SHH07

STUDIES on HISTORICAL HERITAGE

Proceedings of the International Symposium

Antalya, Turkey
September 17-21, 2007

Edited by Görün ARUN

Organized by
YILDIZ TECHNICAL UNIVERSITY
RESEARCH CENTER for PRESERVATION of
HISTORICAL HERITAGE
TA-MİR

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PREFACE

Historical heritage that contain the architectural forms and the artistic values are under the danger of deterioration through the crucial environmental problems of urbanization and pollution, natural hazards, ignorance and new demands of the society. Safeguarding the continuously deteriorating material and construction of a historical complex, city or archaeological site with their natural and manmade environment necessitates integrated management and harmonious work of a multidisciplinary team of specialists dealing with history, urban planning, architecture, archaeology and different fields of engineering. Besides the interdisciplinary language the conscious participation of the society is also required so that the proper political decisions can be assured.

The International Symposium on "Studies on Historical Heritage" in Antalya, Turkey on September 17-21, 2007 is organized by Yıldız Technical University, Research Center for Preservation of Historical Heritage. The symposium is as a continuation of the previous international symposia entitled "Studies in Ancient Structures" held in Istanbul in 1997 and 2001.

The symposium provides an international and interdisciplinary forum for researchers, leading experts and people from application to exchange their experience and knowledge and disseminate information on preservation of historical heritage. Its aim is to enhance knowledge, increase awareness of the current technology and methodology and encourage studies of different disciplines working on historical heritage.

Studies on Historical Heritage highlight the state of the art in the diversity of professional skills, experience and knowledge necessary for preservation of historical heritage. Contributions of different disciplines from 22 countries contribute their own experience and attempt to express in interdisciplinary way the new concepts, technologies, methods and materials for the conservation and management of historic cities, sites and complexes.

These Proceedings containing papers sent by the specialists of different fields to the SHH07 Symposium is grouped according to their content, rather than according to their presentation, in order to make it more useful as a reference text. The Chapters are on: Historical Aspects and Documentation of Architectural Heritage and Their Environment; Archaeological Studies; Future of Historical Heritage- Heritage Management; Experimental Methods and Test Results of Materials; Structural Concepts**;** Intervention, Restoration And Preservation Techniques and Methodology. The author index is at the end.

The proceedings contain the papers that are reviewed. We wish to acknowledge and express our sincere gratitude to the Scientific Committee for spending their precious time in reviewing, editing and making significant recommendations to the authors. Special thanks to or keynote speakers; L. Binda, A. Galla, K. Kawaguchi, E. Madran, P. Roca, Y. Schaffer and T.P. Tassios whom we greatly appreciate their views on preservation of historical heritage. Of course, without the timeless efforts of the organizing committee members, this

symposium could not have been realized. Many thanks go to our sponsors and supporters for their invaluable and generous financial and technical contributions which indeed provide important link between the people in application and academia.

Finally warm thanks to all the authors from different parts of the world that have made considerable scientific contribution from their ongoing research activities. It is hoped that these contributions may be useful for professionals and researchers engaged in the problems of preservation and for those who have interest in the Studies on Historical Heritage

Dr. Görün Arun
On behalf of the SHH07
Organizing Committee
August, 2007

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THE OLD CITY OF ACCO – A CONTINUOUS LABORATORY OF URBAN PROBLEMS AND CONSERVATION BETWEEN 1990–2007

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ABSTRACT

The complicity of coping with the conservation of an urban environment especially with its physical aspects is not new for professionals in the field. I would like to concentrate on 10 issues that we dealt with in the last 17 years at Acco (Acca, or Akko or Acre or Acri).

1. INTRODUCTION

Fig 1 - Map of Acco

Fig 2- Acco from the south

The complicity of a historic living city

The complicity of coping with the conservation of an urban environment especially with its physical aspects is not new for professionals in the field. I would like to concentrate on 10 issues that we dealt with in the last 17 years at Acco [Acca, or Akko or Acre or Acri].

1. To approach and convince national and local authorities that the city has real values as a Cultural Heritage Site". This was achieved in the years 1992-1995. In 2000 the city was declared as "World Heritage Site" on the list of the World Monuments!!!!.

2. To convince the responsible authorities that the physical-structural approaches used since the early 1990' are destructive on long term and more expensive than the modern conservative approaches and Acco doesn't gain from it. [We succeeded and began to get budgets for a detailed physical and structural survey of the whole city, including designing and planning of details that were prepared as technical protocols].

3. To begin to distribute conservative technique for conservation of buildings and sites, by learning also from other places in the world. To create a team of professionals who were able to give "first aid" with the right approach of rehabilitation and conservative direction. [This was achieved and we got budgets for training courses and specializations and by inviting of specialists from abroad].

4. To allocate budgets for various pilot projects and local researches with the flexibility to change details, if needed. In spite of the high prices it was absolutely needed to save also features and decorative details of the various sites and buildings. [We succeeded and stopped the destruction of wooden decorative ceilings and the use of concrete slabs. We also implemented pilot projects on single buildings, special features in sites and buildings and on materials mixture prepared on the site or imported].

5. To create an infrastructure comprise of architects, engineers, project managers, workers in historical buildings and sites and conservators and to maintained it for a long period of time. [we mobilized a good staff including archeologists, architects, engineers, conservators and workers].

6. To convince that a good and right conservation and rehabilitation plans can't be executed by bits based of the lowest price. [We failed to implement this issue!!!].

7. To create a long term working plan for the various professionals and specialists, so that a new generation would be able to continue and develop the urban conservation and rehabilitation. [We failed to achieve this because there was an intense turnover in the personnel without continuity!!!].

8. The "momentum" that we created was relatively short in time so the mass of work in rehab and its results did not have an immediate impact for long term. [10 years passed between the initial pilot project and the main urban conservation complex pilot project!!!].

9. We learn that local inhabitants who live in the buildings and near the large sites has to feel that they benefit from them, but also to be convinced that the

conservative approaches are the right way. [No success was achieved in this issue!!!].

10. We learn that the legal and planning systems have to back-up all the conservation acts of urban environmental activities. [There was no change in the "non-interference" policy of the legal system as for the implementing the law in the rehabilitation at the old city of Acco.

Following is a description of the projects that were completed in the last 7 years. This will provide you with the opportunity to understand the complicity of the task to conserve the old city of Acco.

In the last fife years and due to the improved economic condition in Israel the old city of Acco [Acca] also enjoyed important development in its Cultural Heritage:

- Planning, designing and the beginning of the rehabilitation of the "Pilot Project" on the Block 10 (the "Square Quarter").
- The positive decision enabled the implementation of the conservation of the " Museum of Heroism " as a part of the Ottoman Pasha Palace that was converted into the British Prison, both situated above the fort of the Crusaders Hospitalar Order .
- Opening to the public of the "Turkish Bath of El-Giazar Pasha.
- Preparing to open a new part of crusaders under ground complex of streets, mainly the "East and South Crusade Streets" around the Fortes.
- The decision and the beginning of its implementation to establish in the College of Western Galilee in Acco, a 4 years program on the Cultural Heritage. This will be integrated with the Center for Conservation established in one of the Ottoman buildings in the Old City.
- Other research projects concerning of conservation and adaptive use continued their path. Among these are: rehabilitation of the Ottoman walls of the Old City, rehabilitation of buildings and the final touch of the converting the "Old Court House" into a hotel.

2. "THE PILOT PROJECT"

This project was proposed in 1999 by the Israel Antiquities Authority [IAA], approved in 2001 and began to be planned in 2003. It deals with the rehabilitation with conservation criteria of about 50 buildings in the Block 10 on the western sea coast of the Old City.

It is the first time that an interior residential quarter is considered for urban conservation. It was intended to demonstrate the right urban conservation in this old city. From the economic point-of-view it was designed to use the empty apartments and infill them by using the Antiquity Law to demolish parts of the buildings in order to do "Anastylosis" for increasing the potential of those buildings.

Based on the estimated feasibility, the rehabilitation and conservation systems, time, costs and problems it was decided to plan 13 buildings that where work was mainly finished some months ago. Another 80 endangered apartments were technically and structurally treated.

Fig 3 – Buildings in rehabilitation

2.1. The " Museum of Heroism "

After many years of discussions, programs, plans and designs a budget was allocated for the executive phase of the conservation and the reuse of the former Ottoman palace of El-Gazar Pasha as a museum. The museum will present the Israeli struggle for independence from the British Mandate [1917-1948]. Being the museum located in part of the crusade ruins, with later additions of the 16^{th} through 20^{th} centuries, it requires a sensitive conservation approach from the cultural heritage, political and administrative aspects.

The work needed large scale engineering static works and conservation and infrastructures input. These gave an opportunity to treat the upper "Museum of Heroism" and the underground "Crusade Forte" with the same criteria, same architects, engineers and implementing staff. It is only when the whole complex is considered together it is possible to understand its shape and dimension of this site.

About 18,000,000 Shekel (= 4,300,000$) were invested till now.

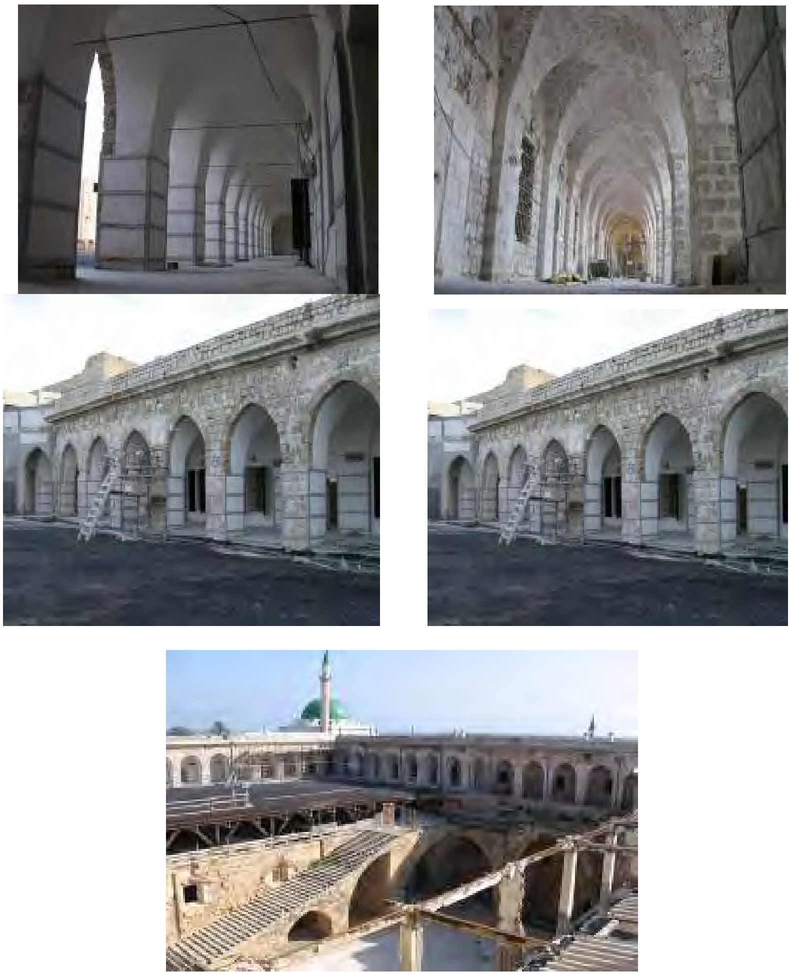

Fig 4 – The Ottoman and Crusade Fort

2.2. The Opening of the Turkish Bath of El-Gazar Pasha"

This project included the conservation and rehabilitation of the buildings and courtyard of the Turkish bath. Being one of the two Ottoman baths in the old city, the decision was made to use this one as a museum named the "Last manager of the Bath" which presents by audio and video means the atmosphere of this monument, its stories and legends and its uses.

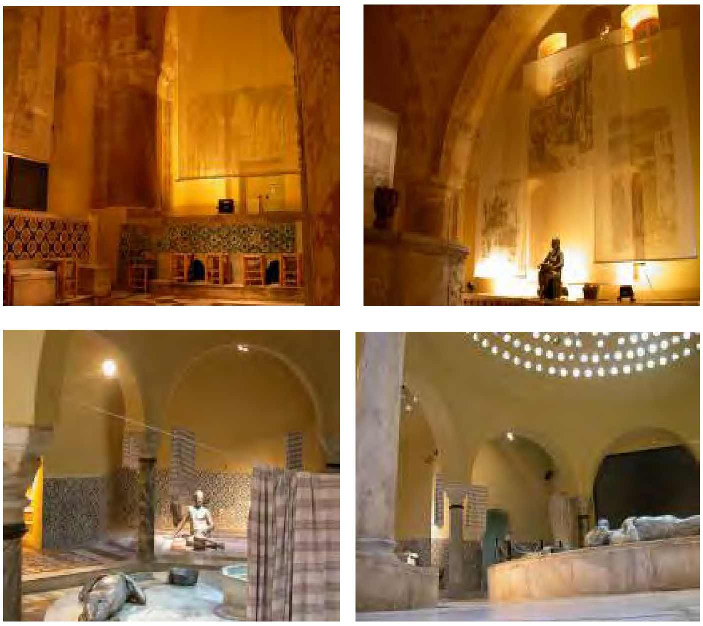

Fig 5 – Interior of the Ottoman Bath

The rehabilitation recovered parts of the building, connected it with the Crusade Hospitalar Fort via an underground passage.

About 9,000,000 shekel [=2,100,000$] were invested so far.

2.3. Opening of the Underground Crusade Streets around the Hospital Fort

After 12 years of engineering stabilization and conservation and 6 years after the discovery of the "graffiti of pilgrims" on the walls of the buildings annexed to the street, we finally opened the complex. The path is around the Fort and it consists of facilities for the disables.

About 5,000,000 shekel [= 1,000,000$] were invested in this project.

Fig 6 - The south underground street

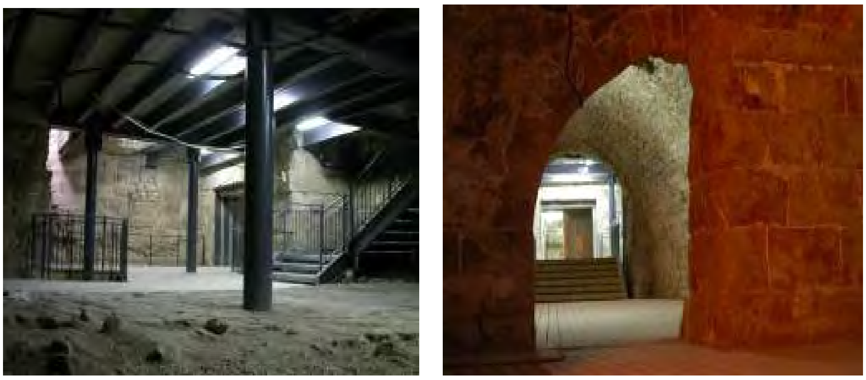

Fig 7 – the east underground street

Fig 8 – other underground streets

3. THE CONSERVATION CENTER AND THE PROGRAM IN CULTURAL HERITAGE IN CONJUNCTION WITH THE COLLEGE OF WESTERN GALILEE IN ACCO

The Conservation Center of Acco was established in a historic Ottoman buildings on the southern side of the old city. It has a central large Ottoman Palace and right to use other buildings as well. This is a joint project of the IAA, the College of Western Galilee, the Company for Development of Old Acco and the Municipality.

A 4 years BA program in Cultural Heritage will be offered in the Center.

Until about 1,300,000 shekel [300,000 $] were invested.

3.1. The rehabilitation of the Ottoman Walls

The rehabilitation and conservation works of the exterior walls of the Old City continued concentrating on the northern and eastern sections.

More than 16,000,000 shekel [= 3,700,000$] were invested till now.

Fig 9- The city walls

3.2. The Templar Tunnel

All the engineering and stabilization works and archeological excavations were completed. The tunnel connects now the western sea shore of the Old City with Khan el-Umdan on the eastern part.

The budget in the project was 14,000,000 shekel [3,000,000$].

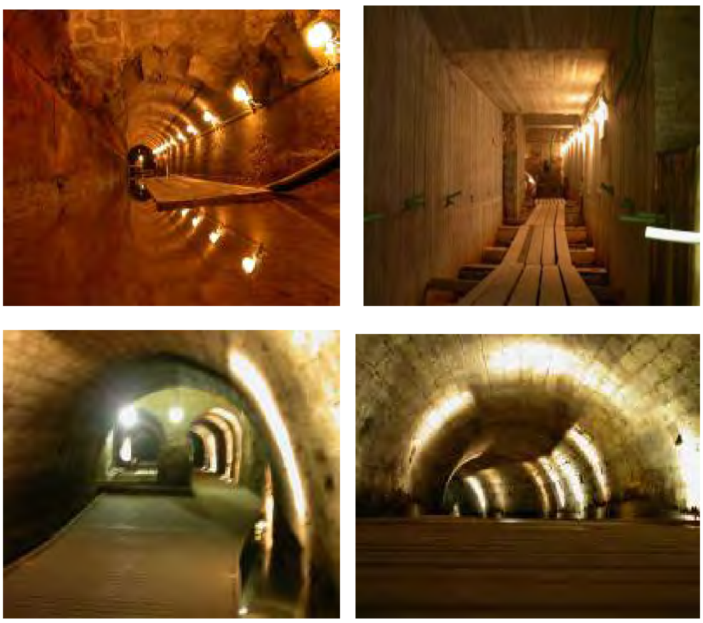

Fig 10 – The Templar tunnel

4. SUMMER SITE LABORATORIES WITH STUDENTS FROM ABROAD

During the last 14 years, students of various conservation skills are coming to Acco for several months from all over the world, to practice field experience. The works are conducted on different sites such as the Hospitalar Fort, historic Ottoman Sabils" or Ottoman historic houses.

Fig 11 – Volunteers in conservation works

"Rampart"

Beginning in this year, Israel is participating in the France project "Rampart" which was created in France. This project deals with conservation of medieval fortresses with the assistance of volunteers from all over the world. The project was implemented in the Hospitalar Fort.

5. CONCLUSION

After more than 17 years of large and intense conservative activity in Old City of Acco, it is worthwhile to examine the physical issues relating to the rehabilitation and conservation of the sites and buildings that are yet to be resolved, as the following:

1. Professional understanding, planning and designing of the sites.
2. The use of light materials for additions which creates statical problems for the original buildings.
3. The moratorium to extract the "kurkar" stone from all the quarries in Israel, create a need to find a solution to the building materials as another type of stone or plaster o other materials.
4. Urban and social problems.

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HERITAGE & URBAN DESIGN – THE FUTURE OF THE PAST

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ABSTRACT

The dynamic of the city is to be seen in the tension between the existing cityscape and the demands of later periods for change. It is in this struggle with the landscape, and later in the zones between landscape and the city, between natural place and man-made space that the city arises and develops. It is in the struggle between tradition and renewal, between permanence and change that the city matures, gathers and incorporates the many cultural statements and achieves its individuality.

Whatever the conditions, certain fundamentals have held over the last couple of thousand years. The cities that have flourished have been planted in favourable locations on trading routes, and yet far enough away from each other to not compete directly. They impress us with their compactness, which partly comes from being walled in for protection, and also because narrow streets serve to minimise oppressive natural elements and maximise land values. The key to survival, however, is ensuring that people want to live in the city.

For a city to survive today it needs to provide more than security and employment – it has to provide the kind of places people want to inhabit, without becoming fossilised. The streets and public spaces are not merely functional means of moving around; they provide the theatre in which everyone can be an actor and live their lifestyle.

1. URBAN DESIGN

There are numerous definitions today for ‘urban design’, each denoting a range of concerns and activities that differ from one another in scope, objectives and practices. The Urban Design Group, UK, suggests that urban design is "concerned with the careful stewardship of the resources of the built environment in the creation and maintenance of those parts of the public realm that are new or have been cherished"… but it still does not define urban design.

Although pre-designed urban surroundings existed long before any definition, it was in the 1970s that the concept of urban design was introduced.

The reasons for this conceptualisation may be embedded in specific situations, acknowledged by professionals and the public in the late 1950s. They formed the raison d'etre for the newly defined sphere of activity and were constantly reaffirmed in urban design discourse: to give people back that which modernist sterility, abstraction, uniformity and minimalism had taken from them.

The outcome of modernist urbanism was placelessness.

Urban design was directed towards placemaking.

Urban design was established in opposition to modernist urbanism and there was a broad common denominator among creators of normative theories, such as, the intention to re-establish quality of place in the public realm.

Just as the renewed interest in postmodernist urban fabric arose from the need to exploit all possible local assets to assist the reorganisation of post-industrial inner cities, and especially the tourism industry, so did placemaking. Evoking a 'sense of place' is related to human scale, emphasis on the local (historical, natural or cultural), legibility, defined urban spaces, pedestrian circulation, stimulation of all senses – the essential characteristics of downtown.

Although nowhere has urban design become a distinct profession, it has been embraced into the heart of 'good practice' guidelines, particularly in Britain and other European countries. For the better part of the last century, visions of the city were reduced to what could be engineered to fit the abstractions of a technological milieu and its economic dictates. This became a world of immediacy, of concreteness, where the real and the possible were framed by the Cartesian dictates of technological determination, which, in turn came to be indiscriminately understood as the only form of realism possible.

There is an emerging need for a triumvirate of influences to guide the development of urban centres (Figure: 1).

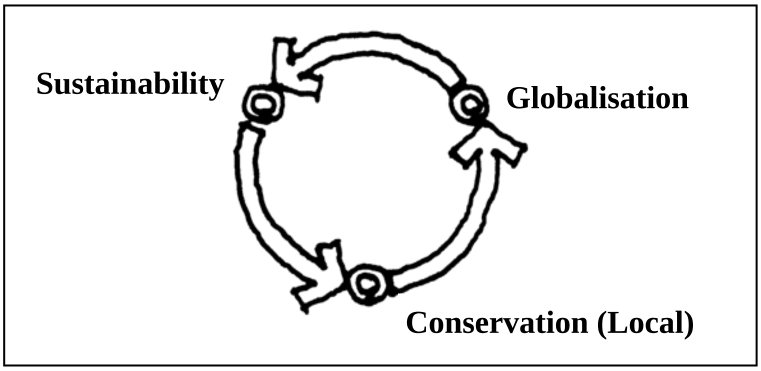

Figure 1: Influencing Urban Form

1.1 Globalization

More than ever, markets appear to transcend the borders and interests of nation states, while the ability of individual countries to direct their internal economies and shape the way in which they interact with external forces has declined. These changes reshape urban networks and rearrange the distribution of opportunities and income in cities, regardless of a city's participation in global economics.

Due to the modern-day capacity and ability of capital to switch locations, all cities- with the exception of 'global cities' which are decision centres- have become interchangeable entities to be played off against one another from positions of comparative weakness for the investment of capital. In this situation, the task of urban governance has become the creation of urban conditions attractive to lure investments.

In many places, there has been a shift in the attitudes of urban government from a managerial approach to entrepreneurialism. This entrepreneurial stance views the city as a product that needs to be marketed. This marketing approach, and the emphasis on restructuring the city so it appeals to businesses, has led to the dominance of economic interest in the decision-making process of urban planning. 'Urban regeneration' has become a growth industry in itself as a variety of options have opened up to rebuild cities…derelict industrial sites have been converted to heritage parks, old canals have become housing or shopping areas, warehouse conversions have become something "chic" to live in.

Uses of urban design fitting into their development prospects involve redevelopment, renewal, reconstruction and revitalisation of urban space. Larger cities in economic decay, such as port cities and old industrial centres, have often considered reconstruction, redevelopment, renewal and revitalisation of historic centres, or declining urban areas or waterfronts, etc; as a top priority in the hierarchy of their actions to restructure the local economy. One example could be taken of Liverpool and the redevelopment of the city's docks in the 1980s as well as Rotterdam and the waterfront redevelopment of Kop van Zuid in the 1990s. In both cases, redesigning of urban space was focussed on adding to the architectural heritage and producing at the same time new space for flourishing economic activities and lively uses such as cultural, leisure, housing and commerce.

Larger cities have also been making great efforts to accommodate major international events, such as the Olympic Games and international exhibitions. These kinds of events are considered catalysts for major urban makeover exercises. For example, the Olympics at Barcelona in 1992 served to accelerate the city's physical, economic and social restructuring during the period 1986-92.

Smaller cities flourished in the late 1970s and 80s – a period which was marked by counter-urbanization. Smaller cities were the major beneficiaries of this phenomenon and exhibited rapid growth due to a series of factors. The diseconomies associated with larger cities, such as congestion, lack of space, high costs and expensive overheads for services prompted decentralisation of certain economic sectors (e.g. Manufacturing industries) from metropolitan regions towards smaller cities.

However, the majority of smaller cities usually suffer from major structural weaknesses: inadequate infrastructure, limited inward investment and technological underdevelopment. Some of the cities lack indigenous resources, i.e. archaeological and cultural heritage or a particularly attractive natural environment. In such cases, urban design may become a determinant factor for their future. The production of a new urban image – whether contradicting local heritage or not – can, if successful, counteract the sense of alienation and shape a new form of localism.

Much of the recent interest in urban design repeats the familiar deficiencies of the past: a focus of the superficial aesthetics and the picturesque aspects of cities (instead of the role that aesthetics play, say, in community development), an understanding of urban design primarily as a finished product; instead of an ongoing long term process linked with social and political mechanisms.

1.2 Conservation

The most common reason for preserving old buildings, leaving aside historic interest, is that they are useful resources. This might seem rather obvious, but is often forgotten.

A building usually reaches the end of its 'natural life' as a result of external economic forces and operational obsolescence rather than because it has ceased to be capable of repair. An example may be taken of the sturdily engineered warehouse buildings in various docks around Britain in the 1970s, which rapidly decayed and were demolished by the hundreds. These had not become unmaintainable, they had simply become redundant.

There are some buildings that are worthy of preservation for their own sakes, these may be celebratory and magnificent; rare and curious; commemorative and associative; exemplary and instructive or perhaps pleasing and picturesque. These are usually monuments in our cities, and ample evidence exists of preservation and conservation efforts for these kinds of buildings through history. As early as 1877, societies such as SPAB (Society for the Protection of Ancient Buildings) in England, have led these efforts. The manifesto of SPAB can be summed up in three basic tenets:

1. We are custodians of the ancient buildings we have inherited. We should not regard ourselves as free to do as we please with them.
2. Effective and honest repair should always be the first consideration.
3. We should do no more than prudence demands. In particular, we should not fall into the trap of allowing scholarly or artistic ambitions to dictate what is done.

The Manifesto had another thought which was later withdrawn, namely, that it was better to raise a new building rather than enlarge or alter an old one which had become inconvenient for modern use. This was replaced by:

4. Any permanently necessary new work should be clearly distinguishable from the old and should not reproduce any past style.

The aim of conservation is to retain or recover the cultural significance of a place and must include provision for its security, maintenance and future. The object of conservation is seldom to prevent all change, but rather to manage it positively. Policies must aim to keep the asset or area alive, yet ensure that any new development accords with its special interest.

1.3 Sustainability

Sustainability, a global issue of our time, is not yet so well defined or covered by practical policies or guidance, but is readily integrated into both conservation and urban design. It is concerned with how we develop in this generation without taking from the next. Buildings which last and continue to be useful can bring economic benefits and act as an engine for regeneration. Conservation can thus be justified not only on environmental grounds, but also because it can create confidence and a climate in which economic activity can flourish.

2. HERITAGE & URBAN DESIGN

Urban design conservation has evolved dramatically during the last 30 years or so as an urban design discipline necessary for dealing with older city districts that were previously reduced to being the location of monuments worthy of architectural restoration. Recent international experiences in urban conservation vary greatly in their focus and intent and still demonstrate the conflicting interests of archaeologists, who focus on monument restoration, and urban designers whose interest is in conserving the spirit of the past. However, it is probably best for the skills of planning, archaeology and urban design to collaborate to create a truly lasting and significant urban experience that has a historical identity.

