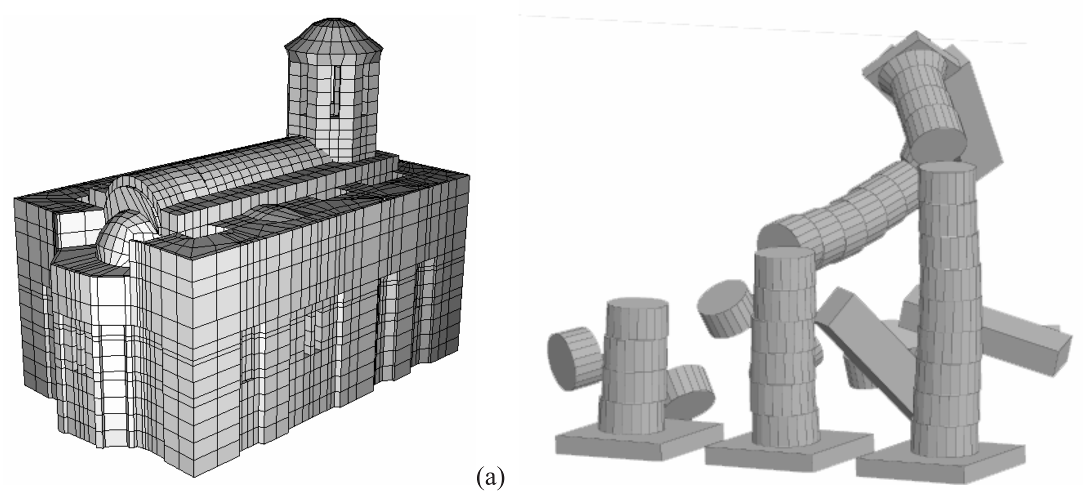


Figure 21. FEM models: (a) St. Nikola Church; (b) Greek temple columns.

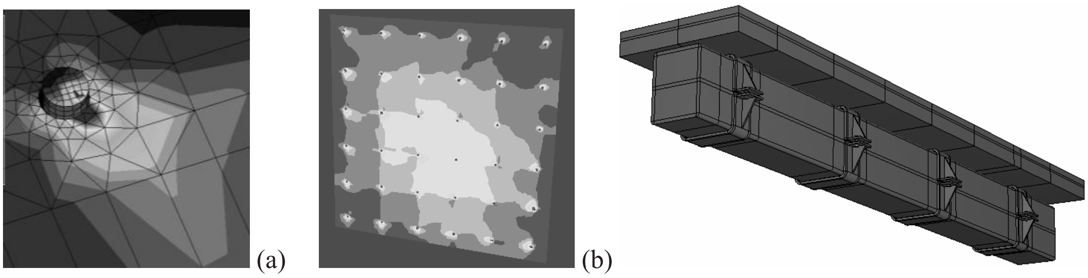
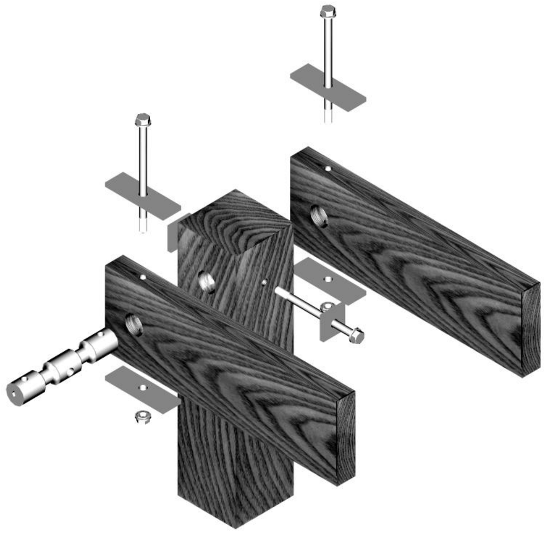


Figure 22. Numerical models: (a) interface between connector and steel plate ; (b) masonry wall reinforced by metal panels; (c) timber composite floor beam.

5.5 *Models of devices*

The activity concerned with the numerical modelling of innovative devices has been subdivided in several steps, following the same approach of the numerical analyses on sub-systems. In fact, after the pre-experimental analyses aimed at setting up adequate numerical models and carrying out preliminary investigations, the post-experimental analyses have been focused on the modelling of the devices, on the comparison of the numerical results with the experimental ones and, as a final step, on the calibration of numerical procedures for the analysis and the design of the devices.

The devices modelled numerically are: iron connections (University of Naples “Federico II” – Italy), architrave connections (University of Ljubljana – Slovenia and National Technical University of Athens – Greece), wood-to-concrete connectors (University of Naples “Federico II” – Italy and Istituto Superiòr Tecnico of Lisbon – Portugal), wooden node dissipative device (University of Naples “Federico II” – Italy) (Fig. 23), pure aluminium shear panels (University of Chieti-Pescara “G. d’Annunzio” – Italy) (Formisano et al., 2006; Brando et al., 2007), magnetorheological devices (Second University of Naples – Italy), and DC90 dampers (University of Ljubljana – Slovenia).


(a)

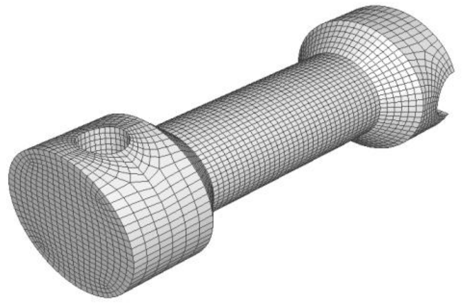

(b)

Figure 23. Dissipative beam-to-column wooden connection: (a) geometry ; (b) FEM model of the nodal metal element.

5.6 *Models of materials and elements*

The characterization of the behavioural features of the materials and the elements used for the construction of the models of devices, sub-systems, large scale and full scale systems has represented the basic issue for carrying out the numerical activities. In fact, the calibration of material and element simple numerical models is essential for the set up of more complicated models, from the modelling of the single devices to the numerical investigation of the complex behaviour of the full scale building retrofitted by reversible mixed systems.

In this perspective, numerical models of adobe, stone, marble, iron and aluminium have been set up. The models have preliminarily been used for carrying out pre-experimental numerical analyses; then, after the experimental tests, the numerical models have been calibrated, and numerical post-experimental analyses have been carried out with the aim of calibrating the numerical constitutive laws to be used in the models at larger scales.

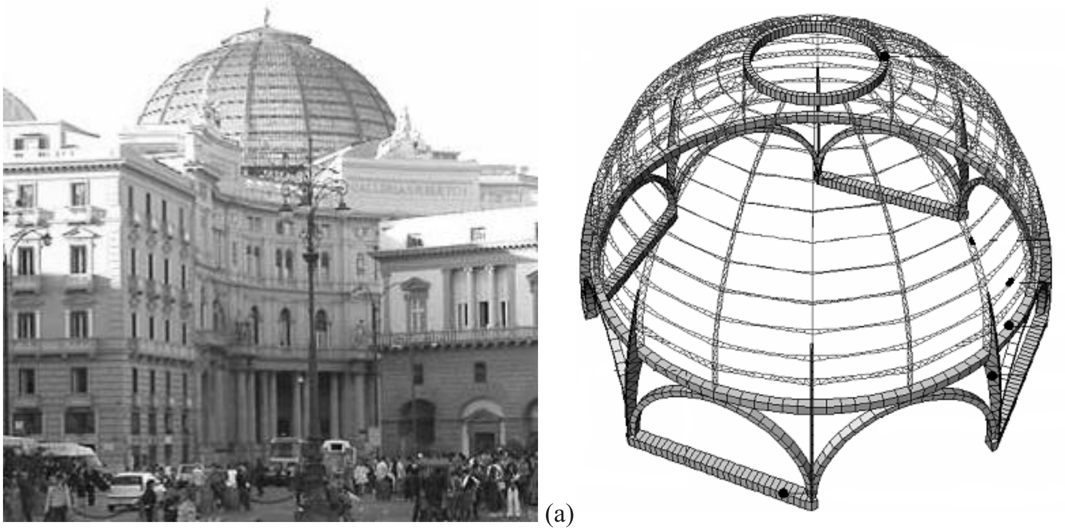
6 CASE STUDIES

The knowledge acquired within the project has been conveniently applied to some selected study cases, consisting in historical buildings belonging to the heritage of Mediterranean Countries, in order to perform analyses of feasibility of seismic protection interventions by means of reversible mixed technologies. The selected study cases have been:

- Mustafa Pasha Mosque in Skopje;
- Saint Nikola Church in Psacha;
- Parthenon in Athens;
- Gothic Church in Fossanova;
- Beylerbeyi Palace in Istanbul;
- Gallery «Umberto I» in Naples (Fig. 24);
- Koletti building in Athens (Fig. 25);
- Royal Palace in Naples (Fig. 26);
- Medina in Salé.

Besides, the first four study cases, which have also been selected for both experimental and numerical analyses, the others have been selected on the basis of the following considerations.

The Royal Palace of Naples and the Gallery “Umberto I”, both in Naples (Italy), are representative of wooden and steel study cases, respectively. The Koletti building in Athens (Greece) is the only r.c. structure considered, while the Beylerbeyi Palace in Istanbul (Turkey) is interesting for studying the interaction between timber and masonry elements. The Medina of Salé in Morocco has been also selected for considering the complex behaviour of undiversified building blocks.



(a) (b)

Figure 24. The Gallery “Umberto I” in Naples: (a) global view; (b) FEM model.

Figure 25. The Koletti building in Athens.

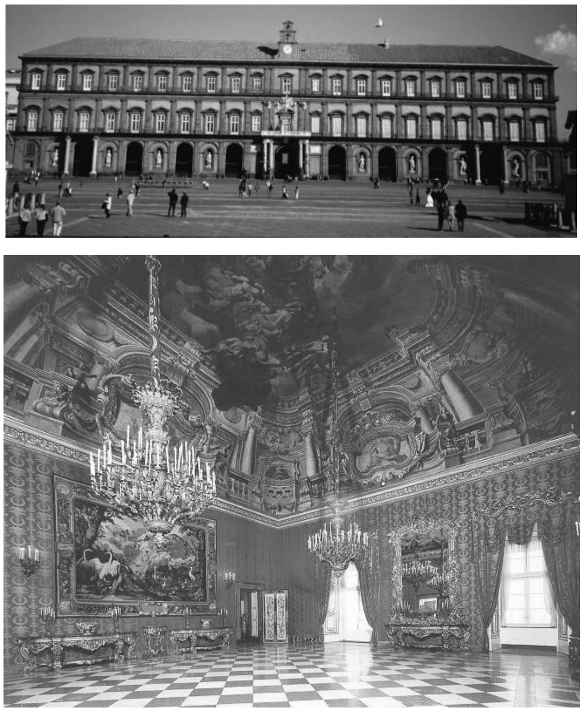


Figure 26. The façade and the Diplomatic Hall of the Royal Palace in Naples.

7 CONCLUSIONS

The PROHITECH project has been an important opportunity to develop knowledge and technology in the field of the seismic protection of the Euro-Mediterranean cultural heritage. The innovative character of the technical solutions proposed for seismic retrofitting is mainly based on the concept of reversible mixed technologies.

The complexity of the whole research project has been shown, as well as its evident comprehensiveness.

An up-to-dated state-of-the-art concerning advanced systems of seismic protection for existing constructions has been acquired, so providing a contribution to the specific demand of all European and Mediterranean Countries for a more comprehensive framing of anti-seismic rehabilitation.

A valuable contribution to both conscience and knowledge about “new” materials and technologies as a suitable alternative to “traditional” solutions has been provided, since the last ones are proved to be often inadequate to provide a satisfying seismic performance, in particular when applied to historical and monumental constructions.

The adoption of materials and systems which are reversible, recyclable, environmentally friendly, and economically sustainable has been supported.

An extraordinary contribution in terms of both experimental and numerical work on the behaviour of historical constructions consolidated by means of reversible mixed techniques has been given. The experimental results have confirmed the previsions obtained by the numerical analyses and, above all, the effectiveness of the developed and implemented intervention systems.

A large effort for transferring the acquired knowledge, based on the performed studies on experimental and numerical models, to real study cases belonging to the cultural heritage of the Euro-Mediterranean area has been made, obtaining very satisfying results (see the actual interventions on the Mustafa Pasha Mosque in Skopje and on the Diplomatic Hall of the Royal Palace in Naples).

A deep dissemination activity of the outputs of the performed studies within the PROHITECH project has been made by the partners, who have produced a large number of documents focused on the work carried out. In the PROHITECH Final Report, in fact, about 150 papers dealing with activities developed within the project have been listed, and it is expected that several new papers will be presented at international Conferences or published in international scientific journals.

In addition, the activity, which has involved more than 100 researchers belonging to Euro-Mediterranean Academic Institutions, has led to the production of 16 Project Deliverables and 4 Main Deliverables, the latter ones being arranged into 6 published volumes.

The above activity is expected to have important effects on the practice of seismic consolidation and protection of historical buildings, also considering the effort carried out within the project to collect the existing codes and guidelines related to the seismic rehabilitation of buildings by means of innovative techniques, with special emphasis on reversible technologies.

The out-put of the PROHITECH project has been presented during the Inernational Conference held in Rome in June 2009 (Mazzolani, 2009).

ACKNOWLEDGEMENTS

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The General Coordinator would like to express his satisfaction for the effective cooperation given by all Partners and their teams, which have enabled the project to be a success story.

In particular, he expresses his gratitude to the Technical Coordinator Gianfranco De Matteis and to the Management Officer Xiaoling Song for the constant help, also in some critical situations, during these four years of intense activity, as well as to Matteo Esposto for his enthusiastic contribution to the technical management of this complex operation.

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Steelwork in Structural Restoration

Federico M. Mazzolani
Department of Structural Engineering, University of Naples "Federico II", Naples, Italy

1 INTRODUCTION

It can be observed that the building industry is getting more and more devoted to these activities of consolidation, rehabilitation and modernisation of old buildings, where the presence of steelwork is becoming wider as far as the list of cases increases.

The old masonry buildings are very often damaged by age and by the ravages of time and, therefore, they require structural consolidation and functional rehabilitation. But also more recent buildings made of reinforced concrete sometimes need refurbishment operations due to their bad state of preservation.

In these operations steelwork can be considered a suitable system both from structural and architectural point of view. In fact, it offers flexibility of execution and ease of erection, giving at the same time "prefabricated" types of elements, which allow the designers to find "ad hoc" solutions and to achieve optimum results tailored to specific requirements [1, 2, 3].

Steel technology expresses its advantages of suitable material in term of strength and lightness. These prerequisites are being particularly appreciated when the building to restore has architectural and historical importance, because the use of steel, as "new" and "reversible" material, is in strict agreement with the main criteria of the modern theory of restoration.

The following is devoted to show the main aspects arising from the use of steelworks to solve problems of strength and stability of existing structures in rehabilitation operations. The recent developments of these activities acknowledges steel as a suitable material both in consolidation and restoration of all kind of structures, made of common constructional materials, i.e. masonry, timber, reinforced concrete and also steel itself. The flexibility of the technological systems is shown by many examples.

2 STRENGTHENING REQUIREMENTS

From the structural point of view steel is widely used at all levels of consolidation. These levels are differentiated according to their importance on the basis of the following classification: safeguard, repairing, reinforcing, restructuring [4, 5, 6].

Safeguard represents the first level in chronological order, when action of a temporary nature is required – sometime urgently – prior to starting any other intervention of a final nature; its aim is to achieve adequate safety at a temporary stage for both the public and the site. Steel scaffoldings are normally used to organise the site and to protect the works in the building under rehabilitation operations (Fig. 1).

Fig. 1 – Temporary steelworks used in rehabilitation operations (*safeguard*).

Repairing involves to carry out a series of necessary operations on the structure of a building in order to restore its former structural efficiency, before the damage occurred. It is the case where some structural members are upgraded after the damage effect of an earthquake. In many cases a provisional repairing can become permanent.

Reinforcing requires the improvement of the structural performance in order to enable the building to fulfil new functional requirements (for example, new heavier load conditions) or environmental conditions (such as the location in an area recently declared to be subject to seismic conditions). Reinforcing operations can in turn be subdivided into to different levels:
- the lowest (simple improving operations) involves a variety of work on individual structural elements of a building in order to achieve a higher degree of safety, but without significantly modifying the overall performance;
- the highest (retrofitting operations including seismic upgrading) provides a series of works required to make the structure capable of withstanding the new design actions. This is compulsory:
  - in the case of vertical additions or horizontal extensions;
  - when changes in use entail increases in the original loads;
  - when transformations lead to a different structural system from the original one;
  - in all cases generally involving a change in overall performance.

Within the repairing and reinforcing stages, there are numerous technological consolidation systems based on the application of steelwork, which are often used to restore both masonry and reinforced concrete constructions.

A level of consolidation of a more general nature takes place in *restructuring*, which consists of the partial or total modification of the functional distribution and volumetric dimensions, together with all the other characteristics of the building, including the original structural system. It is carried out when a new intended use requiring a different arrangement with new volumes and new areas is planned.

3 FUNCTIONAL ASPECTS

Apart the structural aspects, restructuring operations are usually requested for functional needs which give rise to different kinds of interventions [7]. These interventions can be classified as follows.

Degutting consists of the total or partial substitution of the internal structures of a building by others of different type. It is resorted to when architectural and/or town-planning reasons require the complete conservation of the façades of a building, whilst the layout of the interior is changed. Steel structures have been successfully used in many examples of degutting of buildings with façades of notable architectural merit (Fig. 2).

Fig. 2 – The internal court of the Justice Palace in Ancona (*degutting*).

Insertion comprises all those interventions providing for integration of the existing structure with new structures or structural elements inserted inside the same overall volumetric dimensions. The internal areas thus acquire new features derived both from their more rational layout and from the presence of new structural elements endowing the building with new stylistic values. The most common example is the additional floors created in order to increase the usable area within the limits of a given volume (Fig. 3a,b).

In these cases, due to the necessity not to interfere with existing structures, steel is the most suitable and efficient material for constructing inserted structures, thanks to its special characteristics: high strength, low weight, reversibility of steel installations

Fig. 3a – A new steel mezzanine inside of the Ducal Palace in Genoa (*insertion*).

Fig. 3b – A new ramp connecting the second floor of the Ducal Palace in Genoa (*insertion*).

A special case: a big tuff cavern in Naples has been used as a garage and a new floor made of composite steel and concrete structure has been inserted in order to considerably increase the parking area (Fig. 4a,b).

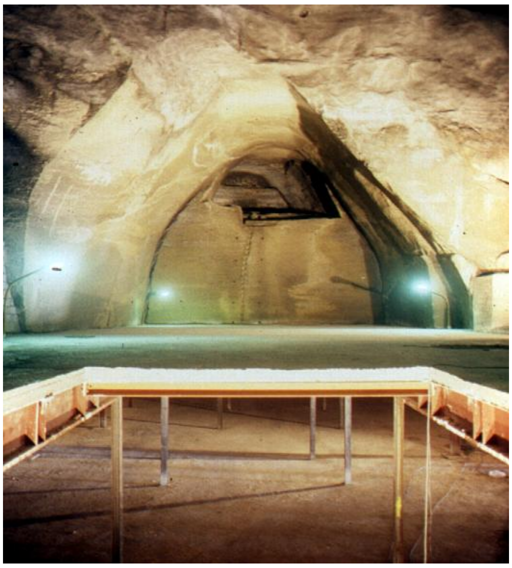


Fig. 4a – A new parking area in a tuff cavern in Naples (*insertion*)

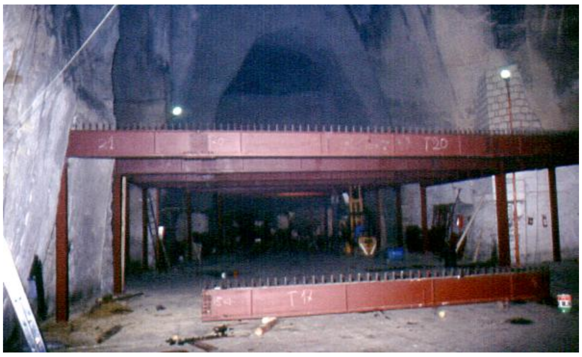


Fig. 4b – Structural details of a new composite floor for increasing the parking area (*photo Lo Cascio*)

Vertical extension consists of adding one or more stories above the existing structure, resulting in an increase of the overall volume of the building as well as an increase of weight.

Depending on the size and height of the new additional masses, it is necessary to re-check the load-bearing capacity of the original structure in order to decide whether or not to take consolidation measures on the structures bellow, including foundations.

The necessity to minimise the weight of the new structure added above makes steel the most suitable material due to its excellent mechanical performance (high "*strength-to-specific weight"* ratio), which characterizes steel as a "light" structural material.

Fig. 5a - Eight additional steel stories on an existing R.C. structure in Toronto (*vertical extension*)

Fig. 5b – The final facade after super elevation, where the distinction between the old and the new parts is clearly identified

An interesting example of the possibility of steel for vertical addition is given by the building in Toronto (Fig. 5a, b). It was a reinforced concrete building of six stories, which was designed to be super-elevated of more four stories in the same material. Contrary, it was decided to use steel for the additional structure. Thank to this choice, instead of six stories, it was possible to add new eight stories. Therefore, at the end the building is composed by fourteen stories, instead of ten, with an important increase of volume.

Lateral extension does not require specific strength features, but it is sometime used in order to increase the functionality of the lay-out. In case of monumental buildings, steel structures can provide an aesthetic combination between old and new materials.

Both vertical and lateral extension has been obtained by means of large steel portal frames which three floors have been suspended to (Fig. 6 a,b), for increasing the volume of the hotel between the two existing R.C. buildings.

Fig. 6a – New extension, both vertical and lateral, in the Jolly Hotel in Caserta, with three additional floors.

Fig. 6b –The new facade of the Jolly Hotel in Caserta, which has been aesthetically improved by the presence of steel portals.

The opposite of vertical extension is *lightening,* which can include the demolition of one or more levels at the top, when this is required because of the necessity to limit the loads involved in order to reduce the stress state in the existing structures. In a more general sense, lightening interventions are all operations substituting floors, roofs or masonry parts of the existing structural organism with lighter materials. In fact, the substitution of heavy wooden and masonry floors with light steel I-sections and corrugated steel sheets as well as the complete remaking of roofs with steel trusses are very common choices in structural restoration (Fig. 7).

Fig. 7 – A new steel structure for roofing a church, substituting the old one (*lightening*).

4 RESTORATION PRE-REQUISITES

The examination of the various levels of consolidation and types of restructuring shows that the choice of steel is substantially based on its high mechanical performance and on the flexibility of the constructional systems. When the building to be consolidated is of historical interest, its restoration is a very delicate operation, for which the use of structural steel has further advantages.

The criteria, upon which restoration operations are based, tend basically towards the conservation of pre-existing buildings and their integration with new works necessary to ensure their return to functionality. Such new works must be clearly modern in features; they must be surely distinguishable and they must be reversible, by using technologies and materials which can be removed without damaging the existing structure.

The various international restoration "Charters" in fact state the incongruity of reconstruction by using the methods of the past, which can no longer be reproduced for many reasons, above all technological. Other reasons are related to sentimental feelings or construction tradition, to new functional requirements and lack of availability of old materials. At the same time these "Charters", especially in cases where the restoration operation involves restructuring with partial reconstruction, indicate the need to use well adapted technologies and materials in a clearly modern way.

A logical application of these principles undoubtedly shows that steel, as a material and its technology, have the necessary advantages of being a modern material with "reversible" characteristics, particularly suited to reconcile with the materials of the past and to form integrated structural systems.

In conclusion, the use of structural steel in rehabilitation of old monumental buildings is perfectly in line with the recommended criteria of the modern theory of restoration. Steel is therefore widely used in restoration works in all kind of ancient monuments and historical buildings.

5 CONSOLIDATION SYSTEMS

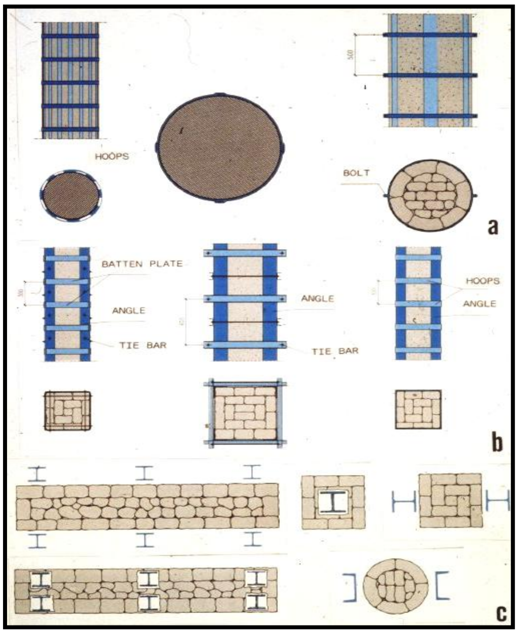
Existing buildings both in masonry and in reinforced concrete can be consolidated by using steel techniques at the different stages of intervention, going from simple safeguard, through repairing and reinforcing, up to final restructuring operations [8].