Authenticity in urban design needs to be dealt with sensitively, as it involves conserving streets, alleys, buildings, social practices and community cultural beliefs that are spread over a large urban area. There is danger of the urban designer ending up with a 'Disney-esque' version which is merely an illusion that bears little or no connection to the history of the area. Authenticity is vital to the honesty of the urban conservation project but there need not be false accuracy or unnecessary sensitivity about all the urban or social details of the project.

To pursue this idea, it is essential to differentiate between a conservation concept and a conservation methodology. A methodology is a practical way of following a process for conservation, while a concept is the central bonding idea behind the choices made during the practical process. In most cases the urban designer's task shall be limited to formulating the urban conservation concepts and putting in practice a part of the conservation methodology. Seldom will an urban designer make managerial or financial decisions for a community. Consequently, the urban design conservation concept becomes a part of a larger consideration for the area. However, the concept can go a long way in influencing the project and can ensure, for example, community support and the encouragement of local businessmen.

The economic objectives of urban conservation, as of any other human activity, have been impacting heavily on urban conservation projects during the last 20 years or so. Cultural tourism has become the major source of finance for costly urban conservation projects and a major determinant of their form and methodologies. This economic impact of cultural tourism directed the methodologies of urban designers to create place to attract tourists. Both urban designers and city administrators became interested in the concept of genus loci, the power of place. The spin-off was the other urban phenomena that reflected a ‘personality’ and identity of the place. Having a historical identity in urban conservation became desirable and capable of attracting tourists to the place through honesty and authenticity. The physical and historic identity of an urban area may stem from its streets, its urban mass and its overall urban character.

The concepts are simple. The urban conservators/designers need to develop the meaning and function of the place so that it becomes comprehensible to the public. This meaning might be economic, cultural, social or political, with a definite heritage bias. If such meaning coincides with the choice of an authentic place to start with, a successful urban conservation intervention may result.

Successful urban intervention in depends upon achieving a constructive relationship between regulatory policy, financial feasibility, the design approach and relevant context (Figure: 2).

Regulatory policy cannot be ignored, for legal reasons. Financial feasibility shall ensure the commercial success of a project and thus it’s potential to form a sustainable and sustained economic contribution. If the design approach is wrong, quite simply, the project objectives will not be met and the quality of the delivered project shall be poor. Not responding to the local context shall render the project generic.

This implies that while the project may be easily replicable, it offers nothing to the local and thus is in no way unique. Such projects, in turn, do not often succeed financially or gather community support.

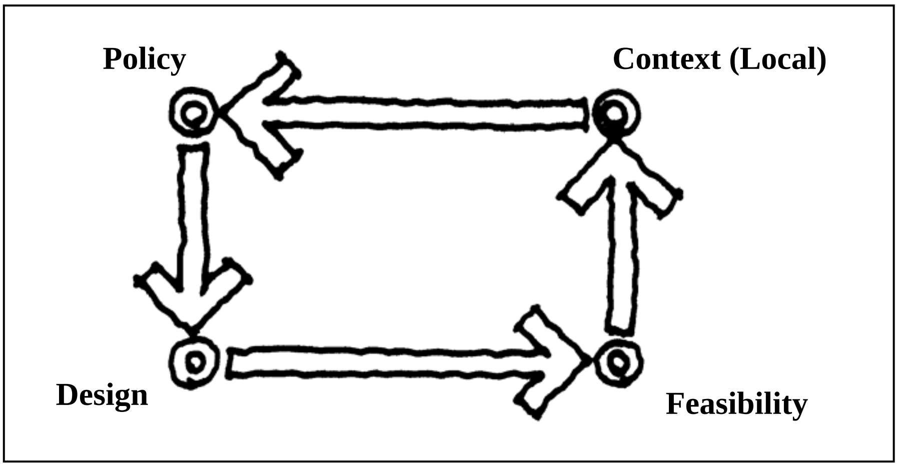

Figure 2: Process of Urbanisation

3. CONCLUSIONS - THE FUTURE OF THE PAST

In most Asian cultures, the idea of simply keeping an old building or parts of old urban fabric, simply because they are old, would not be thought to be at all reasonable. From this viewpoint, every building, city, or city quarter, has an indestructible soul - a permanent reality that can survive any number of renewals and rebuilding and still remain intact. In the case of most revered ancient monuments and temples, entire structures may be destroyed and rebuilt from the ground up without losing any cultural or social significance.

Historic spaces of a city are valuable for their contribution to the setting and disposition of the enclosing buildings. They are also important for creating a sense of place and providing a vehicle for memory - imagine the Taj Mahal as a traffic island surrounded by high-rise offices. Responsibility for the care of these spaces and sustaining a sense of place is borne by no single discipline. All must be committed to stewardship and contribute to securing quality. The management of the historic environment requires a special degree of sensitivity and understanding. In providing this, the urban design discipline takes on an important role. It becomes more of a way of thinking, applicable to all disciplines and especially architecture, town planning and infrastructure engineering.

The re-emerging giants of Asia have a wealth of historicity that can be severely and permanently damaged if these issues are not taken up immediately and addressed in the government policies. This is even more critical in these times of frantic economic growth (in these parts of the world) where the desire to create advantageous business environments can often result in negligence in this regard.

While the seeds of urban fragmentation were sown by the garden city movement, it was Le Corbusier who campaigned against the corridor street and encouraged architects to look at urban buildings as sculptural objects sitting in space. This powerful concept has permeated into the Modern Movement ethic to the extent that even today many architects have difficulty in designing larger layouts in which buildings are not arrayed as shapes on a plan that have no meaning viewed at ground level. More recently, deconstructivist design has played games with building forms and hard landscape which are intelligible only on reading the plan, not even when walking around the completed scheme.

But perhaps the most disruptive has been the effect of catering for motor vehicle movement, circulation and parking. This form of thinking assumes the car to be the smallest element in the cityscape – not the human. Vast tracts of urbanscape in Europe and much of North America are mute testimony to this.

Clearly, there needs to be a relationship between the influences on urbanisation and the process itself. The best candidate to be the lynch pin between these, is the ‘local’ or the context (Figure: 3). Heritage can form a lasting bond that connects these disparate issues, needs, and demands in a meaningful way. It is the vital ingredient that makes for vibrant and dynamic cities. The historic environment, including buildings, the spaces between them, urban parks and other incidental spaces, is a significant marker of quality and a source of local distinctiveness.

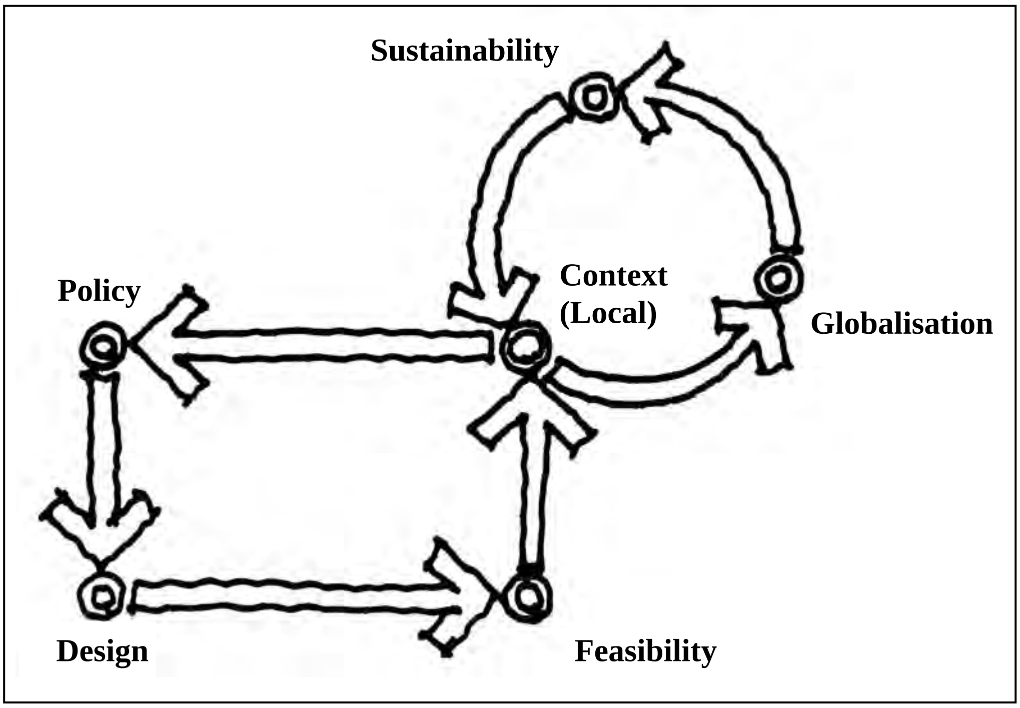

Figure 3: Context (conservation) and Urbanisation

It provides a basis for reinstating patterns and helps to provide references to repair the tears in the urban fabric. Cleared urban brownfield sites, for example, are seldom totally devoid of traces of the past.

Just as we do not preserve the ornamental parts of a listed building and dismiss the rest as unimportant connecting fabric which could be replaced by something new and 'appropriate', we must employ similar logic while dealing with city quarters and the urban fabric.

Very often, the whole is much greater than the sum of its parts.

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FACTOR DETERMINING LOCAL RESIDENTS' EVALUATIONS FOR CULTURAL LANDSCAPE PRESERVATION

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ABSTRACT

In this study, factors determining local residents' evaluations for cultural landscape preservation were considered to be the following three points: the first point is that local residents be provided with "expert information" about the evaluation of cultural space; the second point is that local residents actually have "experience" with cultural space; the third point is that local residents recognize "the aspect in which cultural space is being ruined." Results demonstrated the following: "Experience" and "aspects in which cultural space is being ruined" have a large effect on "attachment", "payment" and "risk of ruination". Also, "expert information", "experience" and "aspects in which cultural space is being ruined" have an effect on the "importance" of preservation. In addition, "serious aspects in which cultural space is being ruined" have a large effect on "risk of ruination".

1. INTRODUCTION

In recent years, natural landscapes, townscapes, historical landscapes, and industrial landscapes have been recognized as "cultural landscapes." Preservation activities have allowed some of them to be registered as world heritage sites. The concept of cultural heritage to future generations is very important. This inheritance of culture allows for the attainment of a better affluence of life for people.

However, few local residents recognize the value of cultural heritage. In order to practice preservation, restoration, reconstruction and rehabilitation, it is required that local residents share values and maintain, manage, and preserve cultural space.

In this study, factors determining local residents' evaluations for cultural landscape preservation were considered to be the following three points: the first point is that local residents be provided with "expert information" about the evaluation of cultural space; the second point is that local residents actually have "experience" with cultural space; the third point is that local residents recognize "the aspect in which cultural space is being ruined." The effects of these factors have been investigated based on four measures. The first measure is "importance" for preservation. In other words, local residents considered whether cultural space preservation is important. The second measure is "payment" for preservation. This is how much local residents are willing to pay economically for preservation. The third measure is "attachment" to cultural space. This is how much local residents have attachment themselves to a cultural space. The fourth measure is "risk of ruination" of cultural space. This is the risk factor that local residents would feel if cultural space is allowed to fall into ruins.

2. EXPERIMENTAL METHODS

The author conducted the following experiments in this study: 1). The landscape surrounding Kokubun Temple in Soja City, Okayama-Prefecture, was used as a case study. The picture was shown in Fig. 1. 2). Pictures of the landscape in the case study were used to investigate and evaluate the initial stage. 3). Results of a previous evaluation by participants on "importance," "payment," "attachment," and "risk of ruination," were studied (previous evaluation).

Fig. 1. The picture of a case study

Fig.2 The picture of the good place Fig.3 The picture of the bad place

And then, the participants were provided with special information from an external subject matter expert evaluation on the landscape. The pictures of the landscape were shown, and then, evaluations based on the same procedures as prior evaluations were studied (post evaluation 1).

Following these experiments, the participants actually experienced and walked around the landscape space, took photographs of good places and bad places, and described their reasons for considering them good or bad.

The good place was shown in Fig.2, and then the bad place was shown in Fig.3. The pictures of the landscape were then shown and evaluations based on the same procedures as prior evaluations were studied (post evaluation 2).

Furthermore, pictures showing aspects in which cultural spaces were in bad states of ruination were shown. The picture was shown in Fig.4. Evaluations based on the same procedures as prior evaluations were studied (post evaluation 3).

Finally, pictures showing aspects in which cultural spaces were in worse states of ruination were shown gradually. The picture was shown in Fig.4. Evaluations based on the same procedures as prior evaluations were studied (post evaluation 4).

Fig.4 The picture of bad states

Fig.5 The picture of worse states

3. RESULTS AND CONCLUSIONS

A result of the scale based on "importance" was shown in Fig. 6; a result of the scale based on "attachment" was shown in Fig. 7; a result of the scale based on "payment" was shown in Fig. 8; a result of the scale based on "risk of ruination" was shown in Fig. 9. Vertical axes were the average value which the subjects evaluated. 1 of a horizontal axis was as a result of previous evaluation; 2 of a horizontal axis was as a result of post evaluation 1; 3 of a horizontal axis was as a result of post evaluation 2; 4 of a horizontal axis was as a result of post evaluation 3; 5 of a horizontal axis was as a result of post evaluation 4.

It was regarded that the difference between 1 and 2 of a horizontal axis was the influence of "expert information"; it was regarded that the difference between 2 and 3 of a horizontal axis was the influence of experience"; it was regarded that the difference between 3 and 4 of a horizontal axis was the influence of "aspects in which cultural space is being ruined"; it was regarded that the difference between 1 and 2 of a horizontal axis was the influence of "aspects in which cultural space is being ruined severely".

Results demonstrated the following: “Experience” and “aspects in which cultural space is being ruined” have a large effect on “attachment”, “payment” and “risk of ruination”. Also, “expert information”, “experience” and “aspects in which cultural space is being ruined” have an effect on the “importance” of preservation. In addition, “serious aspects in which cultural space is being ruined” have a large effect on “risk of ruination”.
Therefore, it is essential to clearly provide local residents with “expert information,” “experience” and “aspects in which cultural space is being ruined,” so that action for preservation of cultural landscapes can be activated and cultural heritage can be handed down to future generations.

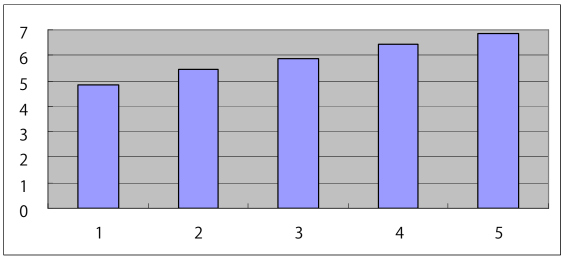

Fig. 6: a result of the scale based on “importance”

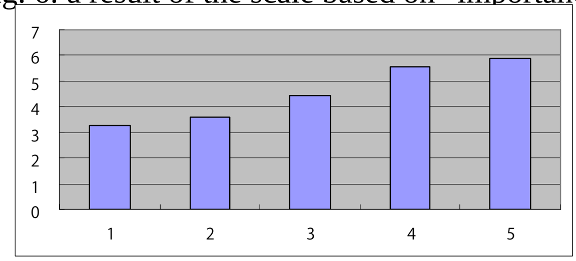

Fig. 7: a result of the scale based on “attachment”

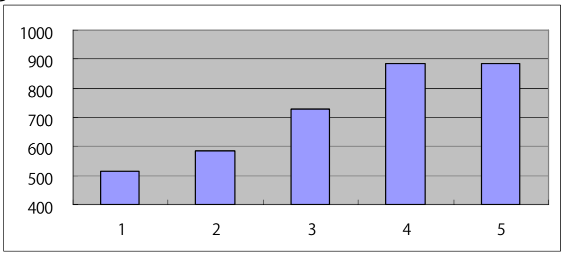

Fig. 8: a result of the scale based on “payment”

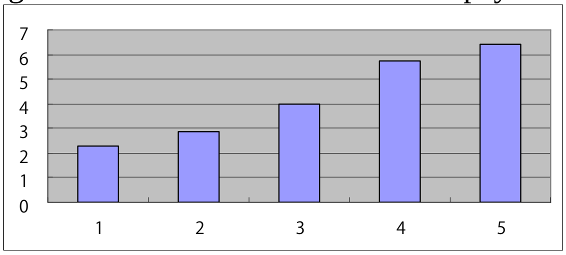

Fig. 9: a result of the scale based on “risk of ruination”

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DRIVEN-MECHANISM FOR LOCAL HERITAGE CONSERVATION: SAMSHUK OLD MARKET DISTRICT, SUPHANBURI, THAILAND

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(2) Sripatum University, Bangkok, Thailand

ABSTRACT

Samshuk old market district typically expresses how, in our grand (grand) father generation, the commercial area had been settled and evolved and it represents the unique architectural and urban character where had existed in many canal-based cities overall the central region of Thailand. Nowadays, influenced by modernization, many of them have been changed and demolished. To survive such a built environment, local community at Samshuk has rigorously attempted promoting out the conservation and heritage agenda to public sphere. This attempt has brought some positive changes – the emerging mechanisms to survive local heritage. The paper would discuss on two issues. Firstly, it is the supporting mechanism appeared since many inputs and activities have been addressed, but chaotic and unorganized. Based on the authors' direct experiences and participatory observation as well as action, there have been three levels of mechanism embracing and steering conservation process. Secondly, therefore, the bridging networks and partnerships among local and district authorities, professional/academic institutes, and NGOs, have become a platform of long-term working mechanism on which the conservation plan relies. We hope that this illustrated scenario could be, somehow a small step to begin on local heritage protection and shed the further light as another experience to locally initiate the urban and architectural conservation and could be contributed to conservation paradigm and theory, especially in Third World country's local political context.

1. INTRODUCTION

Heritage conservation paradigm could be explained in a multiplicity of parameters among epistemological multidisciplinary movements, such as, identity of place [1], tourism activity [2], and cultural capital [3]. Likewise, collaborative planning is one of the approaches highlighted by many prominent scholars, particularly in the field of urban conservation planning. According to the mentioning parameters, they could be employed as the principal factors and methodologies.

Based on collaborative approach, this paper aims to explain the phenomenon of heritage conservation via Samshuk Old Market, Thailand. The paper is organised into four parts. The first addresses on the context of case study in both of spatial and procedural problems. The second analyses the case through communicative concept [4] and multi-stakeholder process [5]. Then, the third elaborates more on the level of driven-mechanisms for conservation, being categorized into three fundamental scales – community, city and network, and policy-making. Eventually, the nature of communicative action, dynamic structure, and multi-mechanisms would be discussed as the conclusion.

2. CONTEXT OF THE CASE STUDY

2.1 The decline of market attraction

Approximately last 1890s, Samshuk historical market had been flourished as one of central districts of Suphanburi, middle region of Thailand. Having been investigated via the storyline of forefathers, the community history could be conceived as a sharp-developed society, not merely on commercial activities but also historic and cultural diversities. The value of Samshuk Old Market has been represented by embraced both tangible and intangible aspects.

Considering on its evolution and change, the local economic activities at the inner market during last decade were gradually decreased by at least three factors. First is that the government district regeneration projects had been undertaken. The governmental offices – police station, primary school administration, and state property, which had been the essential economic activities contributed to the old market were relocated. This magnetic absence became one of the negative presumable impacts, affecting to local commercial liveliness.

Secondly, in the wealthy era, the water-based market was an elemental nexus that links central district of Samshuk to other markets as a commercial network. In recent year, the river accessibility has been rarely occupied and replaced by motor vehicle-based transportation, the highway. The role of commercial hub in the old market has, therefore, continuously been deteriorated.

Thirdly, by a macro economic failure of Thailand and Asian region in 1997, it was the outpouring impact, not merely to Samshuk but nation-widely. The serious economic drawback had been caused initiating a market alternative, especially *caravan market*. It has become a significant impetus encouraging the high competition in local market. Consequently, Samshuk old market, having been unattractive, failed to compete the *caravan market*.

2.2 Procedural barrier

By procedural barrier, two arguments are analysed. Firstly, due to discursive definition of conservation concept in Thailand, the circumstance had brought to a confrontation among controversial stakeholders, particularly the state and local community. Hillier and Hajer claimed that a discourse is one of momentous factors to people’s understanding of their own issues in consensus-building processes [6]. Also, it could possibly be the bureaucratic apparatus in the game of power.

The second presumable controversy, the unbalanced structure in consensus-building mechanism, is one of greatest impediments for implementation. According to Zunino [7], the level of mechanism would be categorised into three scales; policy-making, co-ordination, and operation level. In the case of Samshuk, it seems that the co-operation and operation could effectively handle a plenty of problems in community. Meanwhile, the policy-making movement is still likely to be a significant obstruction of the process because of its poor bureaucratic system and the absence of authentic public participation to the policy-making arena.

3. FROM COMMUNITY TO INSTITUTIONAL MOVEMENT

3.1 Communicative action approach

To tackle such a complex conflict in the community, Samshuk Old Market Development Committee [SOMDC] has created many magnificent activities which could, therein, progress to the conceptualisation of revitalisation. Amid the stakeholders, the communicative action movement could narrow the gap among them – local residents, state officers, and scholars. In this regard, the local reconciliation had been addressed through interpersonal activity, social learning, and mutual assessment [8].

Being relevant to an antagonism in conceptualisation of community conservation, social learning and communicative action were exercised by the heuristic mean, via debating, discussing, brainstorming, and negotiating. By debating, a few informal meetings among multi-stakeholders were initiated by SOMDC and three mobilised groups, sub-committee, were formulated and also mandated to investigate the local history, to create revitalising activities, and to promote local economic development.

Hence, by the community level, the local history, narration of storylines, and architecture had fundamentally facilitated on historical assessment and shed the further light on the regeneration programme as well as the regulatory amendment. Having been unsupportive by policy-making level, the institutional outcome, for instances, conservation guideline and building control, have been impermeable into the municipal regulation although the principle of knowledge-based planning has been dialogued. Fortunately, it could potentially be community self-regulated as the social norm. In conclusion, the local conservation, herein, is tentatively defined from local and experienced knowledge instead of expert and administrative skills.

As far as revitalising activities are concerned, it is possible that there is a turning point of people mindset. Actually, a former procedure of the old market revitalisation had not been likely to integrate the conservation approach. Later on, SOMDC as sub-mechanism stepped forward through many momentous activities, such as, food festival, historic safari and rally, local historic forum, community cleaning day, and so forth. Thereby, the benefit of such a movement directly accomplished flourishing economic and tourism betterment by approaching heritage capital's concept.

3.2 Multi-stakeholder process

In the last 1990s, many pundits in the field of urban planning, sociology and politics constituted the multi-stakeholder processes. Evidentially, the public policy studies have been increasingly concentrated in Europe, the United States, and Canada [9]. The three aspects derived from Hillier's concept [10] – representation, actor-network, consensus building, would be deliberated and discussed.

Hillier portrayed the terms of representation that they are not merely the type, but also the coverage of cultural and social capital whichever they should be related. In the case study, in the previous time, most of the representations were elected by local administration. They were associated of several actors, especially state officers and experts instead of community residents. Thus, it seemed that the preliminary driven mechanism is malfunctioned because of its incapability to comprehend the common problems of community. Thereby, the agency formation had been evolved and transformed into the community-based driven process accompanying the client (residents) rather than the bureaucracy and by this moment, it has been more efficient tackling the prevalent troubles in achieving local heritage conservation ever since the 1997's economic drawback.

The second, the actor network, based on Hillier's work, is depicted into two basic aspects. Firstly, the issue-based network is both the core-driven mechanism and social learning. In Samshuk case, the nucleus of mobilisation, consisted of SOMDC, local and external scholars, and NGOs, was a vigorous movement to refresh the liveliness of the old market. Otherwise, secondly, the policy network that three-forth of partnership is state agency, would be centrally a crucial function of consensus-building process. According to network movement in this study, the authors would claim that either the former or latter network should be the multi-level layer that contains dynamic, discursive, flexible, and changeable form.

Ultimately, three chief characters of relationship in the power arena are examined based on consensus-building, social learning, and the possibility of financial support. Figure 1 is revealing the actors in several clusters. One of the significant interactions is social learning which generally took place within the issue-based network. Also, these correlations benefited to reconciliation among controversial stakeholders, in particular local community and state agency. Moreover, Figure 1 recapitulates that the consensus-building and financial support are tools in the game of negotiation in public sphere especially in the realm of policy-based networks. Nevertheless, the community representation is the fine-grained function to sort out the conflict from both networks

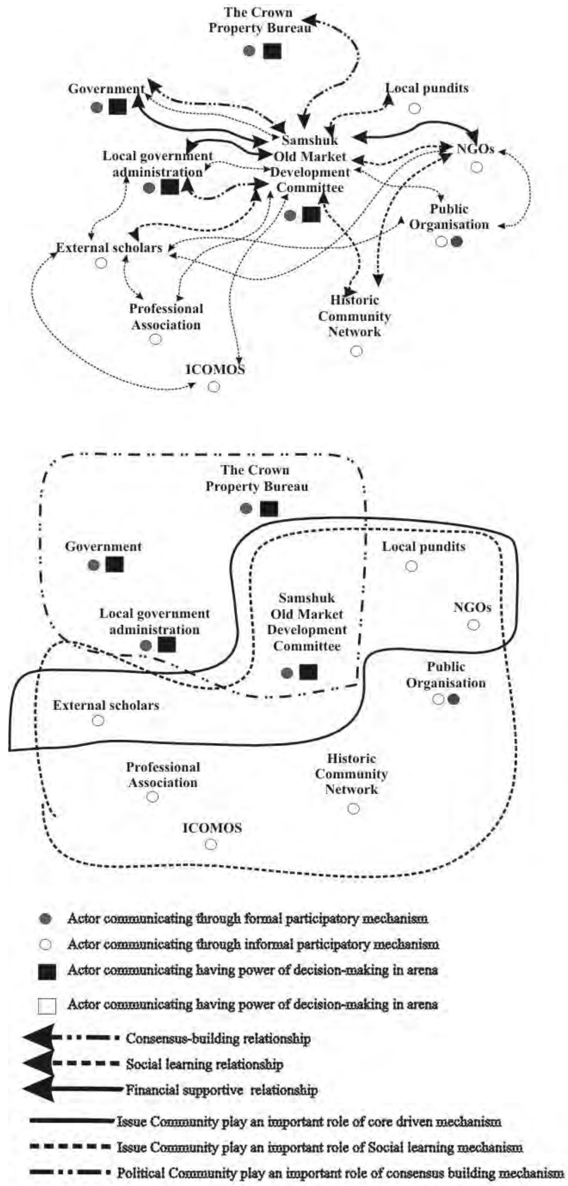

Figure1: Relationship among actors (upper) and driven-mechanism (lower) in heritage conservation at Samshuk Old Market Community, Thailand

4. MULTI-LEVEL BASED DRIVEN MECHANISMS FOR HERITAGE CONSERVATION

4.1 Community-based mechanism

Nigel Thrift [11] had summarised the institutional concepts referring Bourdieu and Sztompha hypothesis. For Bourdieu, the institution is scanned into three parameters – culture, structure, and power. Meanwhile, Sztompha had focused on the relationship between structure and agency-praxis system. Regarding the community-based approach, it could be postulated that both concepts, synthetised by pivotal parameters, influence to local heritage conservation. Eventually, this celebrating circumstance has been because of the marvellous community culture and diversity of agencies.

4.2 Citywide-based mechanism

Concerning with citywide processes, the nexus of consensus building and fellowship was a part of this important impetus. The former was organised as an apparatus of bargaining, negotiating, arguing, and discussing among multi-stakeholders. Simultaneously, the latter was mobilised via the knowledge-based and mutual learning movement. Obviously, from Figure 1, the consensus-building network probably interweaves in a formal interaction, meanwhile, the webs of fellowship are likely to be an informal structure.

4.3 Policy making-based mechanism

In the case of Samshuk, it is seemingly that neither the multi-level mechanism in community and citywide process nor the policy making-based movement could mechanise because of the limited governance culture in Thai society. Although, the grassroots or bottom-up mechanism has been overcoming several limitations and has been locally intertwined the conservation methodology, yet, the upper structure still dominates and is trapped in the traditional bureaucratic culture. Consequently, the authorizing power could not be fully delegated into local and community level and therefore, the outcome of the conservation planning in this case is merely a project-based conservation, not a political movement.

5. CONCLUSION

5.1 Nature of communicative action and social learning

Even if the social learning and communicative action approach were remarkably underpinned in a *priori* practice encouraging the community revitalization, notwithstanding, it was probably that stunning activities are fairly decreased in the coming year because it becomes reluctant, repetitive, and monotonous, which could not attract people interest. The familiarity is a dilemma in the communicative approach. As a result, it can possibly underpin as much as undermine the activity atmosphere. Frequency, style, and the patterns of behaviour should be reconsidered and also be refreshed for the atmospheric betterment to fascinate the people. In short, the activities organised for social and conservation momentums would not be annual corny programmes

5.2 Dynamic and nebulous structure

To deal with the complexities of post-modern society, the forms of mechanism should be in dynamic and nebulous structure. Flexibility of system could encourage more on the wide-range of stakeholders to share idea in conservation planning direction instead of merely being the representations. Hence, it could, perhaps, conceived that the new configuration of system and structure should be three dimensions interactive [3D interactive] – horizontal, vertical, and diagonal. The authors would wed the *3D Network* concept that, somehow, could amend the asymmetry structure of power in consensus-building and negotiation.

5.3 Multilevel-based mechanism

In conclusion, Samshuk case has illustrated that the historical area should be focused not only on the physical aspect, but the hidden agenda in public interests should be simultaneously scrutinized as well. This investigation, therefore, recapitulates that the multilevel-based driven mechanism should accompany in the conservation process regarding the complexity of decision-making power beyond the heritage site. As Healey [12] claimed that *"spatial is the generally arena to exercise the power"*. Although it is not yet the time to encounter the unbalance of power structure, but the conservation planners and practitioners must be anxious about these issues.

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ATTEMPTS FOR UNOCCUPIED HISTORICAL URBAN FABRIC RELATED TO SPATIAL ORGANIZATION, SOLUTIONS FOR AYVALIK CONSERVATION AREA

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ABSTRACT

Urban conservation areas are not only the physical patterns which transfer some former values to present, but also include some social, economic, artistic and architectural assets. In this respect, urban conservation areas are considered as potentials for local development in a retrospective context. However, urban conservation areas are facing and serving a large variety of problems as; urban and social problems including infiltration, lack of urban facilities, economic and spatial organizational problems including maintenance of historical buildings, rehabilitation of the physical environment and infrastructure problems. The objective of this paper is to focus on the historical urban fabric of Ayvalık* conservation area in terms of defining the spatial needs while considering the local problems and determining alternative functions both for the unoccupied buildings and urban open spaces in accordance with the identity of the settlement.

1. CONTEXTUAL INTRODUCTION

This study, which particularly aims to focus on some proposal approaches on the unoccupied and dilapidated historical urban fabric in Ayvalık conservation area related to urban spaces, consists of three subtopics, namely the contextual description of Ayvalık conservation area and related problems, discussion of solutions and relevant proposals related to re-organization and re-functioning of historical urban space.

1.1. Description of Ayvalık Conservation Area

Ayvalık is a district of Balıkesir province situated at the north coast of Aegean Region (facing Lesvos Island). Ayvalık is founded on a narrow coastal plain and slopes of low hills which are covered by groves of pine and olive trees surrounded with a group of fascinating landscaped islets encircling Ayvalık Bay and a peninsula in the southwest.

Various archeological excavations proved that Ayvalık and its environs were inhabited since Ancient periods. Today the existing urban settlements in Ayvalık Bay are Ayvalık (Kydonia) and Cunda (Nesos). While Ayvalık is situated on the mainland side of the bay, Cunda is oriented to the bay facing Ayvalık on Alibey Island. Ayvalık established on the trade route to the harbour over the southwest slopes of İlk Kurşun Hill (see figure 1). The milestone during the development of the city was the achievement of administrative autonomy from the Ottoman Empire in the 18th century. Under the international investments of entrepreneurs, Ayvalık became a prominent industrial port city with her piquant agricultural productivity (outward trade depending on olive oil and its products) which was quite alien for the other Anatolian cities since the mid 19th century brought prosperity and thriving urban identity to the city. A periodical review which was published in 1894 had demonstrated these features of Ayvalık with some original data about the existing facilities in the city, stating expressly that the population was 20.630 and mostly consisted of Anatolian Greeks (Rum) [1]**.

After the Turkish Independence War, in 1923 and 1927 almost all of the local inhabitants were emigrated to western Aegea. In these years one of the most dramatic fractures in the history took place which languished the city's cultural diversity and bourgeois urban life flowered by agricultural industry. This was the policies' sanctions on both side's communities to permute the Anatolian Greek population in the city with the Greek Turkish population living in Lesvos, Crete and Greek Macedonia. Besides privative socio-economic decay, population exchange also brought out several problems of ownership of housing, olive groves, institutional organization of land and so on.

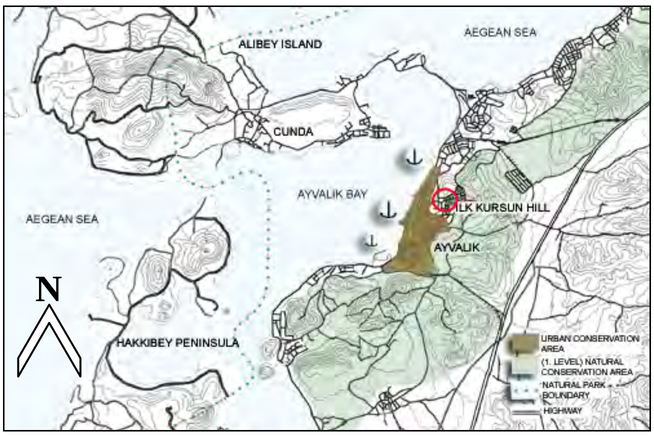

Figure 1. Ayvalık

Today, more than 31.986 people lives in Ayvalık and 17.000 inhabitants of this population live in the conservation area [2] (figure 1). As a port town, Ayvalık still sustains most of her original and local distinctive character of mercantilist soul of an industrial city and the residential fabric. The city also symbolizes a perfect harmony between the nature and the original physical structure. Churches, chimneys of industrial plants and factories, the orientation of public squares, the concinnity between the physical space and natural peculiarities such as curvilinear paths sometimes with stairs, buildings respecting the restrictive topography, climate and prevailing winds, the building material, local architectural and esthetic assets of façades (pediments, doors, windows designed for flowers, overhangs, eaves, colors …) are the main elements of the physical pattern impressing the silhouette. On the other hand, hills adorned with pine and olive trees, surrounding islets, peninsula at a close distance, long beaches are the very natural characteristics performing amazing and variable sceneries from every different direction. Entirely unique environment of Ayvalık possesses very rich potentials to be attended as a catalyst for the local development in a retrospective context.

Table 1. Characteristics of Ayvalık Conservation Area

Factors	**Explanation**
Size of the Conservation Area	112 hectares
Population	17.000 people
Building Order	Mostly attached and semi-detached in some parts, no front gardens
Construction year of the buildings	40% before 1923, 11% between 1924-1950, 14% between 1951-1980
Functions of additional buildings in the gardens	Toilet (12%), other service areas
Unoccupied building stock	19% unoccupied and 6% partly occupied
Urban facility deficiencies (according to the actual legal obligations considering the existing population)	Social, educational, recreational facilities are needed
Transportation modes that the inhabitants use in order to reach their homes	70% by walking, 16% public transportation, 13% private car, 1% other vehicles
Major deficiency problems stated by the inhabitants	Lack of urban open space (11%)

1.2. Problems of Ayvalık Conservation Area

Upto the late 1950’s, the economy depending on agricultural industry (olive oil and other products leaning on olive oil, flour …) has played a dominant role on Ayvalık’s physical structure and identity. The factories and the plants where the production of olive oil and sub products were embroidered, located on the shore in order to load directly from the front quays. This mutual relation between the city and the coast was the expression of economy until an (urban) artery (Cumhuriyet Street) had been constructed parallel to the coastline damaging the waterfront character rather into conveyance by land in 1950s. Another vital issue is the population exchanges in 1923 and 1927, since all of the original owners and employees of these factories left the settlement. These radical changes caused the factories to be carried out far from the city along the interurban highway route leaving their waterfront facilities. So that, today, most of the factories located in the coastal zone of the urban conservation area are unoccupied and also potential in terms of proposing new functions.

Latterly, 1980’s were the years for tourism and conservation policies undergo a rise in Ayvalık and its near environs. Although tourism is not a problem itself, appropriative activities have to be considered respecting Ayvalık’s natural, cultural, historical heritage and assets. Otherwise, this process would be destructive on the city’s unique character in an immediate future.

The organizational policies introduced by autonomous mode which eliminate the right of local to determine their needs and solutions in the urban space have also provoke decisions which create several problems on natural environment to be adopted. In addition to the inadequate information and financial problems, house owners experiences difficulties in maintaining and adapting their registered houses. In this respect, ignorance about the financial instruments and funds is a very crucial issue.

Popular culture and its converter effects on user behaviors’ preferences appear as another aspect on daily habits of consumptions since 1980’s. Particularly, some fashionable concepts are increasingly operating as instruments for defining the identities (personal, family …) while the city is mutating into a consumption body [3] [4]. Relatively, housing preferences are also a part of this context indicating two different processes in Ayvalık conservation area. According to that, while some house owners living in the conservation area affords to move to the new residential areas (which were constructed over the olive groves after the plan approved in 1980s’) in order to live in ‘comfortable modern houses’***, some other groups out of the city have desires to buy the historical houses to live in.

In these perspectives of dynamics, it is possible to classify the problems in Ayvalık conservation area as;

- Urban decay (dilapidation of historical buildings, infrastructure, unoccupied historical urban fabric),
- Social problems (erosing urban identity, infiltration, gentrification),

- Rising demand for new residential zones (both from the inhabitants and from the outcomers),
- Organizational problems.

2. DISCUSSION OF SOLUTIONS

Considering the problem set of Ayvalık conservation area consists of two dimensions, three different macro approaches could be formulized. First of these dimensions' is the dynamics which force this area to change (reasons of the problems) and the other is problematic consequences. In this respect the above-mentioned approaches are;

1. Orienting the dynamics (reasons) set without directly touching to the consequences (problems) and plan to observe some positive effects on consequences (problems) in a long term period.

2. Trying to solve problems (problematic consequences) without directly touching to the reasons of these problems, assuming that some of the solved problems would affect some of the reasons positively.

3. Trying to orient both dimensions simultaneously as long term and short term preventions and solutions.

In this study the third approach is accepted as a proper one, but will particularly be focused on solving some of the problems in a short term period, through a re-organization and re-functioning process of historical urban space. Considering that, 40 percent of the building stock in the urban conservation area was constructed before 1923, it is vital to find urgent solutions for these rapidly dilapidating unique buildings. Thus, it is aimed to propose several solutions on the unoccupied urban fabric and dilapidation of empty buildings in urban scale.

3. RELEVANT PROPOSALS RELATED TO RE-ORGANIZATION AND RE-FUNCTIONING THE HISTORICAL URBAN SPACE

Two basic principles are accepted while re-organizing and re-functioning the unoccupied urban fabric. One of them is answering the needs of the inhabitants mentioning the lacks (that are stated in the first and second subtitles of this paper) of Ayvalık conservation area, and the other is specifying the functions which are suitable (or harmonious) with the unique identity of the settlement, also considering the potentials and properties of the urban stock.

Following the first principle, it is thought to upgrade the administrative, educative and health facilities of the conservation area by creating some additional space for these functions. Re-mentioning the urban open spaces (like the open bazaar and main squares) is also be targeted within these actions.

Depending on the second principle; pensions, bars, cafés, offices and socio-cultural facilities (like neighbourhood administrative buildings, offices for meeting and education purposes, NGO facilities) are determined as appropriate functions which are seen harmonious with the local identity. This re-functioning process will be beneficial both for the local inhabitants (in terms of improving the quality of urban life besides creating employment) and for the visitors. One vital aspect within this process is matching up the proper functions with the proper building stock.

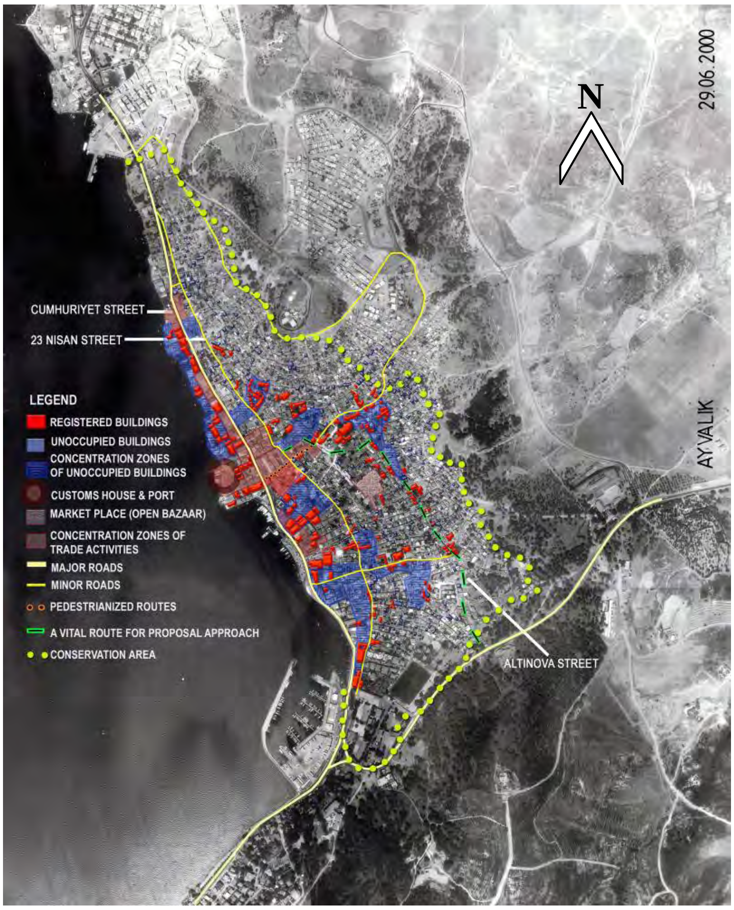

Figure 2. Characteristics of the Conservation Area

There are several problems and potential zones in the urban conservation area. One can easily evaluate the building stock in terms of their original functions. Industrial buildings (olive oil and soap factories and warehouses) are located in the zones that have close relation with the seashore. So, almost all of the factories and warehouses, being relatively large buildings, are situated along the coastal zone (see registered buildings and concentration zones of unoccupied buildings on the seashore in figure 2). The remaining part of the registered and unoccupied buildings was constructed (originally) as residences which were organized around religious buildings. Both the registered -of most of which are dilapidating- and unoccupied buildings also could be seen as potential spaces to create the above-mentioned functions and facilities. Actual vehicular transportation selections of the area could be classified within the problematic issues. The major road

(Cumhuriyet Street) along the coast cuts the pedestrian access through the seashore, therefore accepted as an artificial edge between the coastal zone and the main body of the settlement. Parallel road to Cumhuriyet Street inside the urban conservation area carries intensive vehicular traffic which is not compatible (contradicting) with its width and identity (retailers and several registered buildings are situated along this road-23 Nisan Street). The open bazaar, custom house & port and the trade activities along the route connecting them, represent another vital functional relation within the area.

For this purpose, in the urban conservation area the linear densification of economic and service facilities along the main (artery) roads parallel to the coastline can be contemplated with an approach which will predict to compensate them with possible solutions for vehicular and pedestrian traffic and new functions for the unoccupied buildings. Parallel to the scope of the study, the proposals related to the re-organization and re-functioning of historical urban space in Ayvalık conservation area are stated below:

- The open bazaar is a part of the traditional physical pattern and takes place in the central location of the conservation area mostly surrounded with residential units reflecting the historical ambience. Peculiarly the bazaar serves as the only magnet node attracting the activities in contradiction to the linear process. Thus, the location of bazaar provides a pivotal role in order to sustain the functional briskness in the urban essence which must be preserved.
- Re-functioning the unoccupied buildings can enable to relieve and activate the isolated social life. However, while re-functioning, two assets, the historic role and the compatibility between the proposed necessities of facilities and the intensity of vehicular and pedestrian traffic should be taken into account. So that, Altınova Street (vital route in figure 2) performs appropriate ample unoccupied buildings and location for offices, health services in neighbourhood scale, community education, nursery school, assorted courses and training, social associations and club facilities which may exhilarate social vitality in the conservation area.
- As an Aegean settlement, buildings in Ayvalık possess very rich and unique architectural features of elements such as entrance spaces between road and house, doors, windows designed for flowers, overhanging, eaves, chimneys … in traditional houses, urban open spaces, surprising curvilinear paths that can immensely grab the attention of foreign visitors. Such features also offer potentials for daily visits and for accommodation (all purposes). Therefore, the unoccupied houses where they gathered can be possibly renewed for accommodation in an organizational model extent. What is more, the unoccupied buildings with gardens, especially next to the charming public spaces and squares could be furnished as bars, cafés and restaurants for the visitors and local citizens.
- On the other hand, there should be particular complementary decisions on management of the area in order to live in better conditions and to preserve the traditional physical pattern. In this respect, the narrow and curvilinear streets

and paths necessitate crucial arrangements restricting the vehicular traffic. In the urban conservation area there are three streets (Cumhuriyet Street (coastal), 23 Nisan Street, Altınova Street) stretching parallel to each other and Dereboyu Street, which was formerly linking the land trade route to the harbour, intersects all. However except Cumhuriyet Street, the widths of the older streets do not allow vehicular traffic in both directions. For that reason, inside the urban conservation area one way application for service traffic should be arranged. The roads should be designed mainly for the pedestrians and a network for cycling should be edited. Also, car parking should be forbidden within the urban conservation area and the cars should be stored on the edges of the pedestrian scale of the old settlement (urban conservation area).

All these proposals could be seen as macro scale approaches. It is also worth-mentioning to remember that this study is in urban scale and not concluded yet. Forthcoming steps of this study are (dealing with the set of) dynamics and reasons that create the problematic consequences, actor based models, financial issues and micro (building) scale proposals.

END NOTES

* The research related to Ayvalık carried out in 2005-2006 academic year in the context of planning education of the Department of Urban and Regional Planning of Yıldız Technical University.

** According to this periodical "the city was composed of 11 neighbourhoods, 1 mosque, 12 churches, 6 monasteries, 26 soaperies, 40 tanneries, 78 olive oil mills, 25 windmills, 2 hotels, 2 restaurants, 3 casinos, 5 taverns, 70 coffee houses, 1 'kıraathane' (coffee-served reading room), 7 olive oil and flour factories, 45 bakery, 95 stores, 4773 houses, 1 administrative and customhouse, 1 military hospital, 3 military police stations and 1 telegraph office. Also the total number of the buildings was 5320".

*** In Ayvalık, two different case areas are confirmed. These are Ayvalık conservation area and Armutçuk (new developing residential area). In both patterns 307 surveys (143 sample in Ayvalık conservation area, 164 sample in Armutçuk) are applied by using 'stratified sampling' method and area sampling is determined as %3.

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THE MORPHOLOGICAL TRANSFORMATION OF THE URBAN FORM: HISTORICAL EVOLUTION OF THE BLOCK AND BUILDING/LOT SIZE OF KADIKÖY YELDEĞİRMENİ

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ABSTRACT

The paper describes the morphological evolution of the urban structure of the Kadıköy – Yeldeğirmeni. The purpose of the study is to analyse the effect of different block sizes and forms on the subsequent urban development, in terms of land parceling, building forms, land use, and urban patterns. The study considered the evolution of the block and layout pattern from the end of the nineteenth century to the present. In this way, block sizes and circulation patterns are compared based on some international researches. The findings demonstrate that some certain blocks have better sizes than the others in accordance to these researches in Yeldeğirmeni. Although blocks had minor modifications throughout the historical development, lots have undergone major revisions. Rise of the population – according to demographic diversity – in the region after the 1980's, height of the built environment increased dramatically. The method of the study offers a comparative analysis of the urban fabric in both historical and contemporary fields.

1. INTRODUCTION

Cities historically have different layout plans. They have not only regular patterns but also organic urban fabrics. Both patterns can be observed in different places of the Istanbul. Because of the distinct topography of the city regular and organic patterns had opportunity to be applied to different locales. Since the nineteenth century, regular grid layout plans have been used consciously in city planning. Some crucial reasons can be suggested but most fundamental one was the great fires of Istanbul. It changed the urban fabric in historical peninsula significantly. In subsequent period, similar fires can also be observed in Kadıköy district. According to records, 966 buildings were fired between 1856-1922 years. 140 buildings of them were in the Yeldeğirmeni [1].

After the huge conflagrations, the regularities which were called as “Ebniye Nizamnameleri” marked the entire face of the city at the end of the nineteenth century. The regulations were also the gate to the western world and the efforts to accept the activity of planning as a scientific endeavor [2]. The fruit of the struggle in the urban space was the gridiron plan. Grid layouts have been applied to Aksaray, Hocapaşa, Pera, Fener-Balat, Samatya etc. regions after great fires in historical peninsula. Henceforth, grid plans not used only after fires as reorganization but also in the new settlements of the districts. Therefore, Yeldeğirmeni as a new urban area which had simple patterns of streets and blocks evolved as morphologically planned settlement in Kadiköy.
The study tries to describe urban form of Yeldeğirmeni from the beginning of the twentieth century onwards as morphologically. The effects of the grid layout are the regular streets and block patterns. Their size had minor alterations since the one hundred years. But some of them have better size than the others in terms of circulation. Blocks in the selected area will be compared with the other international researches and performance of them will be determined. Lots which form the blocks designate the building sizes. Buildings have been used as a house function in general. Most of them are the attached row houses and bound the streets. This paper describes the effect of different block sizes and forms on the subsequent urban development, in terms of land parceling, building forms, circulation patterns and land use.

2. SCOPE OF THE STUDY: KADIKÖY-YELDEĞİRMENİ

Yeldeğirmeni is a considerable part of the Rasimpaşa quarter of Kadıköy district. Its importance arises from having nineteenth century row houses which are the integral part of the city of Istanbul. Its name comes from windmills which supplied the flour requirement of the environment. Haydarpaşa train station in the north, Anatolian Railway in the east, Söğütlüçeşme Street in the south and Rıhtım street in the west which connects the area to the Marmara Sea constitutes the borders of the place (Figure: 1).
It has a cosmopolitan character in its own. Beginning of the twentieth century Rum, Jewish and Muslim people were living together and their evidences transformed to the space as a stylish building activity. That’s why Neoclassic, Art Nouveau, Empire, Baroque styles can be observed in the region [3].
Few reasons can be taken into account for developing the region as residential area e.g. connection of place to the center of the city by sea lane, closeness of Haydarpaşa during the construction of Anatolian Railway, openness to new settlements. Lots of workers were inhabited in north side of the Yeldeğirmeni in the Railway construction. For instance, Valpreda apartment as it is called Italian apartment built in the first ten year of the twentieth century for German engineers who work in the construction of Haydarpaşa Train Station.
Today typology of the environment which developed as two or three story row houses transforms to the five, six or seven story reinforced concrete row

apartments. The row or nineteenth century houses are mainly disappearing; the scale of the environment drastically changing and the memory of the city building are losing.

Figure 1. Location of the Yeldeğirmeni in Kadıköy.

3. THE MORPHOLOGY

Yeldeğirmeni gets higher from the sea approximately twenty five meters and the entire layout locate in this sloping topography. Regular streets of the region could be seen after the orders of III Selim between 1789-1809 years. Although main urban fabric of the place has been evolved after 1885, “Tarik ve Ebniye Nizamnamesi” – city regulations – dated 1280/1864 had affected the layout [4]. North side of the urban area has regular grid patterns includes square blocks but towards a west side the regularity transforms to rectangular ones and block sizes get longer than the others.

First regular site plans can be seen at the beginning of the twentieth century. Goad Pasha had prepared plans for the site but they were not showing the parcels. In the insurance plans which was drawn by Pervitich in 1936 were showing the lots, buildings and functional differentiation. The analysis which is based on Pervitich plans denotes the built environment in 1936 (Figure: 2). North east side of the plan has regular grid pattern and some of the junctions repeat one after has broken corners which is the indicator of the westernization. Because Storari had applied same motif in Aksaray fifty years ago and he also repeated the motif three times along street [5]. Not all the areas of the blocks had been divided into lots because of the population. Widths of the lots were very narrow. Lots which contained row houses had 4.5 – 6 meters wideness, 12-30 meters lengthiness. Buildings either used lots completely in small ones or placed in street sides of them. Most of them had a garden in the backside but as a property of the houses there were no garden usage. Only some of the lots had an addition in the backyards of the houses for using as storage purposes.

Figure 2. Morphology of lots and buildings in 1936 (Pervitich)

Current municipal plans of the area show that all the empty lands used and divided new parcels. Some lots attached one another to make bigger lots in accordance with contemporary requirements. Land use gradually turned to mixed use and commerce got into the area. Nowadays lots of building are used for small business activities. After the 1980's many people immigrated to Istanbul and population increased dramatically. This caused to rising of rate of the buildings in the city and Yeldeğirmeni. Number of buildings and height of them rose approximately thirty or forty percent in the area. Buildings defined the borders of the blocks and the streets (Figure: 3).

4. PERFORMANCE OF THE BLOCK SIZE

Moudon, Panerai *et al*. and Siksna have made important contributions to the study of blocks with respect to many viewpoints. Some of them are the processes governing the lot pattern within blocks, adaptability and interaction of buildings, lots, blocks and urban form, and the dimensions of the urban structure of streets and nodes [6] (Figure: 4). According to studies, 60-70m is very fine block and circulation size for pedestrians, 100m is very convenient and 200m is very coarse size for pedestrians.

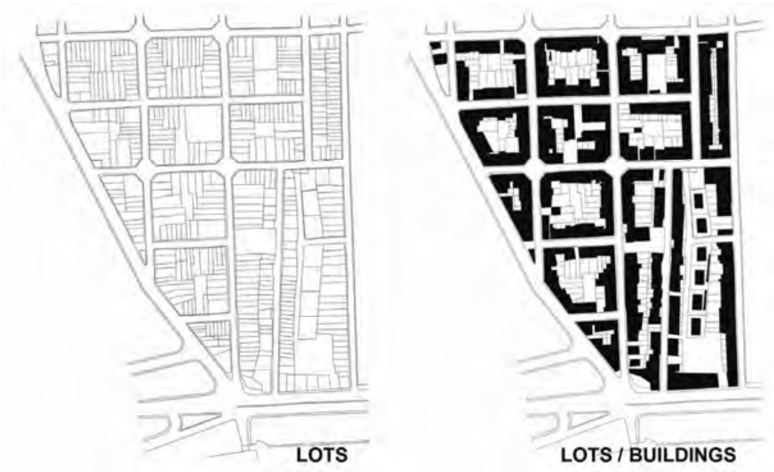

Figure 3. Morphology of lots and buildings in 1987 onward.