The load-bearing capacity of masonry walls can be improved by several methods (Fig. 8a,b):

- encircling damaged masonry with vertical steel profiles and cross stiffening brackets;
- insertion of new steel columns in suitable cavities or simply placed alongside the wall to be consolidated;
- restoring the strength of the wall around openings by means of steel girders above the hole or frames inserted into the opening.

The capacity to withstand horizontal actions, due to subsidence of foundations, geometric asymmetry, unevenness of load, or - a far more heavy circumstance - seismic quakes, can be conferred in different ways, such as:

- enchaining façade walls with steel profiles arranged to form horizontal hoops at each level joined together by tie-beams;
- enchaining corners by means of girders or tie-beams;
- insertion of steel bracings in the main walls.



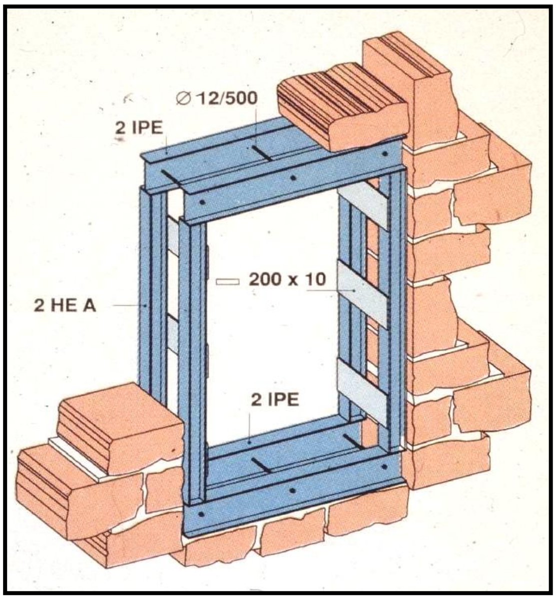


Fig. 8a - Consolidation techniques for masonry columns and walls.

Fig. 8b – Steel frame around an opening in a masonry wall.

The use of steel bracings is very effective in strengthening reinforced concrete structures against earthquakes. It allows the introduction of shear walls with lattice scheme, which has the dual purpose of considerably increasing the resistance of the structure to horizontal forces and at the same time balancing the distribution of internal rigidity with respect to the shear centre, so as to minimise dangerous torsional vibrations. Such steel bracings can be obtained by inserting steel profiles connected to the perimeter of the meshes of the reinforced concrete frame, inside which diagonals and counter-diagonals are arranged in the classical “St. Andrew’s cross” pattern on two floor levels. In addition to the important structural contribution in upgrading the overall behaviour, it can be recognized that the presence of steel braces gives a new architectural feature to the façade (Fig. 9 a, b).

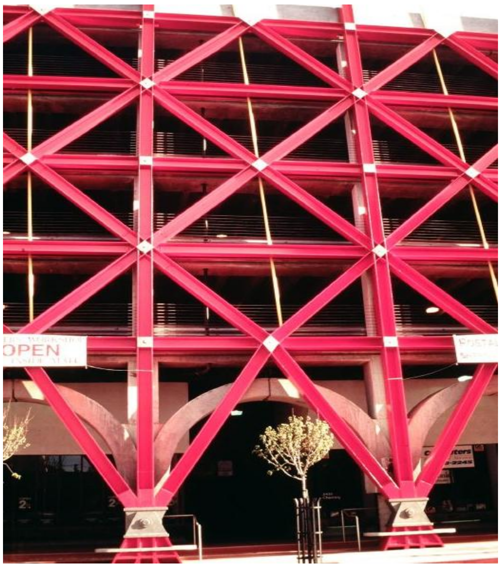


Fig. 9a - The University Hall in Berkeley (California, USA): the R.C. structure has been upgraded by means of steel concentric braces.

Fig. 9b – Steel bracing structure for upgrading a multi-storey auto-silos in Berkeley.

As far as the consolidation of the horizontal structures is concerned, the types of floors usually found in old buildings belong to three main categories, which are characterised by the structural materials used, such as:

a) wooden beams (Fig.10 a, b, c);
b) steel beams (Fig.11 a,b);
c) mixed reinforced concrete beams and tiles (Fig.12).
d)

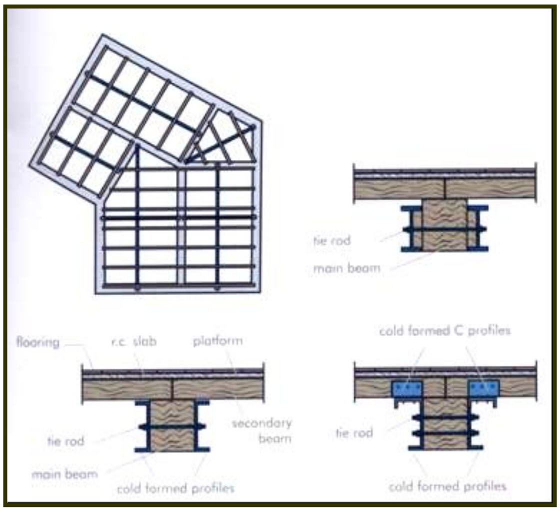


Fig. 10a – Consolidation techniques for wooden beams in floor structures, operating from the bottom to the top.

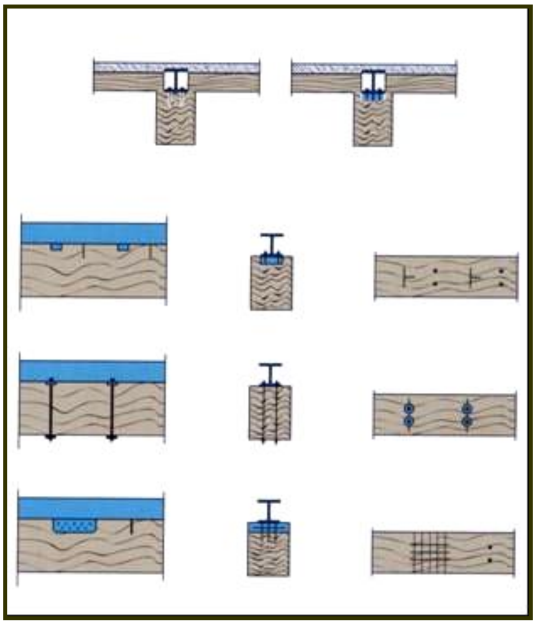


Fig. 10b – Consolidation techniques for wooden beams in floor structures, operating from the top to the bottom.

As an alternative to complete substitution, wooden floor beams (type a) can be reinforced by two constructional methods:

- working from the bottom upwards, each wooden beam is strengthened with a pair of steel profiles integrated by metal sheets or plastered nets to support the secondary elements (Fig. 10 a);
- working from the top downwards, if the wooden beams are in good condition and are worth exposing, the upper steel profiles are connected to the wooden beams by double system of connectors (Fig.10 b).

Figure 10 c shows the details of the consolidation of a floor structure by means of a multi-composite solution, where the main wooden beams are reinforced with an upper steel beam, which is connected to the reinforced concrete slab cast on trapezoidal sheeting.

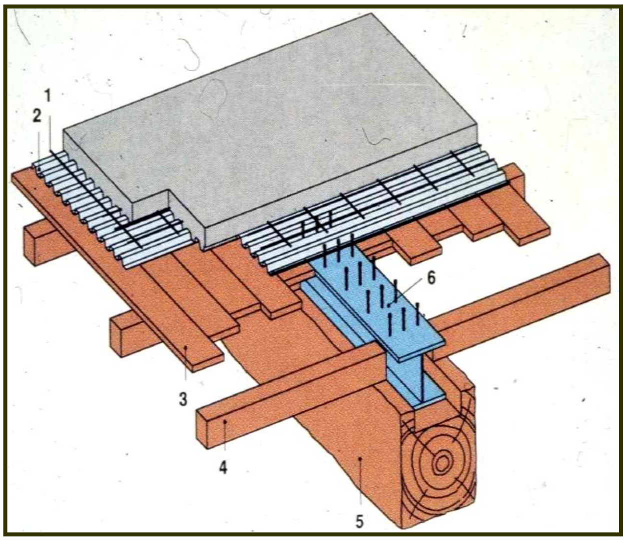
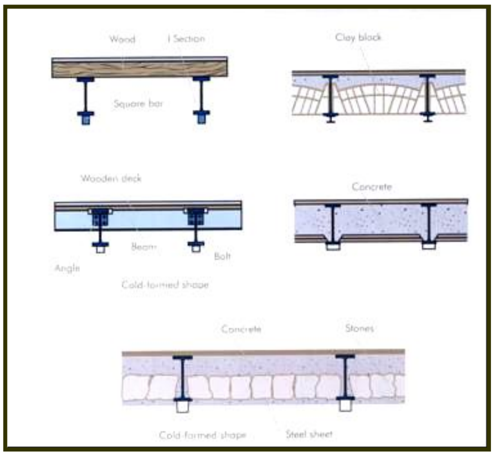


Fig. 10c – Multi-composite system by using steel profiles, trapezoidal sheeting and cast concrete.

Floors with steel beams (type b) are frequently found in buildings dating back to the beginning of last century, when the first I-shapes started substituting the wooden beams, in conjunction with brick or tile vaults or hollow blocks (Fig.11 a, b).

Due to gradual degradation of the restraint conditions, increasing of both rigidity and section modulus is usually required, what can be obtained by two constructional methods:

- working from the bottom upwards, the modulus of resistance of the beams can be increased by welding to the bottom flange of the I-beams a suitable steel section (Fig.11 a);
- working from the top downwards, a reinforced concrete slabs can be created, joined to the beams below by suitable connectors and cast on corrugated steel sheets, or simply connecting a new steel profile to the upper flange of the existing one (Fig.11 b).



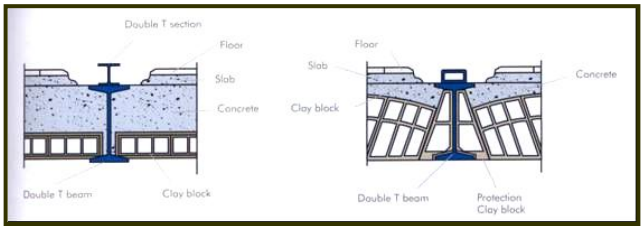


Fig. 11a – Consolidation systems of floor steel beams, by increasing the section modulus with additional steel elements, which can be welded or bolted to the bottom flange of the existing beam.

Fig. 11b – Consolidation systems of floor steel beams, by increasing the section modulus with additional steel elements to the top flange of the existing beams.

Mixed floor structures made of reinforced concrete beams and hollow clay blocks (Fig.12) can be consolidated by means of steel elements in different ways with the following methods:

- plating the bottom of the individual concrete beams by means of steel plates, without breaking the tiles;
- reinforcing the individual concrete beams
- by means of cold-formed steel sections;
- inserting double T profiles between concrete beams in suitable housings;
- strengthening with double T beams placed and forced below each concrete beam.

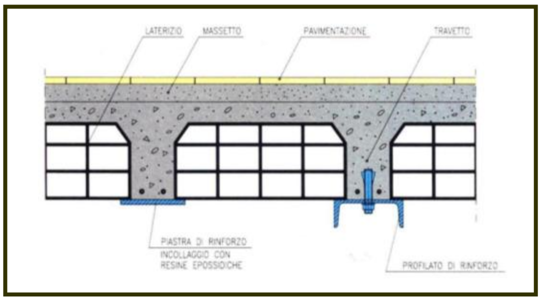


Fig.12 - Consolidation of the beams in a mixed floor structure.

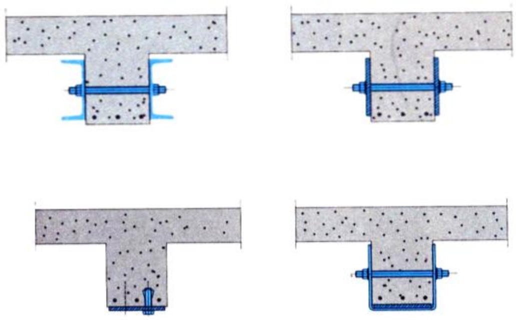


Fig.13 – Consolidation systems of reinforced concrete beams.

The strengthening of R. C. beams can be obtained by integrating the cross-section with steel plates or profiles, which are connected to the concrete by means of bolts or ties and glue. (fig.13).

The consolidation of reinforced concrete columns can be done by following similar techniques to the ones used for masonry (Fig.14).

Fig. 14 – Steel angles in the corners and transversal batten plates for strengthening r.c. columns in Mexico City.

With regards roof structures, masonry buildings are generally covered by wooden trusses, which deterioration is always made worse by direct contact with atmospheric agents. An optimum solution can be attained by substituting the old timber structure with new steel structures, completed by corrugated steel sheets. This method is very frequently used for roofing of church buildings. If the church is located in an earthquake prone area, it is also advisable to create a steel grid below the trusses in order to obtain an horizontal diaphragm, which provides a rigid connection between the top of the walls (Fig.15).

Fig. 15 – A new steel truss as a roof in the structural restoration of a church.

When the church is regarded as irrecoverable because of a large amount of damage, a new roof structure can be made completely independent of the masonry below, following the typology of insertion and giving rise to a strong contrast between old and new (Fig.16). In this way the building has been transformed in a "Sacrarium" in memory of the victims of earthquakes.

Fig.16 – The church of San Rocco in Morra de Sanctis (Avellino. Italy).

Fig. 17 – The former Stock Exchange Hall in Bologna, now Civic Center.

A very common activity is now-a-day the rehabilitation and the re-use of the old iron and steel buildings of the 19th century (Fig.17).

Particular attention must be paid to the connection between the old and the new steel in relation with the state of conservation. In many cases welding is not advisable due to the impure composition of the old material and the use of bolting is therefore suggested.

From the structural point of view it must be observed that the old steel schemes are usually well conceived for carrying vertical loads, but they are weak for horizontal actions and therefore require the integration with new bracing systems.

The same activity is devoted to old steel bridges. A significant example is given by the old very famous Paderno bridge built in 1886 on the Adda river near Milan, which needs restoration operations (Fig.18). Its structural scheme is very similar to one conceived by Gustav Eiffel in the bridges of Garabit (France) and Maria Pia in Oporto (Portugal).

Fig.18 – The Paderno bridge on the Adda river (Italy).

6 RANGES OF APPLICATION

Several activities of refurbishment, rehabilitation and extension by using steelwork are in progress in all over the World [9, 10]. Old industrial constructions have been transformed in apartments or in offices (Fig.19).

Fig. 19 – Re-use of an industrial building in Paris.

Fig. 20 – The gasometer has been included in the Maria Callas museum in Athens.

The old gasometers have been transformed and re-use for many different purposes (Fig. 20) in rue de l'Ourque, Paris. The old gasometers are transformed and re-used for other purposes (Fig.20). Monumental buildings have been entirely degutted by keeping the original façades and the interior has been completely substituted with a new steel skeleton.

Self supporting steel structures have been inserted into historical monuments by providing a suitable integration with modern stylistic values. This use is becoming more and more common for museums and exhibitions halls. Many old churches have been covered by steel roofing systems, composed by trusses and trapezoidal sheets. Important buildings have been restructured by vertical and horizontal extensions made of steel components which are harmonised with the existing building both from structural and aesthetic point of view (Fig.21). In other cases the contrast between old and new is purposely enhanced for better valorising the new technologies (Fig. 22).

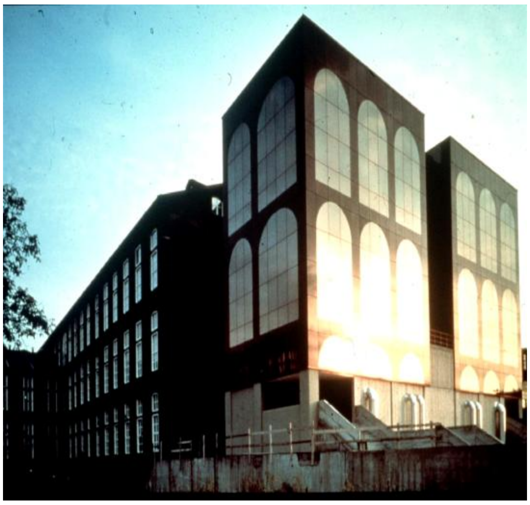


Fig. 21 – The new Faculty of Economy in Turin.

Fig. 22 - Old-to-new combination in the "La Villette" park in Paris.

The 19th century iron markets represent a precious heritage which is normally preserved and valorised (Fig. 23).

Fig .23 – The restoration of the San Lorenzo market in Florence.

Entire districts of old towns in Italy have been completely rehabilitated after being seriously damaged by recent earthquakes; steel components have been used in order to improve the seismic resistance of old masonry buildings Concrete structures have been repaired by means of steel elements after being damaged. They have been reinforced with steel, when heavier serviceability conditions are required. Reinforced concrete structures can be also transformed by a drastic changing of the structural scheme from the original one (Fig. 24), when a modification of the structural lay-outs is requested. In this case, an industrial building has been transformed into a gymnasium.

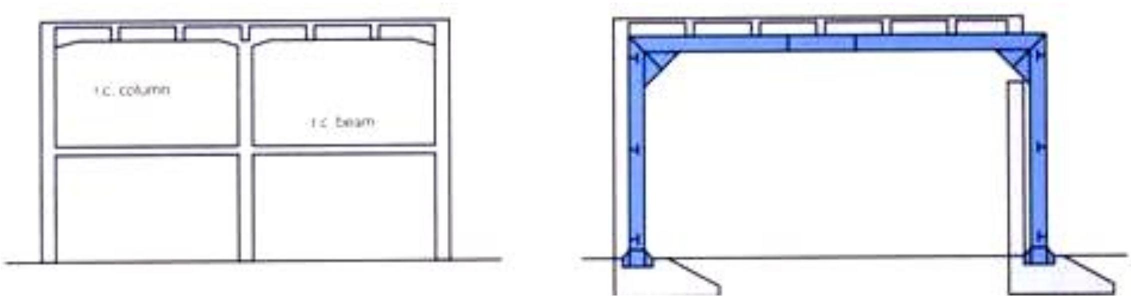


Fig. 24 – Drastic transformation of a two spans – two stories R.C. structure.

Recent experiences demonstrated that steel-based systems (like eccentric and buckling restrained braces, metal shear panels) can be profitably used for the seismic upgrading of existing reinforced concrete buildings.

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Fort Manoel - Rehabilitation of a 19th century Steel Bridge

A. Torpiano,
aoM Partnership,Malta; Faculty for the Built Environment University of Malta

S. Sammut
aoM Partnership, Malta

D. Zahra
Heritage Malta (formerly aoM Partnership, Malta)

ABSTRACT: The Fort Manoel steel/timber bridge, built in the last decade of the 19th century, provided a landward 'vehicular' access into the Fort. After 1973, Fort Manoel was abandoned for a long period, and because of the close proximity to the sea, the steel elements in the bridge structure suffered extensive corrosion, particularly at the contact between the ditch rock and the embedded steel. This paper describes the restoration interventions undertaken, to recover the original design intent and functionality, following the indications of a 1898 record drawing discovered during archival research, which showed that most of the original elements could still be traced. It was originally envisaged that certain elements would need to be completely replaced, because of their apparently advanced state of corrosion. However, the careful inspection of all elements, after dismantling, suggested that only minor repairs were necessary. Eventually, all original elements were restored and reassembled on site.

1 INTRODUCTION

The original purpose of both Fort Manoel and Fort Tigne', as extensions to the defence system of Valletta, was to prevent enemies from setting up batteries on these vantage points, to attack Valletta. In fact, these fortifications are well protected against potential attacks from the landward side; on the other hand, they have very effective connections to the sheltered harbour. Hence, it is can be understood that the main access to these Forts was oriented to the seaward side, that is, towards Marsamxett Harbour. Fort Manoel is no exception.

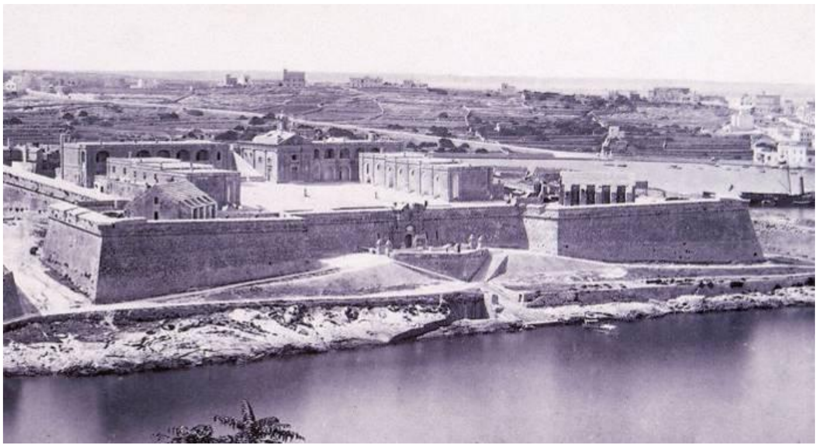


Figure 1: An old photograph of the seaward side of Fort Manoel from Valletta. (Courtesy: I. Ellis)

For several centuries, the natural harbours of Malta, were the backbone of the local economy, with seaborne transport being the most effective means of transportation of goods and people. Gradually, the risk of landward attack receded, and the risk of seaward attack increased. Fort Manoel, in particular, was changed from a Fort with guns looking landward, to an emplacement for heavier guns looking seaward. By the last decade of the 19th century, it was deemed necessary to provide a landward access into Fort Manoel, rather than the original seaward access – which was more appropriate for boat traffic to and from Valletta. It was also deemed necessary to ensure that this access could accommodate the new 'carts' and 'vehicles' of the 19th century.

The solution was not simple to implement; Fort Manoel, a typical 18th century fortification, is surrounded by an impressive dry ditch. Any form of landward access necessitated spanning over this rock hewn ditch; in addition, and to allow circulation of these vehicles within the Fort, a large area of rock had to be excavated within the Fort, hence altering the original levels of the open spaces.

A steel/timber Bridge, designed and built in the last decade of the 19th century, proved to be an effective solution for over a century. However, the lack of maintenance, over the last thirty years, resulted in a rapidly increasing rate of corrosion damage; hasty repairs carried out during the latter half of the 20th century had exacerbated the problem, making the bridge unsafe. In 1999, temporary propping was erected, whilst restoration works on the Bridge commenced in March 2004.

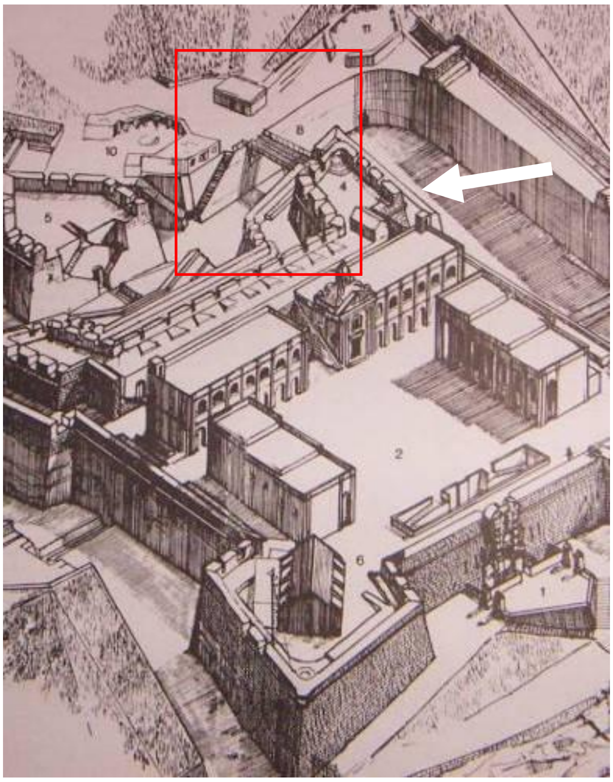


Figure 2: An artist's impression of Fort Manoel showing the location of the landward access – the Bridge (Courtesy: S. Spiteri)

Figure 3: A photograph of the area showing the extents of the drastic alterations in the original floor level of the Fort to allow 'vehicular' access into the Fort.

2 THE RESTORATION INTERVENTION

The structure of the Bridge comprises three main beams (divided in three sections), spanning across the ditch, and each supported by inclined struts, at either end, embedded into the rock face and grouted in concrete. The horizontal beams were joined together by a steel plate and bolted into four (4) anchors, two (2) on each end of the Bridge. Since historical evidence was scarce, and access to the bridge elements difficult, before the intervention, detailed documentation of the structure was undertaken during the dismantling operation itself. Nonetheless, it was soon evident that the general structure of the Bridge tallied with the details illustrated on a 1898 original drawing, discovered in the National Archives. It was concluded that no major alterations had been carried out during its life, with the exception of:

1. the replacement of the timber decking by a series of transverse rolled steel joist that supported a metal sheeting deck;
2. the replacement of the original cast steel railing standards by a rudimentary angle iron railing system;
3. the insertion of steel corbels into the rock face, beneath the severely corroded ends of the inclined struts, in order to reinforce the supports of the structure.