Siksna notes that, small or medium blocks are more suitable for general functioning of city centers than larger blocks. According to him layouts with square blocks will maximize circulation space, whereas rectangular blocks will maximize developable land. Small blocks produce finer-grid circulation networks than larger blocks. Street spacing of 80-110m offer a circulation mesh which is convenient for pedestrians but 50-70m is finer-grid and appropriate in areas of intense pedestrian activity [7].

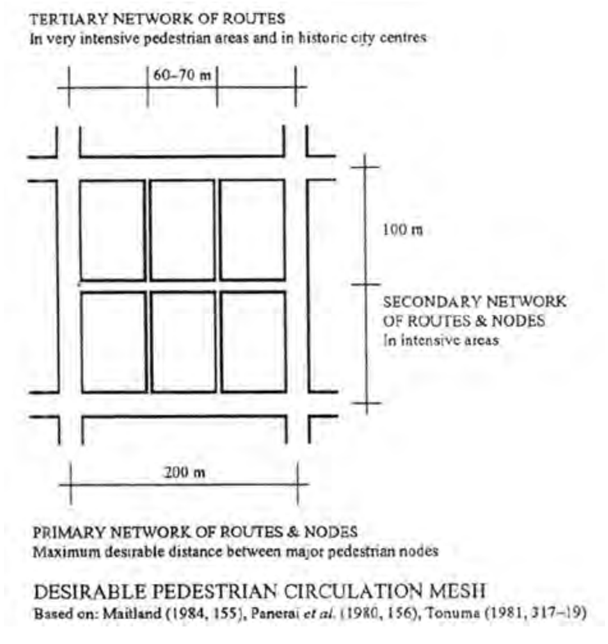

Figure 4. Optimum block and circulation sizes.

Selected area of the Yeldeğirmeni generally has optimum block and circulation network size. Many block size vary between 70-60m north-south and east-west directions. Two of them are slightly larger than 110m: 130 and 152m. The block which has municipal number of 195 is very larger than 110m: 232m. This block has dramatic circulation size for pedestrians whereas it had appropriate size in 1930's. All of the sizes of blocks of the selected area can be seen at the table as shown below (Table 1).

Table 1. Block and Circulation Performances of Yeldeğirmeni

Block Sizes of Selected Area of Yeldeğirmeni				
Block Number	**Original Block Sizes**		**Present Block Sizes**	
	Street Spacing		Street Spacing	
	N-S (m)	E-W (m)	N-S (m)	E-W (m)
195			45	232
207	36	80		
207 (a)	43	151		
196	44	53	44	53
197	74	68	74	68
198	75	69	75	69
199	36	84	36	84
200	73	61	73	61
201	73	62	73	62
202	17	56	17	56
205	76	61	76	61
206	76	62	76	62
211	76	61	76	61
212	75	60	75	60
213	30	130	30	130
997-204	74	152	74	152
998-204 (a)	60	71	60	71

5. LAND PARCELLING

There are different lot sizes in the environment and most of them used for the houses. Schools, churches, synagogue and mosques have special lots in their own. Most of the lots which are used for the houses have similar character. Their sizes vary 4-6 meters in width and 10-30 meters in length. Few lots are wider than these optimum sizes were used for the apartments which have required larger ones, for instance, Italian apartment.

Lot sizes determine the building design. Street side of the lots is very narrow means that the houses have generally slight facades in the nineteenth century. Streets are designated by the houses and the entrances of the buildings are from the streets (Figure: 5). Few has small garden in front side of the lot to enter to the building. Back sides of the buildings are vacant land. Similar to the row houses which are built in the several places of the Istanbul in nineteenth century, people don’t have a habit using the back side of their houses. Back sides are generally used for warehouses or outhouses. Similar usage habits still continue in our times.

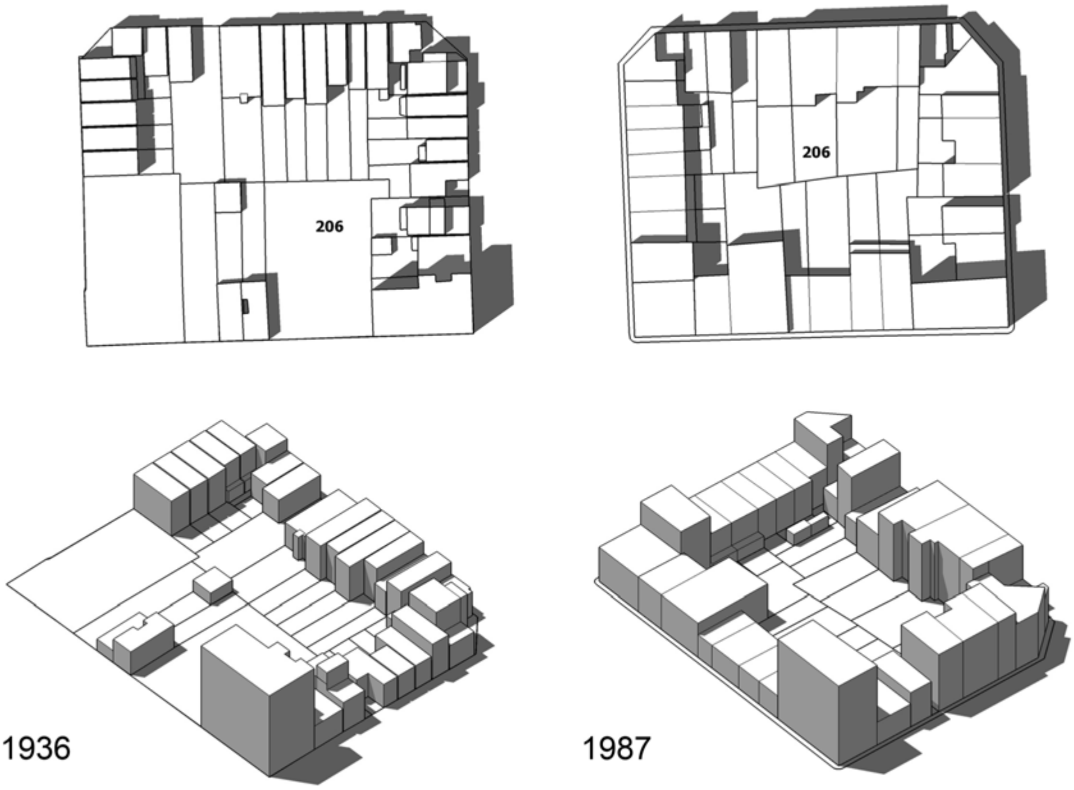

Figure 5. Lot and building relations in block 206 (without topography).

6. CONCLUSIONS

Yeldeğirmeni and its particular selected areas generally have been evolved as regular street and block urban pattern. It still preserves its initial urban forms. Small modification only occurred in the west side of the region by joining two blocks to obtain a larger one. This amalgamation isn’t suitable with the theories of research studies. Joining of two blocks created a larger one than previous ones means that new larger block isn’t appropriate for pedestrians in respect for circulation.

But urban blocks in the region generally have proper sizes according to works of Panerai *et all* and Maitland [8]. Most of the grid blocks have approximately 75-60m width sizes and they are accurate for pedestrians. Dimensions of blocks explain the stability of its forms over times. They produced fine-mesh circulation patterns, more potential lot frontages, more coherent block fabrics.

The study has identified certain factors and processes which enable morphological layouts of lots, blocks and streets to be modified over time. From one side, small lots amalgamated to obtain larger ones in the second part of the twentieth century caused large lots and high building blocks. But the other side it shows the adaptability and the performance of the blocks for past, present and future developments.

Turning to large lot size is related to technological improvements and the large space requirements. That's why slight row houses turn to large adjacent apartments which have concrete structures and accommodate more family than the others.

Morphological investigations in the center of the Yeldeğirmeni and the identification of the optimum block sizes also suggest that they might be used as "models" for the improving existing urban fabrics. If certain block forms have produced particular effects in the past, they can perform similarly in the future.

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GENTRIFICATION PROCESS AND PLACE ATTACHMENT IN HISTORICAL SETTLEMENTS: A COMPARATIVE STUDY

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ABSTRACT

The need for projects on urban regeneration in historical settlements is quite important as the attempts to meet the needs of globalization caused an undeniable neglect on historical and cultural heritage. An understanding of gentrification in traditional urban areas is crucial because; there are many positive outcomes related to gentrification, including; upgrading of existing buildings, new neighbourhood amenities, economic development for the city, neighbourhood stability and renovation of vacant and abandoned properties. However, besides these positive outcomes, gentrification may cause many problems such as displacement of original local residents. This study aims to focus on gentrification process and place attachment in historical settlements of Istanbul. Based on literature research, in the theoretical framework, some keywords such as "gentrification", "displacement" and "place attachment" were discussed in general terms. A number of regeneration efforts of Istanbul's old city centre (Cihangir, Galata, Fener-Balat etc) which have been made in the form of gentrification were briefly described. Because the gentrification process in Kuzguncuk, which is one of the old Bosphorus Villages has a different structure from other examples, this paper focused primarily on the residential transformation of this neighbourhood. An empirical study, which was carried out to explore the effects of place attachment on historic preservation in the case of Kuzguncuk was briefly examined. In order to explore semantic responses of local people related to the concept of place attachment, different methods of data collection were analysed. A comparative review of the theoretical and empirical literature on gentrification in historical settlements showed that, although there are similarities between the problems, goals and conditions, gentrification involves different actors and proceeds with varying consequences.

1. THEORETICAL FRAMEWORK

Urban regeneration can be described as a comprehensive and integrated vision and action which leads to the resolution of urban problems and which seeks to bring about a lasting improvement in the economic, physical, social and environmental condition of an area that has been subject to change [18]. Thus, the urban regeneration process starts from an analysis of problems. Different kinds of problems need to be dealt in different spatial levels. Traditional urban areas, squatter areas and historical centres are examples of the most preoccupying issues. The need for projects on urban regeneration in historical settlements is quite important because the attempts to meet the needs of globalization caused an undeniable neglect of historical and cultural heritage. The present research aims to focus on gentrification in historical settlements of Istanbul, which is the capital of two empires, and land of different nationalities and cultures. Based on literature research, in the theoretical framework, some keywords such as “gentrification”, “displacement” and “place attachment” were discussed in general terms.

1.1. Place Attachment

Relationships to places reflect people’s psychological landscapes, their personal issues and their particular journey in the world. Because of this, people develop relationships to a wide variety of places, the combination of which reflect people’s particular way of ‘‘being-in-the-world’’ [8]. The people place relationship has been explored through a variety of concepts. One concept in particular, which is largely accepted and used in the researches on environmental psychology, is the phenomenon of place attachment. It has been defined as “the collection of meanings, beliefs, symbols, values, and feelings that individuals or groups associate with a particular locality”. Attachment used in this context can be defined as an affective relationship between people and the landscape that goes beyond cognition, preference or judgment [15, 17]. Place attachment is generally conceptualized as being comprised of two components: functional place attachment and emotional place attachment. Functional attachment reflects the importance of a place in providing features and conditions that support specific goals or desired activities. In this sense, the people who use the place may or may not feel a strong sense of attachment to it. Functional attachment is embodied in the area’s physical characteristics. On the other hand, emotional place attachment refers to the emotional aspects of a person-place relationship and how place contributes to an individual’s self-identity [1]. Emotional/symbolic meanings, concern the importance a person attaches to the place because of what the setting symbolizes. It refers to the symbolic importance of a place as a repository for emotions and relationships that give meaning and purpose to life [6, 12].

1.2. Gentrification

Historic preservation generally leads to gentrification, which had a number of contrasting definitions in the substantial academic literature. Gentrification in traditional urban areas is important because; there are many positive outcomes related to gentrification, including; upgrading of existing buildings, new neighbourhood amenities, renovation of vacant and abandoned properties [20]. However, besides these positive outcomes, gentrification can cause many problems such as displacement of original local residents [7, 14]. The word of gentrification has become so loaded with economic, social, cultural and often racial overtones that rational, reasoned discussion is often simply not possible. To some gentrification means new investment, homeownership, neighbourhood stabilization. To some gentrification means loss of affordable housing and a revitalization of the physical character of a neighbourhood at the expense of the human character of the neighbourhood. To some gentrification simply means “not like us”. Some studies use the term of gentrification interchangeably with urban regeneration that is the process of enhancing the physical, commercial and social components of neighbourhoods and the future prospects of its residents. According to this approach, gentrification may be synonymous with any urban revitalization activities that result in any physical improvements made to residential and commercial developments [11]. They consider gentrification as physical upgrading of low-income neighbourhoods. In contrast to the property-focused visions of the gentrification process, others describe gentrification as the class and racial tensions and dislocation that frequently accompany the arrival of new residents into a neighbourhood [11]. Under this definition, gentrification involves a process of differentiation amount social groups according to increasingly specific criteria. It can involve class and ethnic antagonism and cause residential segregation, resulting in the emergence of a new urban built environment, which has serious implications for social inequalities [19]. According to this approach, the population change, the loss of the stable communities and the displacement of the local residents may be described as unavoidable results of the gentrification.

2. GENTRIFICATION IN HISTORICAL SETTLEMENTS OF ISTANBUL

Gentrification process in Istanbul first begun in the 1980s in the city centre and especially in neighbourhoods with historical and cultural value. The first gentrified settlements were the most prestigious residential areas of Istanbul like Bosphorus neighbourhoods (Kuzguncuk, Ortaköy etc). In 1990s, Istanbul’s old city centre was affected by gentrification in different ways (Cihangir, Galata, Beyoğlu, Tunel etc). Then, since the beginning of 2000, the process of gentrification was observed in the Historical Peninsula and southern side of the Golden Horn (Fener, Balat etc). Although there were similarities between the goals and conditions; reasons, actors and proceeds were different from one another. Every settlement that has some sort of historical value affected by the gentrification process in a different way, with respect to its physical location, social and economic characteristics. In most of the examples, renovation activities were undertaken individually by artists, architects and academics (Cihangir, Galata, Kuzguncuk). The central location of the area (preferring to keep away from commuting long distances from home to work and unbearable traffic problems), aesthetic, historical and architectural value of the buildings and nostalgic ambiance attracted pioneers of the first phase of gentrification. In this phase, intellectually upper class moved to the area and they bought or mostly rented architecturally distinct but dilapidated properties for residential use. Generally, gentrification process started with individual attempts. The cases of institutional gentrification are very limited in number (Fener, Balat). In most cases, there was no economic support and direct impact of governments, associations and municipalities. In some cases, spatial transformation has been observed in inner residential spaces and reflected only in conservation of some of the old tissue (Cihangir). Since the culture and art have been more evident in the first stage of gentrification [5], in addition to residential purposes, some historic buildings transformed from houses to art galleries, coffee houses and recreational units (Galata, Tunel, Ortaköy). However, in the second phase of gentrification, the scale of the process has changed, from the level of flats, to the level of entire buildings. So, the main impetus behind gentrification process switched from a desire underlined by a “preference to live in a historic area”, to a materialistic desire determined by “earning profit” [10]. In this phase (after a huge attempt of the municipalities for widening roads and regularization of the main streets), rather than individuals, large-scale investors bought and renovate the buildings for the use of upper classes (commercial purposes, boutique hotels etc). The process initiated spontaneously and market forces stimulated transformation [21]. The resulting increases in prices and cost of living led to the further attraction effect of the high-income groups and to a pushing out effect on the existing residents in the old settlements. Increase of rents forced old residents to leave the neighbourhood in spite of their desire to stay there. Although the first pioneering group tried to revive the area’s old identity and historic value, displacement was unavoidable. In such examples, the increased land values and prices constituted at the same time a serious obstacle before the success of the gentrification.

3. GENTRIFICATION AND PLACE ATTACHMENT IN KUZGUNCUK

Kuzguncuk is located on the Anatolian side of Istanbul along the coast of the Bosphorus, Spanish Jews settled here in the 15th century, followed by Armenias and Greeks [3, 13]. It was also a settlement where the non-Muslim and Muslim population lived together for many years in a close and easy-going relationship. The quarter, in which synagogues and Orthodox churches are neighbours and a mosque and an Armenian church share the same piece of property as twin buildings, counted as a cosmopolitan paradise that lasted for centuries (Figure: 1).

Figure 1. The historical ambiance of Kuzguncuk.

The minorities left Istanbul in response to the political climate between the 1940s and the 1960s [5]. The socio cultural profile of Kuzguncuk in the late 1950s and early 1960s displayed a rural migrant population. In the 1980s, a number of artists discovered Kuzguncuk as a historical idyll, as one of the few places bearing witness to the cosmopolitan Istanbul believed destroyed. Today the largest population group in Kuzguncuk is Black Sea migrant community, which began to arrive in the late 1930s. Very few minorities remained. The others are newer residents who moved there during the gentrification process. The transformation and gentrification process in Kuzguncuk started at the end of 1970s, with the dedication of one internationally well known architect-author, who has received Aga Khan Award in 2001 [9]. Cengiz Bektaş used historic renovation as a vehicle for specific aims and goals intended to create community and a sense of belonging in local neighbourhood life. The architect encouraged the inhabitants to renovate their own houses. In the 1990s, the restoration movement was a precursor to a larger wave of gentrification. The first gentrifiers began to organize social activities in the neighbourhood, along with upgrading and rehabilitating the built environment with the long-term residents [16]. Community oriented activities in neighbourhood began with wall painting on a street called as Uryanizade Street (Figure: 2). Local participants were given instruction in relevant techniques (such as mural painting, or setting pebbles in cement for decorative paving). In order to nurture a sense of bonding among residents, a number of cultural events (workshops, summer schools, library etc) were organized. A particularly resonant intervention was the erection of an open-air theatre at the top of the stairs of Bereketli Street (Figure: 3) [9]. All these were intended to improve the social and cultural interaction among the residents (long-term and newcomers) and to improve the environmental quality of the neighbourhood at the same time. Against the plans to build a private dialysis centre on the Kuzguncuk Bostanı (historic market garden of Kuzguncuk) a thousand signatures were collected from local residents. Kuzguncuk born residents who are the young members of Black Sea migrant families worked closely with a group of professionals who moved to the district after 1980. “The garden belongs to the people of Kuzguncuk” (Figure: 4), “Our soul, our pride, our everything, our garden” were the slogans carried by local residents who wanted to keep the garden green [16].

Figure 2. Pebbles [3]. Figure 3. Open air theatre [9]. Figure 4. Slogans [16].

4. A CASE STUDY ON PLACE ATTACHMENT IN KUZGUNCUK

An empirical study was carried out to explore the effects of place attachment on historic preservation in 2000 [2]. The sample was selected from local residents using a random process (Figure: 5). In order to explore semantic responses of people related to the concept of place attachment in man-environment dialectics three methods of data collection were analysed: (1) Semantic differential scale, (2) Cognitive mapping techniques (3) Visual research methods. Beside these methods, to explore what is the meaning and image of the district in respondent's mind, a questionnaire included close ended and semi-open ended questions was employed. For the particular purposes of this research, only questionnaire and semantic differential results were summarized.

Figure 5: Local residents who migrated in the late 1930s [2].

The demographic data indicated that there was a permanent population in the historical area. The question of "Do you feel that, you can identify yourself as people of Kuzguncuk" was generally answered with "yes" by the local residents. When the answers to the question of "If you have a chance to choose a place to live in Istanbul, where will you prefer?" was analysed, the length of residence seemed to be a major factor in preferences. There was a positive correlation between the length of residence and preference of historic area. The sample who has been living in the area for a long time, generally answered this question as "Kuzguncuk". A review of the literature suggested that the length of residence in the neighbourhood causes the development of physical, psychological and emotional bonds with the area [4]. The results from the present study provide evidence to support this.

Semantic differential scale was employed to measure subjective evaluations of respondents in an objective manner. The description of “emotional attachment to place” had a dominant repetition frequency. The result showed that place attachment in Kuzguncuk may be conceptualized as place identity (emotional place attachment) rather than goal directed (functional place attachment). The other most repeated adjectives were “interesting” and “historical”. Although the description of “interesting” is more related to the first image and can only be used by people who are alien to the area, local residents considered this term in the most effective adjectives. While determining the image of the district, pragmatic factors stayed behind and local residents described the area in a more general approach. The repetition frequency of “historical” showed that local residents were aware of the fact that the historical background of Kuzguncuk relates to the local identity. In the second part, using positive adjectives of Semantic Differential chart, some sentences describing a well-qualified environment were given to participants. The aim of this part was to compare the most important criteria of a well-qualified environment with the characteristics of Kuzguncuk. Thus, whether the area was carrying the well-qualified environment criteria from the respondents’ viewpoint was explored. In this part of the empirical study, local residents put primary importance on the functional qualities of the area. While evaluating an area as a well-qualified environment pragmatic-functional factors (housing standards, comport conditions, accessibility of social services etc.) were more efficient than the others. The answers given to open and semi-open questions showed that, although Kuzguncuk don’t have all necessary conditions for a well qualified environment, local residents prefer to live there in future. While the study is evaluated as a whole, it may be suggested that, in spite of some inadequacies including pragmatic conditions, local identity and place attachment play an important role in choosing a place to live.

5. CONCLUSION REMARKS

A comparative review of the theoretical and empirical literature on gentrification in historical settlements showed that, although there are similarities between the problems, goals and conditions, gentrification involves different actors and proceeds with varying consequences. The case of Kuzguncuk is differentiated from other gentrification experiments in terms of its dynamics and processes. While some of the samples can be evaluated as individualistic process or institutional gentrification, regeneration in Kuzguncuk, represents a model of successful conservation of a valuable social and physical environment through community action process. Gentrification in Kuzguncuk may be defined as a successful example of neighbourhood activism, which is a way of achieving urban regeneration in settlements facing tremendous displacement pressure. It can be suggested that, in the case of Kuzguncuk, gentrification is achieved through the way of place attachment and displacement of original local residents is prevented. The theoretical and empirical findings of this research showed that, in the gentrification process, preservation of historic and cultural characteristics of a neighbourhood may be sustained with the consciousness of local residents who have developed some sort of place identity.

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ENHANCING THE IMAGEABILITY OF A HISTORICAL CITY CORE IN THE PROCESS OF URBAN REGENERATION A CASE STUDY OF THANJAVUR

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ABSTRACT

The focus of this paper is on urban regeneration of Public Realm within a larger framework of Indian historic city core. It confines itself to the enhancing the image and identity of the historical city core of Thanjavur, the famous temple town of South India as a cultural resource. The objective of this paper is, to propose a method of analysis that can contribute to the identification of the most appropriate strategy for enhancing the imageability of the historical city core of Thanjavur. The applicability of this methodology has been demonstrated in context of the historic core area of Thanjavur.

1. INTRODUCTION

Historic urban areas developed gradually over time, are an expression of the diversity of societies throughout history. They make up a key part of the character of the city core and embody the values of traditional urban cultures. Traditional buildings in the historic core play an important role in many towns and cities. They lend character to an area and also have deep associations for local residents and communities. Today many such areas are being threatened, physically degraded, damaged or even destroyed, by the impact of the urban development that follows industrialization in societies everywhere. The often aggressive development of certain urban functions, especially in the historic centre, creates conflicting situations, in which the traditional elements are at the risk of being demolished or endangering the heritage, artistic or ecological values that constitute the very reason for its protection. It is important to seek solutions to the conflicts which give priority to the preservation of these values. There are many approaches for revitalization and conservation of such heritage areas. Urban regeneration is one of them which, aims to improve such historic public realm by a way of enhancing the imageability and also economically revitalizing them. The need for urban regeneration in a historic city core arises usually from a combination of circumstances: expansion of the town, lack of modern facilities, traffic problems, outworn buildings, the area in themselves lacking interest, color and any pleasant feeling, the abandonment of buildings and not reconstructing buildings after damage by natural disasters. The main objective of urban regeneration is the removal of blight and urban decay from the historic city core.

2. HISTORIC CORE AREAS IN INDIAN CONTEXT

In India, many traditional cities are developed around a historic core, where the core area is called as walled city or inner city. Usually the temple or Mosque is placed at the centre and the markets immediately adjacent in typical inner cities. The seat of government / palace is seldom at the centre and is usually on the outskirts. Bordering these public areas are the residential districts. In historical south Indian cities like Madurai, Srirangam, Thanjavur, Chidambaram, Kumbakonam, the temple dominates the plan at the centre. The main streets that are wide enough for the temple cars to move around the temple during festivals run around the temple in all cardinal directions. These traditional cities have developed over many centuries and every city has its own identity and a different morphological structure.

3. STUDY AREA - THANJAVUR

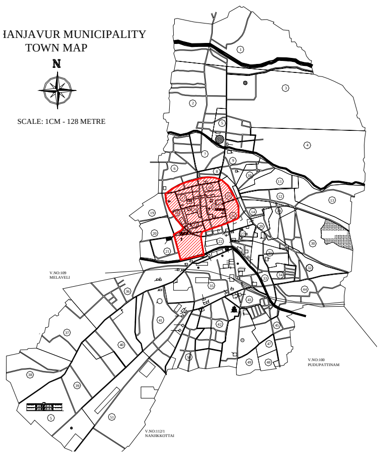

Figure 1: Thanjavur town map

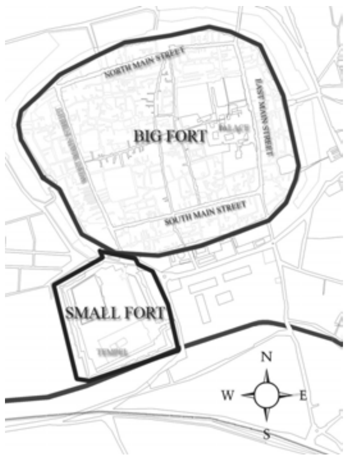

Figure 2: Thanjavur Historic area map

Thanjavur is a historical city located in the central eastern part of Tamil Nadu state. It is one of the important heritage towns of south India. It is situated between 9º 50' and 11º 25' north latitude and and 75º 45' and 79º 25' east longitude and spreads over an area of 30 SqKm and has a population of 2,15,725 according to 2001 Census. Thanjavur was the capital of Imperial Cholas and was ruled by different rulers starting from 8th century Cholas, the Pandyas, the Nayaks, the Marattas and the British. Each ruler contributed to the development of the town in a unique way.

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Figure 3: Brahadeeswara Temple

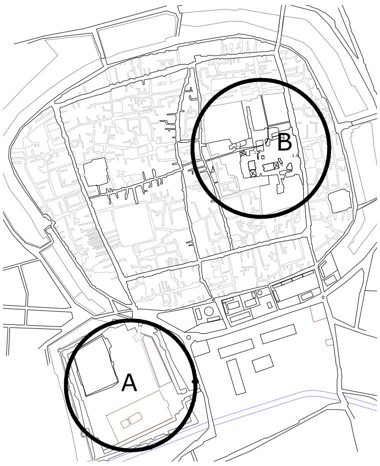
Figure 4: Palace complex

3.1. PROBLEMS AND ISSUES OF HISTORIC CORE OF THANJAVUR

Thanjavur historic area is located in the heart of the present city (fig 1), surrounded by the remains of the rampart wall on western side and temple fort on the south west corner. The historic area in Thanjavur is divided into two forts Big fort and Small fort (fig.2). The small fort extends over an area of 0.33 Sq.km and consists of Brahadeeswara temple (fig.3), Sivaganga garden, tank, Schwartz church. The big fort extends over an area of 1.33 Sq.km [6] and consists of a large inhabited area, magnificent palace (fig.4), granary of Nayak period and many temples of different period.

The historic core of Thanjavur suffers from an enormous pressure on its traditional urban fabric, which is constantly getting transformed to accommodate and adjust to the new land use, materials and transport systems. The major problems include traffic congestion, commercial activity which attracts large volumes of traffic; lack of parking space and regular traffic jam; inadequate public facilities, lack of proper signage, and improper solid waste management; increasing pressure on infrastructure systems; change in land use resulting in the breakdown of the traditional social fabric. Lack of awareness and appreciation of traditional architecture and the heritage value of the town with its inherent advantages and breakdown of the traditional local governance system have further aggravated the problem. Involving the community, spreading awareness about the need for urban conservation and more importantly, putting a check on the demolition of heritage properties in the historic core to build commercial centre, remain important The shifting of commercial activities from the core area towards the newly developing areas like Medical college road and new bus stand area, are likely to cause further economic decline to the old town.