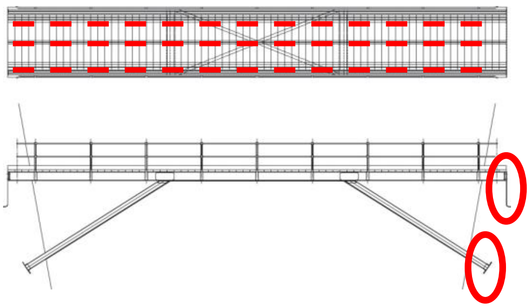


Figure 4: A plan and section of the Bridge identifying the main structural elements, i.e., the three main beams; the anchors; and the abutments.

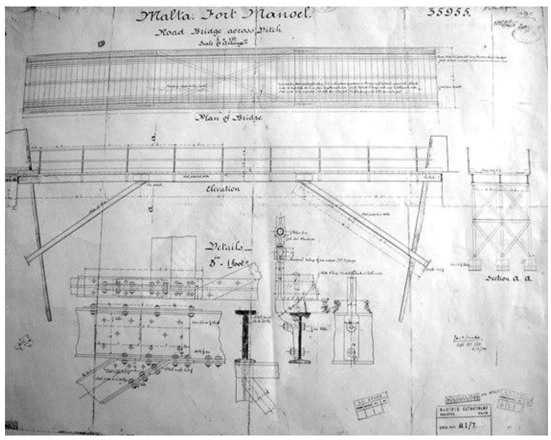


Figure 5: A photograph of a copy of the 1898 drawing: 'Malta: Fort Manoel. Road Bridge across Ditch' (no. 35955). All steel details of the bridge were identified on site (Courtesy: National Archives of Malta).

Figure 6: photograph showing the previous 'repairs' on the bridge: the rudimentary angle iron railing uprights; the series of transverse beams that supported the metal sheeting deck; and steel corbels beneath the original abutments.

Figure 7: The anchor detail at each end of the bridge.

2.1 *Objectives of the Intervention*

The aim of the intervention was to recover the original configuration of the Bridge so as to provide access for vehicles into the Fort. The tender document prepared for the actual restoration included a range of possible interventions. The envisaged methodologies involved:

1. Dismantling of the whole bridge structure and transporting to a specialised workshop;
2. Dismantling of, and detailed inspection, of all the different elements of the Bridge;
3. Cleaning of all elements;
4. The repair of the damaged elements;
5. The replacement of the severely deteriorated members;
6. The application of a new corrosion protection system and finish;
7. The replacement all bolts;
8. The removal of the recent corbel interventions, and the grouting of the resulting recesses in the rock face;
9. The recovery of the original abutment details;
10. The re-assembly of bridge structure on site;
11. The installation of new douglas fir planking decking and railing as per original drawing.

2.2 *The dismantling operation*

The dismantling operation commenced with the removal of the metal sheet decking and transverse beams all along the bridge. The concrete grouting at the ends of the bridge was also broken up. This exposed the original anchor abutments, one in each corner of the bridge. The identification of such details confirmed the preliminary analysis that the constructed bridge details tally perfectly with the 1898 drawing. Therefore, the information and details on the drawing were taken as the basis for the detail of the reinstatement of the missing elements of the Bridge. The main structure of the Bridge was dismantled in five (5) different sections and transported to the specialized workshop.

2.3 *The cleaning operation*

At the workshop, all the bridge sections were individually marked and dismantled. A close inspection of all the various steel sections enabled the assessment of the state of deterioration. Amongst the detachment and missing sections of the various paint layers, typical corrosion products normally associated with steel (iron) members were identified, these included:

1. Lepidocrocite (orange)
2. Geotite (red/brown/yellow)
3. Magnetite (black and lustrous)

In addition, pitting corrosion was also identified in several parts of the Bridge.

Trial cleaning, using a grit-blasting machine, on one of the transverse steel members, removed from the bridge (not part of the original members - to be discarded), was carried out. This methodology was discussed with representatives of the local Heritage Authorities, and the desired level of cleaning was eventually approved. Hence, the cleaning of various steel elements of the bridge was carried out.

Figure 8: View of the ditch after the bridge was dismantled and the last section loaded on the trucks to be taken to the workshop.

2.4 *The Repair*

After all the steel elements were cleaned, and inspected, it was concluded that that no elements needed to be replaced, with the exception of practically all of the bolts, and with the proviso that minor localised repairs were carried out. Furthermore, any World War II shrapnel damage, that did not compromise the structural performance of the bridge, was left as a testimony of the history of the Bridge, and the Fort.

It was however deemed necessary to reinforce the flange of the central beam, in the first section of the bridge. Subsequently, a 3mm plate was welded all along the upper flange. Other localised repairs were carried out in the flanges of the steel beams, involving welding of a plate in the missing sections. Such plates were chosen with a slightly smaller width than the existing flanges, to make the repaired sections identifiable on close inspection.

Figure 9: Details of the state of deterioration of the various steel elements. Various sections of the bridge were also damaged with shrapnel that punctured the web.

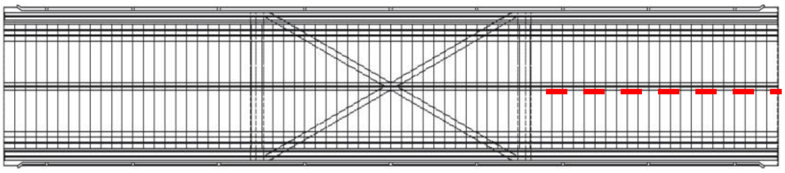


Figure 10: The red line indicates the extent of welded plate to the flange of the (first section) central beam.

It was however deemed necessary to reinforce the flange of the central beam, in the first section of the bridge. Subsequently, a 3mm plate was welded all along the upper flange. Other localised repairs were carried out in the flanges of the steel beams, involving welding of a plate in the missing sections. Such plates were chosen with a slightly smaller width than the existing flanges, to make the repaired sections identifiable on close inspection.

The major intervention carried out was concentrated at the abutments. The steel corbels were removed and the existing concrete, around the ends of the inclined struts, broken-up. Such an operation exposed the original plates to which the inclined struts were connected. These base plates were then manually cleaned on site.

Figure 11: The trial cleaning on one of the transverse beams, before (above) and after (below).

Figure 12: Detail of the localised repairs. Note the change in section with the original flange.

Figure 13: Detail showing the severely deteriorated ends of the inclined strut.

Figure 14: Detail of grouting of the resulting holes from the removal of the steel corbels. Grouting was left short of the rock face to allow application of hydraulic lime mix to achieve original abutment detail

Figure 15: Detail of the repair plates at the ends of one of the inclined struts.

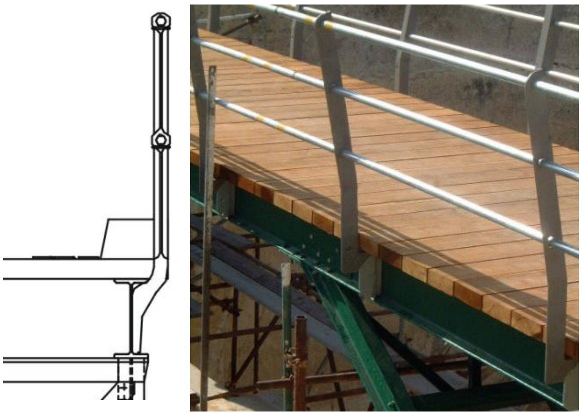


Figure 16: (i) Detail of Fir decking. (Note the temporary railing system installed for safety purposes) (ii) Detail of the edge of the bridge, i.e., the railing, oak kerb, and iron strips fixed over the decking.

2.5 *The re-assembly operation*

The individual steel elements were assembled in five (5) main sections in the workshop, and transported to the site. The anchors and abutments (repaired in-situ) were the fixed points on site, to realign the bridge during the reassembly procedure.

Figure 17: The various stages during the re-assembly operation on site

2.6 *The Finishes*

A polyurethane-based finish was chosen as opposed to an epoxy-based finish, because of the limited performance of epoxies in humid and exposed environments. This finish was also applied to the replica cast-iron railing standards that were eventually chosen to replace the existing railing system, details of which being taken from the 1898 drawing.

The finish colour, applied to all the steel elements of the Bridge, was chosen after comparison with various samples taken from various parts of the Bridge. This was the last coating of a paint system involving:

1. Primer – Temashield EMP700 – Epoxy Blast Primer
2. Intermediate – Temashield EMM801 – Epoxy Undercoat Finish
3. Top seal – Temathane PLV – Polyurethane

The Douglas Fir decking was installed directly over the beams as specified in the original drawing. The Oak kerbs, at either edge, were also procured, to be installed, when the new railings are positioned. Finally, galvanized steel strips were fixed along the tyre-tracks to protect the wood decking.

3 CONCLUSION

The restoration of the Bridge was the first of a series of interventions planned for the restoration of Fort Manoel; this intervention was fundamental in restoring the vehicular access to the Fort, and therefore, enabled the commencement of restoration works inside the Fort.

The Conservation of Globigerina Limestone: current research within the Department of the Built Heritage

JoAnn Cassar

Department of the Built Heritage, Faculty for the Built Environment, University of Malta

ABSTRACT: This paper is a review of the research on Globigerina Limestone being carried out by the Department of the Built Heritage of the University of Malta, research which commenced under the auspices of its predecessor, the Institute for Masonry and Construction Research. The main areas of research concern the characterization, durability, deterioration, conservation and treatment of the local building stone and other building materials, including traditional mortars. This work is being carried out primarily by postgraduate (Masters and PhD) students. Current research topics include the characterisation and durability of building stone, and the treatment of Globigerina Limestone with oxalates, nanolimes and salt inhibitors. The evaluation of the effects of linseed oil coatings is also being carried out.

1 INTRODUCTION

The Department of the Built Heritage was set up February 2009, following the incorporation of the Institute for Masonry and Construction Research as a Department within the Faculty for the Built Environment. One of the main spheres of activity of the Department is research on the characterization, durability, deterioration, conservation and treatment of the local building stone and other building materials, including traditional mortars. This research is being carried out primarily by postgraduate (Masters and PhD) students, also in collaboration with other University of Malta Departments and foreign institutions.

Current research topics include:

- Characterisation and durability of building stone
- Treatment of Globigerina Limestone with :
    - oxalates
    - nanolimes
    - salt inhibitors
    - linseed oil.

2 THE LOWER GLOBIGERINA LIMESTONE

The local building stone - Globigerina Limestone - can be described as a typical "soft limestone", being very easy to carve and shape. It forms part of the large family of Oligo-Miocene “soft limestones” which are widely found in the Mediterranean basin, including Turkey, Israel, Tunisia, Spain and Italy. Although there is more than one type of Globigerina Limestone, in general the

Lower Globigerina Limestone can be described as a pure limestone, containing small amounts of quartz, feldspars, apatite, glauconite and clay minerals. The porosity of this material is very high, reaching values of up to 40% (Cassar, 2004).

Freshly quarried Globigerina Limestone is fine-grained and homogeneous in texture. Sections where bioturbation is concentrated also occur, and in other areas concentrations of yellow or brown stains are to be found, but it is the unblemished stone that is traditionally chosen as building material. Here, quarry workers have long recognised that two facies occur, locally called “franka” and “soll”. “Franka” is generally reputed to weather well whereas the “soll” facies generally deteriorates at a much faster rate depending on exposure. However, in many cases it is impossible to distinguish the two facies on freshly exposed surfaces, or indeed in hand samples (Cassar, 2002).

3 CHARACTERISATION AND DURABILITY OF GLOBIGERINA LIMESTONE

This research area was initiated in the early 1990s when the Department of Chemistry of the University of Malta launched its first undergraduate research projects on the geochemical characterisation of Globigerina Limestone, under the supervision of Prof Alfred Vella. This theme was pursued throughout several undergraduate dissertation cycles, and was then developed into a PhD research topic by the current author. The aim here was to characterise, both geochemically and mineralogically, the Lower Globigerina Limestone member in the largest quarry area of the Maltese Islands (the Mqabba/Tal-Handaq area, which encompasses also the localities of Qrendi, Kirkop and Siggiewi). An additional aim was to identify “franka” and “soll” before deterioration sets in (Cassar 1999). These research projects resulted in two publications, one by Vella et al (1997) and another by Cassar and Vella (2003). Table 1 gives a summary of the studies on Globigerina Limestone carried out in the 1990s.

This research continues through the work of an MPhil candidate who is continuing the characterisation of different Globigerina stone types by studying their physical parameters to establish which of these parameters shall be of use to determine the durability of Lower Globigerina Limestone.

Table 1. Summary of types of analyses carried out in the 1990s (from Cassar 2002).

Sampling and analyses	Location	Researcher	Year of publication	No of samples	Analyses				
					Geochemical	Mineralogical	Petrographical	Physical	Soluble salts
Fresh samples									
Boreholes	Mqabba/Tal-Handaq	Cassar	Unpublished	90	x	x	x		
Quarries	Mqabba/Qrendi/Kirkop	Cassar	Unpublished	28	x				
	Naxxar/Siggiewi/Kirkop/ Qrendi/Mqabba	Farrugia	Unpublished	12				x	
	Mqabba/Siggiewi/Naxxar	Fitzner et al.	1995, 1996	14				x	
Weathered samples									
Quarries	Mqabba	Vella et al.	1997	23	x				
Prehistoric temples	Qrendi, Tarxien, Gozo	Vannucci et al.	1994	70		x		x	x
Historical building	Siggiewi	Fassina et al.	1996	47					x

4 PROPERTIES OF STONE AS RELATED TO WEATHERING PROCESSES

Work on the theme of stone characterisation and its relation to weathering processes continued into the new millennium. Research carried out with the University of Gottingen (Germany) focused on the fabric-dependent weathering processes of Globigerina Limestone. In this respect detailed analyses were carried out on Globigerina Limestone samples obtained from the two well known stone types which were characterized according to petrographical, geochemical and physical properties. These included porosity, pore radii distribution and tensile strength, as well as water and humidity transport properties. Investigations by means of salt crystallisation tests on quarry samples of both stone types reinforced the idea that the extent of salt weathering depends on salt type and concentration and pore-space properties. Visible weathering damage was recorded and evaluated for a representative monument (the Church of Santa Marija Ta' Cwerra in Siggiewi) by means of a monument mapping method, which was carried out twice over a period of 9 years (1995 and 2004). The identified weathering forms were also correlated with a previously developed weathering model for Globigerina Limestone. According to the results of the mapping, salt analyses carried out on samples from the church and salt-loading tests on quarry samples, there exists a significant correlation between visible damage and salt load. The zoning of weathering damage is obviously related to different salt concentrations. The zone with severe weathering damage is characterised by a high concentration of halite. Consequently it was concluded that salt weathering represents the main damage process for the Globigerina Limestone of Malta (Rothert et al, 2007).

5 TREATMENT OF GLOBIGERINA LIMESTONE

Also in this period a research project within the framework of a PhD programme coordinated by the University of Florence, organic and inorganic consolidation methods were evaluated in the laboratory on Globigerina quarry samples, and were then also tested on deteriorated stone of local sea-side fortifications (Lower Barrakka Garden bastions). The products studied and various related parameters are given in the Table 2. (Croveri et al, 2007).

6 FURTHER TREATMENT WITH OXALATES

The studies on the surface conversion of Globigerina Limestone to calcium oxalate commenced by Taniguchi (Taniguchi et al. 2003) and Croveri (Croveri, 2004) is being continued at present by a PhD candidate. Taniguchi had induced the formation of calcium oxalate as a surface protective treatment on quarry "franka" samples and deteriorated "soll" samples while Croveri had worked on the application of ammonium oxalate to quarry "soll" samples as well as on weathered stone in situ. In the practical field, the treatment had also been used on two Globigerina Limestone historical monuments. In these latter two cases, unlike the former, the extent of weathering that had been observed prior to their treatment was slight.

The current work is focused on the performance of an induced surface conversion of weathered Globigerina Limestone from calcium carbonate to calcium oxalate and the prospects of it being used for the conservation of this stone. This first part of the research had concerned the verification of the surface conversion, and the determination of its extent, using X-Ray Diffraction. The testing was carried out on laboratory treated samples and on exposed statuary treated in situ by others in 2003. The laboratory treated samples consisted of initially salt weathered quarry samples, fresh quarry samples and naturally weathered samples. Both desalinated and non desalinated samples were treated. In addition to these, quarry samples treated in 2003 by others were also tested. The results obtained confirmed the formation of calcium oxalate in all cases, and its extent, relative to the stone's surface texture and its salt content (Mifsud, 2006; Mifsud & Cassar 2006).

Table 2. Consolidants tested, quantities applied and mode of application (adapted from Croveri et al. 2007)

Symbol	Consolidant type	Theoretical quantity per m^2	Surface / cm^2	Quantity applied	Note
A	Ethyl silicate [SiEt]	500 g/m^2	3016	315.5 g	Solution consisting of 75% of active component in white spirit (dry residue 26%) Applied wet-on-wet by brush
B	Barium hydroxide [$Ba(OH)_2$]	-	2446	-	Saturated water based solution (10% w/w) of $Ba(OH)_2 \cdot 8H_2O$ applied by means of cellulose compresses Arbocel BC1000 with an interface of Japanese paper
C	Akeogard Z1074 [AkZ74]	50 g/m^2	1572	157.2 g	Solution of 5% w/w in ethyl acetate applied by brush
D	Ammonium oxalate [AmOx]	-	1724	-	Saturated solution in water (6% w/w) of $(COONH_4)_2 \cdot H_2O$ applied by means of cellulose compresses Arbocel BC1000 with an interface of Japanese paper
E	Akeogard PU [AkPU]	50 g/m^2	1534	153.4 g	Water based emulsion at 5% w/w applied by brush
F	Microdispersion [$Ca(OH)_2$]	350 ml/m^2	1420	49.7 ml	Dispersion 0.06 M in 2-propanol applied by brush
G	Acrisil 201/O.N.	1 l/m^2	1572	131.3 g	Applied by brush diluted in solvent 1:1 (Diluente AC 204)
H	Akeogard CO	50 g/m^2	1610	160.6 g	Solution at 3% w/w in ethyl acetate applied by brush wet-on-wet (theoretical quantity to apply 312.1 g)
I	Barium hydroxide $Ba(OH)_2$	-	-	-	Saturated solution in water (10% w/w) $Ba(OH)_2 \cdot 8H_2O$ applied by means of cellulose compresses Arbocel BC1000 with an interface of Japanese paper
L	Ethyl silicate	500 g/m^2	1600	110 g	Solution at 75% of active component in white spirit (dry residue 26%) Applied by brush wet-on-wet

Table 3. Laboratory sample types (from Mifsud & Cassar 2006)

Sample type	desalinated	non desalinated	treated	untreated
Quarry	X		X	
	X			X
		X	X	
		X		X
Naturally weathered	X		X	
	X			X
		X	X	
		X		X
Artificially weathered	X		X	
using sodium sulphate	X			X
Artificially weathered		X	X	
using sodium chloride		X		X

The current phase of this research is to relate ammonium oxalate treatment of Globigerina Limestone to site conditions in the given local site context. Laboratory testing includes quarry, artificially weathered and naturally weathered samples of various stone pathologies (powdering, flaking, friable, disintegrated surfaces) with "franka" and "soll" types, desalinated and non desalinated, being investigated.

7 TREATMENT WITH NANOLIMES

Here again preliminary research carried out in the 1990s is being continued and extended by studying the performance of nanolime/lime microdispersion consolidants on Globigerina Limestone. Consolidation processes utilising the application of slaked lime were used extensively in the past, however, in most cases the results were unsatisfactory due to limited amount of calcium hydroxide deposited into the stone. In 1996, research in Italy led to the first experiments in the application of nanolimes, namely micro- or nano- sized calcium hydroxide particles dispersed in alcohol. Nanolime consolidants are traditional lime based products applied by a fairly innovative technique of nanotechnology. The work at the Department of the Built Heritage concentrates on the performance of nanolime products on "franka" and "soll" types of Globigerina Limestone. These products are interesting in the local context because they are known to form a binder similar in composition to Globigerina Limestone (calcium carbonate). Furthermore one manufacturer of these nanolimes claims that this type of consolidant gives very good water vapour permeability, good hydrophilic properties and does not alter the colour of the stone. Thus the aim of this work is to evaluate the performance of these products by determining the ability of the product to penetrate the stone and improve its physical properties without the formation of a surface crust.

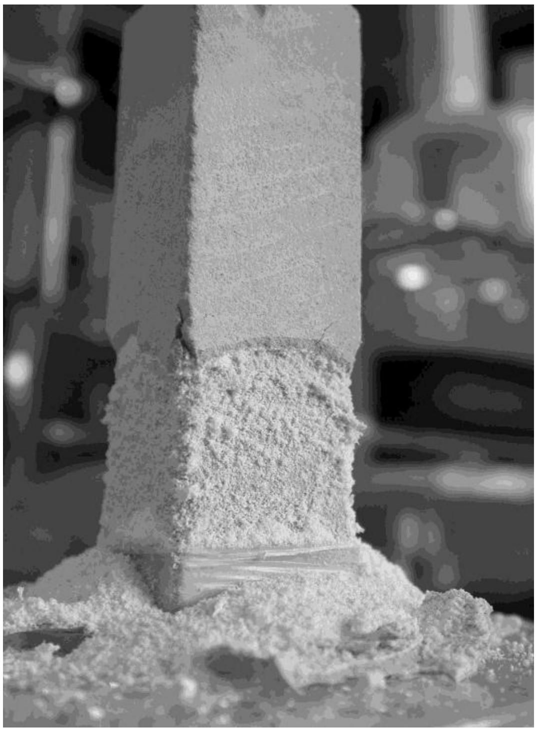
8 CONTROLING STONE DETERIORATION THROUGH THE USE OF SALT INHIBITORS

An undergraduate dissertation carried out in 2006 within the Faculty of Architecture experimented for the first time in Malta on salt inhibitors in order to control the deterioration of Globigerina Limestone. This followed an increasing international interest towards the use of environmental-friendly, non-invasive crystallization inhibitors as a new means of controlling crystallization damage within porous stones. The initial research project centered on the application of these new non-destructive methods to prevent and/or to control crystal growth in porous stones.

In particular, attention was being focused on the crystallization inhibition properties of functionalised organic compounds. These products are soluble in water or alcohol and are non toxic. Their use thus ensures safety during conservation works. These compounds have been tested on the main types of Globigerina Limestone, "franka" ("bajda" and "safra") and "soll", using fresh quarry samples; the treated and untreated samples were also tested with regards to sodium sulphate crystal growth (Muscat 2006).

Two types of fresh "franka" as well as fresh "soll" stone blocks, were obtained, based on the visual identification by quarry owners. Their designation was confirmed by geochemistry. Physical and mechanical properties of the three were investigated, including uniaxial compressive strength, water absorption by capillarity, permeability and porosimetry. Both treated and untreated stones were then subject to salt crystallization tests, using sodium sulphate in different concentrations. Encouraging results were obtained in that the presence of even very low concentrations of the inhibitor was found to help crystallization occur on the stone surface and not within the pores (Figure 1). These encouraging results led to the conclusion that salt inhibitors can be used to treat salt-infested stone (Cassar et al. 2008). Further research in this respect is continuing within a PhD research programme, aiming to verify the efficacy of the application of salt inhibitors in different concentrations with different methods of application and under different environmental conditions. This testing regime will eventually be extended to in situ testing, investigating the behaviour of materials making up salt-loaded walls, particularly Globigerina Limestone, as well the short and long term effects of the application of salt control measures (the 'inhibitors'). The study on the effectiveness, or otherwise, of the applied treatment is being carried out in view of the potential use as a conservation treatment that significantly slows down the process of deterioration induced by the presence of salts.

a



b

Figure 1. Weathered *(a)* non-treated and *(b)* treated "soll" sample (from Cassar et al. 2008)

9 EVALUATION OF LINSEED OIL TREATMENTS ON GLOBIGERINA LIMESTONE

In 2006 an undergraduate dissertation on 'A Study of the Use of Linseed Oil on Building Materials with particular reference to Globigerina Limestone' was submitted to the Faculty of Architecture and Civil Engineering. This first dissertation consisted of background investigation on the tradition of applying linseed oil to stone, including public as well as domestic buildings, purportedly as a protective coating. This is in the light of the fact that for the last decades it has been widely claimed that linseed oil is not beneficial to stone. However, locally, to date, only limited studies have been carried out to show the effect such applications are having on the Globigerina Limestone. This study, which is now being continued in the framework of a Masters programme, aims to study the effect of its application to Globigerina Limestone and what happens to an aged sample, with the ultimate intention of understanding whether linseed oil is affecting negatively our Globigerina heritage.

10 CONCLUSION

The main aim of this paper has been to give an overview of work being carried out on Globigerina Limestone by the Department of the Built Heritage. It includes a summary of research on the characterisation of this building stone of great local importance, on its durability and weathering, and possibilities of its treatment in order to increase its resistance to deterioration. This research is of great importance not only to the built heritage of our Islands, including the historical and archaeological patrimony, but also has repercussions on the quarrying and building sectors, as well as the tourism sector, with ramifications for the local economy. It is a great pity that such important research proceeds at a slow pace, due in great part to the lack of funds and shortage of laboratory facilities. This area has not yet been recognized by the authorities as one worthy of being given adequate research funds, greatly limiting the work that can be carried out in this sphere of great national importance. Should adequate funding be made available, the scope of this research can be extended also into other areas of interest in the field of the conservation of our built heritage.