In spite of large number of tourists coming to see Brahadeeswara temple and the palace complex, the town lacks basic tourist facilities like information kiosks, hygienic toilets, pedestrian paths and good restaurants in the movement corridor connecting Brahadeeswara and palace complex.



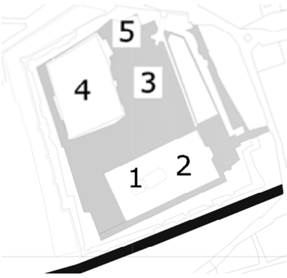
A - Temple complex

1. Main vimana
2. Temple courtyard
3. Sivaganga Garden
4. Sivaganga Tank
5. Schwartz Church

B - Palace Complex

1.1 Arsenal tower
1.2 Bell tower
1.3 Sangeetha Mahal
1.4 Saraswathi Mahal Library
1.5 Maratta Durbar Hall

Figure 5: Historic Core Area of Thanjavur



A - Brahadeeswara Temple & Sivaganga Garden

B - Palace Complex

The new construction coming up in the historic areas are not compatible with the character of the area, especially in the palace complex. The area on the southern side of the Brahadeeswara temple needs a special attention, at present the advertisement hoardings on the terraces of buildings in this area obstructs the temple view. Any new development in this area will have impact on the temple complex setting, so the developments in that area should make use of the temple view and should not block the view of temple from other areas of the city. Building heights and signage needs to be controlled in this zone. The town has tremendous tourist potential and the tourist arrival is also increasing every year. If the town’s heritage value is revived, it will certainly enhance the image and identity of the town, which in turn will attract more tourists.

Figure 6: Arsenal Tower

Figure 7: Bell Tower

4. METHODOLOGY FOR ENHANCING THE IMAGEABILITY OF THANJAVUR'S HISTORIC CORE

Systematic analysis techniques are used here to identify certain characteristics and illustrate them in a way that can be used to guide and inform policy and proposals. Accordingly the methodology for enhancing the imageability of Historic core includes wide range of issues including, Historical Resources; Legibility; Views and Landmarks; Active Ground Floor Uses; Access to heritage areas which include Pedestrian Paths and Parking Spaces and Hierarchy of Routes and Spaces and Signage Components. This analysis should then become the base for formulating policy guidelines and strategies for improvement of historic core area. The applicability of this methodology has been demonstrated in context of the historic core area of Thanjavur.

4.1. Analysis of Historical Resources

Heritage value of the area has been analysed by identifying historical resources through the study of historical records. The historic pattern of developments that have influenced the routes and spaces their location, hierarchy and character which form the urban structure has been studied. Presence of large number of heritage buildings in the city core area reveals the city centres historical legacy. As mentioned earlier, there are two important heritage areas in the historic core of Thanjavur, one is the Brahadeeswara temple complex (with Sivaganga garden and tank) and the other is the Palace complex. The important heritage buildings in these two areas are: Brahadeeswara temple, Schwartz church, Bell tower (fig.7), Arsenal tower (fig.6), Sangeetha Mahal, Durbar Hall and Sarja Madi. The historic core area of Thanjavur is full of historical resources which have enormous potential for contributing to the economic development of the area, adequate efforts needs to be put for making guidelines to protect and enhance the historic environment.

4.2. Legibility Analysis

The image of identity of a place remains stronger on a tourist only when a place offers a clear image and if it is easy to understand. This analysis is done to find out the important landmarks, gateways and focal points in the historic core area of Thanjavur, which gives a clear image and enhances the legibility. Fig 9 shows the important paths, gateways, city hub, edge, nodes and landmarks. The important paths identified inside the historic core area are southmain, eastmain, westmain and northmain streets. The important gateways are identified as street leading towards the old town near oldbus terminus, entry opposite to sivaganga garden, entry from Karanthatankudi. The corridors which run along the moat namely southrampart, east rampart, and west rampart roads, where the ruined fort walls form the distinctive edge. Rajarajan junction, Anna statue, oldbustand junction are the important nodes of the town. A detailed analysis of views and landmarks is further required to be done, so as to identify the strategic views and viewing corridors.

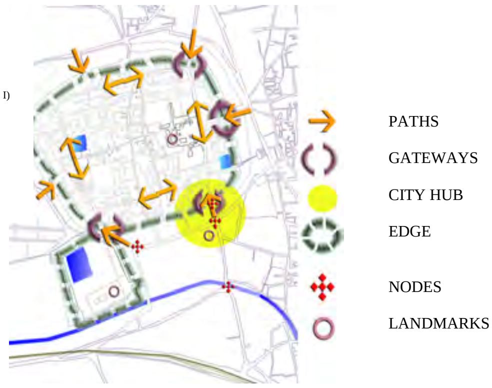


Figure.8 Historical Buildings and Conservation Areas **Figure .9** Legibility Analysis

4.3. Views and Landmarks

Analysis of **views and landmarks** (fig 10) has illustrated the importance of the Brahadeshwara Temple Vimana not only as a visual landmark, which is almost a city icon, but also the importance of other landmarks like Bell tower (fig.7) and Arsenal Tower in Palace complex and Rajagopalswamy temple gopuram and Clock tower which taken together create a varied skyline in the historic core of Thanjavur. Many of the landmarks located in the historic core area have significance to certain areas of the city centre others have city significance because of their height. Some other buildings are identified as landmarks but have poor quality in terms of their appearance namely, Mahalingam press building and Modern Radio service building near the oldbus terminus. Analysis of important views of the landmarks which needs to be preserved are shown in fig.9. The local landmarks namely rajarajan statue, anna statue, clock tower, Thopil pillayar temple near cauvery super market have local significance. Views which need to be enhanced from the street corridors are also identified from this analysis. This analysis has shown the important landmarks and views in the historic core area which needs to preserved and enhanced to improve the image of the city.

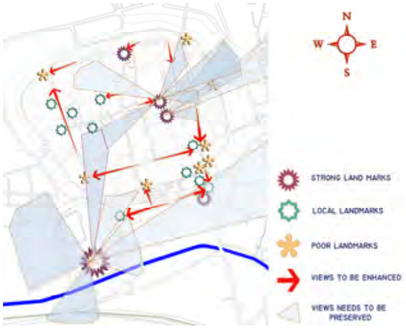


Figure.10 Views and Landmarks   **Figure.11** Active Ground Floor Uses

4.4. Active Ground Floor Uses

The location of **active ground floor uses** (fig 11) identifies those parts of the historic city, which attract more pedestrians. Active Frontages are those that have the main retail and commercial activities. The majority of active frontage is contained within the inner circulatory streets namely, the south main street, Ayyankadai Street and Manojiappa Street leaving large areas of the city centre unattractive to visitors. Even these frontages lack visual interest characterized due to gap sites, on-street parking and lack of exclusive pedestrian paths in these areas, presenting a poor image of the city centre. This analysis of active ground floor uses has shown the active frontages in the streets and the pedestrian access to them.

Figure.12 Access to the Historic Core   **Figure.13** Pedestrian Paths and Parking Spaces

4.5. Access to the Historic core

Access to the historic core area from different parts of Thanjavur city and from outside the city is achieved through movement corridors. The significance of these corridors and their hierarchy with respect to image and identity gains important due to the heavy tourist movement. The analysis of approach links to the heritage areas has shown the vehicular movement and Pedestrian circulation (fig 12 and fig

13) in the historic core area. It also illustrates the need for better pedestrian linkage between heritage areas.

5. CONCLUSION:

Urban regeneration and preservation of historic towns is, today one of the most important aspects of the policy of safeguarding the monumental and historical heritage in many countries. In India many historical inner cities are characterized by an exceptional concentration of magnificent traditional buildings, which gives a unique visual character to that town. It is evident from the study and analysis that renewal of Thanjavur historic core should involve renewal of economic base, an increase in investment in the core area and the revitalization of the economic and financial structure in addition to restoration of monuments. This is essential to meet the restoration costs and the maintenance of the restored environments and other public realm in the historic core. The main issues to be considered for the regeneration of Thanjavur historic core is the balanced approach of conservation and development and community involvement in the planning process and design, adaptive reuse, provision of infrastructure and administrative structure to deliver the project and creation of awareness and responsibilities among the local people. Successful regeneration of historic environment in Thanjavur will bring social, economic and environmental life back to its historic core area. It will transform places, enhance the community's self-image and will re-create attractive places which will encourage sustained inward investment. Understanding how places change and recognizing the significance of their history in the historic core area, is the key to successful and sustainable urban regeneration.

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THE ANALYSIS OF PHYSICAL TRANSFORMATION AND PROBLEMS IN SANDAL AND CEVAHIR BEDESTEN OF THE GRAND BAZAAR AND SOME SOLUTION PROPOSALS

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ABSTRACT

Mosque and bazaar which they found the neighborhood together are two important part of a classical Ottoman district. While mosque represents religious life, bazaar symbolizes economical life of the neighborhood.

It is seen that The Grand Bazaar as a very important historical, cultural, economical and touristic heritage has loose its original identity. Therefore, this study is formed the care of the continuity of its value. The aim of the study is to make a preliminary research which gets data in order to prevent the physical damage of The Grand Bazaar. Problems of the building first were examined by researchers in 2003. The second examination was done in 2006.

In the study, problems, which were determined at two different period of time by using interview and observation techniques, were asked to users of the Grand Bazaar by using questionnaire technique. With data of the study, this research is aiming to generate pre-data for user-based rehabilitation works and projects.

INTRODUCTION

Beside to be one of the most important economical powers of Istanbul, the Grand Bazaar is significant for the social and cultural identity of Istanbul as well. While trying to protect his identity, it faces many physical, economical and social problems. Regardless of all other feature of the Grand Bazaar, to be the biggest covered bazaar of the world, is simply enough to protect its historical, cultural and social values.

Mosque and bazaar are generally located either very close or together in Ottoman cities. Therefore, the dynamic texture of social, economical, cultural and theological structure of Ottoman society determines the location of both structures in the city. Since it serves as the center of the city, as the focal point of people's movement and as the intersection point of all roads, bazaar is one of the most important society forces in Ottoman cities. [1].

The geographical situation and location of Istanbul has always influenced on economical life of the city. Because of this reason, Istanbul has been the most important import/export place of Turkey [3]. It has been known that bazaar generally constructed in surroundings of big mosques with some other places such as medrese (theological schools) and imaret (place which served free to the poor and to others, such as medrese students). The Grand Bazaar, located between Nuruosmaniye Mosque and Beyazit Mosque, is one of the most important bazaars that still carry on its activity.

The Grand Bazaar was not a structure built on an empty lot, but a complex of building which took many years to come into being. The development of the structure was a slow growth rather than a sudden development. Some of its bedestens and hans were large buildings originally constructed of stone or brick, while some of the shops were originally wooden structures, which were in time converted stone or brick buildings. [2].

CASE STUDY

To understand the social and physical situation of The Grand Bazaar, a literature study aims to analyze former study about The Grand Bazaar was done. Sandal and Cehavir Bedesten, calls core of The Grand Bazaar, selected as the area of study. Beside the determination of present situation, interview, observation and questionnaires techniques are used as well to get data. After that, the physical problems of two bedesten are examined deeply.

Findings

Table 1

CEVAHİR BEDESTENİ	*SANDAL BEDESTENİ*
According to you, what is the biggest problem of the Grand Bazaar?	
1. Difficult to reach, uncared conditions	1. Unsystematic, Insufficient introducing/advertisement activities
2. Physical problems, Environmental arrangements	2. Economical problems
3. Unsystematic	3. Insecure
4. Insufficient-introducing/advertisement activities	4. Management problems
5. Insufficient cultural activities	5. Uncared conditions
6. Excessive tourist activities	6. Excessive trade activities
7. Management problems	7. Insufficient cultural activities, Excessive tourist activities
8. Insecure	8. Environmental arrangements
9. Excessive trade activities	9. Difficult to reach
10.Economical problems	10. Physical problems

Figure 1. Humidity problems on the walls (Photos: Ö. Şenyiğit)

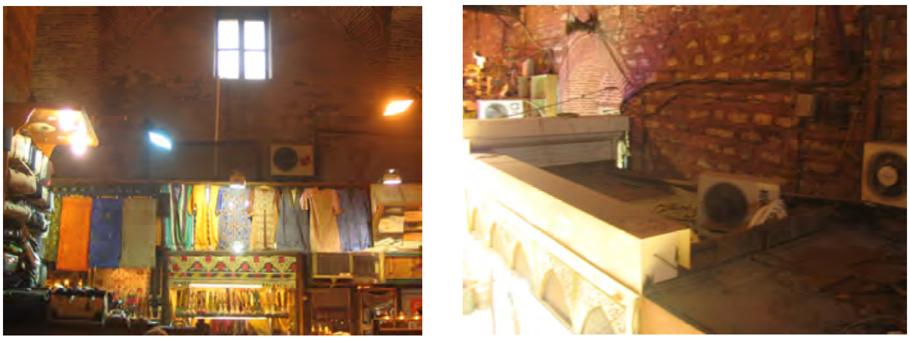
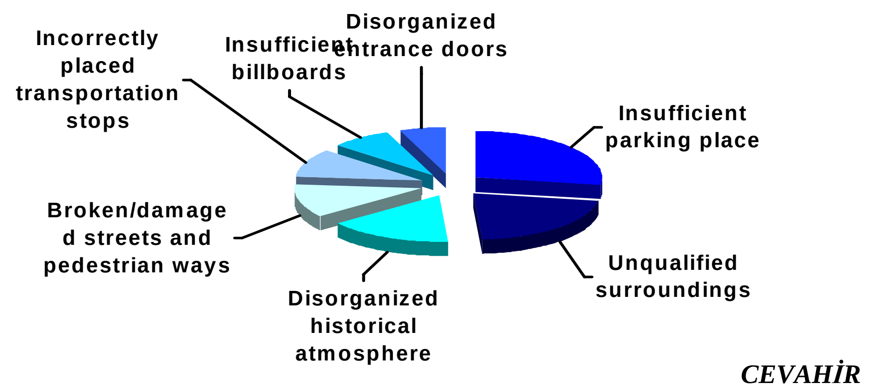


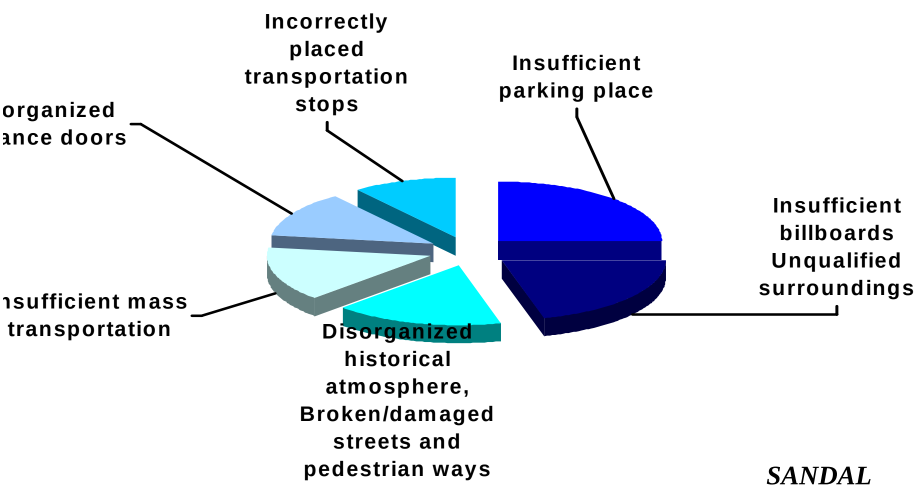
Figure 2. Ventilation problems of Bedestens (Photos: Ö. Şenyiğit)

Table 2

According to you, what are the problems of the Grand Bazaar's surroundings?



CEVAHİR BEDESTEN



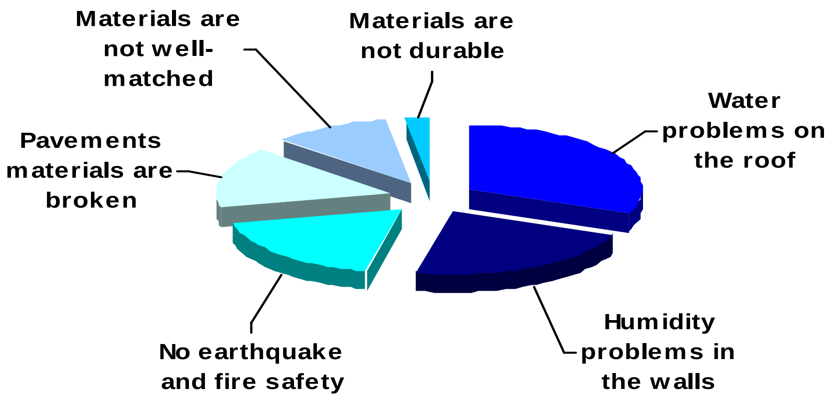
SANDAL BEDESTEN

Table 3

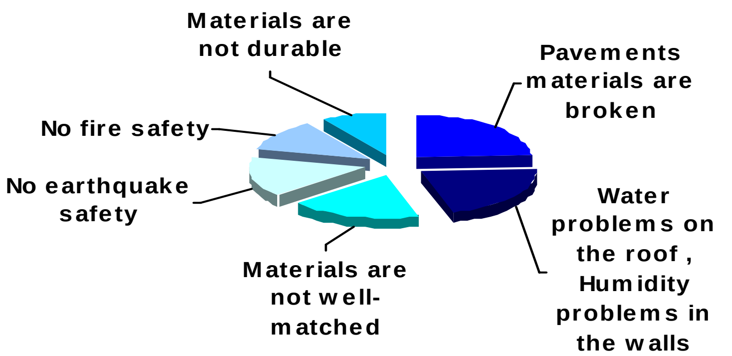
CEVAHİR BEDESTENİ	*SANDAL BEDESTENİ*
According to you, is there any orientation problem inside of the Grand Bazaar?	
There are orientation problems	There is no orientation problem
The numbers of shops are incomprehensible	
The shop signs are not enough	
The street signs are not enough	

Table 4

According to you, what kind of physical problems appear in the Grand Bazaar?



CEVAHİR BEDESTEN



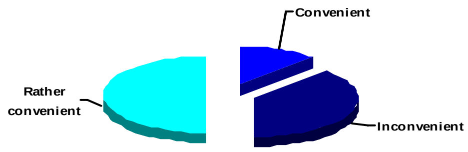
SANDAL BEDESTEN

Table 5

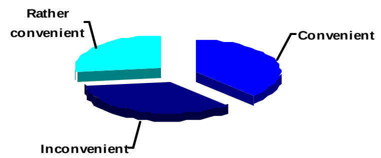
CEVAHİR BEDESTENİ	*SANDAL BEDESTENİ*
According to you, how are the conditions of maintenance in the Grand Bazaar?	
Roof, streets, toilets, doors, walls and pavements are in bad-condition	Doors are in well-condition
Shops are in well-condition	Roof, toilets, walls and pavements are in bad-condition
	Streets and shops are neither in well nor in bad conditions

Table 6

According to you, is the location of shops in systematic?	According to you, are the inside arrangements of shops convenient?



SANDAL BEDESTEN



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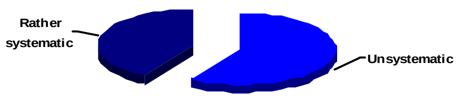
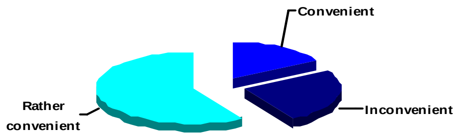


SANDAL BEDESTEN



CEVAHİR BEDESTEN

Proposals

The priorities of the users of the two bedestens differ. The owners of shops at Cevahir Bedesten which has more developed economical conditions and which greatly differ as of customer profile express the priority problems as physical problems and environmental organization, the users of Sandal Bedesten state economical problems as a priority and think that the structural (physical) problems are not as important as them.

- It is seen through meetings and observations that some owners of shops have damaged the structure in order to expand the locations and this is a serious structural problem for the earthquake safety of the bazaar.

- In Cevahir Bedesten, fire safety is provided through the fire extinguishers that are placed at the doors, it is necessary for both bedestens and the bazaar in general to apply a general fire extinguishing system.

- As a result of the meetings, it is expressed that there is heating-cooling problems of the bedestens and the bazaar. Thus, expertise opinion shall be consulted for solving this problem and solutions shall be developed such as using suitable insulation material in the walls.

- Because the breaks in the wall are worn out, there is a serious humidity problem especially with rain. For this reason, in order to prevent the walls and floor to be influenced from the humidity due to the rain, materials with high insulation shall be used in the breaks.

- On the ground of the bazaar, due to the usage of weak material, there may be short term breakdowns. On the other side, usage of different floor materials in the two bedestens also damages the identity of the bazaar. For this reason, choosing a material that is durable for intense usage, suitable to the identity of the bazaar and that can form a common language can be a proper solution.

- In the section of the bazaar covering the bedestens, the roof cover is in a serious wearing. Covering of the roof as well as renewing the drain pipes shall be done immediately and it shall receive periodical maintenance afterwards.

- Insufficient amount of toilets within the bazaar is another important problem that is frequently expressed. For this reason, intense usage shall be found over the roof area and their numbers shall be increased as is necessary or the current areas shall be expanded.

- The insufficiency of the bedesten ventilation is seen in the meetings and questionnaires of both bedesten employees as well as the observations made. For this reason, examining of the bazaar by the experts of the issue and bringing solution alternatives has priority in order to prevent the negative effects due to lack of ventilation.

- As a result of the interviews, it is expressed that because there is no system of a central generator, there are problems of bazaar safety and ventilation in power outage. For this reason, starting to use a generator at least in the main arteries of the bazaar shall be targeted.

- As a result of the interviews and questionnaires, the lack of parking space has been seen as one of the high priority problems. In developed countries, instead of reaching the historical center with a car, collective transportation and parking the cars outside of the historical center is encouraged. For the Grand Bazaar, the transportation problem of the users and visitors can be solved with a suitable collective transportation policy.

CONCLUSION

The evaluation of data is seen that physical damages are the most serious continuing problems of whole The Grand Bazaar. On the other hand, it is also seen that works which aim to prevent from physical damage can not be done in a real professional way. Especially in Sandal and Cevahir Bedesten, the goal of all works done by authorities is to increase the economical value of the places.

As the first step of the work, the findings from the observations and interviews made in 2003 are compared to the data of the work that is extended in 2006 and it was seen that the problems showed continuity.

As conclusion, the main goal of all works in The Grand Bazaar is not only to make an oriental shopping center for tourists but also to protect the original identity of The Grand Bazaar. All studies about The Grand Bazaar can be used as a valuable data sources to let it live to the next generations.

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CULTURAL HERITAGE AND THE MENACING OF FLOODS

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ABSTRACT

The paper deals with the protection of Cultural Heritage against floods in accordance with the objectives of the research project CHEF funded by the European Commission. At the beginning, the structure of the World Heritage Centre of UNESCO in Paris and the Romanian Heritage are presented. Then the recent Romanian floods and how the Cultural Heritage is menaced are discussed. European Strategy of prevention and protection against floods together with the specific measures provided by the Romanian authorities are further described.

1. INTRODUCTION

Flooding is a global phenomenon as recently was highlighted by the major catastrophic events in Central and Northern Europe. In the Sixth Framework Programme the project entitled “Cultural Heritage Protection against Flood” was recently launched by the European Commission. This project, with the acronym CHEF, that gathers ten partners from Austria, Czech Republic, Germany, Italy, Romania, Slovakia and United Kingdom, is coordinated by Dr. Christiane Maierhofer from BAM in Berlin [6].

CHEF proposes the integration of multidisciplinary research as scientific support to European policies. In this frame the necessary scientific and technological basis as well as cost efficient and effective tools for the development of new and innovative strategies will be provided. For avoiding or mitigating flood-related damage of Cultural Heritage, a lot of aspects have to be considered, like historic significance and object context, building structure and its location in risk areas. But also technical problems like lack of documentation, unspecified structural condition and assembly, unknown material characteristics and parameters of exposure require intense investigations. Project objectives are: 1) Classification of Cultural Heritage in terms of their vulnerability to flood; 2) The Convention is a document divided into thirty-eight articles that define the scope of within UNESCO and the signatory states are to work together to protect the heritage of mankind. The General Assembly of UNESCO elects the World Heritage Committee and the World Heritage Centre acts as it secretariat as part of UNESCO. The Bureau of the World Heritage Committee is composed of seven elected members in charge of preparing Committee's work. There are also some NGOs composed of experts like IUCN, the World Conservation Union, and ICOMOS, the International Council on Monuments and Sites, ISCARSAH including, which assist at request the World Heritage Committee.

The Committee decides upon all the treasures, which should be 1) unique; 2) irreplaceable and 3) authentic, if they will be inscribed or not on the World Heritage List. Preparing, updating and distributing the List is one of the main tasks performed by the Committee. To help clarify matters, the Convention split the heritage as a whole in two parts, the Cultural one that includes 1) Monuments, 2) Group of buildings in cities or villages and 3) Sites such as urban or rural landscapes and the Natural Heritage consisting in 1) Physical and biological formations like forests, glaciers, lakes, caves, mountains, etc., 2) The habitats of endangered plant and animal species like coral reefs, tropical forests, wetlands, etc. and 3) Precisely delineated natural sites or areas such as specific national parks. Further the Guidelines for Implementing the World Heritage Convention identifies other six selection criteria [1].

2. ROMANIAN CULTURAL HERITAGE

Romania is an East European country rich in natural resources and consequently also rich in Cultural Heritage. Treasures from all historic époques do exist on the Romanian territory. The Megalithic Culture is represented by the sacred complex at Sarmisegetuza-Regia in Transylvanian Carpathians [5]. The diameter of the Circular Temple has the same value like the Stonehenge Temple in UK [3]. The Middle Ages Culture is represented by fortresses, castles and churches (Figures: 2, 3 and 4), while the Modern Culture is expressed by architecture and sculpture (Figures: 5 and 6). It is worth to mention that the Endless Column in Tg. - Jiu was created by 32 miniatures of the Babel Tower erected about in 1,100 BCE [7, 8].

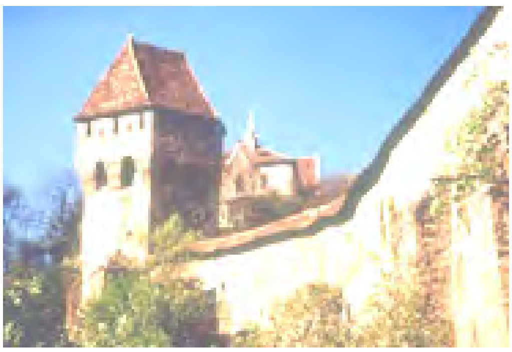


Figure 2 Sighisoara Fortress, 1191

Figure 3 Dracula's Castle, 1377

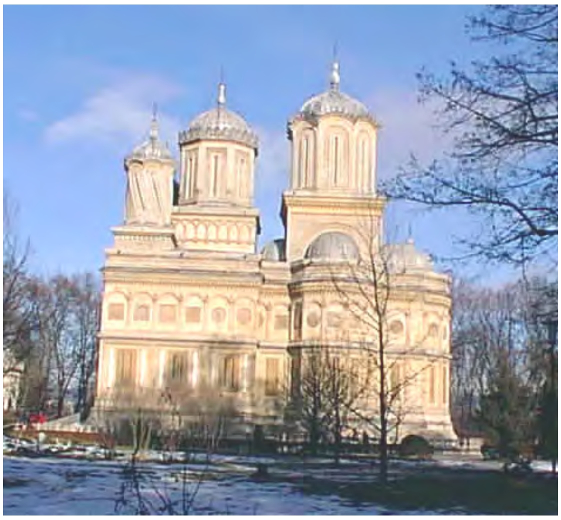


Figure 4 Arges Church, 1512

Figure 5 Romanian Athenaeum, 1888

Figure 6 Memorial of Unknown Soldier created by Brancusi at Tg.-Jiu in 1937 [4]

The explanation why so few Romanian treasures are inscribed on the World Heritage List is the lack of interest of some former governments to pay the due of 1% to the World Heritage Fund. Nowadays, beside floods other natural catastrophes are menacing the rich Romanian Cultural Heritage [2, 9, 12].

3. ROMANIAN FLOODS

As a consequence of Global Clime Change in 2005, e.g., the records of rainfalls

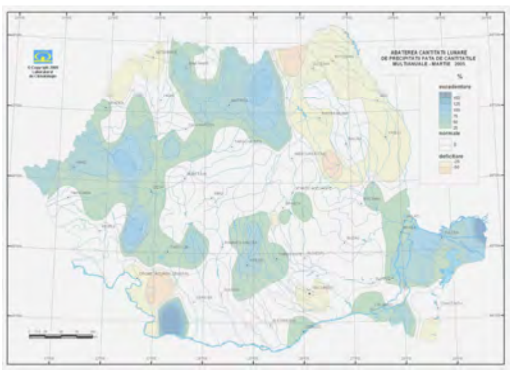


Figure 7 Rainfalls March 2005

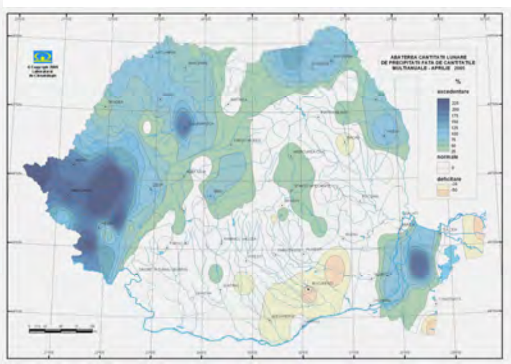


Figure 8 Rainfalls April 2005

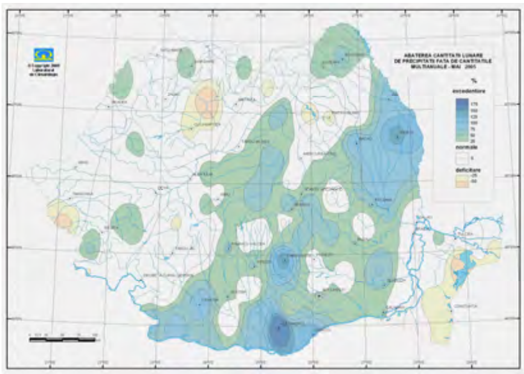


Figure 9 Rainfalls May 2005

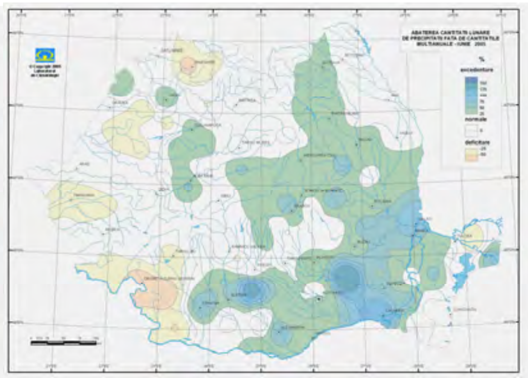


Figure 10 Rainfalls June 2005

on Romanian territory have shown a nonuniform distribution (Figures: 7-12) even if the mean values for the same year of rainfalls and temperatures appeared as normal (Figures: 13 and 14). In the following period of March-May 2006 the situation was worse. Rainfalls of 60l/m^2 in 24 hours were recorded. On the same dramatic period Danube debits increased over the values ever recorded between 1840-2006, while the level of the Black Sea rose with 30cm. The debit scenaries of 13,600-16,000m^3/s were overpassed while the increasing tendency of debits at Buzias was of 1,000m^3/s. The losses were to the same extent like the floods.

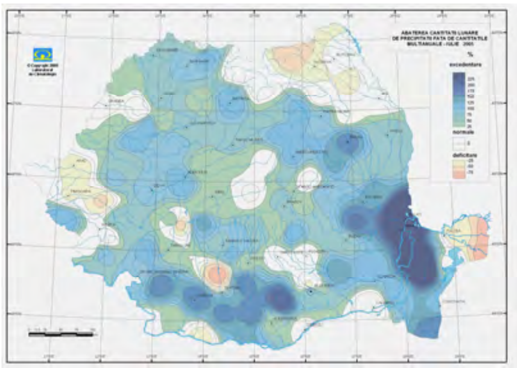


Figure 11 Rainfalls July 2005

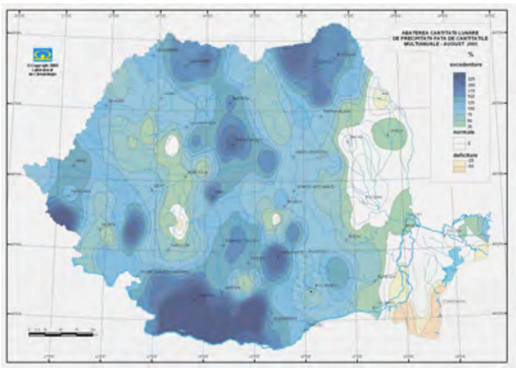


Figure 12 Rainfalls August 2005

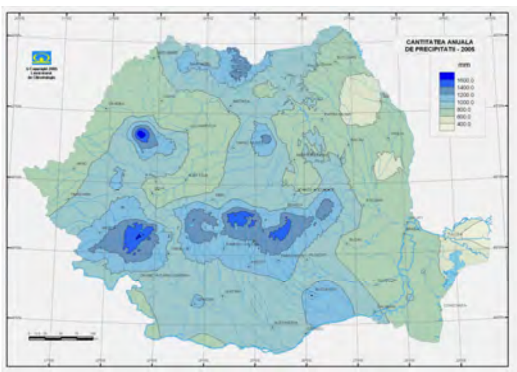


Figure 13 Mean rainfalls in 2005

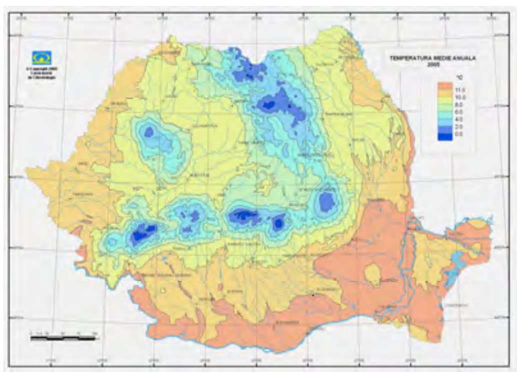


Figure 14 Mean temperatures in 2005

on Romanian territory have shown a nonuniform distribution (Figures: 7-12) even if the mean values for the same year of rainfalls and temperatures appeared as normal (Figures: 13 and 14). In the following period of March-May 2006 the situation was worse. Rainfalls of 60l/m^2 in 24 hours were recorded. On the same dramatic period Danube debits increased over the values ever recorded between 1840-2006, while the level of the Black Sea rose with 30cm. The debit scenaries of 13,600-16,000m^3/s were overpassed while the increasing tendency of debits at Buzias was of 1,000m^3/s. The losses were to the same extent like the floods.

4. EUROPEAN STRATEGY

On 25 April 2007 the European Parliament and the Council in Strasbourg adopted the Directive C6-0038/2007. According to *Article 1*: The purpose of this Directive is to establish a framework for the assessment and management of flood risks, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods in the Community. *Article 4:* Member States shall complete the preliminary flood risk assessment by 22 December 2011. *Article 6:* Member States shall ensure that the flood hazard maps and flood risk maps are completed by 22 December 2013. *Article 7:* Member States shall ensure that flood risk management plans are completed and published by 22 December 2015. *Article 9:* Member States shall take appropriate steps to coordinate the application of this Directive focusing on opportunities for improving efficiency, information exchange and for achieving common synergies and benefits having regard to the environmental objectives laid down in Article 4 of Directive 2000/60/EC. In particular: 1) the development of the first flood hazard maps and flood risk maps and their subsequent reviews as referred to in Articles 6 and 14 of this Directive shall be carried out in such a way that the information they contain is consistent with the Directive 2000/60/EC. 2) the development of the first flood risk management plans and their subsequent reviews as referred to in Articles 7 and 14 of this Directive shall be carried out in coordination with, and may be integrated into, the reviews of the river basin management plans; 3) the active involvement of all interested parties under Article 10 of this Directive shall be coordinated, as appropriate, with the active involvement of interested parties; *Article 16:* The Commission shall, by 22 December 2018, and every six years thereafter, submit to the European Parliament and to the Council a report on the implementation of this Directive. The impact of climate change shall be taken into account in drawing up this report.

5. ROMANIAN APPROACH ON FLOOD PREVENTION

Recently, Ministry of Environment and Waters in Bucharest decided three engineering solutions for protection against floods. The first one consists in surrounding all urban and rural settlements exposed to the risk of flood with defending dikes. Consequently, all the roads and communication ways will be accordingly adapted or changed. The second solution consists in building up along Danube and other main rivers isolated polders or chains of polders in cascades for storing up the exceedingly waters supplied by floods (Figure: 15). For safety reasons the polders will be also protected by dikes. Finally, the third solution and the most extensive one consists in the biological consolidation of river beds and their banks (Figures: 16 and 17). This old approach will be applied according to some innovative rules of maintenance and dynamic use in order to obtain the highest engineering performances at the lowest costs [10, 11]. The plantations also act as buffer strips against the strong winds and prevent soil erosion.

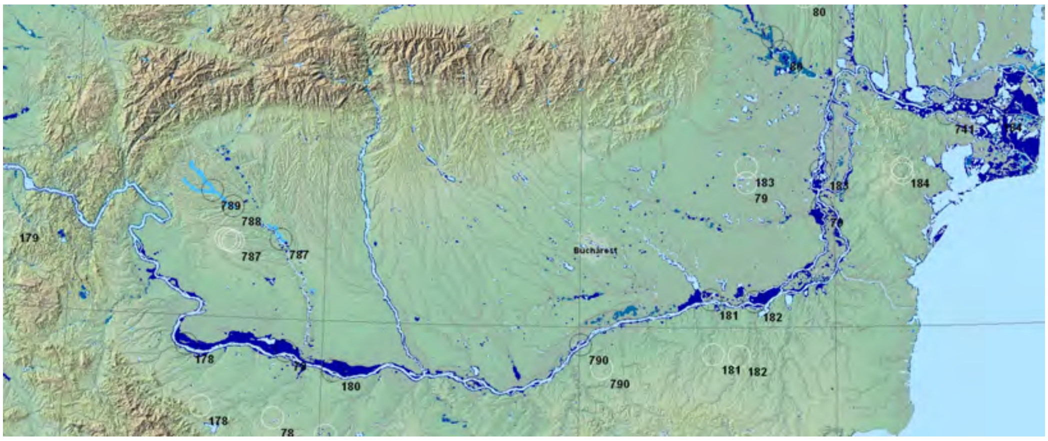
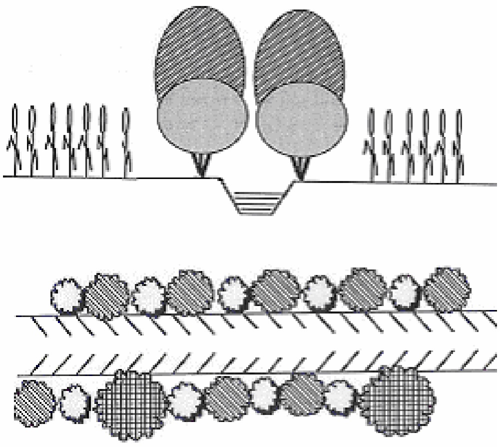


Figure15 Satellite view of the Danube River, the Delta including



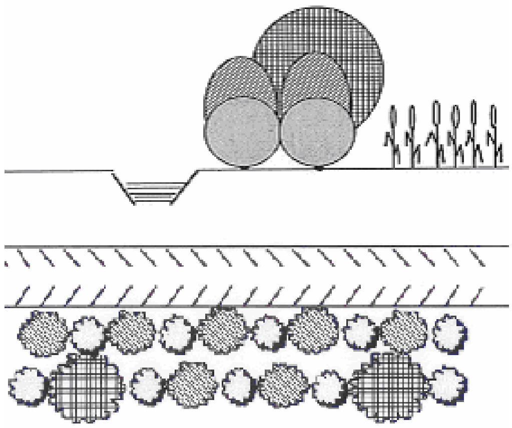


Figure 16 Double biological buffer strips Figure 17 Single biological buffer strip

6. CONCLUSION

Paradoxically, nowadays the History is repeating. The City Walls once used for protection of agglomerated settlements against barbarian invasions are now provided as defending dikes against inevitable floods. The Global Clime Change became an undeniable reality that anthropically cannot be stopped, and floods are nothing else but water invasions. The Romanians, who some decades ago drained out the natural lakes existing for centuries along the Danube and other main rivers, are now in the uncomfortable position to restore the lands they have formerly mutilated. Isolated and cascades of polders, aiming to prevent further catastrophic floods, should be building up in the next future. Unfortunately, this is the only choice for surviving. The Cultural Heritage, besides its historic value, is witnessing how different civilisations are bridging over the time. Reducing the impact of Global Clime Change on the structures of Cultural Heritage involves indeed high costs. However, any human and economic efforts are worth because Cultural Heritage means History that cannot be recovered, and without which humanity faces an impoverished future.

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THE PROJECT OF TRAINING OF QUALIFIED LABOUR FORCE WHO WORK IN THE RESTORATION OF HISTORICAL KULA HOUSES

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ABSTRACT

This project was prepared in scope of Central Finance and Contracts Unit, The Project of Active Labour Force Programs (New Opportunities Programme) in 2005 and awarded with the donation of 117.000 Euro passing through commission. This project which was prepared within the collaboration of the Municipality of Kula and Special Provincial Administration of Manisa and executed in Kula.

In the scope of this project, it was intended that the unemployed people in Manisa should be possessed of a job by raising skilled workforce for the restoration area in Kula. Firstly, the unemployed young people were equipped with the skills that increase the employment probability of them in restoration field and meetings should be held for all the people living in Kula since the success of the project and the provision of adequate participation can only be possible if the people of Kula should develop an awareness for the preservation of their historical and cultural heritage.

In order to provide the workforce required for the restoration applications of the historical structures that have high potential to be included into cultural tourism, 45 people who are regarded as the disadvantaged group, between 15-39, unemployed, graduated at least from secondary school were given vocational training courses, and restoration workshops (wooden,…, mixed) were established. Long-term objective of the project is to develop the tourism sector in Kula by preserving and using the natural and historical values and to ensure the economical and social development of Kula.

1. INTRODUCTION

1.1. Justification

While there are approximately one thousand registered historical structures in the Kula region, there is not any skilled person who knows the restoration workmanship and can work in the restoration works. The restoration works that are to be carried out in the region (for instance, Beyler Evi, Zafer Primary School, which are within the program of the Ministry and Provincial Administration) cannot be performed due to the reason that foreign employees should be transferred and that this shall increase the costs considerably.

It is known that most of the people living in Kula are experiencing problems that are in parallel to the economical problems in the country. In the region that was chosen to be the working area, number of the agricultural activities is small on account of inappropriate soil circumstances. Also movement of the developed industrial sector into the markets of the metropolitans constitutes another factor for the increase of unemployment. Considering the data taken from State Statistics Institute for the statistics studies carried out in Kula, it was found out that the population of center of Kula is 18669 and 6882 people are included in the workforce and 573 are unemployed (data of State Statistics Institute- Annex XIII).

This Project was developed by establishing a partnership between Kula Municipality and Provincial Administration of Manisa. During this project, cooperation of Provincial Culture and Tourism Directorate and the support of various restoration firms that were performing repairs in the region was obtained. The intensive interest of such entities as foundations, universities and Union of Historical Cities as well as the local and foreign researchers for the historical texture existent in Kula ensured the awareness of the Municipality for the restoration. Kula Municipality that started its attempts by becoming a member of Union of Historical Cities laid the foundations of this project in the meetings with Official Institutions by developing these attempts. However one of the most important problems in front of this project to be realized is lack of the relevant skilled workforce.

1.1.1. Reasons for the selection of the target groups and activities

It was found out a large segment of the population of Kula tend to maintain their lives in greater cities due to the lack of employment opportunities and economical shortcomings. Especially it was observed that the young population migrates to the cities. Our aim is to give necessary education to the young and disadvantaged people. These people, who will have a new job profession, will gain and find a new job.

It was noticed that the residents in Kula do not show the sensitivity required for the preservation of the historical and cultural values. In order to increase the awareness of the people for the issue and thus to keep the desired level of participation for the training, seminars and informative meetings were held for each and every individual of Kula. Target group were determined as the unemployed segment of age of 15-39 to participate in the vocational training activity (restoration training).

Since there is not any skilled persons for the restoration workmanship in Kula, repairs of the historical structures are performed via traditional methods. Such implementations cause irrevocable errors in our historical structures. Therefore there is a need for skilled restoration employees to perform correct repairs.

General purposes of the project:

- Training of qualified personnel to work in restoration works in national level.
- Promoting the city in national and world wide scales and make Kula an attractive place in terms of tourism bye preservation and rehabilation of the urban, cultural and natural inheritance in Kula.
- Providing the continuation of restoration workshops by forming related units which will be beneficial for related studies.
- Creating work force who have knowledge and skill for creating work environment in the restoration area in Kula.
- Decreasing unemployment rate in Kula, increasing the consciousness of protecting historical and cultural inheritance by developing social structure of society.

Specific purposes of the project:

- Training 45 persons aged between 15 and 39 who are unemployed and graduated at least from secondary education to work in the restoration field in Kula which has rich values in terms of restoration.
- Making trainees and people of Kula conscious about the protection of historical and cultural inheritance.
- Increasing sight, evaluation, perception and application skills of trainees at the end of training.
- Establishing Historical Environment and Restoration Unit under the management of the Municipality of Kula for maintaining educational activities.
- Giving priority to trainees in employment in the restoration works to be executed by the Municipality of Kula after the training.
- Publishing the project in web since it would be promoted, thus considered by more people in the restoration field.

2. METHODOLOGY

A project promotion team was formed and this group composed of volunteers would carry out activities concerned. This method was preferred for the purposes of informing the people about the project and ensuring their adaptation to the project and thus bringing more sound solutions to the problem.

Professional training course: Trainings including theoretical lessons: Theoretical lessons should be included in the course in order to establish a basis for the trainees to carry out activities toward workforce and in order to provide assistance to the increase of general culture and consciousness about historical and cultural protection.

Practical trainings: Trainees were receive these trainings in order to practice the theoretical lessons and get experienced in practice. 45 persons were divided into 3 different workshops (wood, brick and mixed) in a structure that was a historical building for the restoration workshop and were trained under the control of experts. Practical approach were followed during the training through the applications in the training building and thus the structure would be protected.

A restoration unit was formed in the body of the municipality and activities were carried out by the municipality personnel. Formation of such a restoration unit will contribute to the continuation of the training and provision of consultancy to the trainees even after the completion of the project.

Kulalılar Group were formed and people of Kula working in different professions carried out the relevant activities. This group were formed for the purposes of promoting Kula and increasing job opportunities on the basis of the consideration that the people of Kula should embrace Kula.

Web design will be made and publications were prepared.

a. Web design: Web design was preferred as a permanent and widespread method in future promotion.

b. Preparation of publications: Current developments in the activities were introduced and thus the activity was documented.

2.1. Monitoring

The project was subjected to internal and external monitoring. The project team were conduct the internal monitoring of the practices in project activities. The meetings of project team were included the matters related to the internal monitoring. A questionnaire and testing to be made for the trainees during the internal monitoring once in two months would be a part of the monitoring process. Educational performance of the trainees were assessed during all these activities.

External monitoring was carried out by the Governor of Kula that has given assistance to the design of the project and provided support to the Municipality of Kula. Governor will receive information about the activities held during his monthly meetings with the project coordinator. The periodicals and web site to be activated in the scope of the project was constituted a part of the external monitoring. The local people were informed during the informative meetings to be held by volunteers through on-site practical implementations.

2.2. Assessment

The assessment was carried out in three stages.

2.2.1. Preliminary assessment

The report in which the application forms were evaluated during the informative meetings to be held by the project promotion team were constituted the preliminary assessment.

2.2.2. Interim assessment

Project coordinator and assistant were assessed the improvement of project activities. This assessment was comprise the matters such as the conformity of activities to the action plan, efficiency level of trainees, existing problems and cooperation with institutions.

2.2.3. Final assessment

The project report was prepared upon the completion of the project. This report was submitted to the universities for assessment, which include Restoration departments. Outcomes of the activities of the Restoration Unit to be formed within the body of the Municipality and Kulalılar Group were used for the final assessment. Project report was published in the Internet web site of the project.

3. EXPECTED IMPACT ON TARGET GROUPS

3.1. Estimated Results

a.At the end of these 3 restoration workshops (Wood, brick, mixed) with 45 participants, these people shall gain skill and experience in a way that they may be employed as restoration workers.

b. Establishment of Kula People Group and its activities for 10 months; this group will go on to operate after the end of the project in Municipality with supports of some organizations and some official institutions.

c. A database will be established which is useful for target mass, local managements and employers.

d. Database will be opened for everybody’s access on internet.

e. Kula Municipality and its restoration department will assist apprentices in order to find employment and found their own works.

f. 50 periodicals (magazines) which shall consist of activity reports, will be distributed by Kula Municipality to Kula people in every two month.

g. In the following 6 months, after the end of the course, 40% of the trainees will find employment in restoration companies.

h. The trainees who could not find employment, will have priority in restoration works of the Municipality.

3.2. Estimated changes on target mass

This project will provide unemployed young people (graduate of secondary or hign schools, but unemployed) in Kula with a vocation and it will also make them grow as educated people. Trainees will gain knowledge and skill; they will also be able use Office programs; they will be more sensitive to because they are aware of historical environment and also they will make the environment in which they live their own. Thanks to these knowledge and skill, their possibility to be employed will increase; and they will find a more respected status in public.

In this respect, we will not only chose 45 people from this target mass and make them employed by giving course, but we will also provide entire Kula people with information on protecting historical and cultural heritage, so they will make the environment their own. The people who have historical environment culture, will protect and improve these places. By that way people will not only protect historical places but also turn these places into touristic destinations. With improvement of tourism, some products like textile products, carpet, copper products, packsaddle or felt, which manufactured by Kula People, will find market opportunity. Like other touristic provinces, there will be a market expansion in other sectors as well.

3.3. Multiplier effects

We have negotiated with Tire and Bergama Municipalities on this issue. Gained experience will be shared with these municipalities in order to find a suitable model. After the training which has been given to the trainees, established workshop will make it possible to go on giving training to new trainees. It is also possible to spread this training by courses Public Education Institution and Municipality. Information level of public will continue increasing since Restoration Unit and Kula People Group will carry out meetings and seminars which are like they carried out during project. Project book and web site will consider public attention and these publications will make good examples for future similar activities. When they became masters, these apprentices will employ new apprentices and they will train them, so number of trained people will increase. The book which consists of the experiences of this project, will make a good example for other municipalities and institutions.

3.4. Short- and long-term impact

After 3 months from the beginning of the project, resource search activity were initiated by Kula People Group. There was an evaluation with financers, sponsors or supporting official institutions in order to provide continuousness of the course activities.

(a) The financial aspect (*how will activities be financed when the grant ends?*)
Since workshop which is established for this project will go on operating, these kinds of projects will be able to be organized with less finance in the future. Our

Municipality will provide this fund and go on giving courses. As a result of increasing tourism, there will be a requirement of restoration in historical buildings. So courses will be welcomed since labor requirement in restoration sector. Continuousness of the repairs which is an important outcome of courses, will be possible with budget of some Manisa Governorship's buildings' restorations, restorations performed by Municipality and probable World Bank credit.

(b) Institutional level (*Will structures allowing the activities to continue be in place at the end of the action? Will there be local "ownership" of action outcomes?*)
- Restoration Department of the Municipality will provide project continuousness**.**
- Kula People Group will assist project continuousness**.**
- Since these workshops provide scientific training, universities will be able to give scientific training in these workshops after course.

(c) Policy level (*What structural impact will the action have - e.g. will it lead to improved legislation, codes of conduct, methods, etc?*)

If other municipalities and NGOs apply this model which results from this project, there will be a continuousness in political dimension. Presentation of project activities may be possible with publishing of project results on periodicals and web site; these presentation activities shall support continuousness policy.

4. CONCLUSIONS

Fourtyfive persons were trained eight months and received their certificates at the end of this project. As one of the main aims of this project, a comission of volunteers was gathered in the lidership of the Municipality of Kula. This comission will work in the promotion of the cultural heritage of Kula and also will help in increasing job opportunities for unemployed people in Kula.

Another aim of this project, which was unrealized, was the foundation of the Restoration and Historical Environment Unit under the control of the Municipality of Kula. This unit will help to maintain the educational activities by means of worksops and will work as a consultatnt authority for trainees.

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HERITAGE MANAGEMENT IN POST-CONFLICT REGIONS CASE: MURAD KHANE, KABUL, AFGHANISTAN

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ABSTRACT

The historic city of Kabul, like other cities in Afghanistan had been a witness to conflicts and wide spread man-made disaster to not only the living, but also the cultural heritage of the region. It goes without saying that the one of primary concerns of the contemporary rebuilding activities would include preserving the heritage for the future. The conservation activity is a boon to the Afghanistan region as on one hand it offers to restore the pride of the community shattered by the decades of man-made disasters and on the other offers scientific process for guided development and rebuilding. A number of significant efforts have been made by agencies and NGOs in conserving historic properties in Kabul during the last 5 years. Murad Khane (MK), a historic settlement in the core of Kabul city has been witnessing efforts for protection, preservation & sustainable management of its significance. Through this paper, a management framework is presented highlighting the significance of MK and it simultaneously draws the ideas on conservation policy & management strategy within the concepts of post-conflict heritage management in Kabul.

1. INTRODUCTION – HERITAGE COMPONENTS OF KABUL

Natural heritage:

Kabul is nestled in a **valley** surrounded by the steep Asmai and Sherdawaza mountain ranges (Figure: 1) to the east and west. At an elevation of about 1800 m (about 5900 ft), it is one of the highest capital cities of the world. Kabul **River** or Kabal River (Persian: دریای کابل), a snow-fed river originating in the Sanglakh Range is a major water-body (700km) in the eastern part of Afghanistan. Alingar, Kunar, Logar and Panjshir rivers are the major tributaries of this river. A settlement defined by the dwellings on the constant **rectilinear ranges** and the rising lands of Kabul River. The valley-city has natural defenses in forms of **high ridges and steep slopes**. The topography has outlined this region as transits of caravans with several high **passes** *kotal* that transect the surrounding mountains. Invaders and adventurers have historically set base-camps here as it lay in proximity to the gateway (Khyber Pass) of the rich treasures beyond the Hindu Kush.With the **barren mountainous** areas sparsely dotted with trees and **stunted bushes**, the lapis lazuli mines were found in Kowkcheh Valley. The surrounding valley regions around Kabul were home for **emeralds and rubies** mining.