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The innovation of planning and management of architectural heritage: the morphometric survey and 3D databases

Marcello Balzani
DIAPReM Centre, TekneHub, University of Ferrara, Italy

1 INTRODUCTION

An "identity card" of cultural heritage buildings, defined on digital supports, guarantees the process of their restoration, monitoring, enhancement and protection. It is rather simple to create one for a work of art or a sculpture but, until now, it seemed impossible to imagine such card for a large monument, building or an entire urban block. The cases studies synthetically offered in support of this paper were developed by the DIAPReM Centre (part of the TekneHub of the University of Ferrara that constitutes the High Technology Network of Emilia-Romagna). These case studies, all related to restoration activities completed or in progress, define a framework of operational procedures that are centred on the critical use and objective morphometric data more than on the actual technology of the tools. The geometric memory captures cognitive support value that is essential to organize the 3D database, which contains also other types of survey data (infrared, spectrophotometric, structural). This allows an investigation approach that uses the compatibility and the effectiveness of morphological navigation. The 3D database presents itself as a whole entity, where one can, for example, decide to:

- to amputate parts (to better display others);
- filter data (taking, time to time, the density and stratification consistent with the purpose of the survey);
- place the observer in a free condition with respect to the logical elevation of acquisition itself.

In the traditional graphic representation (orthogonal and 2D) of the surveyed data the significant aspects are: the descriptive position constraint to which adhere the quota, the transcription of the measures and the proportional role that these elements can assume.

However, to operate within a context of hundreds of millions of organized three-dimensional coordinates allows, for example, to read-through volumetric correspondences of each architecture with all the various related integrations (underground areas, attics, etc.). The logic (of the organization, acquisition, registration and management of 3D surveyed data) has interrogation constraints. The criteria, accuracies and the representative processes (from the orthogonal projection to the solid prototyping) must be decided.

2 TECHNOLOGICAL EQUIPMENT AND CRITICAL-CONCEPTUAL INSTRUMENTATION

The major surveying technological tools (3D laser scanner mostly integrated on total stations and digital cameras) are continually updated with regards to speed of acquisition, accuracy of the data in relation to the relevant operating range, portability and lightness of use, interface flexibility.

The degree of innovation that the industry offers to the professional market is not always supported by a level of information and technical knowledge capable of absorbing the real potential of use. For such reason, the DIAPReM-TekneHub has, for over fifteen years, tried to develop optimized procedures and applications that make technology transfers from the productive sector to the construction network (professional engineers, service companies, ministries, local authorities, construction and restoration companies) more accessible and cost-effective. It is not the complexity of instruments that creates problems.

These, year after year, are rounded off by manufacturers sensitive and attentive to the feedback responses. The problems are found, instead, in the logic of creation, management and use of a real 3D data. The descriptive process is, in fact, strongly linked to the traditional two-dimensional drawing, even when it tries to imitate the results represented in the spatial complexity. This procedure is historically connected to the simplicity of such model: the discreet and simple elements of a two-dimensional representation offer a series of limited configurations, that are easy to understand and use. These "drawings" have always imposed a strongly finalized process. However, some of the problems that arise must be pointed out:

- the majority of technicians working on the digital drawing (even if in 2D) forget it is still a spatial operation. Those who do not critically and carefully understand that every sign of change, integration and correction of a project will imply a verification in all the other parts of the project (prospects, sections, plans) will see the limits of the procedure in the work site (in front of the real three-dimensional space);
- until today, the degrees of variation, the operational delta, are offset by criteria of gradual approximation (scarcely referred to the actual surveyed data) that can also be contained in the economic estimate evaluation (from the preliminary to the final one, until the executive project). In other words, the compensation is possible within a value (of the surface, space, and therefore also of the materials, production and processing), which manages a popular error form. The economic damage is significant. It creeps through a configuration discrepancy or a morphological inaccuracy, which, for the more complex realities (often associated with restoration or recovery) can be up to 20-30% (especially in cases of elevation and vertical connection systems);
- the attention given to the existing (whether antique subjected to restoration, even of lesser value, or more recent, to operate upon with reuse, regeneration, refunctionalization, and recoveries) necessarily produces the need to control the object of transformation with greater security; such reasoning is not trivial since during the last thirty years the expansion model of the city suburbs has contemplated project logics that little relied on construction reality; the habit to design in relation (of knowledge and critical consciousness) with the context is not so widespread as one would imagine even if the technical instrumentation and conception are very different. The project that is born on a virgin area of an allotment possesses in its genetic code relationships of form and proportion that relate to independent architectural thinking and often self-referential. The project created within others already existing or next to others, is a project that has to adapt to sensitivity of shape, size, materials that have layered over years and have already undergone comparison with the construction process and time. The tolerances (not only geometric, but also conceptual) to be taken into account are completely different.

It is therefore understandable how an attitude of simplification (from the survey to the representation form) often *does not pay*. To reduce the levels of preventive knowledge on the building produces a series of consecutive damages that are no longer sustainable for a sector such as that of constructions, which will have to change many processes in the coming years (planning, realization, management) to create a better cost/price analysis and a real qualitative competition. Even the environment with its landscape and its architecture constitute (by analogy) a complex living organism. It is a *body* with its own experience and expectation of living a dignified life. *It* requires, before the draftsman takes any action, to be examined (understood, recorded, displayed by images) and to not be forgotten. The innovation that over the past fifty years has generated in the field of life sciences a wide spread development in advance countries originated precisely due to this conceptual attitude. It can be evaluated from different sides and with many indicators.

Understanding (see and measure) before *action* is a great success. Entering the merits of architectural space is not a simple problem. It is not, as we have already said, an instrumental issue, but a conceptual and procedural matter which requires the willingness to:

- make many preventive questions (because the existing, contrary to the new, generates constant curiosity and questions when one comes into contact with it);
- look for critical reasons to generate concrete answer scenarios (metrically and geometrically valid in order to support economic evaluations);
- offer a framework of accessible morphological knowledge, searchable, navigable, flexible and upgradeable over time, cost-effective.

The idea born within DIAPReM-TekneHub was originally very simple and tried to offer an answer to this issue: if a new technology enters the market it should, first of all, *be able to do* (possibly better) what is already being done, hence work in a 2D digital scene. The *improvement* can be identified in the *time factor* (be faster) and *accuracy factor* (generate measures that are more secure in the representation and querying phase of data). If this happens, it is then possible to lead the technical operators towards a second step: make them understand how operating preventively inside an *architectural structure*, according to rules of measurement and geometry (in a 3D morphometric environment in 1:1 scale) can lead to cost effective solutions (that can be shown in analysis and visualizations) for those who work in such sector and for society itself. It is therefore understandable that to act within this issue it is not only necessary to focus on the optimization of the complex phases of survey, but is crucial to:

- understand all the phases of the process from the survey to the planning;
- listen to and embrace all doubts of the draftsmen and institutional commissions;
- spend a lot of time and effort on the process analysis.

The introduction of instruments (with their potential only apparently intelligent) has generated the idea that the processes of awareness and understanding are not needed, or at the best, are less required. It is exactly the opposite. These technologies (from automatic design to laser scanner survey), objectively powerful for speed, accuracy, display capacity, trigger the need to further develop a new critical-conceptual instrument. An effort of awareness that restoration already possesses in its DNA and is ready to integrate.

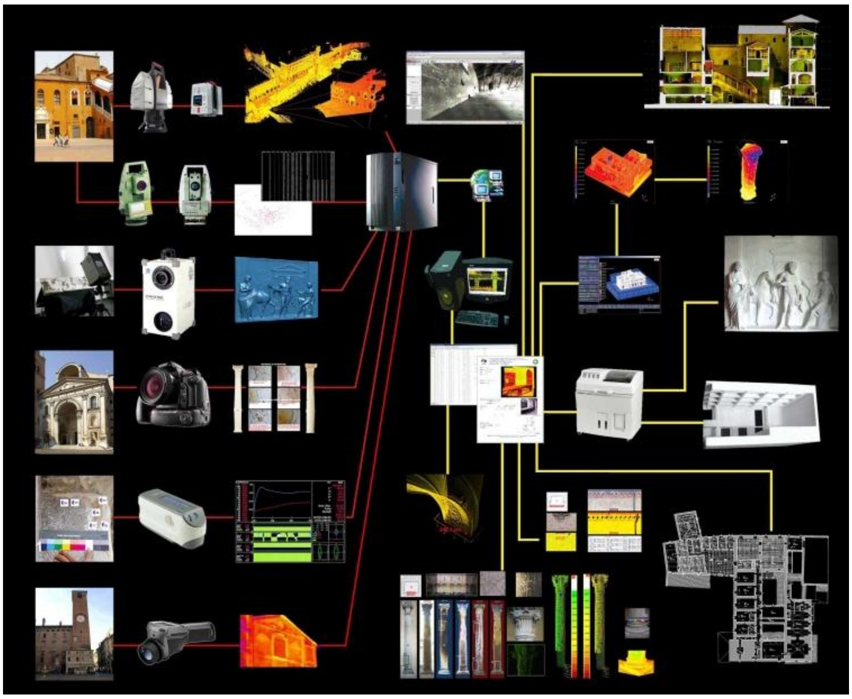


Figure 1. Schematic methodology for integrated survey

3 KNOWLEDGE TECHNOLOGY AND DEVELOPMENT STRATEGIES

The economic crisis requires to operate with an attention that is different from that of the past.

The theme of development and economic sustainability of restoration and following management of the cultural heritage (be it in the field or in a museum) is at the heart of the debate. Many projects, that are being developed, often regard the reunion of these two fundamental objectives. The experimentation thus is not exclusively connected to the restoration process, but also to fit out technologies, museum graphics, the territorial marketing strategy, and the management model. Technologies that need to be planned in synergy together from the first moment. An example: the 3D surveying technology, carried out for the diagnosis and planning of a restoration project, can generate a marketing and communications product for the exhibition, while the opposite is not possible. It always happens that technologies are invented, produced and developed first. Before it is actually realized what they can do, not from the factual and finalized point of view but from view of method. The critical approach is, instead, part of a real acquisition of knowledge that discriminates, selects, verifies and produces differences. The world of the restoration is the place where these conflicts have been mostly expressed and therefore more solutions can be found. A project on historic heritage requires a conscious flexibility and an ethical vision expressed by reversibility. I insert this conceptualization because, even in planning, the reversibility comes into effect in respect of the possibility of backdating. The time transfer, the recovery of a situation ex ante acts (in the one-way sharing of the time) as a historicalmarker. It defines a framework of respect, a network of morphological, material, colour, type, structural, etc. elements, which can be captured as constraints, to set the race back in history in a hypothetical "time machine". The motivations are ethically shared. The realization has to be performed in the most sustainable manner for the capital (environmental, architectural, cultural) on which action is taken. Expressing the value of the assets, the value of uniqueness is also identified. Any intervention should be reversible, in the sense of minimal impact on contamination, destruction, interpretation, and dispersion, to allow those who will follow to enjoy the same heritage treasure. Or better to be able (in the future) to intervene reversibly with planning and conservative technologies even less invasive and more protective. Basically it’s a progressive planning principle. A principle that is not limited in time with a predetermined mode, but that creates foundations for knowledge that acts gradually, through experiments verified over time, which verifies itself and is self-correcting. In short that seeks to improve gradually. Restoration is the real frontier of the future.

3.1 *Note*

To deepen the contents of these case studies and access the specific bibliography and the methodologies of research and practical application of such: www.diaprem.unife.it and www.TekneHub.it.

Also check: M. Balzani, *Il rilievomorfometrico e ilrestauroarchitettonico (The morphometric survey and the architectural restoration) The 3D database for planning innovation and architectural heritage management*, in M. Balzani (edited by), *Restoration, Recovery, Rehabilitation. The contemporary planning in historical contest*, Milan, SKIRA, 2011, pp. 86-95.

CASE STUDY 1

THE 3D SURVEY FOR CONTRACT MANAGEMENT. MORPHOMETRIC DATABASE FOR THE RESTORATION OF THE MAYOR’S PALACE IN MANTUA

The town of Mantua, after the experiment carried out during the during the 6th centenary of the birth of Alberti that saw the application of new technologies for the documentation of the architecture of the Renaissance master, has decided to implement a three-dimensional advanced survey aimed to the restoration of the Mayor’s Palace of Mantua. This study, which involved the centre of DIAPReM of the Department of Architecture of the University of Ferrara and the Ferrara Research Consortium, aims to integrate procedures and develop a morphometric database for the innovation in the methods of the restoration planning and of the subsequent executive and operational phases.

The building is an impressive artefact in the heart of Mantua, developed on different levels, covering a total area of 9,000 square meters, formed by about 300 compartments and an average height of about 24 meters. Given the size and complexity of the building, A 3D laser scanner survey, with a horizontal and vertical alignment, integrated with the topographic survey performed with the total station was carried out. The fieldwork took about sixty days, in which a total of 1,450 hours of scanning were performed, generating approximately 7,000,000,000 spatial coordinates, capable of defining the building for an average mesh of 2 cm, related to each other by a network of 690 three-dimensional targets points. From this information 23 CAD plans, sections and prospects, with detail definition in scale of 1:50 were generated. In addition, native and derivative data were entered into a repository for data access through Web-based systems and Web GIS.

Credits: Mantua Town, Public Works Sector: S. Mantovani, P. Menabò. Ferrara Research Consortium and DIAPReM Centre, Department of Architecture, University of Ferrara: scientific responsible: Marcello Balzani; technical responsible: Guido Galvani; three dimensional survey and restoration: F. Casarini, L. Cosimi, G. Galvani, S. Guidi, M. Guzzinati.

Figure2. View of the Mayor's Palace (Palazzo del Podestà) from Piazza delleErbe
Phases of indoor metric acquisition with Leica Laser 3D HDS 3000

Figure 3. Section in CAD format. It highlights the process of geometric control achieved on many points (blue squares) acquired during the extraction of 3D profiles from the database, in order to understand the deformation of the attics.

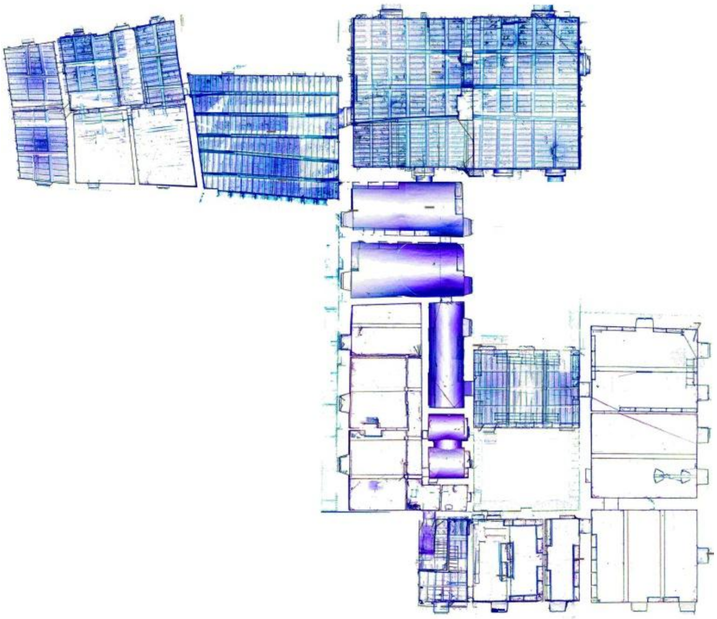


Figure 4. Extraction example of the 17 m plan from the reference project: the descriptive elements are visible on the ceilings and on the plugging systems

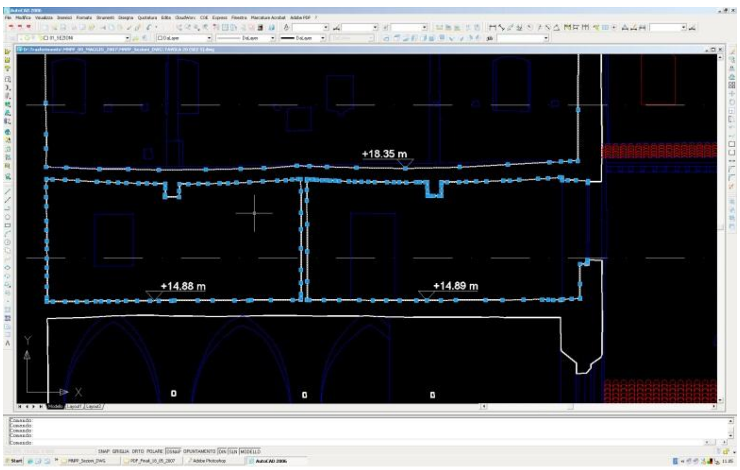


Figure 5. CAD extraction and restoration of a section that shows the volumetric articulation of the building

CASE STUDY 2

A 3D DATABASE FOR THE RECOVERY AND ENHANCEMENT OF THE CAVE OF ST. MICHAEL THE ARCHANGEL IN OLEVANO ON THE TUSCIANO, SALERNO

Unique in its kind in Italy thanks to the presence in the cave and in its branches of a single nave basilica with frescoes of the Byzantine era, two small aediculae with a courtyard, a church and an oratory, in the heart of the rugged mountains, on the hillside of Mount Raione, where the monumental complex of the Cave of the Angel is located. The integrated technology of 3D laser scanning has allowed a successful first survey that has finally pointed out the quality of the site through a thorough documentation action regarding in particular the morphometric of the natural environment, with the aim to recover, enhance and preserve, done by the Superintendence for Architectural Heritage and Landscape, and for environmental and architectonic value.

The three-dimensional scan, performed with a Leica HDS 3000 laser scanner, was integrated with the topographic survey executed with the total station Leica TCRM1101 plus, with an angular accuracy of 2", as a means of compensation on residual errors in the materialization of the targets. The reported three-dimensional model is the product of twenty-four stations for a total of about 55,000,000 acquired points.

Credits: Superintendence for Architectural Heritage and Landscape, Historical, Artistic and Demo-ethno-anthropological Heritage for the cities of Salerno and Avellino: Giuseppe Zampino (Head), GennaroMiccio, Rosalba De Feo. Ferrara Research Consortium and DIAPReM Centre, Department of Architecture, University of Ferrara: scientific responsible: Marcello Balzani; technical responsible: Guido Galvani; three dimensional survey and restoration: G. Galvani, M. Guzzinati, F. Viroli; photographic survey: R. Meschini

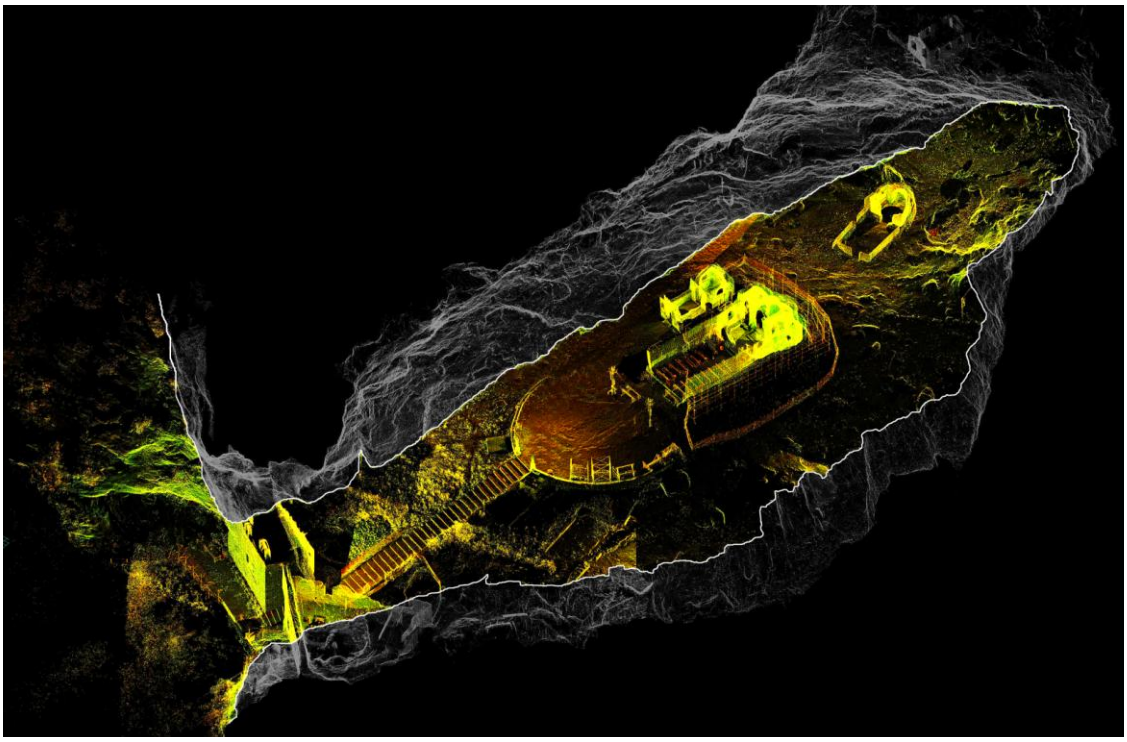


Figure 6. Three-dimensional database of the cave. Visualization of the survey data with an "isometric cross-section" effect, which shows the data of the rock morphology that surrounds the large room (grey scale) vs. the false colour data that shows the internal organization of the access stairway and of the architecture paths of the first main arm

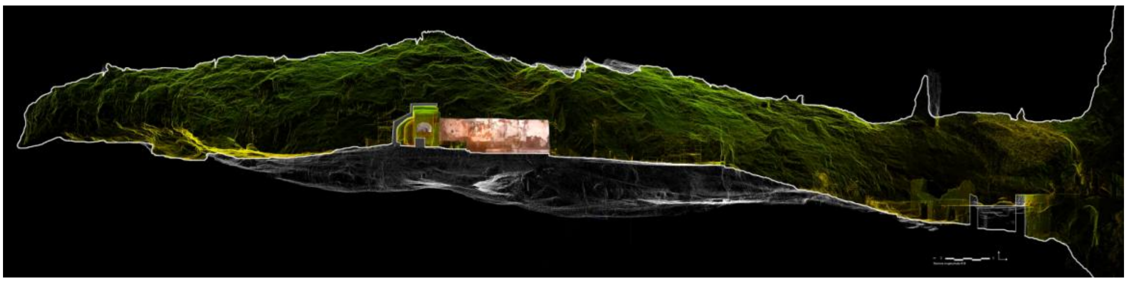


Figure 7. Three-dimensional database of the cave. Visualization of the survey data with an "isometric cross-section" effect, which shows the data of the rock morphology that surrounds the large room (grey scale) vs. the false colour data that shows the internal organization of the access stairway and of the architecture paths of the first main arm

CASE STUDY 3

INTEGRATED THREE-DIMENSIONAL SURVEY FOR THE RESTORATION OF ARESE-LITTA PALACE IN MILAN

Arese-Litta Palace, whose name comes from one of the oldest noble families in Milan, is located in the heart of the city, inside the first wall, not far from the Sforzesco Castle. The building, constructed between 1642 and 1648, spreads over more or less 14,490 square meters, bordering on three sides with private properties while the front imposes itself as an important urban element on Magenta Main Street. The knowledge of such a structure, closer to an urban block than to a single building due to complex of size, geometry and intended use, required to configure a database to enable a 3D study and restoration project management by the Regional Directorate for Cultural Heritage and Landscape of Lombardy, which uses it as its prestigious headquarters. The survey is an example of optimization of 2D and 3D acquisition phases and integrated models of restitution: 45,000 square meters developed in 800 rooms have been described with 1,500,000,000 spatial coordinates, detained in 27 polygonal, working from the underground areas, to the various stairs group, up to the loft.

Credits: Regional Directorate for Cultural Heritage and Landscape of Lombardy - Director: Mario Turetta; Carla Di Francesco, N. Maremoti. Ferrara Research Consortium and DIAPReM Centre, Department of Architecture, University of Ferrara - scientific responsible: Marcello Balzani; technical responsible: G. Galvani; coordination: D. Blersch, L. Cosimi; Three-dimensional survey and restitution: D. Blersch, F. Casarini, L. Cosimi, M. CassaniSimonetti, S. De Mauro, G. Galvani, M. Guzzinati, P. Palka, R. Potenza, A. Righi, F. Vecchi

Figure 8. The face on Magenta Main Street

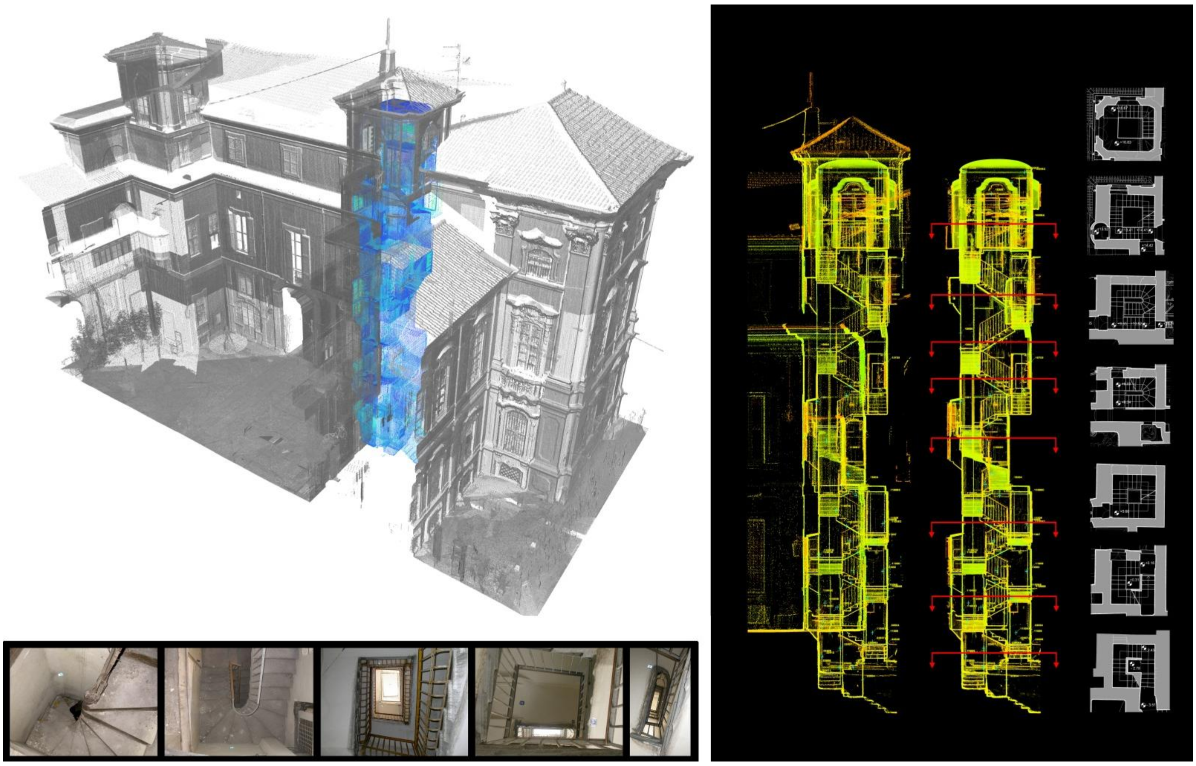


Figure 9. Example of interrogation and data extraction on a group of stairs in vertical connection

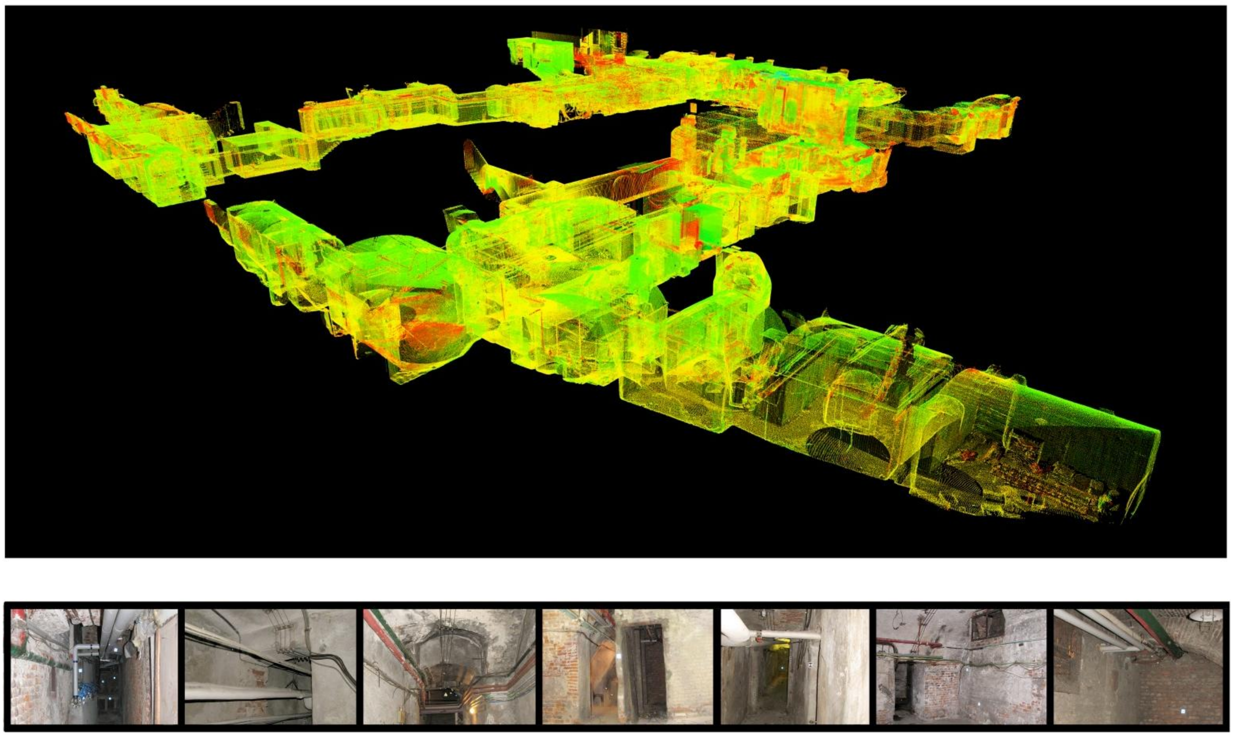


Figure 10. The complexity of the underground area of the sub-basements

The documentation of the built heritage using 3-D laser scanning techniques

Hermann Bonnici
Restoration Directorate, Ministry for Resources and Rural Affairs, Malta
International Institute for Baroque Studies, University of Malta

1 INTRODUCTION

Malta's wealth does not lie in its natural resources, but in its unique and rich built-up cultural heritage, its archaeological and architectural assets, in particular its ancient temples and the baroque churches, palaces, and fortifications, all of which bear witness to a singular historical experience that was chiselled out in stone.

Preserving this vast mass of buildings, sites and remains, and ensuring that they will all be here in years to come is a daunting and expensive task by any standards. The challenge for this, and future generations, therefore, is to make this process of conservation and restoration possible and to extend it to cover as wide a spectrum of buildings as possible. If technology can be roped in to make this onerous task somewhat easier and more exact, then the conservationist is duty bound to learn those techniques that will enable him to achieve a more professional result.

It is science that makes conservation a discipline and no longer simply a craft, and it is science that gives the conservator ever-increasingly effective and sophisticated tools with which to intervene on the architectural fabric efficiently.

During the past years, significant advances have been made in Malta in the field of conservation. Local conservation efforts have become more scientific and specialized in nature and the importance of documentation in the restoration process has become critical to the success of all restoration interventions. Bodies such as the Restoration Directorate within the Project Design and Implementation Department of the Ministry for Resources and Rural Affairs have invested heavily in training of qualified personnel, acquired dedicated software and have created a specialized photogrammetric team.

Great reliance has been made on the use of photogrammetry, but this methodology presents limitations in recording amorphic structures such as complex ancient temple sites. Even so, successful attempts were made in the past using photogrammetry in the absence of high precision techniques, such as laser scanning.

An important milestone in this process of learning and adaptation to new technology has been the Restoration Unit's participation in various EU cultural programmes and its ability to absorb EU funds to undertake large-scale restoration interventions. Foremost among those have been the programmes undertaken in connection with other institutions principally Heritage Malta to document Malta's important archaeological sites, namely the Ggantija, Mnajdra, and Ħagar Qim temple complexes, and the vast network of cartruts and quarry complexes at Clapham Junction in Rabat. More recently the Restoration Directorate undertook the documentation of Fort St. Elmo and more than six-kilometres of fortifications in Mdina, Birgu, Valletta and the Citadel Gozo in preparation of restoration interventions financed through the European Regional Development Fund (ERDF 0039) under Operation Programme I. The fortifications have, in their large part been documented using in-house two-dimensional photogrammetry techniques whereas the more complex fortification system of fort St. Elmo and the Citadel in Gozo were documented using laser scanning technology.

Figure 1. Photogrammetric survey by the Photogrammetry Section of the Restoration Unit showing bed of an ancient classical period quarry at Misrah Ghar il-Kbir in Malta (Culture 2000 project CLT2004/A1/MT-49)

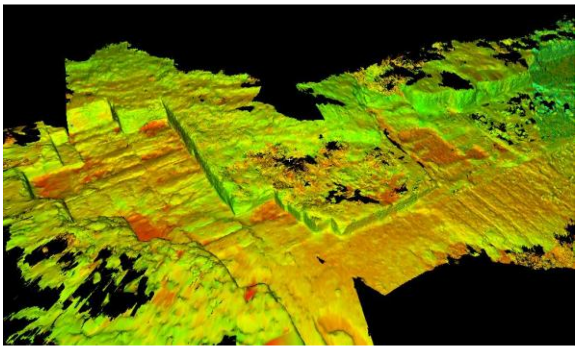


Figure 2. Laser scans by the University of Urbino in collaboration with the Photogrammetry Section of the Restoration Unit showing quarry complex at Misrah Ghar il-Kbir in Malta (Culture 2000 project CLT2004/A1/MT-49)

2 3-D DOCUMENTATION OF PREHISTORIC TEMPLE STRUCTURES

The analysis of historic temple forms has nothing to do with the classic concepts of a plan with horizontal and vertical layouts, for their original geometry is based on curved lines, on the juxtaposition of concave and convex surfaces with complex hollow volumes. The most appropriate instruments for such work are those that allow accurate recording of all the constituting elements with their complexity of shape and dimension. Therefore, scanning is a suitable instrument for interpreting, and at the same time it provides the proprietary result for subsequent inspections and research on the structural character of the building as a whole and of the single parts of it , while providing qualitative information on the materials and the alterations the same have been subjected to.

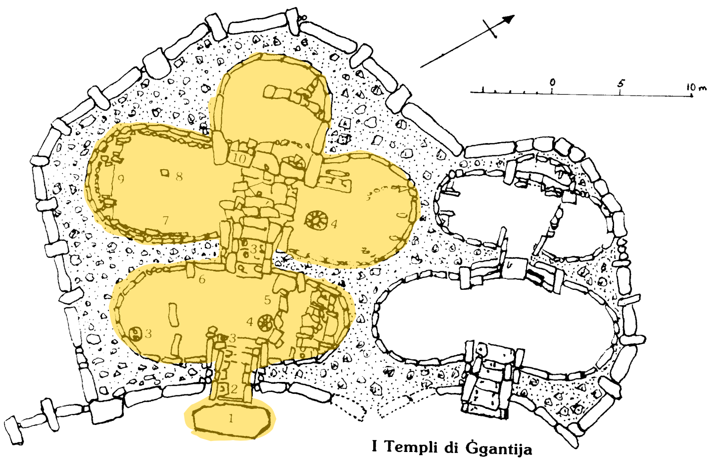
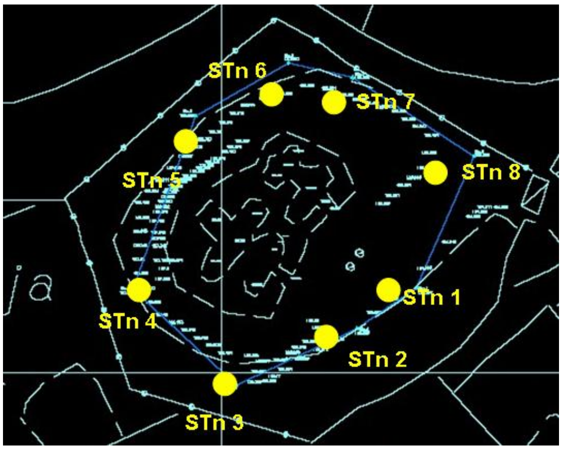


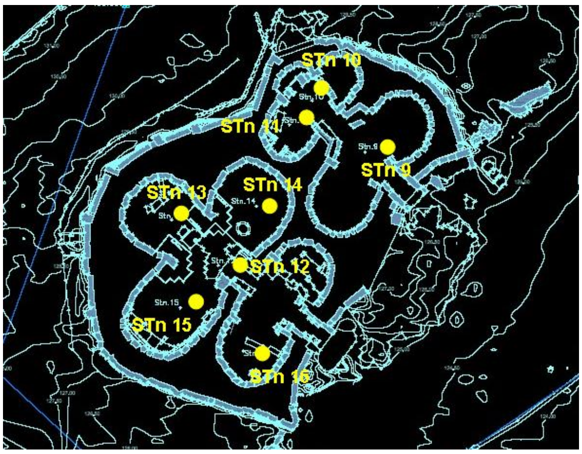
Figure 3. Plan of Ggantija Neolithic temples

The first of these projects to be carried out in 2005 involved the documentation of the Ggantija Neolithic temples in Gozo. This is actually a complex of two temples constructed facing the south-east, with the temple on the left dating to as early as 3600BC being the older. Of interest in this temple complex is the sensitive use of local stone. Hard durable coralline limestone was used for both the facades and large megaliths in the internal rooms. Globigerina limestone, softer, but easily worked, was used for door jambs, internal passageways, and flooring. Due to its greater workability, it is also used for carving decorative elements. The older temple incorporates five large apses, with the inner apses measuring 23.50m from end to end. The floor of the central apse stands at a higher level. The second temple is of later origin, and has a 4-apse form, with its central apse reduced to a mere niche. Its overall length internally, from the outer end of the passage to the back of the niche is only 19.50m as against the 27m of the other temple. The documentation exercise here focused on combined use of various disciplines, mainly topographic surveys, photogrammetry and laser scanning techniques. The technology to carry out such high precision documentation was not available locally and therefore Heritage Malta took the decision to give the work out to tender. The Restoration Unit was responsible for setting down the standards, monitoring the works and ensuring that high levels of quality were attained. The brief for the documentation of this temple necessitated the finished work:

- To record in great detail and a minimum accuracy of +/- 5 mm the structure and the megaliths of the temples/ archaeological sites.
- To permit accurate (minimum accuracy +/- 5mm) and easy measurement of points etc. on the structure in the form of Cartesian co-ordinates, distances, etc. between the different points.
- To be compatible with existing cartographic system used at present in the Republic of Malta.
- To enable a continuous digital updating of the 3-Dimensional computer generated model to include for any modifications to the structure, the inclusion from any archaeological excavations, etc.
- To enable accurate and high quality scaled printouts of 3-Dimensional views, orthographic plans (plans, sections, elevations etc.).
- To enable the 3-Dimensional virtual model to be presented in a digital format which could be used for virtual walk through presentations.
- To enable the 3-Dimensional virtual model to be presented in a virtual model which could be used as a base map for a database which will be set up by the Employer.

The first process in the documentation process entailed the setting up of a topographical traverse. This had two specific aims; the generation of a reference topographic polygonal, and the creation of references for future scans. The traverse consisted of a closed polygon, with eight stations at its vertices. Some topographical stations were joined, according to the geometry of the main polygonal, and located within the two temples.





Figures 4 and 5. Location of stations

The location of these vertices was established such as to ensure adequate enclosure of the monument to be documented, and to guarantee adequate vista by the surveying instruments of the fiducials (markers) set as a reference for the correlation of the point of clouds. Polar distances were measured with an electronic total station, (Leica TPS 700). Comprehensively, sixteen stations, twenty-four scan markers, and several detail points were measured, enabling the plotting of a preliminary planimetric survey of the temple complex.

The survey was carried out with a time of flight laser, Leica HDS 2500. This laser scanner has a maximum range of 100 m with the optimum performance in the 1 and 50 m range, a field of view of 40 degrees in both horizontal and vertical directions. This instrument has a high single point accuracy, of 6 mm within the optimum working range. The scan speed is one column per second for a 1000 points-column, and two columns per seconds for a 200 points-column. The minimum distance between points is 0.25 mm, both horizontally and vertically, while the maximum line and column sizes are 2000 and 1000 points, respectively.

Figure 6. Laser scanning in progress

Figure 7. Cloud of points

In all, one hundred and twenty-eight scans were made producing a cloud of some 67 million points. Additional aerial scans covered the uppermost sections of the structures. The scans were run with a variable step of between 0.8 and 1 cm. Numerous targets were positioned on the external surfaces of the structure facilitating the automatic correlation of the scans. Scans taken within the interior of the temples were joined by acknowledging corresponding points, possible by positioning a sufficient number of targets for the dimensional control. A similar methodology was used for the documentation of the Mnajdra and Ħagar Qim temple complexes.

Data acquisition is only one of a series of processes involved in this rather challenging documentation process. A second, rather complicated, stage is the so-called post processing of data, where most of the uncertainties and problems connected with surveying techniques do accumulate. This operation sums up all those computer-aided processes, both automated and manual that lead from the cloud of points as the raw output of the instrument to the final desired graphical result.

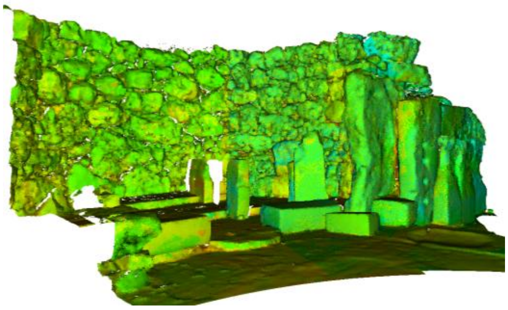


Figure 8. Mesh generation

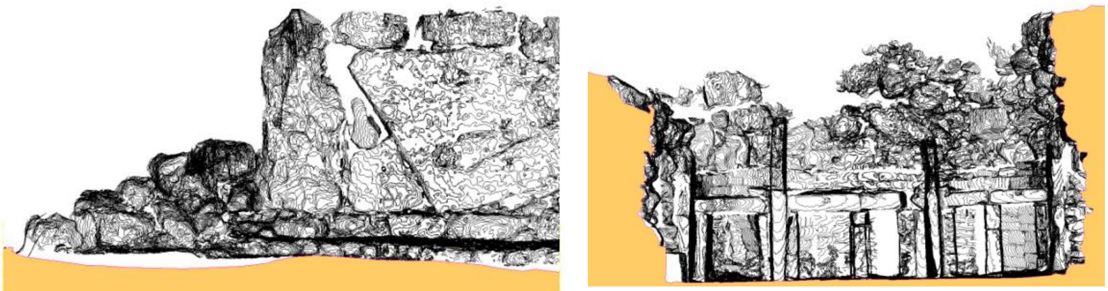
Figure 9. Mapped models

The cloud of points was merged using Cyclone software. Uniform or intelligent discrimination operations were performed in the post processing stage to clean unwanted information, noise, such as trees, cars, people etc in the background collected by the scanner. No reduction of data was made at this stage, regardless of the fact that the survey file generated was rather large.

The fact that individual scans were oriented by the topographical survey enabled the geo-referencing of the final model through the successive adding of scans. The second method entailed the placing of flat or spherical targets on the structure identifiable by the laser scanner. During the post processing phase the software computes the centre of mass of these targets as a weighted average of the cloud of points, thus minimizing the error. This method enables the automatic merging of all scans.

The large number of scans generated and the morphological complexities of the sites make the registration and merging together of the scans one of the most complicated processes in the whole surveying process. Further post processing operations include the mapping of the model with digital photographs.

The mesh models for Ġgantija, Ħagar Qim and Mnajdra models were generated with Cyclone 5 software, and then exported in Drawing eXchange Format (.dxf) files. The mesh models generated were then mapped with Rapidform 2004 software.



Figures 10 and 11. Contour models

3 3-D DOCUMENTATION OF THE CITADEL IN GOZO

Albeit on a much larger scale the documentation methodology employed for the Citadel in Gozo was similar to that used for the Ġgantija, Mnajdra and Ħagar Qim prehistoric temple sites some four years earlier. The Gozo citadel is built on a rock outcrop with its enceintes rising from the margin of a circular upper limestone formation which gives way downwards to a friable greensand formation and underlying unstable blue clay slopes. The inclination of the strata is such as to result in a steep descent (cliff) towards the North-Northwest and a gentle descent in the opposite direction. Differential weathering of the upper rock formation has produced frequent ledges and overhangs on the cliff face. Furthermore, weathering and movement of the underlying blue clay layer has formed vertical joints and fissures in the upper coralline limestone formation.

Figures 12 and 13. North – Northwest enceinte

The main aim behind the documentation of the Citadel was the drawing up of detailed plans, sections and elevations which enable the conservators to map, on a stone by stone basis, the current state of conservation of the material form. The topography of the site made it difficult for two-dimensional photogrammetry techniques efficiently adopted for the surveying of the fortifications of Birgu, Mdina and Valletta to be employed for the documentation of the North and West-facing enceintes of the Citadel. To this end Laser scanning technology was identified as the most suitable surveying methodology with the brief for the documentation exercise including also the generation of a three-dimensional model of the fortified enceinte including the topography of the embracing clayey terrain up to a distance of some one hundred and fifty metres away from the fortifications.

Figure 14. Laser scanning in progress

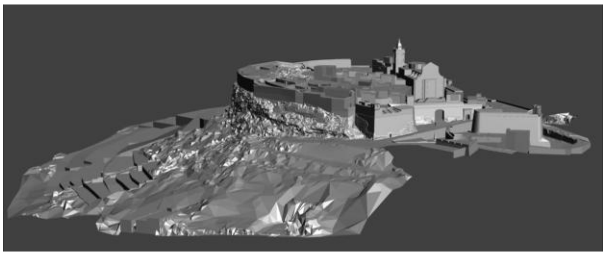


Figure 15. 3-D model of the Citadel

Figure 16. St. Martin's Bastion

Figure 17. Orthophoto of St. Martin's Bastion

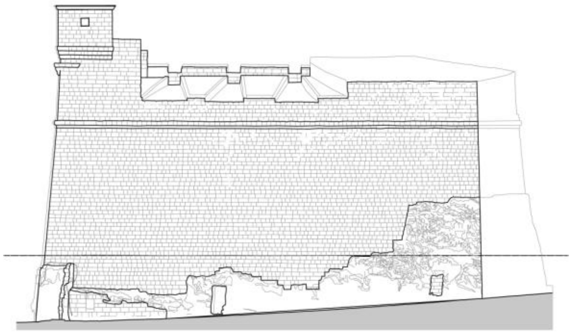


Figure 18. Drawing of St. Martin's Bastion

The information was collated on site by two Leica HDS Scanstation 2 laser scanners over a period of forty days. These laser scanners employ time of flight technology. The gathering of information focussed on the surveying of the enceintes of the Citadel, with special attention being given to the documentation of the various elements which together constitute the defensive system of the Citadel. Albeit not to the same level of detail the medieval settlement within the fortifications was also surveyed. In all a surface area of some 95,000 sq m was documented by a cloud of 4,010,262,849 points. The scans were taken from six hundred and seventy-two (672) distinct stations which were all surveyed using a Leica TCR 1202 total station.

The MUDI Project

Roberto Di Giulio
Department of Architecture, University of Ferrara, Italy

1 THE DESIGN CONCEPT

The “IstitutodegliInnocenti” is an ancient institution in Florence dedicated to the care and education of children. It has been operating for almost six centuries in a building that surely represents one of the most marvellous examples of Renaissance architecture.
In 1419 the Silkmakers’ Guild gave Filippo Brunelleschi a contract for the construction of their headquarters. The contract is still in the historical archives of the organization. Brunelleschi, with this building, established the rules for the new Renaissance architecture.

The Institute still today in this building manages three family homes for children and mothers in difficulty, three nursery schools and a play centre. It also runs the MUDI (MuseodegliInnocenti) to display its artistic and historical heritage.

The “Galleria delloSpedale” has about fifty works – mostly paintings from the 14th to the 18th centuries – that are part of the artistic heritage built over the centuries by the Institute, either by commission, by inheritance, or by canonical rights. The Historical Archives include a huge amount of documentation, from the 14th to the 20th century, that tells the story of the ancient Hospital starting from its construction and the stories of the numerous organizations that it worked with in the course of several centuries.

The solutions for the new museum were inspired by the need to reaffirm the ties between the history of the building and its current activities: the need to show the works and the history of the building and of the institution that has been both its creator and its user.

The main objective is to uncover not only the enormous cultural, artistic, monumental and archival heritage of the Institute, but also its current activities and initiatives. So the project tried to find layout and functional solutions to allow a museum and the daily life of the Institute to share the same building.

It would be difficult, and probably wrong, to imagine a museum detached from the daily life of the Institute, since the cultural, artistic and archival heritage is an integral part of the Institute.

Figure 1. The Istituto degli Innocenti from Piazza SS. Annunziata

The project, therefore, simply brings to light, unveils, accentuates and shows off all that which has remained hidden from the city for centuries and remains hidden even today.

The project consists of two interdependent actions:

- the architectural project of the spaces and setup of the museum, tightly tied to the proposed organization of the museum and full of interconnections and implications for the entire building;
- an intervention to the building, consequence of the architectural project, with a series of consequences for the functional organization of the museum.

To clarify, an example is the new access from the public square in front of the building. This solution is urgent for access to the museum, but at the same time it solves a general access problem for the whole Innocenti complex and for conventions, an important activity of the Institute.