Figure 1 – Murad Khane Neighborhood


Figure 2 – Built Heritage typology

Built heritage:
Residences, Sarai, Masjid, Takiakhana, Ziayarat, Tombs, Palaces, Fort walls, Enclosed gardens etc., are some of the built-heritage typologies observed in the city of Kabul. The indigenous vernacular residential settlements designed on the Islamic principles of neighborhood planning represent the bulk of the built heritage components (Figure: 2) sweeping across the slopes in and around the city of Kabul.

Founded on stone rubble, the dwellings of rectangular/ square forms with 2 - 3 storey height are characterized by the mud/clay-based constructions with timber screens. Saces built around or along an open courtyard, thus making the dwellings habitable in extreme summers and winters. The top storey flows in this multiple-use exterior space through set-back balconies and windows. The walling system constitutes of timber members supporting the infill of brick masonry or by the Pakhsha/ mud-blocks. The interiors carry forward the character of open spaces through the architectural ornamentation of numerous patterns laid on niches that are built with layers of mud plaster. The opening's frames/ arches are timber carved and used in series to form screens with movable shutters. The flat roofs covered with protective mud coating are spanned by purlins, rafters and laced with a decorative wooden false ceiling. The building materials are prone to seasonal maintenance while being vulnerable to natural and man-made hazards.

2. DESCRIPTION OF SIGNIFICANCE OF MURAD KHANE

2.1 Location

Northern bank of the Kabul River, the topography (steady contour level difference 0 - 5 meters) building activity is sensitive to the gradual slope and the water shed areas, thus ensuring drainage flow by natural means.

2.2 Historical [1]

18th century – Caravan Serai to store and practice trade along the Silk route. Later addition of shops, bathhouses (hammam) and teahouses (samavar) observed.

19th century – Evolution of neighbourhood character from trade spaces i.e. warehouses (serai) to include residential structures/ complexes and open spaces such as gardens.

Early 20th century – Bustling neighbourhood with an estimated 2800 – 3500 families as MK is in close boundary of royal palace.

Mid 20th century – Redevelopment of parts of the city by Zahir Shah. 1958 – 1984 witnesses large parts of Murad Khane being demolished to make way for new roads, private development, public buildings and civic spaces.

Late 20th century – Government during mid 1980's orders parts of western MK to be acquired by the municipality and sold to developers. During 90's many buildings damaged or destroyed and majority of residents in MK forced to leave the area because of heavy fighting in Kabul among rival Mujahideen factions.

2.3 Associational [1]

Sardar Murad Khan, General to Afghan King Abdul Shah Durrani acclaimed as the founder. Its proximity to the palace of King Abdur Rahman results in.Nobel men/ High ranking officials' residing in MK; First house with iron roof in Kabul

2.4 Architectural

Shape / Form – Rectangular/ Square in form with 2 3- storey in height. Also constitutes of cellar beneath in some dwelling units.

Spatial planning – Built around an open space, usually a courtyard, while some dwellings have openings facing a common court-yard space/ street. A setback at upper level to accommodate a balcony with a balustrade that opens in the courtyard.

Interiors – Architectural ornamentation can be observed in form of niches that are made by layers of mud plaster (simgel)

Openings – Timber frames and arches carved & used in series to form screens with movable shutters (oorsi). These screens at upper levels let open the interior spaces in the central courtyard

Figure 4 – Spatial arrangement & Courtyards

2.5 Structural

Foundation – Stone rubble foundations with mud mortar.
Walling – Walling system constitutes of either Pakhsha or Fired bricks. Timber members support the infill of brick masonry.
Spanning – Timber members are predominantly used as structural members.
Roofing – Flat roofs supported by wooden members and outer layer with protective mud coating

2.6 Site Planning

Planned on the Islamic settlement planning principles.

2.7 Socio-economic [2]

The social infrastructure constitutes of sacred structures such as Masjid, Hammam, Ziyarat, Takiakhana. Residential and commercial activity mutually share the land-use in MK, while serai i.e. traders godown, shops are along the major pathways.
Community – MK social profile constitutes of the minority Shiite i.e. Kizilbash while many rented accommodation are used by the Tajiks.

3. TOOLS FOR UNDERSTANDING THE SITE

Various forms of inventories are developed to investigate the heritage potential of the site and simultaneously to analyze the issues affecting the resource. Inventory-making was followed at all levels encompassing the neighborhood. The various inventories conceptualized for this site are:

3.1 Area-level inventory – Murad Khane

Information assimilated includes
Values related: Historical, Associational, Events, Persons, Architectural, Building & Construction system, Site planning, Social, Economic, Activities and Community
Typology of spaces: Vernacular houses, Residence plus shop; Sarai, Masjid/ Ziyarat/ Takiakhana; Shops (permanent/ temporary); Traders godown, Hammam
Occupational composition: Traders, Craftsmen, Government service, Private Service, Laborers, Mixed
Transformations related: Surface utilizations, Spatial components – Built / Open/ Semi open / Network; Architectural system, Building & Construction system, Community, Cultural/ religious links, Activities of neighborhood
Infrastructure: Sacred (Ziyarat /Takiakhana/ Masjid / Hammam Murad Khan); Social (Community hall/ School/ Post office/ Police station/ Dispensary/ Hospital); Physical (Electricity/ Sewage/ Water/ Transport)
Other inventories

Streets inventory (Abul Fazel/ Afshar/ Amela ha/ Kishmish Paki/ Labe Dari/ Maidan-e-Murad Khane, Masjid-e- Maidani); Thakiakhana (Ahmed Shah, Gulam Abbas, Hajji Yakub, Muhammad Mohsin) and Hammam (Murad Khan)
Vernacular houses inventory
Bazaar street/s inventory
Open spaces inventory (Maidan, Chowk etc.,)

3.2 Site-level documentation

A detailed documentation is sought to facilitate analysis related to Architectural systems, Building & Construction systems, Slope (Figure 5). Vegetation, Hydrology (Figure 6) etc.,

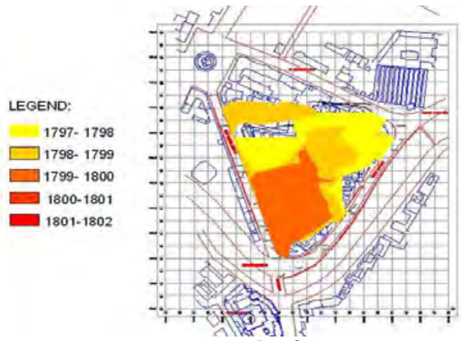

Figure 5 – Relief map

Figure 6 – Hydrology map

4. PROCESS OUTLINING THE FRAMEWORK

Table 1 – Process involved in CMP preparation

		Tasks involved	**Actions**	***Consultant/s involved***	***Phase***
Understanding - Site Significance	To identify the various associated components and typologies in Murad Khane	Preparation of inventories		TMF team Architect volunteers	
		Mapping of components & typologies		TMF team Planning volunteers	
		Historic evolution of site and surroundings		TMF team Historical research volunteers	
		Architectural system/s		TMF team Architect volunteers	
		Building and Construction system/s		TMF team Architect volunteers Engineer volunteers	
		Users and Uses		TMF team Social sciences volunteers	

Understanding - Systems	Protection system	Examine & report the legislative & regulatory mechanism/s in operation at site*		TMF team Lawyer/s	
	Management system	Examine & report the practices at site*		TMF team Social scientists	
	Decision-making system	Examine & report the participatory mechanism/s practiced on site*		TMF team Governance experts	
	System for Planning & upgrading infrastructure	Examine & report the instruments/ processes involved for planning, implementation, monitoring, evaluation and feedback; *		TMF team Planning officials Urban Planning / infrastructure experts	
	* - To include existing, traditional & global (wherever required) mechanism				
Understanding – issues	Cultural resources related to site	Report the statement of threats/ issues/ problems		TMF team /Volunteers	
	Protection system	„		TMF team / Lawyer/s	
	Management system	„		TMF team / Social scientist/s	
	Decision-making system	„		TMF team Governance expert/s	
	System for Planning & upgrading infrastructure	„		TMF team Planning official/s Urban Planning / infrastructure expert/s	
Preparation of CMP - draft	Cultural resources	Outlining the Conservation measures / Interventions required		TMF team	
	Protection system	Stating the protective mechanism that shall be used to safeguard the resources/ boundaries etc.,		TMF team Lawyer	
	Management system	Defining the process/es or procedures required to manage the resources at site		TMF team Social scientists	
	Decision-making system	Stating the participatory mechanisms for both short & long term		TMF team Governance experts	
	System for Planning & upgrading infrastructure	Defining the planning instruments, their role in upgrading infrastructure & CMP implementation.		TMF team Planning officials Urban Planning / infrastructure experts	

5. CONCLUSIONS

'Conservation' as an act of preserving the heritage and prolonging its life can definitely support and scientifically streamline the rebuilding activity not only in Kabul but also in the Afghanistan region. Conservation policy for a post-conflict area such as Murad Khane can be characterized by factors such as:

- Emergency consolidation of services
- Absence of
  - legislative / regulatory framework
  - management / governance systems
  - planning / implementing mechanisms
  - infrastructure facilities
  - professionals / supervisors
  - skilled workmanship / craftsmen / masons / contractors
  - material supply / equipments / tools
  - financial resources

To attempt in defining the heritage management for a post-conflict area like Murad Khane, first step would be to understand and record a database of the place/building by using inventories, measured drawings, historical maps, photographs, archival materials etc. Since the building materials are prone to frequent maintenances and replacement, a comprehensive material sampling database is required. The new materials need to be evaluated for their compatibility against the old and existing building materials. This database when organised and assessed will lead to ascertain the significance or the outstanding value of the heritage resource.

Next stage is drafting a conservation policy that necessarily includes

- Aspects of significance that shall be part of conservation management.
- Options outlining the existing/ new framework of protection/ regulations.
- Explicitly stating the scope of assets – Human, financial, socio-economic, community and site carrying capacity.
- Possible interventions including uses, transformations and changes permissible by international principles/ charters.

Vulnerabilities and strengths of the resources would always have to be the basis for any decision-making in heritage projects. Likewise the conservation policy shall have to be framed within the wider network of regional planning for any disaster risk and emergency response.

The best starting point to heritage management in a scenario like Kabul would be of upgrading the infrastructure facilities like water supply, storm-water drainage, and sewer system of the neighborhood so as to instill the feeling of habitation/dwelling of the surroundings. A simultaneous step to involve the community to develop a sense of belonging for the heritage and the resources is also recommended. The material and structural conservation have to be guided by a site-manual that includes

- The guidelines for carrying out - Preservation, Prevention, Rehabilitation, Restoration, Reconstruction etc.,

- Permissible changes to form, design, materials, structural components
- Materials palette – existing & compatible new materials.
- Addition of permissible services - integration of lighting, water-supply, drainage, HVAC conforming to modern upgrades.
- Additions and alterations confirming and sensitive to the significance of the heritage.
- Regular and seasonal maintenance

In the absence of any protective/regulatory framework, the stakeholders, municipal agencies and the related community should be involved and agreed upon to solve the management related disputes through methods such as negotiation, mediation, conciliation and arbitration. A framework of "Agreeing to Manage and Managing to Agree- AMMA" [1] needs to be established. These non-adversary methods would ensure speedy decision-making/contracts and prevent any further damage to the heritage resource. The way forward for heritage conservation in this region has begun to be tread by all the concerned. As small drops in the ocean, these will surely lead to form a wider regional network of institutions and conservation practices.

It is absolutely important to be sensitive to the natural heritage components while planning and designing for new colonies/ structures. The typical examples still lay intact as one observes the old settlements built in Kabul respecting the site topography while judiciously using the natural features for habitation and protection. The lessons demonstrated by the built heritage components like usage of local building materials (mud/clay, timber), indigenous craftsmanship, and climatically sustainable spaces with little dependence on artificial HVAC, while applying regular maintenance measures. These models offer most-economical solutions and would definitely help to restore the regional significance in the rebuilding/ new development activity. Patronage to the local architectural and building systems is the only important factor that can prevent the loss of heritage of this region. Embedding this patronage policy into the new development activities would perhaps be the biggest contribution of the conservation process to the rebuilding activity within this region.

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HERITAGE MANAGEMENT OF TEMPLE TANKS IN AN URBAN SCENARIO - A CASE STUDY OF THIRUPPORUR, A TRADITIONAL TOWN IN THE STATE OF TAMILNADU, INDIA

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ABSTRACT

One of the most characteristic features of the early South Indian cities and towns are the temple tanks which are a part of the temple. The process of urbanization of leads to the reduction of ground water level resulted in the drying of temple tanks. This paper will look at the case of Thirupporur temple tank located near Chennai, the metropolitan city and capital of the state of Tamilnadu, India. The valuable heritage of the town in terms of temples, temple tanks, rain water harvesting systems and the architectural heritage is documented. The urban issues have been identified which could degrade the temple tank particularly and its surroundings areas and guidelines are suggested for the heritage management of the town.

1. INTRODUCTION

Water has played an important role in the architectural heritage of India from the earliest times. In India, the traditional methods of water harvesting systems and water management systems had been done successfully right from the ancient times. Each region has its own unique system depending on its topography, rainfall and local needs of the community out of which temple tanks served multiple purposes - aesthetic, spiritual and practical.

2. TEMPLE TANKS OF SOUTH INDIA

One of the most characteristic features of the early South Indian cities and towns are the temple tanks which are a part of the temple. Temple tanks were powerful tools in town planning and served a very practical purpose - that of maintaining ground water tables and replenishing community water supplies- besides serving spiritual needs. By linking a natural resource to a divine objective, temple tanks were protected by a code of conduct that bound everyone in their vicinity.

3. ADDRESSING THE PROBLEM

Today, many of the temple tanks in Tamilnadu have fallen into a state of disrepair. The main cause is urbanization, leading to the reduction of ground water level which resulted in the drying of temple tanks. The network of inlets and outlets that nourished the tanks is blocked either by unauthorized construction or with debris and litter. Saline seawater has entered some tanks in the vicinity of coastal areas that have over-exploited ground water. With unchecked withdrawal of water by private bore wells across the state, the water has literally been sucked out of the once full tanks. Ground water tables are under such stress that even rains have not succeeded in replenishing the beautiful tanks.

Chennai city, the capital of Tamilnadu, India alone has around 40 temple tanks which are important urban elements. Looking at the vital role played by temple tanks in the structuring and functioning of the settlement around them various NGO's and government departments have come forward to revitalize these tanks and restore them to serve the local and spiritual needs of the community.

4. CASE STUDY – THIRUPORUR TEMPLE TANK, CHINGLEPET TALUK, KANCHIPURAM DISTRICT, TAMILNADU, INDIA

4.1 Introduction

Thiruporur is a town 43 km south of Chennai on the Old Mahabalipuram Road (OMR) in Chinglepet Taluk, Kanchipuram District, covers an area of 7.9 km and its most important landmark is the Kandaswamy temple dedicated to Lord Muruga with the temple tank- Saravana Pogai.

In recent times the OMR has been identified as the IT corridor of Chennai city connecting the city with the Chinglepet highway and the ancient town of Thiruporur is at the southern end of the IT corridor. The Second Draft Master Plan of the Chennai Metropolotan Area (CMA) published in April 2007 has brought Thiruporur within the CMA jurisdiction integrating this town with the rapid urbanization of the OMR. Hence there is a great danger to the historic, architectural and cultural fabric of the town and its temple tank the chief source of natural water supply to the community.

4.2 Historic and cultural heritage of Thiruporur

‘Thirupporiyur’ as the town has been mentioned in ancient inscriptions, the Megalithic burial sites from the Neolithic period excavated from the surrounding hills indicate that a settlement existed in ancient times. Legend has it that Saint Chidambara Swamigal built this temple 400 years ago dedicated to Lord Kandaswamy. A water body Vallaiar Odai to the west side of the temple fed by underground springs was converted into a temple tank- Saravana Poigai [1]

The annual festival of the temple draws around one lakh devotees spread over ten days in the Tamil month ‘Maasi’ (January - February). The deity is taken in procession through the main processional streets. In addition other festivals and auspicious days spread throughout the calendar year draws a large number of devotees especially in the Tamil months of ‘Aypassi’ (September - October) and ‘Maasi’ (January). During these days the devotees take a dip in the sacred waters of the Saravana Poigai before making the ritualistic passage to the temple [2]

4.3 Physical structure of the town

The main streets run east- west connected at the ends by streets running north-south. The temple car procession is taken around the four streets- N. Mada Street, E Mada Street, S Mada Street and the W Mada Street. At the meeting of the West Mada Street and the North Mada Street the Malayadi Varam leads to the Kailasanathar temple on the hillock to the western side of the temple and the Vembadi Vinayakar temple at its base thereby defining the inner sacred geography of the town.

The sacred topography is laid according the principles laid in the ‘Mayamata’ which says that the ground should rise slowly towards the south and the west, ie. must slope towards the north and east. Thiruporur was noted for its irrigation canals and its water supplies. The 1772 record lists five ponds and 4 tanks. However today the only visible water bodies are the Kandaswamy temple tank-Saravana Poigai and the Thamarai Kulam(Lotus Pond). One of the other ponds at the north eastern end of the settlement is converted into a sewage pond.

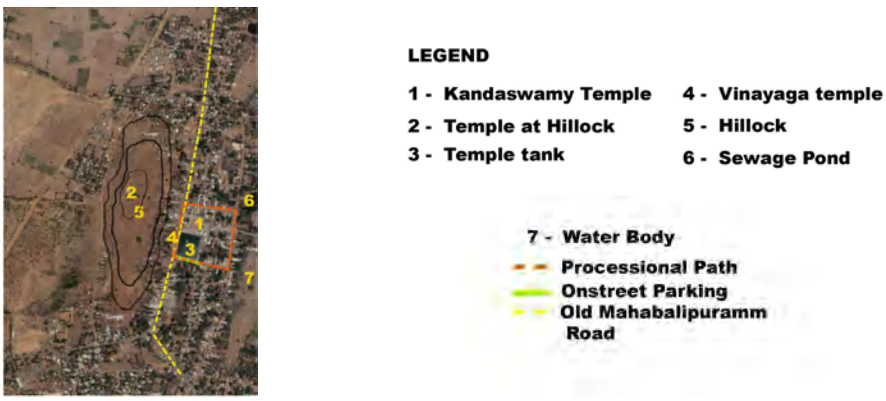

Figure 1 Physical infrastructure of Thiruporur Town

4.4 Architectural heritage of the town:

Figure 2 View of Temple and temple tank

Figure 3 View of Chatrams

Figure 4View OMR-Traffic congestion

Figure 5 View of Lotus pond

The temple and its gopurams (entrance gate), mandapams (pillared halls) and temple tank; the chatrams (rest houses); the traditional thinnai (verandah) houses with the pan tile roofing are standing examples of the rich and ancient heritage. The Kandaswamy temple covers an area of 4 acres of land and the gopuram stands 21.5 M tall. The temple has a 24 pillared mandapam a 16- pillared mandapam, Sarvavathiya Mandapam where all the musical instruments are kept and played during festivals and poojas.

The unsympathetic approach to these heritage structures is evident within the temple complex itself where the granite walls are covered with ceramic tiles in a number of places. Besides other heritage structures are being modified or replaced by the new commercial developments which are changing the traditional town fabric into a commercial urban fabric.

4.5 Kandaswamy temple tank- Saravana Poigai

Saravana Poigai is the tank attached to the Kandaswamy temple measures 200’ x 200’ and has a mandapa built of granite in the geometric center of the tank. The Saravana Poigai is fed by rain water collected from the hillock to the west of the temple and conveyed to the tank by means of an underground channel with its outlet at the higher south western end of the tank. During the monsoon the excess water is conveyed to a pond to the south east of the settlement through a drainage channel at the south eastern end of the tank. It is said that there are nine wells sunk in the bed of the tank but no one has really seen them as the tank has never run dry.

The Saravana Poigai therefore not only serves as an important lung of this traditional settlement, but also serves in controlling the micro climate of the place and helps maintain the hydrological balance of the area.

4.6 Impact of Urbanization on Thiruporur and key issues

(i) Thiruporur is at the tail end of the IT Corridor which is a 30 M wide road and it tapers to a 12 M road – West Mada Street. A bottleneck is therefore created where the OMR runs through the town. The 12 M wide road is sandwiched between the hillock and the Saravana Poigai (temple tank). Therefore there is no scope to widen the road to take the traffic of the OMR. If the hillock is cut to accommodate the OMR then there is a danger that the temple tank will get cut off from the source of water supply.

(ii) Small scale commercialization is already evident on the West Mada Street and in case the road is widened by cutting the hillock heavy commercialization will take place disturbing the traditional fabric and making the tank inaccessible to the devotee on the western side. Eventually the tank and its environment will face degradation.

(iii) On street parking takes place on streets around the tank which are barely 12M wide making it inconvenient for the pedestrian and polluting the vicinity of the temple tank.

(iv)The North Mada Street and the East Mada Street are 18M wide streets. When this town is integrated into the Chennai Metropolitan Area (CMA) when the Master Plan comes into force will succumb to land pressures and multi storied structures which are permissible under the Development Control Rules of the metropolitan city. This will put pressure on land, infrastructure and the ground water.

(v) Sporadic growth and uncontrolled development may lead to the blocking of the underground rain water drains which serve not only to replenish the water of the temple tank but the pond beyond which serves the domestic needs of the community.

4.7 Heritage Management of Thiruporur and its temple tank

As the town of Thiruporur has emerged as a very sensitive zone due to growth of the Chennai Metropolitan city there is a necessity for an integrated conservation and heritage management of the town as issues cannot be looked at in isolation. This will directly help in the heritage management of the temple tank and the traditional rain water harvesting system.

(i) **Status of the town:**

The town of Thiruporur was a cultural center in earlier times and continues to be one owing to the importance of the deity consecrated in the Kandaswamy temple and the numerous activities worship generates. **Hence this town has to be recognized and declared as a cultural and heritage center**.

(ii) **Listing of Heritage resources:**

The following structures have to be listed as heritage and protected structures in the town of Thiruporur:

a. Archaeological sites: Megalith burial sites belonging to the Neolithic period.

b. Religious structures and complexes:
   (i) Kandaswamy temple (1200A.D)
   (ii) Kailasanathar temple (1200A.D)
   (iii) Vembadi Vinayakar temple

c. Traditional systems:
   Rain water harvesting system linking the two outlined water bodies.
   (i) Saravana Poigai (Temple tank of the Kandaswamy temple)
   (ii) Thamarai Kulam (to be checked)

d. Secular Buildings:
   (i) Nagaveedu or Kathirikka Mudaliar Chatram
   (ii) Senguntha Mudaliar Chatram
   (iii) Thondai Mandala Vellala Aadi Saiva Vellalar Chatram

A number of other chatrams have fallen to a state of disrepair and beyond conservation and restoration. Besides heritage resources need to be identified and incorporated in the Chennai Master Plan II for future sustainability.

(iii) **Demarcation of Heritage Zone:**

A comprehensive heritage and development plan needs to be drawn up demarcating the heritage zone. In Thiruporur, the area defined by the four processional streets and the hillock to the west needs to be delineated as the heritage zone and in the detailed conservation plan, building controls in relation to height, material, architectural and other aesthetic details should be exercised.

(iv**) Management under a nodal agency:**

Urban management framework is generally characterized by the administration and technical sectorisation of responsibilities. With the declaration of the town as a heritage settlement and cultural center there will be a necessity for coordination and convergence in conservation under a nodal agency and formulation of locally based community development programs which will include up gradation, regeneration and provision of essential infrastructure in areas where there is a concentration of identified heritage structures.

(v) **Preservation of Environmental Quality:**
The nodal agency should guide the local body on any project or development proposal. In this context it is necessary to seek solutions to re- route the OMR around the hillock on the west so as to prevent high rise development in the vicinity of the heritage zone which otherwise would have a detrimental effect on the process of conservation and the heritage management of the water harvesting system of this area.

(vi) **Land use Planning:**
Government offices to the west of the tank draw large crowds for land registration and other related work on a day to day basis. These offices can be relocated to more suitable locations to prevent the over commercialization of this stretch. The land use around the tank should be largely residential with small scale commercialization to cater to the needs of the devotees. This should also applicable to the area delineated as the heritage zone.

(vii)**Water Resource Management**
A water resource management plan needs to be drawn up to identify the traditional concepts of the historic rain water harvesting which includes Thiruporur the temple tank and the Lotus pond. The municipal water supply to the town has to be stepped up by the government so that the temple tank is not used for domestic purposes like bathing and washing clothes. Besides sewerage system has to be provided for the entire settlement and connected to a sewage treatment plant before disposal.

Besides the other tanks and ponds which are seasonal need to be identified and protected mainly from landfill to which most low lying areas are subjected to in an urban scenario. A comprehensive plan for water management should integrate these tanks and ponds with a rain water harvesting system which at the grass root level deals with implementation of rain water harvesting systems for all old and new structures to enable recharge of ground water and collection of surplus in the ponds and tanks.

Figure 6: Heritage management of Thiruporur temple and temple tank

(viii) **Provision for car parking**
Delineating car parking to the east of the town just beyond the East Mada Street and re routing the pilgrim route to the temple will help decongest the area around temple tank.

(ix) **Maintenance Plan:**
A maintenance plan to regularly inspect the heritage structures, resources and their surrounding areas needs to be outlined to prevent untoward developments and damage/ deterioration of the heritage resources.

5. CONCLUSIONS

To conclude, change is inevitable but what is important is that change needs to be regulated and monitored before the irreversible happens and heritage is lost to mankind. Thiruporur is on the threshold of that change and only a comprehensive and integrated approach to urban and heritage management will guide its sustainability for posterity.

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CHAPTER IV

Experimental Methods and Test Results of Materials

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INVESTIGATION AND DIAGNOSIS OF HISTORIC MATERIALS

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ABSTRACT

Historic building, either famous monuments or “minor” architecture of historic centers need to be investigated in order to carry out repair aimed to their preservation. Non destructive techniques should be applied on site and destructive investigation limited to minor sampling. A methodology for investigation is outlined describing advantages and limits of the different techniques.

1. INTRODUCTION

Historic buildings, no matter whether they are famous monuments or so called “minor” or even vernacular architecture, represent an important part of our cultural heritage. This patrimony which is the living memory of the country history and development must be preserved as much as possible as an historic document of our past. In the last decade the word “restoration” has more and more been substituted by the term “preservation”. Also in the case of damages due to earthquake or other calamities the expression “to adequate” was substituted by the expression “to improve by minor repair and strengthening”.

Prevention and rehabilitation can be successfully accomplished only if a diagnosis of the state of damage of the building has been formulated. The diagnosis should result from an experimental investigation on site and in the laboratory aimed to define the characteristics of the materials and of the structure itself. The investigation on site must be non-destructive as far as possible and give information with good precision.

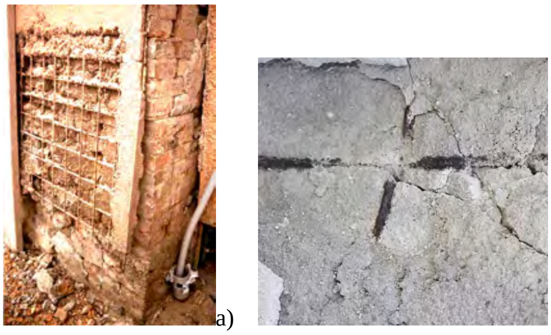
2. LACK OF KNOWLEDGE AND FAILED REPAIRS

The last 1977 Umbria and Marche, Italy, earthquake effects have shown that: a) structural models need to be adjusted to the real behaviour of the buildings according to their typology and to the masonry morphology, b) the retrofitting techniques applied after the previous earthquake of 1979 still need improvement.

The interventions, carried out according to the previous seismic code indication in Italy assumed the safety criteria applied to new buildings. Therefore the most used techniques were the following: a) to substitute the original timber floors and roofs with reinforced concrete ones; b) to built r.c. tie beams in the wall thickness at every floor level and under the roof; c) to use jacketing and/or injections of the walls in order to improve their shear strength.