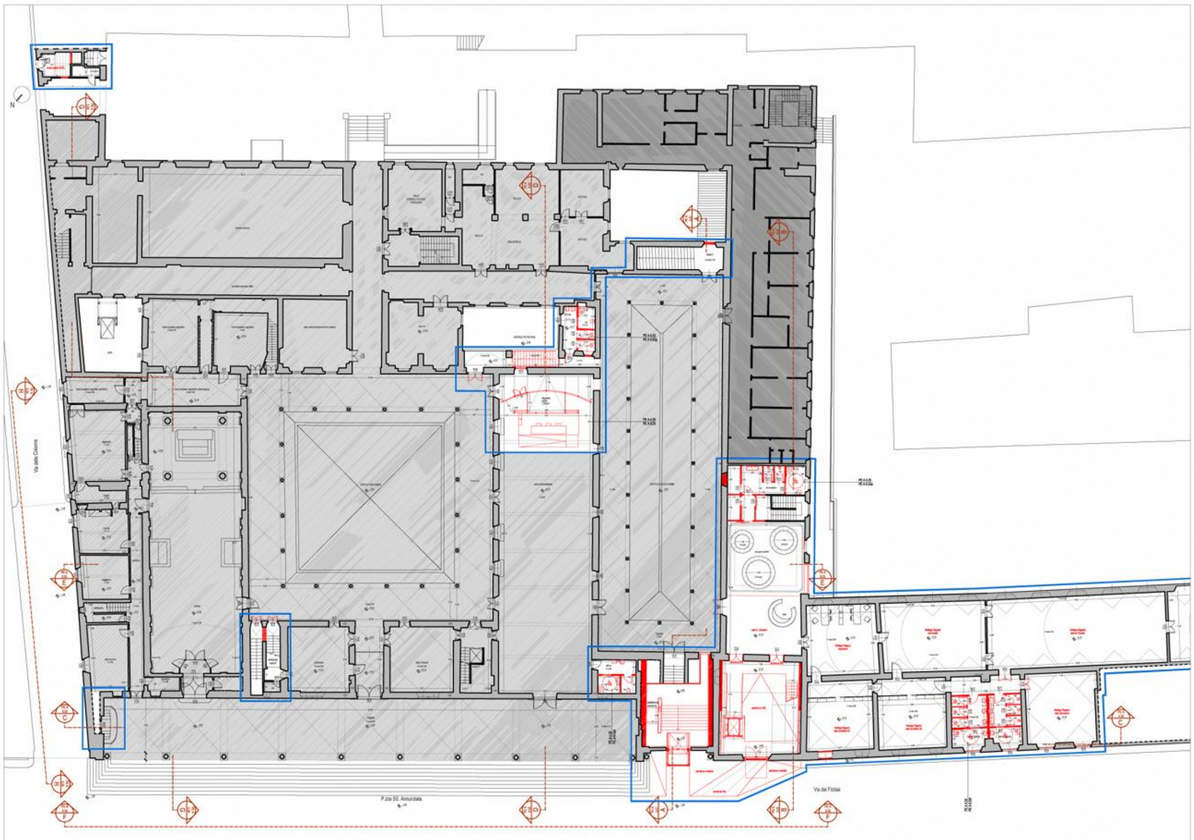


Figure 2. Layout of groundfloor

2 ACCESSIBILITY

The Institute, by its very nature open and inclusive, in reality has some accessibility problems for disabled persons.

It is built on a "podium" that with its famous staircase makes the light, elegant arcade even more fascinating – the arcade that makes this one of the most beautiful public squares in the world. But it constitutes an architectural barrier.

To remove this problem, the project found a decisive solution: a new access for pregnant women, the elderly, parents with baby carriages, and disabled people, who can access the whole building directly from the square.

Beyond this objective, the new access opens up two heretofore hidden places: a below-grade floor that today serves as a basement that could instead become a vital living space for the Museum, and the Balcony, a place that hardly anyone knows today and from which one sees one of the most spectacular views of Florence and its dome.

The invention of a new access for everyone directly from the square, because of the desire to work on the weaker parts while leaving unaltered the image of the complex from the square, leads to the choice of putting the main access to the museum at the entrance that currently leads to the “Cortile delle Donne” (Courtyard of the Women), to the right of the staircase.

The new museum entrance will be quite visible from the outside but perfectly integrated into the historical complex. Since the complex will still have diversified functions, the visitor interested in the building itself can enter either from the current entrances along the arcade or from the new common entrance.The new entrance will take advantage of the small difference between the public square and the level of the basement, a little more than a meter below street level, that is, the base of the whole structure. Going down, one arrives at the basement in a big hall where the visit to the new museum will begin. From this new lobby area, the whole building will be accessible by a new lift and a new staircase in the adjacent area, which will in turn be accessible from the outside for mothers with baby carriages.

The new museum entrance will be located symmetrically with respect to the Foundling Wheel, a sort of back door, almost as a way of remembering the way abandoned children entered the building (certainly not by the main entrance). The new access, using a door that still has the ancient offering box, is a new “wheel”: a mechanism that appears and disappears from the day to the night and clearly identifies the new museum entrance. Brunelleschi’s idea of continuity between the inside and the outside will be recalled and implemented by the large moving door as it appears and disappears inside the building.

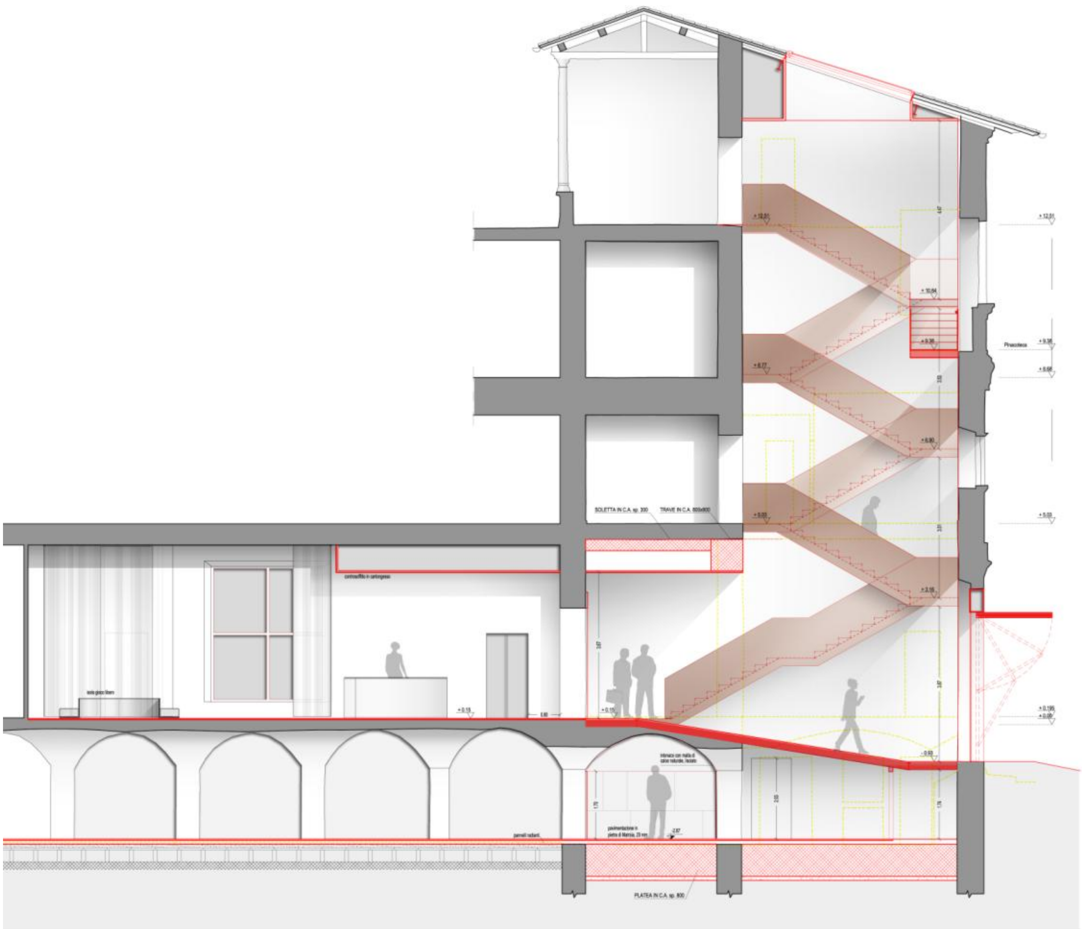


Figure 3. New entrance to the ground floor level and new stairs

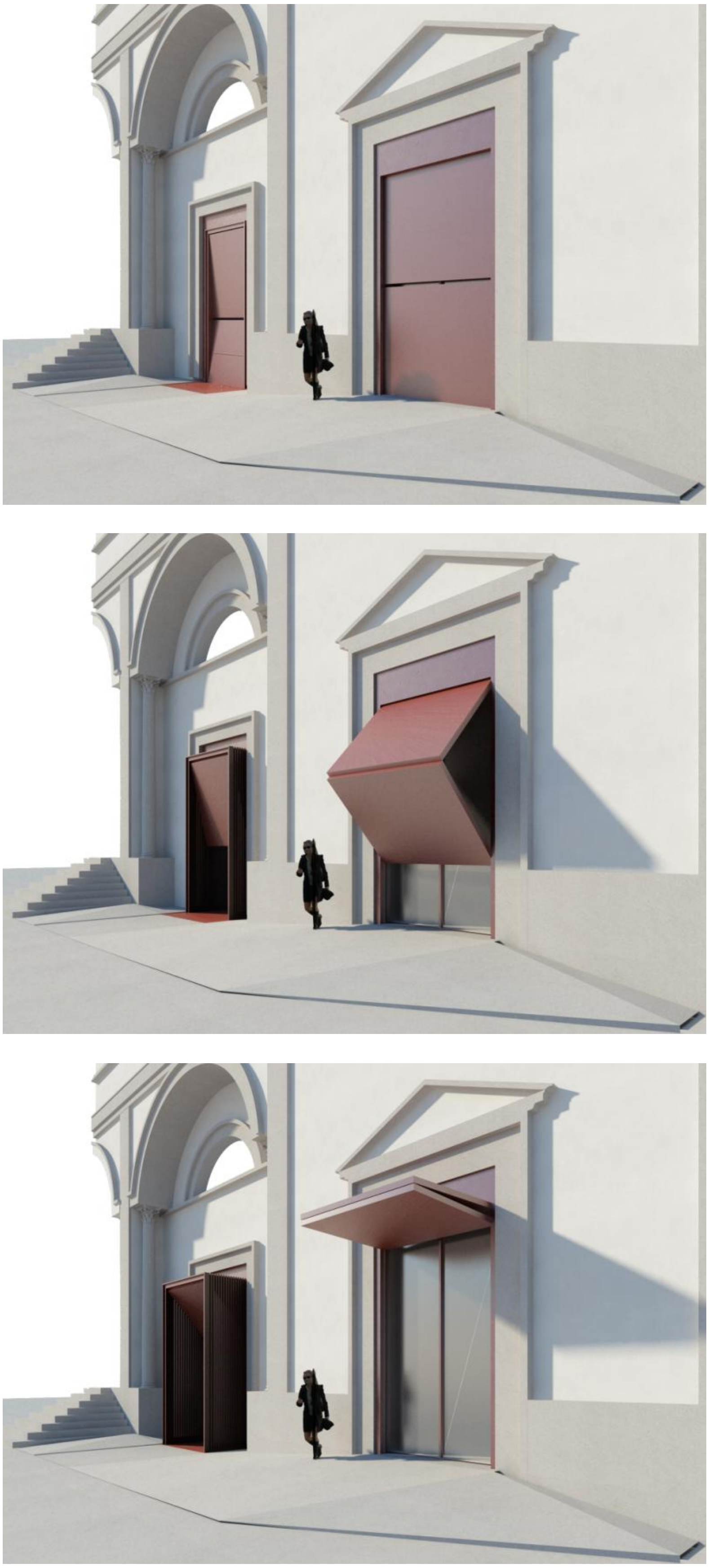


Figure 4. Doors of new entrances

3 LAYOUTSAND FUNCTIONAL CONCEPT

3.1 *Basement*

The basement is today used only in part for small temporary exhibits; it lacks organization and pathways. It will become the point of departure for discovering the museum and the Institute in general. From here a suggestive space will welcome visitors and accompany them in the discovery of the museum by showing a few significant pieces from the collection, organized by theme, with special multimedia aids.

3.2 *Ground floor*

Today, the entrance to the monumental parts of the building is from the staircase that leads to the “Cortile degli Uomini” (Men’s Courtyard) as designed by Brunelleschi; but this constitutes an architectural barrier particularly for mothers with carriages. This barrier is overcome today in an inappropriate way by an inconvenient ramp under the staircase. The new entrance removes this barrier by creating an access for all users without affecting Brunelleschi’s masterpiece. This floor is dedicated mainly to education, to cultural activities, and Institute services like the nursery school and a surgery of the local branch of the national health service.To call the attention of the citizen to the artistic value of the building, the project proposes that the “Cortile degli Uomini” become part of the museum through artistic installations that all can see. The Brunelleschi Salon will host cultural events and conventions.

3.3 *First floor*

This level has the Gallery of Frescoes that today appears closed in on itself because the double volume of the Brunelleschi Salon blocks its passages. The project for the new connection through the Salon will unite the Gallery of Frescoes and the upper arcade of the “Cortile delle Donne”, creating a continuous flow between the vertical paths and allowing the visitor to understand better the architecture of the building.In the area of the passage into the Brunelleschi Salon, the project proposes substantial improvements in the organization of the spaces dedicated to conventions.

3.4 *Second floor*

The art gallery, already an exhibit space, is located above the main entrance and has a splendid view of Piazza S.S. Annunziata. Today access to this space is through the stairway built in the 1800s. This will still be the main entrance, but it will also be accessible from the lift. In this gallery, the project proposes to enrich the exhibits with metal curtains.

3.5 *Third floor*

The loggia on the top, called “Verone”, was built at the end of the 1400s for drying clothes. It was closed in during the 1800s and has only with recent restorations recovered its original panoramic opening on two sides that makes it an exceptional vista point to see the city. The project plans to develop its role as a covered panoramic terrace looking out on Florence by creating a bookshop and cafeteria inside a box of glass set back from the two open sides of the existing structure. Access will be from the arcade along a raised path covered in wood that on arrival widens to cover the whole terrace: this makes the whole space accessible by overcoming differences in height and permitting installation of building plant under the new floor. Both the bookshop-cafeteria and the connection [in the Art Gallery] are glass structures so as to give the best sensation of transparency and lightness in the new space: the panes of glass in the gallery, the partitions in glass and the walls in the cafeteria, using hinges that open 180°, will permit total communication between the outside and the inside. The space on the open terrace of the Verone is closed by a glass railing set back from the perimeter so it cannot be seen from the interior courtyard of the building. The lighting system will improve the new elements: perimeter lighting will run along the glass walls flush with the floor to mark the perimeter; this is helped by the “box” for the services, the mobile bookshop and the bar, built with parts in satin-finish backlighted glass.

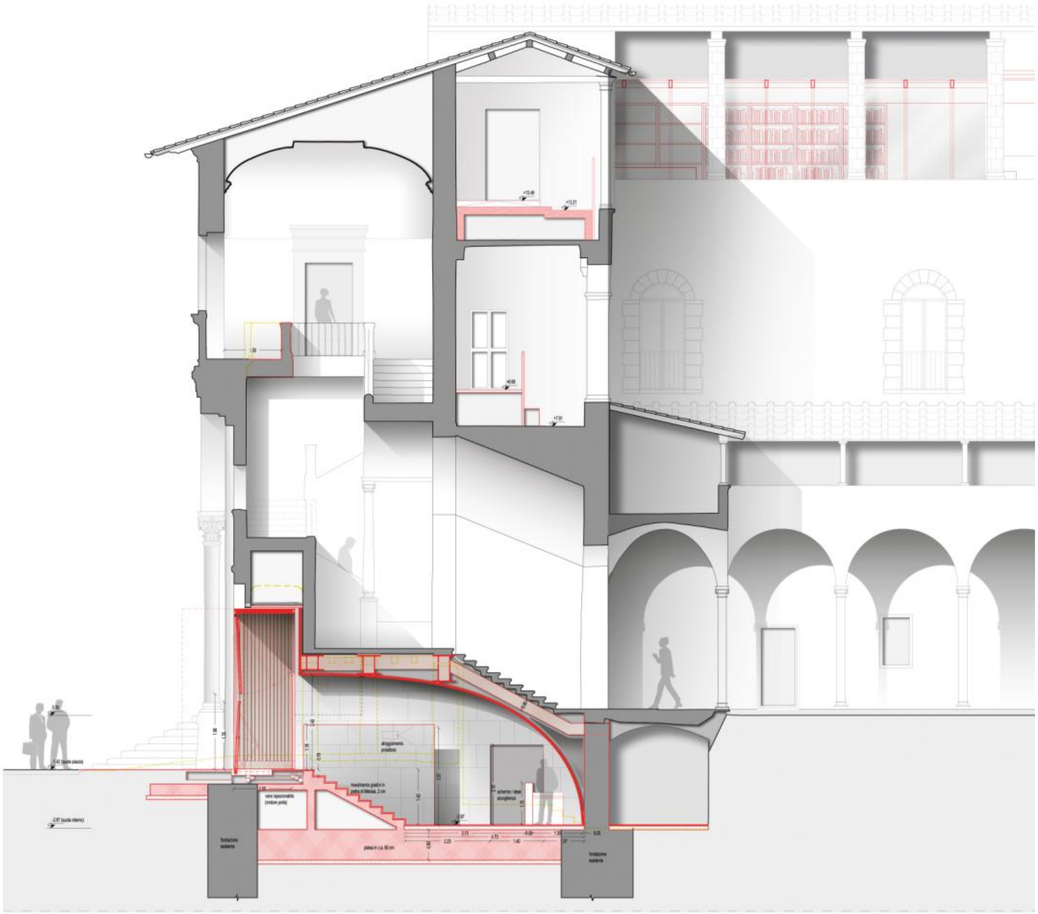


Figure 5. New entrance to the basement

4 THE MUSEUM PROJECT

The current exhibit area of the Institute offers only a glimpse of that world full of life that the complex represents, illustrating only the heritage of donations and inheritances accumulated over the years: works of high artistic value, but nothing of the most extraordinary collection, that is, its historical archives that catalogue the life of thousands of boys and girls hosted through the centuries. The new museum will make ample use of this invaluable stock of documents, to show the visitor the history and life of the Institute, putting the rich artistic collection in a larger and more complex picture, full of immense historical, anthropological and documentary values: a museum to live, not just to observe, alive today like the Institute, a museum that fuses history and the present day in a dialogue the visitor participates in. This is accomplished by having the visitor follow a path beginning with the memory of abandonment of babies, recalled by the new “foundling wheel,” a progressive immersion in that unique intersection of the historic, artistic, architectural, and emotional memory of the Institute. This succession of themes tied to the life, the history, and the architecture, makes evident the inseparable ties between these aspects, and how it is necessary to recover and render useful to all visitors the immense heritage of documents in the archives. The central theme of the museum project has been to make sure that the use of the spaces transmits the importance of the Institute as a unique example of an institution dedicated to children for more than five centuries. In this sense, the architectural solution favours, by reorganizing internal pathways, the objective of direct experience, which implies visiting places and being influenced by them – without excluding more didactic spaces full of photographs and significant objects along with narrations of stories and events.

The interdisciplinary nature of the museum, along with the intrinsic complexity of the Institute, has made it necessary to introduce the latest technology in order to recreate virtual user-navigable life scenarios using multimedia tools and to make it possible to virtually handle the archival material currently inaccessible to most visitors.

The use of computer technology and digital reconstruction can be supported by real reconstructions of articles and surroundings, that is, a selection of anthropologically interesting material and documentation in a continuous dialog between the real and the virtual, between the past and present, in which the visitor, from the "ritual" of abandonment to effective cultural education, has a direct experience of life in the city of children and leaves enriched by knowing what the Institute was and is: a unique historical place, a place to return to and appreciate. The project has investigated and highlighted the potential of the exhibit areas integrating them into a system that includes the three great themes: the Institute, daily life, and the building. The permanent exhibit will be on the basement, easily reachable from and in contact with the street – a trip to the origins of the building and of the Institute, an anthropological, historical and artistic narrative, between reality and digital reconstruction.

Figure 6. Exhibition area in the basement

The Art Gallery will be improved by shedding light on the intrinsic value of the spaces, from the wooden trusses to its special place inside the complex. Each work will be connected with the history of the Institute and the daily life of the children. The fittings will speak a single language, simple and straightforward, but able to sum up and communicate the complexity of an Institute that is still living.

The fittings, unitarily defined, will vary according to the characteristics of quite diverse spaces:

- the permanent exhibition, the welcoming area and the bookshop will be on the basement, an area with its own charm and limited height, with cross vault ceilings illuminated by natural side lights, making it a perfect place to begin the museum visit and be immediately involved in the narration of the history and life of the Institute and the building;
- on the ground floor, narration and discovery continue through the Children's Workshop, essential element for understanding the founding values of the museum project, and though visiting the building of Brunelleschi and its courtyards;
- finally, the museum takes shape in the spaces more obviously designed for exhibits: the Art Gallery, which concludes the museum narrative, even by its form.
- The last element, not fitted out as a museum but a space unto itself, the Verone, destined to become a covered space with a cafeteria, but also a place to hang out and discover the skyline of a significant part of monumental Florence.

Figure 7. The "Verone"

CREDITS

The project awarded the first prize in the international competition for the New MUDI - MuseodegliInnocenti, di Firenze 2008

Project Team Coordinator: Prof. Arch. Carlo Terpolilli (Ipostudio Architetti)
Architectural design: Ipostudio Architetti and Pietro Carlo Pellegrini architetto
Restoration design: Prof. arch. Eugenio Vassallo
Service engineering: Consiliumservizi di ingegneria srl
Structural engineering: Favero& Milan ingegneria spa
Museographist: Dott. Cristiana MorigiGovi

The Salini Rehabilitation Project

Claude Busuttil
Department of Built Heritage, Faculty of the Built Environment, University of Malta

ABSTRACT: Since ancient times salt-pans and the salt industry created an environment of particular cultural, environmental, economic and anthropological significance within the Maltese Islands and the Mediterranean. This industry is remarkable for its efficient use of natural resources which are fully renewable and create minimal pollution. Apart from the human-made rock-cut salt pans, the same areas have a particular ecological significance. Salina represents the largest, and one of the last, remaining salt marsh areas in the Maltese Islands, a rare habitat locally which supports a specialized flora and fauna, including a number of endemics. The Salina area now represents the best remaining example of a coastal marshland in the Maltese Islands, although it is likewise under threat, and in urgent need of management and rehabilitation. The Salini Rehabilitation Project is intended to address a range of objectives which will holistically lead to the improved status of the Salina site and to the full realization of the site's considerable potential. The objective of this proposal is to revitalise and support the traditional industry of sea salt extraction through solar evaporisation. The aim of the project is to regenerate this site not only with regard to salt manufacture and the restoration of the salt pans, but also taking into account several other features that enrich and enhance the Salini area.

1 INTRODUCTION

Beyond its basic uses and utilities, salt is a point of inspiration. At the same time salt, as a resource, represents a concise piece of the History of Man, in the context of use of Natural Resources since the antiquity and even long before. In a way the History of Salt is also the History of Human Culture. Man collected salt and appreciated its taste and realised that salt was a useful good; so he carved rocks to regularise its possession, and created pools and built saltpans to increase its production creating the salina! The brine attracted all types of creatures: bacteria and algae, crustaceans and insects, fish, and a large variety of birds, for the satisfaction of the Creator, scientists and nature conservationists.

Man continued to work the salt, using different techniques and devices in order to facilitate his job and alleviate the extreme labour he invested in its production, but alas salt was too expensive! So, remarkable changes were gradually introduced in the salinas in order to make them more productive and the salt less expensive. The salina surface areas were extended and manual labour was reduced employing modern elaborate machines. Modern saltworks came into existence and salt was no more expensive. Smaller and less productive salinas were therefore shut down, regardless of their potential economic value. The European Mediterranean salinas became bigger and bigger, but increasingly fewer. The new salina landscape, the post-modern one, emerged: large expands of shallow pools and saltpans scattered in few spots, more economically viable. Due to market globalisation, the trend of closing down salinas is more enhanced nowadays in Europe, as plenty of salt produced elsewhere in the world, more competitive to that locally produced, is imported, threatening the still operating saltworks of the Mediterranean.

Among the scientists, technical experts, as well as the local societies, there is a unanimous consensus towards positive decision-making in favour of the conservation, re-qualification, rehabilitation, and, in some cases, alternative use of the old, not very productive, or abandoned salinas. Furthermore, modern mechanised saltworks, when ecologically managed, are no more to be considered as mere salt yielding sites, but as an invaluable source of natural resources useful for man and his needs and nature conservation. Both these perspectives are very important for the survival/rehabilitation of saltworks.

In addition to their expected economic value, saltworks are often important historical and cultural sites. In several instances saltworks have been the terrain of action of big historical events, national or international, and this makes them historical museums as such. On the other hand, their ethnological value, although poorly documented, is high. This is related to the architectural aspects of the salinas, to the traditional ways of production and equipment used, to the working and social conditions of the people employed in the trade of salt making, to the product itself as a cultural element, and to the local gastronomy based on this product. None of the above aspects has been really studied in Malta. The lack of an ambitious documentation project clearly evident, before all this knowledge, experience and tradition is lost forever.

All around the European and Mediterranean coasts, from Brittany (Bretagne) on the French Atlantic coast to the Black Sea and on many islands such as Malta, some sites still produce salt in the same way – or at least with only minor modifications – as it was done a thousand years ago. In Malta salinas are all coastal and man-made. Seawater evaporates in a succession of shallow ponds, the salt is finally collected or harvested for domestic and/or industrial use. However, salinas not only constitute a fascinating cultural heritage but also important wetlands for breeding and migrating birds and play a significant economic role. Traditional salinas are valuable for pedagogical, touristic and scientific purposes. The salt produced is of high quality and these provide jobs for many people. But traditional salinas are also threatened by abandonment, transformation, aquaculture and new land use amongst others.

Since some years Mediterranean salinas have been defended by nature and cultural conservationists, for the simple reason that they are unique for their landscape and wetland values, as well as for making part of the cultural heritage of the Basin. In this respect, some salinas, once degraded or fallen into ruin, were recently upgraded, restored and rehabilitated. The raising interest about them was expressed through symposia and workshops by scientists (historians, ethnologists, ecologists), managers and owners, local developers. All agree with sustainable development and wise use of salinas, where salt-making is combined with soft tourism. In addition, there have been some Mediterranean initiatives aiming mainly at raising awareness and networking on the study and conservation of the salinas. Such initiatives are the Salt Routes of UNESCO, the ALAS project financed by the European Commission, and the recent MedWet/Com4 Technical Session.

Figure 1. Arial view of the Salini Area

2 HISTORICAL BACKGROUND

The Mediterranean climate is ideal for salt making and Malta is obviously not an exception. Although a generous gift of nature, salt has been artificially produced as early as 641BC in the first salt-gardens of Ostia (Rome). Already then, salt was an expensive commodity for the Mediterranean, as well as the world beyond this region. The evolution of salt-making techniques came to a standstill with the method of successive evaporation basins, introduced into the Mediterranean by the Arabs in the early Middle Ages. The basics of this technique remain unchanged until today.

Thus, since the ancient times, hundreds of salinas have operated in the Mediterranean and therefore also in Malta. Mediterranean salinas are recognized among the most important non-polluting industrial activities of the area. Their importance has been more pronounced in the past, when salt was a vital commodity, at least for food preservation, and played a key role throughout history, providing political power to those who controlled its production and trade. The first Salt Routes, through which salt was traded, were probably those of the Protocycladic II period, in the early Bronze Age, later the Phoenician ones. Amongst the most known, the terrestrial *viae salariae* of the Romans, and the marine ones by the Venetians and Genoese, justify the metaphor of "white gold" referring to the economic importance of this commodity, the renowned "edible money" of Cassiodorus. Indeed, for many centuries, states, churches, cities, as well as families acquired power and wealth from producing, trading or simply taxing monopolized salt (the roman *annona*, the byzantine *kommerkion*, the arab *al-quabala*, the french *gabelle*). It is because of its economic importance that salt makes still part of today's monthly payments, at least as a relict in some European languages (*salarium* - salary).

Based on the same basic technique, many varieties of salt-making adapted to the particularities of geology, the vicissitudes of climate, the anthropological temptations, which challenged the Mediterraneans to develop a diversity of devices and tame wind and waves for letting salinas to become white. There are several reasons for qualifying salinas as important wetland sites, and interesting from the viewpoint of nature conservation. First, because of the special biodiversity they host due to the hypersaline character of the saline basins, one of the harshest wetland habitats. Very few organisms can stand the inhospitable environments of these saline deserts, where, however, they can grow into extremely large populations due to lack of competitors. Second, because salinas are biologically rich despite being artificial habitats. This is due partly to the fact that as man-managed they are kept constantly under water, which makes them ecologically invaluable during the dry summer. In winter, however, their ecological value may decline if the pools are left without water. Their biological richness is also due to the wetland mosaic consisting of a combination of basins of a wide salinity gradient, providing diverse niche possibilities to species of different tolerance. In addition, salinas contain a number of relatively undisturbed aquatic and terrestrial habitats that make them vital for the conservation of waterbirds. Furthermore, many salinas constitute the only functioning wetlands among extremely dry areas during the summer months.

The Burmarrad-Salini area is a large rather flat area that is the nearest thing to a 'plain' existing in Malta. It is bound on one side by the relatively high internal cliffs of Targa Gap and Mosta which are divided by several narrow deep gorges or river valleys. On the other side there is a natural marshy wetland known as Salina, part of which was formerly used as salt-pans. This marsh was historically (i.e. in Roman times) much larger than it is today and covered most of Burmarrad itself so that the site was notorious for malaria. In fact, Burmarrad means 'sickly marsh' in the Maltese language.

The earliest evidence of human activity recorded in this locality so far dates from the Temple Culture. This remarkable culture flourished across Malta and Gozo roughly between 4100 and 2500 BC. One of the more modest, but nevertheless important, of these sites is located at Tal-Qadi. The Tal-Qadi temple is located on the rocky terraced slope rising away from the eastern edge of the Burmarrad alluvial plain, a few metres east of the country road which runs along the edge of the plain towards the innermost end of the Salina salt pans. The proximity of the site to a fertile plain is very similar to that of other 'temple' complexes in Malta. On the other hand, however, there is a strong possibility that the coastline along this plain has advanced considerably.

The alluvium that has built up here appears to have been carried down by rain-water escaping to the sea. The valley system draining into Salina Bay is the second largest water catchment area of the Island after that of Qormi. Over the five millennia since the building of the Tal-Qadi temple, the cumulative effect of the deposition of water-borne soil particles carried off from higher ground could, very plausibly, have pushed the shoreline farther out into Salina Bay.

Tal-Qadi was excavated during the summer of 1927, initially under the supervision of L. Upton Way, a fellow of the Society of Antiquarians, and later under the direction of Sir Themistocles Zammit, the first director of the Museum Department. The layout of the Tal-Qadi temple is difficult to make out with certainty. When the site was discovered, it was found that much of the structure had been lost, probably owing to the subsequent use of the site for other activities such as agriculture. Two apses facing each other may be clearly recognized. While it is unclear how the plan of the site may have developed, Evans suggests that this may originally have been a four-apse temple, with its entrance facing downhill towards the Burmarrad plain[1].

The Burmarrad – Salina basin has been a focus of activity during the Punic period. One of the interesting points which emerge from the cases recorded so far around Naxxar is that this area was inhabited from the early years of Phoenician presence in Malta. The distribution of tombs suggests a concentration of activity around the Burmarrad-Salina basin, which by the time Abela was describing the countryside, had become part of the *'parte inabitata'*. We may imagine two principal motives for living here; one is the exploitation of the agricultural potential of this fertile zone, and the other is the easy access to the sea at Salina Bay. These two factors were to continue to influence the perception and use of this area throughout the Roman period.

From the early years of the Roman occupation there is evidence that this pattern was continued and developed. A number of Roman rural sites have been found around this area. These actually appear to have formed part of a number of villa complexes. The site which has received most attention is the villa at San Pawl Milqi, which was excavated by the *Missione Archeologica Italiana* during the 1960s. This site was first established during the Punic period, but was expanded during the late second or early first century BC.[2] It has yielded evidence of olive pressing and the processing and storage of olive oil. Around the Burmarrad-Salina basin, there are also traces of establishments in the Wardija hills and at Bidnija.

The seabed around Salina Bay itself has yielded further evidence of intense activity here during the Roman period. Although it is likely that many of the discoveries that have been made here were never reported, it is clear from a number of reports made by public-spirited individuals that Salina Bay was a significant node of maritime activity. In 1960 and 1961 concentrations of Roman pottery shards were reported along the eastern shore of the bay.[3] The subject of Roman shipping in Salina Bay once again brings up the question of how the coastline may have changed since that period. Did the bay run deeper into what is today the Burmarrad plain? How far has the coastline of the plain advanced into the bay as a result of alluvial deposition? A chance discovery in March 1992 may help provide part of the answer. A field south of the Burmarrad cemetery had just been cleared of soil to make way for the extension of the cemetery which has been built since. During a casual inspection of the stripped area by two archaeology students,[4] a mound of disturbed earth was observed along the old cemetery boundary wall. This contained three large ashlar blocks, as well as a considerable number of pottery fragments, some of which could be dated to the Roman imperial period.

The coming of Christianity to Malta is steeped in mythology and charged with passionate national emotions, centered on an obscure Roman prisoner. St Luke's gripping account of St Paul's shipwreck in around AD 60 has captured the imagination of readers since it was written, and men have argued over the location of the shipwreck for centuries. Throughout this debate, Malta has always remained one of the most likely candidate sites.

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1 Evans J.D., 1971, T*he Prehistoric Antiquities of the Maltese Islands: A Survey,* (London), pp. 41-2.

2 Cagiano de Azavedo M., 1966*, Testimonianze archeologiche della tradizione Paolina a Malta* (Rome), p.10.

3 MAR 1959-60, 3; MAR 1960, 4; MAR 1961, 7.

4 Nathaniel Cutajar and Reuben Grima

A deeply-rooted Pauline cult based on the conviction that he converted these islands to Christianity may be traced back at least to the fifteenth century,[5] and was considerably developed and reinforced by the Order of St John.

The Salina catacombs are one more indication that Salina Bay retained its importance into late Roman times. They are located a stone's throw from the church of the Annunciation, on the southern shore of the bay. Five small catacombs, and a number of floor-graves and rock-cut tombs[6] are spread along a low rock escarpment lying two fields away from the church. Remains of ancient burial sites in this area were first reported by Count Ciantar.[7] The site only returned to the limelight in 1937 when its systematic investigation was commenced by Capt. Charles Zammit then the curator of archaeology in the Museums' Department.

The salt pans at *Salina* were probably constructed during the XVIth century. This new attribution is based after close inspection of one of Matteo Perez d'Aleccio frescoes (1576-1581) depicting scenes from the Great Siege of Malta in 1565 entitled *La Venuta dell'Armata Turchesca a dì 18 Maggio 1565.* In fact one can observe in these paintings a schematic plan of "*Le Saline Nuove*" in the same place where the Salini are located today in contrast with "*Le Saline Vecchie*" at Ghadira Bay in Mellieha. A more accurate schematic plan of the salt pans is also visible in Lucini's engravings, copied from the original engravings of the same frescoes already published by Perez d'Aleccio in 1582. However, to date no documentation has been found in the archives at the National Library testifying this claim.

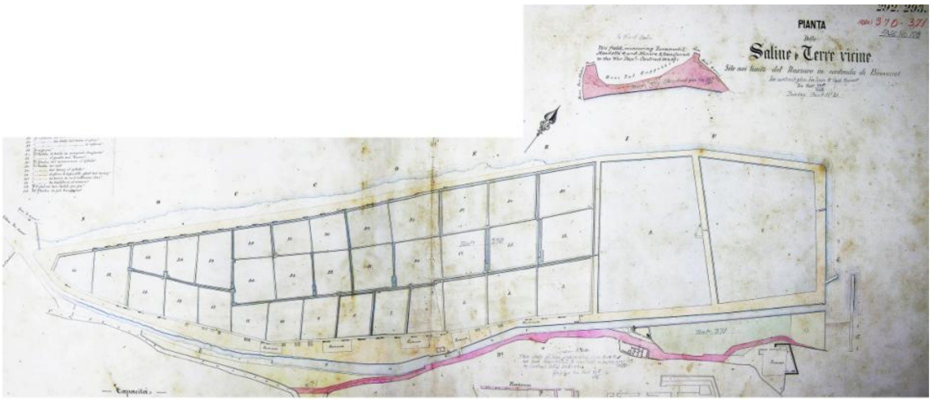

Figure 2. 19th Century Historical Survey

Until the very beginning of the 20th century, salt was an absolute necessity for the preservation of food. However, during the beginning of the 18th century, a need was felt by the Order of St. John to protect the area of the Salina by introducing a defense structure, later known as the Ximenes Redoubt. This undoubtedly proves that the salt pans were already present in the area by that time. The "*Soccorse*" canal, extending from Salina Bay up to Kennedy Grove completely surrounding the salt pans, was most probably built in the late 1600's to convey freshwater runoff from the land to the sea at Salina Bay and to provide sea water in a continuous flow around the salt pans.

The Ximenes Redoubt, a defensive work located on the southern coast of Salina Bay, was erected between 1715 and 1716. In fact, on 28th September 1714 the two commissioners of fortifications, Arginy and Fontet, resolved to visit the coast of Marsaxlokk and Marsascala. Later they extended their inspection to cover the whole coastline and presented their full report on 10th January 1715[8].

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5 Freller T., 1996, *St Paul's Grotto and its visitors*, (Malta), pp. 12-26

6 Buhagiar M., 1984, 'The Salina Hypogea at St Paul's Bay', *Melita Historica*, ix, No.1, p. 1.

7 Ciantar G. A., 1772, *Malta Illustrata ovvero Descrittione di Malta*, I (Malta), 196-7; Buhagiar M., 'Salina Hypogea', p. 1.

8 A.O.M. 6556, f. 2(28 September); they submitted a report on Marsaxlokk and Marsascala by 28 December (A.O.M. 6552, ff. 3v. and 27); the report of 10 January is to found at A.O.M. 266, f. 129v., A.O.M 6552, f. 6v. & A.O.M 6556, f.3; in Spiteri S., 2008, The Art of Fortress Building in Hospitaller Malta, Malta, p. 375.

They recommended that those beaches where a large army might disembark, such as the bays of Marsaxlokk, St. Thomas, Marsascala, St. Julian's, Madalena, Salina, St Paul's Bay, Mellieha and the shore of the Gozo channel, should be protected by batteries and entrenchments and to this purpose they drew up a plan showing the location of the proposed batteries. Between October 1714 and April 1715 a total of 8067 scudi were spent on the defence of the coast[9]. A large salt magazine was added later to this structure by Grand Master Ximenes de Texada.

A few coastal redoubts were built with semicircular or rectangular platforms such as the two Salina Bay redoubts. That known as the Perellos Redoubt, at Salina (now demolished) was particular in that one corner of its perimeter wall was fitted with a small bastion. The Ximenes Redoubt, on the opposite side of the bay, on the other hand, had originally two blockhouses but these were later replaced by a large magazine designed to house salt from the nearby *Saline Nuove*. The Ximenes Redoubt is unique in that it was later also fitted with an internally-placed fougasse.

Figure 3. The Ximenes Redoubt

In fact, in 1743 a fougasse was excavated inside the redoubt itself, while another one was cut a short distance away. Marandon actually appears indeed to have been responsible for developing a novel form of coastal defence, the fougasse: a form of stone mortar excavated out of solid rock. On 28th September 1740 Marandon fired his first experimental fougasse and was so pleased with the results that the following year he excavated a network of fougasses at vulnerable points around the coast of the island[10].

When salt is collected it is never immediately sold or exported. Speculation implicates the stockage for a number of years of the product harvested. The stockage takes place in appropriate structures to which the daily harvest is transported. These structures, which resemble that of a hut or barn, are located just outside the wetland area or on the border of the salt pan structures. The transport of salt takes place usually towards the end of summer of which the major part is stored in these huts better known in France as *salorges.* It is interesting to note that the structures located at the Salini salt pans in Burmarrad are similar if not identical to those present in the north western part of France, such as Guerande and Île de Re. It is understood that the structures at the Salini were modelled on the temporary structures built by the Sappers under the British Regiment posted in Malta towards the end of the nineteenth century. However, no documentation has yet been discovered regarding the construction of our local *salorges.*

[9] A.O.M. 6556, f. 9; in Spiteri S., 2008, The Art of Fortress Building in Hospitaller Malta, Malta, p. 375.
[10] Clerkenwell, MS. O I, item 21; in 1715 the Council had ordered sixty stone mortars to be cut but no action seems to have been taken until 1740; A.O.M. 6552, f. 38 and A.O.M. 6556, f. 187 *list of proposed fougasses; in* in Spiteri S., 2008, The Art of Fortress Building in Hospitaller Malta, Malta, p. 378.

Salt storage huts have usually large dimensions and are generally located at the margin of the salt pans area. These present the best conditions for salt stockage, completely protecting the product from the atmospheric agents. These huts are completely constructed in timber, lacking any windows but having doors on one or both sides of the facades. These salorges are constructed in wooden planks nailed or dove-tailed to each other. The lateral walls of these structures are not vertical, in a way that these withstand the pressures exerted by the salt piles inside. The same inclined structures are built on a coralline limestone shallow parapet wall in order to resist the chemical deterioration caused by the salt. Sometimes other external structures, such as butresses, are added in order to support the internal structure of these salorges when these are filled to the brim with the salt product. The main frame structure consists of wooden columns or pilasters supporting a truss beam roofing structure.

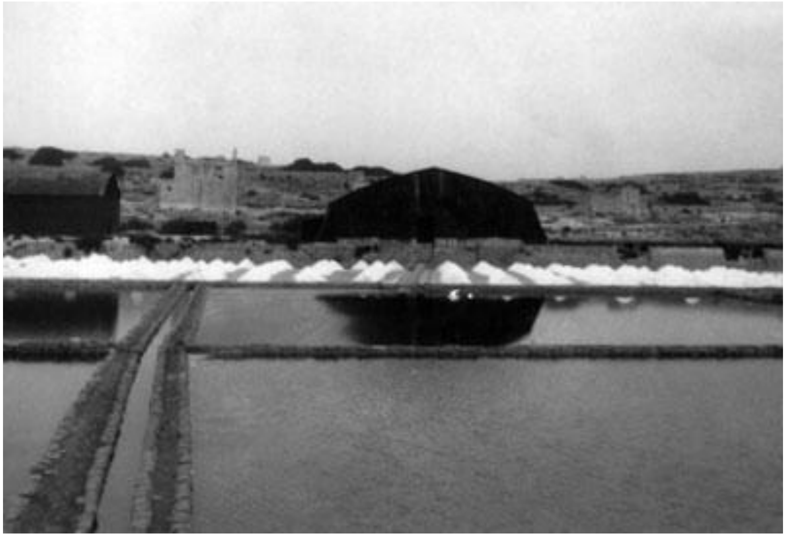

Figure 4. The salt pans

3 PRESENT SITUATION

The *Salina* salt pans located between St. Paul's Bay and Burmarrad are presently inactive. All Mediterranean salinas are actually today facing many pressures and threats due to change of social values and economic stresses leading to complete abandonment or transformation. This has affected the *Salini* salt pans' role as a cultural landscape and the coexistence of sustainable salt production and biodiversity. Landscape quality has additionally been affected by occasional terrestrial events such as flooding and sewage disposal.

The fragile socioeconomic balance of salt production is linked to a market that is subject to competition from cheaper land-produced salt and the "globalisation" of world trade. Faced with the need to be economically viable, salinas are confronted with the choice of closing, industrializing the production, or finding a niche market for quality salt that gives higher market returns. Where salinas close, this leads to a significant loss of their biodiversity. The current trend to cease salt production in many parts of the Mediterranean has created many inactive salinas with buildings and hydrological infrastructures falling into ruin. Malta is no exception and this is what is happening to the *Salini* at Burmarrad.

The *Salina* area is a large rather flat area that is the nearest thing to a 'plain' existing in Malta. It is bound on one side by the relatively high internal cliffs of Targa Gap and Mosta which are divided by several narrow deep gorges or river valleys. The whole region constitutes a 'river drainage system' from the watershed on top of the Targa Gap heights down to the Salina wetland at the edge of the sea. The area is fertile with plenty of water (though this has high saline content) and is worked by many full-time farmers.

One of the main problems facing *Salina* today is that, whenever there are heavy rains, the valleys in the Mosta heights turn into torrential streams and pour large quantities of water down onto the plain. This causes serious flooding of the agricultural area and some fields may even end up under a metre of water so that a considerable percentage of winter or early spring horticultural crops may be lost in this manner. This flooding is partly due to the fact that the abandonment and disturbance of the *Salina* wetland is creating a bottle-neck and blocking the passage of water to the sea. This frequent phenomenon has caused the opening of breaches in and collapse of the retaining walls of the salt pans, disrupting completely the balance between the human activity of salt production and the natural eco-system entirely dependent on the functioning of the same salt pans.

At present two out of the three previously existing storage structures have survived the disastrous effects of the flash floods badly and frequently hitting this area. However, the two existing *salorges* are in a very bad state of conservation and can be described as in imminent state of collapse. The present tenants using these structures are in continuous danger and risking to be completely buried by the collapse of the structures mentioned above. The truss beam structures supporting the roofs are in imminent state of collapse and can be described to be still standing by miracle. All structures in wood are kept together with rusted iron elements which have considerably incremented the damage to the same structures due to the chemical weakness of their material in close contact with salt. The majority of these iron elements are the main cause of the structural failure. The majority of the external timber cladding is missing and has been substituted during the last fifty years, with corrugated steel and/or asbestos creating a terrible eye-sore and health hazard to the environment.

Figure 5. Storm water flooding completely the minor soccorse canal and the salt storage huts in September 2003.

4 PROJECT PROFITABILITY

The Maltese salinas are today facing many pressures and threats due to change of social values and economic stresses, notably:

(a) conversion from low intensity to mechanised production. Worst is the transformation to high salinity brining salinas of almost no biological value.
(b) abandonment or conversion to other uses such as, aquaculture, industrial, urban or tourist zones.

These impacts affect the salinas' role as a cultural landscape and the coexistence of sustainable salt production and biodiversity. Landscape quality may be additionally affected by occasional pollution events, marine (e.g. oil spillage) or terrestrial (floods, wastes, sewage).

Figure 6. Salt pans.

Figure 7. Collection of salt.

It is obvious that the percentage of salt production and food grade salt consumption constitute the weakest market. In addition, the high transport cost per tonne compared to the actual product value, discourages export and import business. Traditional salinas should seek to increase sales of their product in the food industry, because its selling price is much higher.

Furthermore it is essential to consider alternative products and services because the traditional dimension of the salina cannot stand by itself within the market. A traditional business has to be promoted and operate as such in order to be viable. Successful cases within Europe (especially France) have proved the need for developing innovative strategies adjusted to the local macro-environment. The marketing strategy to be analyzed will reflect the needs of a declining market such as the one of salt and seek to find alternative strategies to promote the so called 'artisanal' salt along with additional services which finance the operation costs of a traditional salina.

Alternative business strategies should therefore be designed in order to survive the crisis witnessed in the salt industry. Artisanal salt constitutes a commodity that should be re-presented in the market not only as another 'biological' product, but as a product/ location /service involving a set of qualities bearing the characteristics of:

(a) the ecological importance;
(b) the traditional and historic continuity;
(c) the cultural significance; and
(d) manual maintenance, harvest and processing.

Salt producers can attempt to sustain a competitive advantage in established product markets through differentiation of their product offering or by maintaining a low-cost position. Evidence suggests the ability to maintain either strongly differentiated or a low-cost position continues to be a critical determinant of success throughout both the transition and mature stage of a product or a service. It is essential to mention at this point that a single business is difficult to pursue both low-cost and a differentiation strategy at the same time and for the same products or services. For the traditional salinas the strategy to be followed during a transition period could be different for selling 'innovative and traditional salt products' on the one hand and to keep selling salt in bulk to already existing customers. In the former case differentiation would be appropriate and in the latter case a carefully designed low-cost strategy to already existing customers could support investment in research and development for higher value products.

A salt producing company does not necessarily need a large relative market share to implement a low-cost strategy; it could invent other ways to hold its costs well below those of the salt industry's leaders.

However a number of strategies can be followed for obtaining a sustainable cost advantage which include for instance producing a no frills product, creating an innovative product design, finding cheaper raw materials, automating production, developing low cost distribution channels and reducing overheads. A simplified product design can also lead to cost advantages. In this case the target market has to be specified and diversified. It is obvious that traditional salinas should attempt to offer a major amount of their product to different food markets at a relatively high value compared to other markets. The marketing mix of the traditional salt will gradually form the marketing strategy of traditional salt production, by adding new innovative products and services to the existing ones.

5 RESTORATION PROJECT

Traditional salinas and small saltworks in the Mediterranean have been in a continuous decline until a couple of years ago and many are still under threat. However, since the beginning of the 90s there has been an increasing trend of considering salinas as a tourist product and consequently involving them in many ways into tourist enterprises, both of a traditional or an alternative nature. This encompasses cultural and gastronomic tourism as well as ecotourism, the latter principally related to bird-watching. This new drive resulted in the conservation of the salinas landscape and in many cases the revitalisation of the salinas that were set aside many decades ago. This was the case in western France (Guerande, Noirmoutier, Île de Re), in the Canary Islands, in Slovenia (Secovlje), in a couple of cases in Italy (Cervia and Trapani – Marsala). This re-qualification wind has refreshed the intentions towards the salinas in the whole Mediterranean and more and more salinas, from Cadiz and Aveiro in the Iberian peninsula, to Polichnitos in the Aegean, are intended today to be rehabilitated and their landscape revalued.

The Salina Rehabilitation Project is therefore aiming at the rehabilitation of the Burmarrad-Salina area in a holistic manner in order to revitalise salt production. Both cultural and natural assets should therefore be restored through mutual co-operation between multi-disciplinary experts. The main objective of this project is to regenerate this site not only with regards to salt manufacture and the reuse of the salt pans, but also to take into account other features that enrich and enhance the Salina area. An effort is being made to incorporate these into a recreational and educational park accessible to the public, consisting of both local and foreign visitors, and school children with an emphasis on Environmental Education. This shall only be achieved through the development of an integrated cultural and natural heritage management plan, as well as through a multidisciplinary approach and networking between the various stakeholders.

The salt pans at *Salina* are man made but are not that old to be regarded as an archaeological site. However the conservation of these salt pans and their immediate environment is of paramount importance. Of the same importance is the fact that they should be maintained on a permanent basis. The conservation of this particular site is always facilitated by making use of the salt pans for their original purpose. The salt pans and their use form one integral part; therefore their use must also be safeguarded. The conservation of the salt pans and their immediate surroundings implies preserving the site as it was conceived apart from its function. Wherever the traditional setting exists, it must be kept. No new construction, demolition or modification which would alter the relations of mass and color must be allowed. Wherever it is obvious that a modification or addition has been done, it is important that this is well and truly documented and removed accordingly to present the site in the nearest possible form to how it was in its original state and not to detract the importance to anything that originally formed part of the site. Other details which have gone missing or have been hidden by the overgrowth of weeds must be restored to their rightful position without causing any disruption to the natural environment. Restoration works are to take place section by section and organised in a way not to disrupt the habitat and birds as much as possible. This can be easily done if works are previously organised so that they can proceed smoothly and without problems cropping up hindering the existing habitat and delaying the same project.

The proposed project is intended to address a range of objectives which will holistically lead to the improved status of the *Salina* site and to the full realisation of the site's considerable potential. The objective of this proposal is to revitalise and support the traditional industry of sea salt extraction through solar evaporisation.

Thus, the Salini Rehabilitation Project design criteria aim to achieve the following through active networking:

(a) Development of specific local concepts on the production and use of traditional salt to maintain/create jobs, and conservation of the salinas cultural and natural heritage as an important factor of regional development;

(b) Enhance the wetland values of the salinas through supervised cleaning;

(c) Conserve the Salini through promoting and marketing traditionally produced salt a high-quality product (economic study, labelling, setting-up co-operative structures);

(d) Conservation of the Salina heritage through the compilation of knowledge traditional salt production and related cultural heritage, together with preparation of guidelines and execution of pilot projects on re-establishing/upgrading/operating traditional salinas including training of qualified salters;

(e) Establishing a salt-museum for raising awareness on the cultural and natural heritage heritage of salinas;

(f) Use of the cultural and natural heritage of the salina and traditional salt production for additional quality tourism.

The main interventions of this project as illustrated in the master plan shown hereunder can be described as follows:

1. The unique wooden huts previously used for the storage and processing of the newly harvested salt are unique in the Maltese islands and are an integral part of the whole complex at Salini. It is being proposed that the original existing huts are restored in principle and their original form should be completely conserved. It is also being proposed that the "additional" hut follows in principle the external form of the original structures. The Salt Storage Hut, indicated as A, is to be reconstructed using a modern timber portal frame structure having the same use for salt stockage. The missing *salorge,* indicated as B, previously destroyed by the floods in the eighties, is to be constructed as a Visitor's Centre, similar to that recently constructed in Guerande (France), using a modern timber portal frame structure. The Processing/Packaging Hut, indicated as C, is to be reconstructed using the original design of the timber truss beam structure and columns supporting the roof. All the above structures are to be cladded in timber planks as the original *salorges,* thus presenting a unified external aspect enhancing the whole environment. The Visitors' Centre includes also a temporary exhibition space, gourmet tasting and a permanent exhibition of traditional tools used for the salt harvest. An upper floor balcony would offer a spectacular view over the *salini* and the park across the main canal. The area indicated as B is proposed as a servicing car park whilst an open space in front of the packaging/processing hut is required for heavy vehicles for the transport of salt. It is also envisaged that the entire visitors' route, from the landing place to the Salt Storage hut A, is fully accessible for disabled persons and paved in *franka* stone slabs in keeping with the traditional Maltese paving present also inside the same salt pans.

2. The Ximenes Redoubt and adjacent structure (indicated on the Master Plan as F), utilised for the storage of the salt produced by the salt pans during the Knights period, are to be completely restored. The condition of this structure can also be described as in a precarious state. It is being proposed that this structure is utilised as an Interpretation Centre where visitors are welcomed and acquire a ticket for the visit of the salt pans and the Visitors' Centre. Furthermore, it is also being proposed that the Redoubt is accessed via an underpass and a ramp linking it to the landing place across the Coast Road.

3. The proposed saline marshlands or wetland area, indicated on the same Master Plan as G, consists of a watercourse and marshland vegetation separated form the urban context by the garigue on one side and Kennedy Grove from the main road. Access to this area is permitted only from the boathouses side and the Kennedy Grove side limiting the disturbance of the habitat as much as possible. Vehicle access is only marginally permitted for the WSC

pumping station. A habitat engineering study is to be conducted at a later stage in order to investigate ways how to reintroduce the marshland in this area without interfering excessively with the existing habitat.

4. The adjacent garigue area to the west, indicated on the Master Plan as H, is to be cleared from the existing debris and thoroughly cleaned from all illegal dumping deposited within. However, before proposing a regeneration programme for this area, a habitat engineering study has to be carried out and carefully implemented in respect of the existing habitat. It is proposed that a raised timber decking passageway (indicated on the same plan as J) would link the Afforestation Park to the boat jetty at Q connecting this side of the park to the landing place and the Ximenes Redoubt. The berthing place on this side would be adjacent to the Marshland area in front of the existing row of boathouses.

5. The new Afforestation Park, indicated on the Master Plan as N and P, acts as a buffer zone to protect the more important adjacent sites in the area. No interventions are taking place in these areas except for the introduction of two Bird Observation Posts (indicated on the same plan as K) located at the far edge of this park overlooking the garigue, marshlands and salt pans. Limited access is permitted only from Triq il-Melh and Triq J. F. Kennedy whilst vehicular access is only permitted for servicing from Triq il-Qawra.

6. The major planted site known as Kennedy Grove, indicated on the Master Plan as M, is currently an important recreational area popular also as a camping site. The interventions proposed in this area include a small servicing car park and recreational facilities for children. Passageways have been recently paved by the Ministry of Resources and Rural Affairs.

7. The salt pans require however major restoration intervention and investment. The cleaning of the pans damaged due to the floods is more serious when inspected at close range. Many of the retaining walls have collapsed and are beyond any state of repair and therefore have to be partly dismantled and rebuilt. A restoration project is envisaged in full respect of the original structure and materials. The site requires urgent cleaning form the debris and silt carried down the valley and deposited by the storm water during the 1998 and 2003 floods. Wide breaches are present all along the embankments which require heavy intervention of clearing and reconstruction. The paving of certain areas is also necessary to avoid the collapse of the infill materials in exposed areas. These salt pans should therefore be restored and reutilised to ultimately perpetuate the survival of this type of architectural heritage. If no remedial action is carried out there is the risk that these structures at *Salina* will suffer from the consequences of serious structural failure.

   It is estimated that the completion of the whole project would take at least five years. The Salini Rehabilitation Project is divided into the following three main phases:

   Phase 1
   The Afforestation Park was inaugurated in March 2008. This part of the project occupies the upper section of the Salini area between Kennedy Grove and Triq il-Qawra.

   Phase 2
   This phase of the Project focuses on complimenting the work done in the afforestation park with interventions to upgrade the rest of the Special Area of Conservation (SAC). The interventions in the Kennedy Grove did not originally form part of this project although the area will be later managed holistically. Proposed interventions are low key and aimed more at cleaning the area, managing visitors, controlling access (especially by vehicles), and providing a more pleasant visitor experience that would also compliment the work of the third phase.

Phase 3

This phase mainly consists of the restoration and cleaning of the salt pans so that salt production would be possible once again after a period of six years during which this activity has been interrupted due to the damage caused by the rainwater floods. As a matter of fact the salt production had been affected badly by the floods of 1998 and again in 2003. During this last serious flooding which hit the whole island, but in particular the Burmarrad-Salini area, the embankment of the salt pans was badly damaged and the salt pans (under sea level) were flooded with stagnant water and debris. The drainage overflow problem was recently greatly mitigated due to the provision of an emergency generator to a nearby pumping station; however problems still exist further up valley in the area of *Ghajn Rihana*. The coast road itself is actually blocking the free flow of storm water from the upper section of the valleys directly into the canal (*sokkors*). Thus urgent interventions are required to resolve the storm water problem. Part of this project shall also include the reconstruction of the wooden huts, both for the storage and processing /packaging of the salt produced and the construction of a visitors' centre. It is also envisaged to connect Kennedy Grove to the salt pans area by means of a boat commuting around the canals. This would make it possible for the visitors to access the salt pans and the embankment area equipped with the Interpretation Centre in the Ximenes Redoubt and the visitor's centre. Car parking is also required in this area for visitors and tourists and the exact details still need to be discussed so that the necessary facilities are provided in accordance with the Local Plan for the area. It is estimated that this phase of the project would be completed in three years.

6 CONCLUSION

The whole *Salina* area is presently much degraded due to human activities. On the other hand Kennedy Grove is a popular area with the public but there is no control of its use and no planned program for its maintenance and management. The canal itself has already been cleaned up of domestic waste and is now managed as a nature reserve. The public shall be allowed free access to the area of the rehabilitation project. However this shall necessarily have to be limited to constructed paths. Besides the proposed Interpretation Centre in the Ximenes Redoubt, interpretation panels and signposting shall be provided on the Salina itself and close to the proposed marshland to serve as an educational facility for the visitors. In this respect, it should be pointed out that the *Salina* marsh is a site of great ecological importance and harbours a number of species of scientific interest. Thus, the *Salina* area should be respected also for the heritage of its natural features and not seen as a source of nuisance.

Salt production, which is not contaminated by pollution, should not pose any health hazard. As a matter of fact, as regards the problem of nuisance caused by stagnant water, if sewage pollution is found to be present, then the foul smells are probably caused by the decomposition of sewage effluents, in which case it is the drainage problem that has to be solved. If the site is found to be free from any sewage pollution, foul smells could actually be resulting from water stagnation and/or production of H2S by sea grasses such as Ulva lactuca and Enteromorpha linza, both of which are found presently in the same salt pans. These species are often found in polluted regions and are indicators of pollution.

Furthermore, the narrowing of the channel and the cutting down of the circulation of water flow around the canals, together with the input of terrestrial runoff water containing a high sediment load and rich in nutrients, could make the system very susceptible to eutrophication. Presently, during the first weeks of September, algal blooms are regularly observed in the western channel. Such blooms cause a severe reduction in aquatic life in the same canals. Thus, increasing the water movement along the surrounding canals would reduce the possibility of getting a stagnant condition. This would reduce the nuisance of foul smells and the occurrence of eutrophication. Any strategy adopted must therefore not damage the existing marsh, allow the marsh to establish itself and increase water movement.

However, the above situation would not be acceptable to survive in the same salt pans during salt production due to the contamination of the hand collected harvested edible salt, classified by the European Union as a high quality “gourmet” product. Furthermore, originally all the salt pans were utilised in order to have a profitable harvest of salt production. This is testified by the 1957 aerial photo showing various levels in all the salt pans, clearly indicating their full use during salt production. The elimination of some of the salt pans located towards the “corner” directly adjacent to the Coast Road can be considered **only** if this does not diminish drastically salt production levels, making the salt works at *Salina* unprofitable, or if the retention of the same salt pans in the existing condition would be directly in conflict with salt production and EU health standards indispensable for the classification of high quality salt as a gourmet product. This would force the salt industry to close down due to lack of funds and therefore the salt pans would be abandoned in due course, recreating the conditions of the present situation and the eventual deterioration of the same.

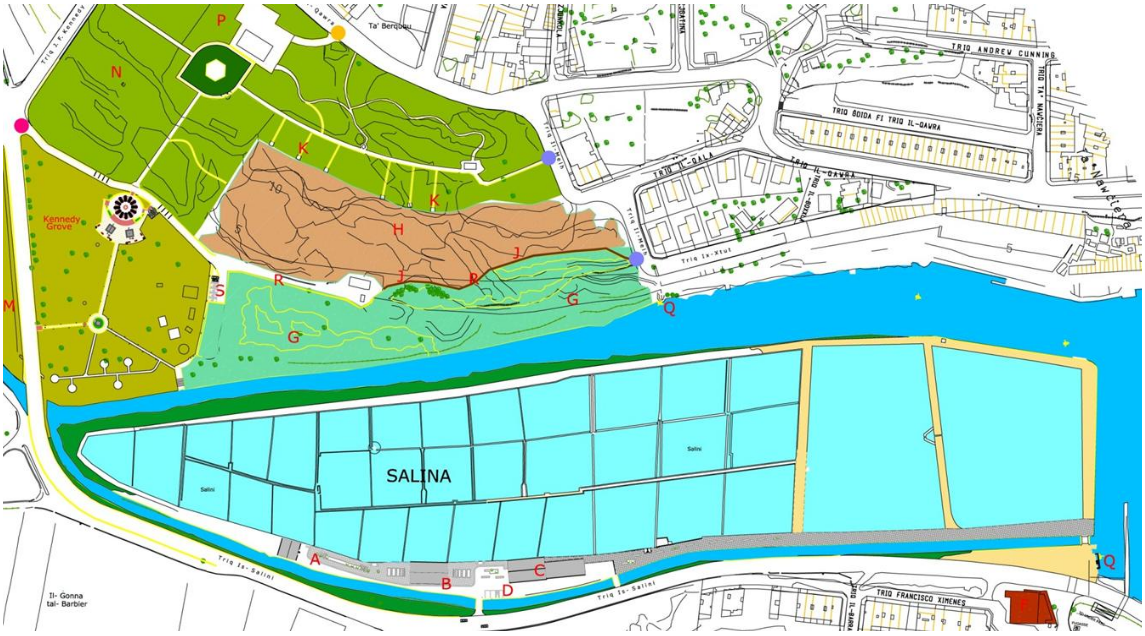

Figure 8. Plan of the Salina in Malta.

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Contributors

Marcello Balzani is an architect, Phd in "Survey and Representation of Architecture and Surroundings", Associate Professor at the University of Ferrara, Faculty of Architecture, where he teaches Architectural Survey and Computer Aided Design. Since 2006, he is the Director of the DIAPReM, the University Research Centre for *Development of Integrated Automatic Procedures for Restoration of Monuments*. Among most prestigious research activities, ha has been leading major research groups in Pompei, Florence, Mantua, Benevento, Milan, Mexico City, Cairo, Salvador de Bahia and Gozo Malta. Since 2009, he is the Director and Scientific Coordinator of *TekneHub*,Tecnopolo of the University of Ferrara, European Platform Construction of the High Technology Network of the Emilia-Romagna Region. He wrote several books concerning architectural and urban survey, development of advanced 3D laser scanner techniques for the conservation and restoration of the cultural heritage, representation and analysis of architecture and urban environment.

Hermann Bonnici graduated in Architecture & Civil Engineering (Hons.) from the University of Malta and completed a M.Sc. in Architectural Conservation (Edin). He is Chief Architect in the Restoration Directorate of the Project Design and Implementation Department in the Ministry for Resources and Rural Affairs, Malta and part time lecturer at the International Institute for Baroque Studies at the University of Malta. Arch. Bonnici is currently reading for his PhD at the University of Malta, where his field of research focuses on the formulation of scientific guidelines for a national conservation strategy for the Hospitaller military architecture heritage of the Maltese Islands.

Ruben Paul Borg graduated in Architecture and Civil Engineering (Hons.) from the University of Malta and completed the Specialisation Degree in Concrete and Reinforced Concrete Structures at the Politecnico di Milano. He lectures at the Department of Civil and Structural Engineering of the University of Malta and is active in lecturing and research at the Politecnico di Milano and at the Universita' di Napoli "Federico II". He has participated on a number of European research projects, and has held various posts including: Coordinator (Work Package Materials and Technology - Sustainable Construction ESF-C25); Vice Chairman (Technical Work Group Refurbishment Strategies - Quality of Suburban Buildings ESF-TU0701); Management Committee member (Urban Habitat Constructions under Catastrophic Events ESF-C26). He is Vice Chairman of the ECCE (European Council of Civil Engineers) Knowledge & Technology Standing Committee. During the past years he was member of various technical committees within National organisations in Malta including the Malta Standards Authority and the Building Industry Consultative Council. His main research areas include concrete materials and structures, sustainable construction, waste management and vulnerability assessment of structures. During the past five years he has worked on structural vulnerability analysis of buildings and the historic centre of L'Aquila following the Abruzzo earthquake in 2009 and in the Vesuvian area in Naples. In his professional activity, he has been active in Malta and other countries, particularly on materials technology, civil and structural engineering, construction products and quality management systems and architectural design. He is Council member and co-chairman of the Built Environment Standing Committee of the Kamra tal-Periti (Chamber of Architects & Civil Engineers, Malta) and coordinates the Civil Engineering Encounters series of events.

Claude Busuttil is an Architect, the director of ARCstudio Ltd. and part time assistant lecturer at the Department of the Built Heritage of the Faculty for the Built Environment of the University of Malta. He has previously worked mainly on restoration and conservation projects, interior design and project management for Government, Ecclesiastical and private entities. He obtained a Bachelors and Masters Degree in History of Architecture and Restoration of Monuments from the University of Florence (Italy) where he graduated in 1998. During the last 10 years, he worked in restoration consultancy for Government entities and other authorities on conservation of monuments, churches and historical buildings, and was Executive Secretary of St. John's Co-Cathedral Foundation between 2004 and 2007. He is currently reading a doctoral degree at the University of Sorbonne – Paris IV.

JoAnn Cassar is Head of the Department of the Built Heritage, Faculty for the Built Environment, University of Malta. Prof. Cassar has lectured at the University of Antwerp, the Artesis School for Conservation in Antwerp, University College London and the Istituto Universitario di Architettura di Venezia, as well as on International Summer Schools for graduates. Having carried out research since 1981 on the composition, properties, deterioration and conservation of building materials, she has over fifty scientific publications to her name. She sits on the Government appointed Scientific Committee for the Conservation of the Megalithic Temples. She is also a member of the Editorial Board of the Quarterly Journal of Engineering Geology and Hydrogeology of the Geological Society of London, as Associate (Overseas) Editor. She is a Fellow of the International Institute for Conservation (FIIC), Fellow of the Geological Society (FGS), Chartered Chemist and Fellow of the Royal Society of Chemistry (CChem FRSC).

Vincent Cassar graduated in 1971 in Architecture and Civil Engineering from the University of Malta. Since then he has worked in the public sector, first as a Junior Architect and Civil Engineer with the then Public Works Department rising to become the Director General of the same organisation in 1992 and leading its transformation into the Works Division consisting of seven Departments. In 2003 he was appointed as Permanent Secretary in the Ministry for Youth and the Arts, later moving in 2004 to the Ministry for Urban Development and Roads from where he retired in June 2008. Since then he runs his own professional practice. Perit Cassar is currently the President of the Kamra tal-Periti.

Roberto Di Giulio is an architect, Phd in "Technology of Architecture", Full Professor at the University of Ferrara, Faculty of Architecture, where he teaches Construction Design and he has been the head of Department of Architecture since 2006. His studies cover a broad range of issues from studies of industrialization of building process and building design methodologies to investigation on real estates and cultural heritage maintenance and management. He is partner of Ipostudio Architects, a planning and research organisation operating in the fields of architecture, design and research, in Florence since 1982. Within his design activity, he has been concerned with building design and took part in numerous architectural competitions. His works with Ipostudio have been published in the book "Ipostudio, la concretezza della modernità" edited by Marco Mulazzani, Electa, Milano 2008. He wrote several books concerning building technologies, design methodologies

Reuben Grima is lecturer in the Department of the Built Heritage (Faculty for the Built Environment, University of Malta), studied archaeology at the universities of Malta and Reading, then read for his PhD at the Institute of Archaeology, University College London, where he held a Commonwealth Scholarship. Throughout the implementation of the Ħaġar Qim and Mnajdra Conservation and Presentation Project, he had the role of Project Leader, while serving with Heritage Malta as Senior Curator responsible for Malta's prehistoric World Heritage Sites. His research interests include landscape archaeology, archaeological site management, the history of colonial archaeology, and public engagement with the past.

Federico M. Mazzolani is full Professor of Structural Engineering at the Department of Structural Engineering of the University of Naples "Federico II". He was awarded a Doctor Honoris Causa at Technical University of Bucharest (1995); Doctor Honoris Causa at Politehnica University of Timisoara (1996); Charles Massonnet award (2001). Prof. Mazzolani is Member of the Royal Academy of Engineers of Spain (since 2000); Member of the Academy of Engineers of Czech Republic (since 2004); President of the Doctoral School of Civil Engineering (since 2005) at the University of Naples "Federico II"; President of the Master in Design of Steel Structures (since 2006) at the University of Naples "Federico II"; Chairman of the ECCS-TC 13 Committee "Seismic Design" (1985-2007); Chairman of the CEN-TC250/SC9 Committee "Design of Aluminium Structures" (since 1992); Chairman of the national "mirror" committee for Eurocode 3 (Steel structures), Eurocode 4(Composite steel-concrete structures) and Eurocode 9 (Aluminium structures) (1990-2006); Chairman of the International STESSA Conferences on the "Behaviour of Steel Structures in Seismic Areas" (since 1994); Coordinator of the ILVA-IDEM research project on "Seismic upgrading of RC buildings by advanced techniques (2000-2005); Coordinator of the international PROHITECH Project on

“Earthquake Protection of Historical Buildings by Mixed Reversible Technologies” (2004-2008); Chairman of the COST C26 Action on “Urban Habitat Constructions under Catastrophic Events” (2006-2010); Chairman of the Steering Committee of SIJLAB “Sino-Italian Laboratory for Archimedes Bridge” (2004-2008); Coordinator of the international Sino-Italian REHICO project on “Innovative methodologies for the rehabilitation of historical constructions” (2006-2009); Member of the Canadian Standard Association (since 2007); Member of the Board of IAESE (International Association for Experimental Structural Engineering) (since 2008); Member of the ESF Pool of Reviewers (since 2009). His main research areas are earthquake engineering (seismic design, passive control) and structural restoration (consolidation, upgrading).

Katya Stroud studied archaeology at the University of Malta graduating with a Masters degree in 2004. Her studies have focused mainly on the history of conservation and management of archaeological sites, particularly the Maltese Megalithic Temples. Between 2000 and 2004 she worked as a freelance archaeologist as part of Archaeology Services Co-operative Ltd. Participating in rescue excavations, Environmental Impact Assessments and the design of various projects for archaeological sites in collaboration with Local Councils and the Malta Environment and Planning Authority. These projects included the design of conservation plans as well as interpretation resources using various media. She has been employed with Heritage Malta since 2004 and is currently Senior Curator of the Prehistoric Sites Department. She was also Chairperson of the Scientific Committee for the Conservation of the Megalithic Temples for five years, and delegate Project Leader on the Ħagar Qim and Mnajdra Conservation and Interpretation Project funded through ERDF Structural Funds 2004-2006. She is particularly interested in the study of the history of conservation and management of archaeological sites and the way these have influenced the way we view and value these sites today.

Alex Torpiano is an Architect and Structural Engineer by training, currently Dean of the Faculty for the Built Environment, but also Head of the Department of Civil and Structural Engineering. Prof. Torpiano has UK Chartered Engineer status, and is a Member of the UK Institution of Structural Engineers. In 1994, he set up, and directed, the Institute for Masonry and Construction Research up to 2009, when it became the Department of Built Heritage within the Faculty. Currently, he is Chairperson of the International Institute of Baroque Studies, and member of the Institute of Sustainable Energy, and of the Institute of Sustainable Development, within the University of Malta, and also currently a member of the University Senate, and of the University Council. He is also a member of the Periti professional Warranting Board. He has had a long career in private practice, since 1988, when he set up what is now a leading architectural and structural engineering practice in Malta, TBA Periti, and since 2000, when he was one of the founding partners of aoM partnership, a multi-disciplinary practice responsible for the Manoel Island and Tigne’ Point Redevelopment Project. He has worked on many projects involving the restoration of heritage masonry structures, including Fort Manoel, Fort Tigne’, Fort Cambridge, Fort Chambray, Garden Battery, Auberge de Provence, Bichi Palace, and the House of Catalunya, as well as on a number of local parish churches, and also on the Mnajdra, Hagar Qim and Ggantija Prehistoric temples. Between 1994 -1996, he was chairman of the Governing Board of the newly-setup Centre for Restoration Studies, and a member of the Board between 1999 and 2001. He was also Chairman of the Valletta Rehabilitation Committee between 1995-1996, and 2000-2001, and President of the Council of the Chamber of Architects and Civil Engineers, between 1994 and 1996.

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Kamra tal-Periti

Faculty for the Built Environment
University of Malta

Dipartimento di Ingegneria Strutturale
Università di Napoli "Federico II"

Università degli Studi di Ferrara

Dipartimento di Architettura,
Università degli Studi di Ferrara

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