As it is well known, the first two types of intervention are intended to improve the structural response of the building: type a) by ensuring “rigid floor” action, type b) by connecting load bearing and shear walls in order to prevent out of plane failures, type c) to obtain continuity in the masonry. In the following a description of some failure is reported which occurred when the above techniques were applied to poor stone masonry [1].

Figure 1: Effect of eccentric loading due to r.c. tie beam



a) b)

Figure 2: (a) absence of connectors
(c) corrosion of the steel net in a jacketed wall

Concrete ties, roof and floor substitution: The damage observed more frequently were the following: (i) partial eccentric loading of the walls (Fig. 1), (ii) lack or poor connection of the tie beam to the walls.

Wall and pier jacketing This technique was largely applied particularly to irregular multiple leaf stone- walls in Italy and it was recommended by the Italian Code. The most frequent failures were caused by: (i), lack of connection between the nets in orthogonal walls and in correspondence to the floors, (ii) lack of overlapping between two different sheets of the net, (iii) absence of steel transversal connectors (Fig. 2a), (iv) use of too short connectors, (v) insufficient thickness of the concrete cover with consequent steel corrosion (Fig. 2b).

Grout injection: Repair and retrofitting of masonry was extensively performed by grout injection. Multiple leaf walls can be made with very poor mortars and stones but have very low percentage of voids (less than 4% of voids is not injectable) and have internal filling with loose material (Fig. 3a), which is not injectable [2]. Figs. 3b and c show two of the cases where injection was very poor.

Figura 3a: Failed injection in a laboratory specimen.

Figura 3b: Poor results of applied injection.

Figura 3c: Only some spots injected in case of this wall with a very low percentage of voids.

3. DESIGN FOR STRUCTURAL INVESTIGATION AND DIAGNOSIS

In the case of historic buildings the constitutive laws coming from a good knowledge of the material is not enough. In fact the historic buildings belong different typologies to which a different behavior of the structure corresponds: (i) isolated buildings, (ii) building in a row, (iii) complex buildings, (iv) towers, (v) palaces, (vi) churches, (vii) arenas. The modeling of these structures can be very difficult. In fact, when the structure is a complex one, only linear elastic models are easily usable. Non-linear models or limit state design complex models are difficult to apply, also because the needed constitutive laws for the material are seldom available. Furthermore when the complexity of the structure is given by its evolution along the centuries starting from a simple volume to a more and more complex volume, then modeling has to take into account all the vulnerabilities accumulated during the subsequent transformations.

The same difficulties can be found in choosing the techniques for repair and strengthening. No doubt that the mistakes shown in Sect.2 could have been avoided if a better knowledge of the materials and of the structure from its geometry to its modifications would have been known. Fig. 4 shows which information can be available from in situ and laboratory survey and how they can constitute the input data for the structural analysis.

4. INVESTIGATION PROCEDURES

Most of the ND procedure can give only qualitative results; therefore the designer is asked to interpret the results and use them at least as comparative values between different parts of the same masonry structure.

It must be clear that even if there is a need of consulting experts in the field, it is the designer, or a member of the design team, who must be responsible of the diagnosis and must: (i) set up the in-situ and laboratory survey project, (ii) constantly follow the survey, (iii) understand and verify the results, (iv) make technically acceptable use of the results including their use as input data for structural analyses, (v) choose appropriate models for the structural analysis, (vi) arrive at a diagnosis at the end of the study.

In the following the most frequently applied procedures are briefly described taking into account their limits and advantages and also the incidence in the cost of the operations.

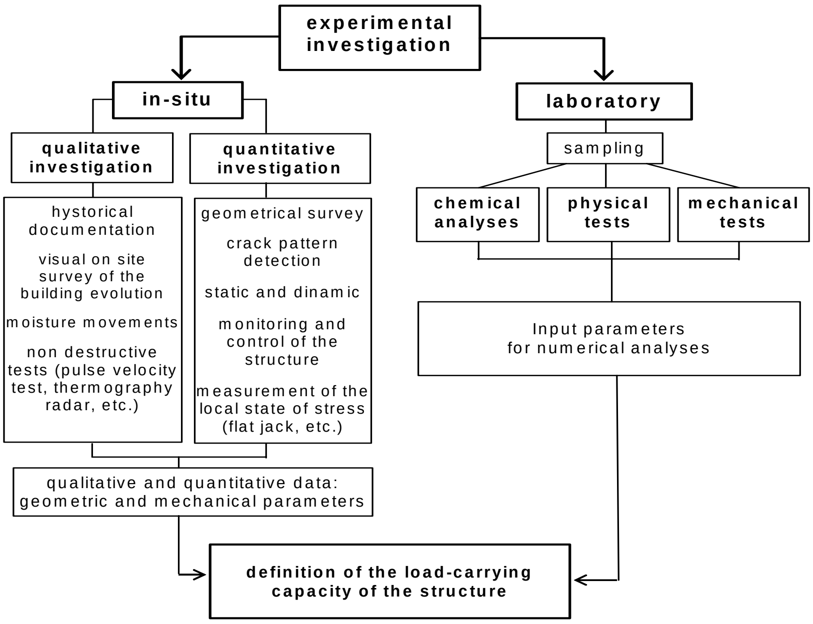
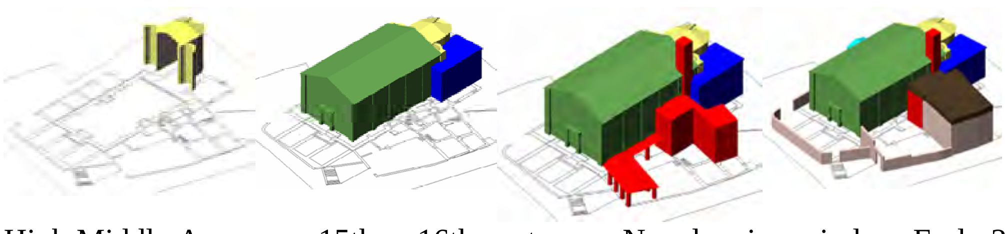


Figure 4: Finalization of the experimental survey to the structural analysis

4.1 Building typology definition, geometrical and crack pattern survey

A preliminary in-situ visual survey is useful in order to provide details on the geometry of the structure and in order to identify the points where more accurate observations have to be concentrated. In the meantime the historical evolution of the structure has to be known in order to explain the signs of damage detected on the building (Fig. 5). Especially important is the survey and drawing of the crack patterns (Figs. 6 and 7). The interpretation of the crack pattern can be of great help in understanding the state of damage of the structure, its possible causes and the type of survey to be performed [1]. The geometrical survey can be carried out with simple tools or more sophisticated as photogrammetry or laser scanners geometrical surveys.



High Middle Age   15th – 16th century   Napoleonic period   Early 20th
century

Figure 5: Construction phases of a church (S. Michele Arcangelo at Sabbio Chiese, Italy)

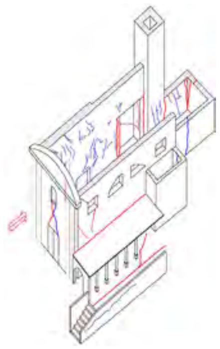


Figure 6: St: A. Abate, Morgnaga (BS)

Figure 7: SS. Benedetto, Pompegnino (BS)

4.2. Structure control by static and dynamic monitoring

Where an important crack pattern is detected and its progressive growth is suspected due to soil settlements, temperature variations or to excessive loads, the measure of displacements in the structure as function of time has to be collected.

Very simple monitoring systems can be applied to some of the most important cracks in masonry walls, were the opening of the cracks along the time can be measured by removable extensometers with high resolution. This simple system can give very important information to the designer on the evolution of the damage [3]. In-situ testing using dynamic methods can be considered a reliable non-destructive procedure to verify the structural behavior and integrity of a building. The principal objective of the dynamic tests is to control the behavior of the structure to vibration. The first test carried out can be seen also as the starting one of a periodical survey using vibration monitoring inside a global preventive maintenance programme. Acceptance of vibration monitoring as an effective technique of diagnosis has been supported by different studies [4]. These tests are very important to detect eventual anomalies in the diagnosis phase and to calibrate efficient analytic models (FEM).

The environmental excitation sources could be the wind, the traffic or the bell ringing in the particular case of towers. The forced vibrations could be produced by local hammering systems or by the use of vibrodines [5].

4.3 Wall construction technique

The structural performance of a masonry wall can be understood provided the following factors are known: (i) the geometry; (ii) the characteristics of its masonry texture (single or multiple leaf walls, connection between the leaves, joints empty or filled with mortar), (iii) physical, chemical and mechanical characteristics of the components (bricks, stones, mortar); (iv) the characteristics of masonry as a composite material.

A direct inspection can be performed by removing few bricks or stones, surveying photographically and drawing the section of the wall. This can be more efficient than coring (Fig. 8).

Figure 8: drawing of the wall section: a) left face of the section, b) photo of the excavation, c) right face of the section

4.4 Minor destructive techniques for masonry

Flat jack test. The method was originally applied to determine the in-situ stress level of the masonry. The firsts applications of this technique on some historical monuments, clearly showed its great potential.

The determination of the state of stress is based on the stress relaxation caused by a cut perpendicular to the wall surface; the stress release is determined by a partial closing of the cutting, i.e. the distance after the cutting is lower than before [6]. A thin flat-jack is placed inside the cut and the oil pressure into the jack is gradually increased to obtain the distance measured before the cut (Fig. 9). The displacement caused by the slot and the ones subsequently induced by the flat-jack are measured by a removable extensometer before, after the slot and during the tests. P_f corresponds to the pressure of the hydraulic system driving the displacement equal to those read before the slot is executed. The equilibrium relationship is the fundamental requirement for all the applications where the flat-jack are currently used : $S_f = K_j K_a P_f$ when: S_f =calculated stress value, K_j =jack const (<1), K_a =slot/jack area const (<1).

The test described can also be used to determine the deformability characteristics of a masonry. A second cut is made, parallel to the first one and a second jack is inserted, at a distance of about 40 to 50 cm from the other. The two jacks delimit a masonry sample of appreciable size to which a uni-axial compression stress can be applied. Measurement bases for removable strain-gauge

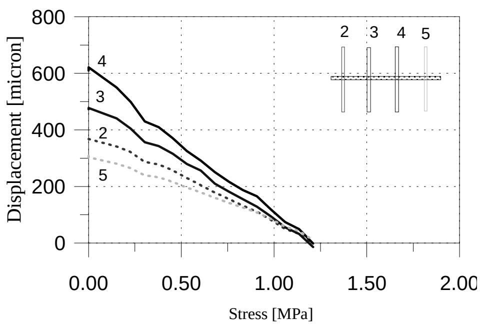


Figure 9: Single flat-jack tests carried out at the Monza Tower

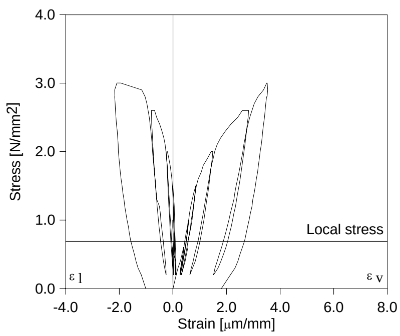


Figure 10: Double flat-jack test on West side of the Monza Tower

or LVDTs on the sample face provide information on vertical and lateral displacements. In this way a compression test is carried out on an undisturbed sample of large area. (Fig. 10).

4.5. Laboratory tests

The aims of these tests are the followings: (i) to characterize the material from a chemical, physical and mechanical point of view, (ii) to detect its origin, (iii) to know its composition and content in order to use compatible materials for the repair, and (iv) to measure its decay and the durability to aggressive agents from new materials used for restoration.

Tests on mortars: chemical and mineralogical-petrographic analyses are useful (and less expensive than other more sophisticated tests) to determine: the type of binder and of aggregate, the binder/aggregate ratio, the extent of carbonation, the presence of chemical reaction, which produced new formations (pozzolanic reactions, binder-aggregate reactions, alkali-aggregate reactions).

The grain size distribution of the aggregates can also be measured, particularly in the case of siliceous aggregates, by separating the binder from the aggregates through chemical or thermic treatments [7].

Tests on damaged and new bricks and stones: when masonry is damaged by aggressive agents, chemical, physical and mechanical laboratory tests can give useful information for the choice of the appropriate material for substitution. The tests have to be carried out on deteriorated and on undamaged existing bricks and stones, and new ones.

4.6. Non destructive techniques (NDT) for masonry

Many authors have mentioned the importance of evaluating existing masonry buildings by non-destructive investigation carried out in situ. ND techniques can be used for several purposes: (i) detection of hidden structural elements, like floor structures, arches, pillars, etc., (ii) qualification of masonry and of masonry materials, mapping of non homogeneity of the materials used in the walls (e.g. use of different bricks in the history of the building), (iii) evaluation of the extent of mechanical damage in cracked structures, (iv) detection of the presence of voids and flaws, (v) evaluation of moisture content and capillary rise, (vi) detection of surface decay, and (vii) evaluation of mortar and brick or stone mechanical and physical properties.

4.6.1. Thermovision

The thermographic analysis is based on the thermal conductivity of a material and may be *passive* or *active.* The *passive* application analyses the radiation of a surface during thermal cycles due to natural phenomena (insulation and subsequent cooling). If the survey is *active*, forced heating to the surfaces analyzed are applied.

A camera sensitive to infrared radiation collects the thermal radiation from the materials. The result is a thermographic image in a colored scale. At each tone corresponds a temperature range. Usually the differences of temperatures are fraction of degree. Applications can be: (i) survey of cavities, (ii) detection of inclusions of different materials (Fig. 11), (iii) detection of water and heating systems, (iv) moisture presence. In the diagnosis of old masonries, thermovision allows the analysis of the most superficial layers.

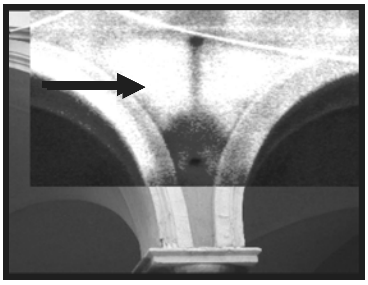


Figure 11: Investigation on hidden steel tie rods

4.6.2. Sonic pulse velocity test

The testing methodology is based on the generation of sonic or ultrasonic impulses at a point of the structure. An elastic wave is generated by a percussion or by an electrodynamics or pneumatic device (transmitter) and collected through a receiver, usually an accelerometer, which can be placed in various positions [8]. The elaboration of the data consists generally in measuring the time the impulse takes to cover the distance between the transmitter and the receiver. The use of sonic tests for the evaluation of masonry structures has the following aims: (i) to qualify masonry through the morphology of the wall section; (ii) to detect the presence of voids and flaws and to find crack and damage patterns; (iii) to control the effectiveness of repair by injection technique in others which can change the physical characteristics of materials. The limitation given by ultrasonic tests in the case of very inhomogeneous material made the sonic pulse velocity tests more appealing for masonry. In general it is preferable to use sonic pulse with an input of 3.5. kHz for inhomogeneous masonry. Fig. 12 shown the application of sonic test to two stone walls of the soma building.

4.6.3. Georadar

Among the techniques and procedures of investigation which have been proposed in these last years, georadar seems from one hand to be most promising, from the other to need a great deal more of study and research [8]. When applied to masonry, the applications of radar procedures can be the following: (i) to locate the position of large voids, cracks (Fig.13) and inclusions of different materials, like steel, wood, etc; (ii) to qualify the state of conservation or damage of the walls; (iii) to define the presence and the level of moisture; (iv) to detect the morphology of the wall section in multiple leaf stone and brick masonry structures.

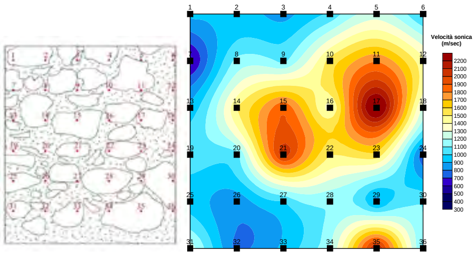


Figure 12: Distribution of sonic velocities in a wall

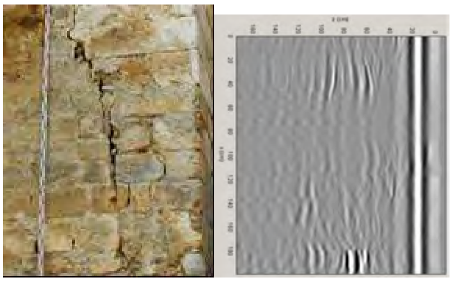


Figure 13: Localisation of cracks by radar

The method is based on the propagation of short electromagnetic impulses, which are transmitted into the building material using a dipole antenna. When the transmitting and receiving antennas, which are often contained in the same housing, are moved along the surface of the object under investigation, radargrams (colour or grey scale intensity charts giving the position of the antenna against the travel time) are produced . The choice of the antenna frequency must be made on a site basis. It is important to show results, as radargrams and graphics, which are significant to operators like architects and engineers .

4.6.4. Radar and sonic tomography

Among the ND applications the tomographic technique is quite attractive for the high resolution that can be obtained. Tomography, developed in medicine and in several other fields, seems to be a valuable tool to give two or and three-dimensional representation of the physical characteristics of a solid. Tomography, from Greek "tomos" (slice), reproduces the internal structure of an object from measurements collected on its external surface.

5. CONCLUSIONS

A methodology for investigation on historic structures aimed to their preservation was outlined.

Knowledge of the building details, materials and structural elements is essential in order to avoid past mistakes.

NDTs and MDTs are efficient only if their application is carefully calibrated on the studied building. Nevertheless the interpretation of the results is a difficult task and should be accomplished in a multidisciplinary approach.

Further research is needed on the complementarity of the techniques and on the development of appropriate software in order to obtain clear interpretations.

In absence of an immediate risk, the investigation can be: (i) prolonged in time and comprehensive, (ii) carried out to *calibrate* eventual *mechanical models* of the building behavior for long term actions or particular single events (hurricanes, earthquakes, etc.), (iii) set up to *control the effectiveness of the intervention* and is characterized by monitoring of the parts, which were previously more at risk.

Finally, investigation is needed in case of *long term maintenance programs* for repaired buildings.

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INVESTIGATION OF THE SLOVENIAN IMPRESSIONIST PAINTINGS BY THE DIFFERENTIAL PIXE METHOD

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ABSTRACT

PIXE method is a technique which allows a non-destructive examination of object composition. It gives us a general view of the elements present in a single point. By changing the energy of the protons we can examine different depths of the paint layer.

1. INTRODUCTION

In the four year period spent studying the paintings of the Slovenian artistic patrimony, scientific and technical research was conducted, whose purpose was to find out painter's use of pigments and learn of their painting technique. Our investigation was limited to various exhibition projects. We have therefore formed an interdisciplinary team of scientists working in research labs, conservators and art-historians to investigate Slovene Impressionist paintings. Our primary goal was to create a referential database which would allow us to reconstruct the general chronology of pigment usage, study differences among individual representatives of Slovene Impressionism and make meaningful comparisons of data gathered from any one subsequently analysed painting.

The works by the Slovene Impressionist painters have become one of most prominent symbols of the Slovene national identity. The information gathered in our research will help us understand artists' painting technique, their studio practices, shared ideas and distinctions. Thus it will help us describe more accurately the nature of the visual effects of their painted surface. The scientific research is complemented by art-historical research of written sources such as artist's correspondence, critique, accounts of their practice as well as archival evidence of their purchases of painting materials and tools, evidence of their suppliers etc.

The need for auxiliary methods for authentication of paintings today is unfathomable. The description of material properties of paintings, which might have changed in time since all of the painters lived relatively long, has practical applicability. By establishing a referential pattern of pigment utilization we could study artists' techniques in depth, expand criteria of discrimination, work out tools that could efficiently help in periodization and classification as well as in attribution. The comparisons could give us also conclusive evidence in the case of more recent forgeries.

Since the aim is to minimize damage to the works of art, we applied the particle-induced X-ray emission (PIXE) method as a nearly non-destructive method used for finding inorganic matter in pigments and binding media, which is being developed at the Jožef Stefan Institute in cooperation with ZVKDS Restoration Centre RS, Ljubljana, Slovenia, The National Gallery of Slovenia, Ljubljana, University of Ljubljana, Academy of Fine Arts and Design, Department of Restoration, Slovenia and University of Ljubljana, Faculty of Mathematics and Physics, Slovenia.

2. A BRIEF DESCRIPTION OF THE METHOD

In the PIXE method, the surface of the object is irradiated by a thin beam of protons accelerated to energy of a few MeV. Protons impinging on the target induce radiation characteristic for the elements present in the substance. The proton dose is normalized by determination of characteristic X-ray intensity stemming from presence of argon (Ar) in air. The characteristic X-ray spectra produced at irradiation are collected with two parallel semiconductor X-ray detectors in order to determine elemental intensity. Thus the inorganic substances, pigments and fillers present in the sample can be identified [1].

In our case the energy prepared at the low energy particle accelerator was between 2,5 and 3 MeV. The surface of the proton beam on the sample is typically half to one millimetre in diameter. The data acquisition time is about 300 s. The radiation causes no visible damage to the art object. And, what is more important, no sample extraction is required since small areas of interest on the work of art can be irradiated by the proton beam on the spot.

Since the method is non-destructive, we need not intervene in the object's surface causing physical damage. Unfortunately the method does not lend any evidence of depth of proton beam penetration as well as on the order and manner of laying down of singular layers of pigments. For that reason concentration profile studies by the differential PIXE method had been introduced for points on three different paintings. Elemental composition of different paint layers was sought by gradual decrease of energy of irradiating protons, reaching thus shallower portions of the objects. Paintings were analysed at 0,5 to 3 MeV proton energy, while energy between 2,5 and 3 MeV proton energy was applied for regular measurements. The collected measurements were processed by a mathematical model [2] developed for investigation of paintings [3]. We thus concocted non-sequential profiles that indicate concentration of particular chemical elements in various depths of paint layers.

The object is fixed on the manipulation table perpendicularly to the proton beam. The table can be moved laterally in the XY plane and adjusted onto the location chosen for measurements.

There were certain limitations imposed on selection of paintings and points for analysis by their size. While we had no difficulties with small canvases, in large ones that can extend up to 5 m along the longer edge, we could not reach the central area by moving the canvas on the XY plane.

3. EXPERIMENTS AND TECHNICAL DEVELOPMENTS

PIXE method was applied for identification of elemental composition of pigments in paintings from the early Modern period - that is early 20th century. Slovene impressionist painters used pigments mixed in traditional way with inorganic pigments as well as industrially produced organic ones.

We have analysed paintings by four main representatives and some of their contemporaries. For the current purpose we shall concentrate on Rihard Jakopič's paintings. 18 of his paintings were analysed by application of the PIXE method with total of 119 referential points in different colours of painted surface. We have selected dated paintings in as dense a sequence as possible for the early years when the painter's experimentation with his means was most intense.

Paintings were systematically selected to cover the entire creative period. The points for analysis were selected in an effort to cover as many different pigments that appear on each painting as possible.

The results were checked against information obtained by optic microscopy (OM), ultraviolet fluorescence microscopy (UVFM) and scanning electron microscopy with energy-dispersive X-ray analysis in low vacuum (SEM-EDS), on the samples extracted from the PIXE measurement points. All methods are part of the standard repertory of investigative techniques for paintings, so we do not describe them at length.

4. RESULTS AND DISCUSSION

4.1 The Jakopič palette

Jakopič palette, reconstructed in the course of our investigation by PIXE method, corresponds only in part to the palette of the main stream of the French Impressionism [4]. We attribute the differences to belated occurrence of the Slovene Impressionism, by that time well informed by the Symbolist practices. Just as important, however, is the fact that French Impressionism's influence was mediated in Munich and Vienna and informed by the very late stages of its development.

We have detected cinnabar only in five of 18 paintings tested. They all date between 1903 and 1913. The same period is also characterized by significant presence of cadmium. Neither older nor younger paintings contain either of the two. If the cinnabar has been in use since Antiquity, cadmium pigments are relatively new [5]. They were introduced in 1870s. Paintings from 1900 to 1905 contain copper arsenate for green colour (Sheele's or emerald green), but in later paintings we have been looking for it in vain.

Chrome pigments, yellow as well as red chromates but also the green chrome oxide, are present in every painting regardless of the time of creation. Green chrome pigments were used along with the copper-arsenate.

Iron was detected in low quantities in all paintings most probably as an addition to other pigments. However, higher concentrations of iron were very rare. We connect higher concentration of iron with red and yellow ochre.

The comparative analysis of cross-section samples of paint layer with SEM-EDS and OM identified the blues as synthetic ultramarine. By application of this comparison we have eliminated Prussian blue that contains iron with a high degree of reliability.

Similarly as iron we have detected cobalt in low concentration under 0,1 % in paintings spanning the entire period between 1900 and 1930. Higher concentrations are very rare. Tin is one metal that we have never hit upon. This evidence and a comparison again with the cross-section samples of paint layer by OM in SEM-EDS allow us to conclude that the blue pigment was cobalt aluminate, accompanied by synthetic ultramarine that contains light elements such as Na, Al, Si, and sulphur - all of them undetectable by PIXE method. OM shows that blue pigment is admixed to every colour of particular paintings. Jakopič evidently strove for a means of unification of the painted surface by the dominant pigment. Thus we can explain low concentration of cobalt in colours other than blue.

Our research has identified a few criteria which allow us to relatively reliably distinguish Jakopič's early paintings from the late ones. No doubt we shall continue to work on refining of his chronology of pigment application. Nevertheless, the results of the investigation of Jakopič paintings enable us to move on to the paintings of other three Slovene Impressionists to describe their differences and similarities. Equally important will be comparison of pigment pattern in paintings by Jakopič students and followers where presence of pigments Jakopič never used, according to the written sources, will be sought.

Black pigments were not detected by OM and PIXE as well as SEM-EDS do not show any characteristics of particles that fetch black. Dark hues were usually a mixture of dark pigments of blue, green and red.

Thus far we have described only inorganic pigments in Jakopič's palette that can be detected by the applied methods. Even here when particles of the same element appear in different colours we can identify them within the margin of probability. Organic pigments will be analysed in continuation of the project by application of appropriate methods such as (FT-IR, Raman spectroscopy).

In comparison to the French Impressionist [4] we have not detected the naples yellow (lead antimonite), chrome green (a mixture of Prussian blue and chrome yellow), the cerulean blue (cobalt stannate) and ivory black.

4.2 White pigments

It is noteworthy that PIXE in any beamed spot in any painting detects three elements: Pb, Zn in Ba in variable quantities which are to connect with three white pigments: lead white (basic lead carbonate), zinc white (zinc oxide) and -baryte (barium sulphate). We have introduced average values of their concentration for each painting into a triangular diagram where every corner represents concentration of each of the elements (Figure 1).

In paintings executed between 1900 and 1913 the main component of the white pigment was lead white. Zinc appears not as an impurity but as an admixture of zinc white which is indicated by typical fluorescence of that pigment in UVF OM. The same can be claimed for baryte for which we think was used as an extender to zinc white.

The second group consists of three paintings: *Sava River*, *Tivoli Park* (NG S 1392) and *A View from Rožnik towards Krim* (NG S 2005), all of them later works after 1925. They all contain less than 10 weight % of lead white, while zinc and baryte are present in equal percentage. This indicates a change in utilization of certain materials in comparison to the pre-war time. It remains to investigate whether the change is due to artistic intention or to a crass fact of social and political change.

The attractive results of the statistical analysis should be treated critically. One painting, *Winter* (*On the Hill in Wintertime*, NG S 1399), dated 1905 by a consensus of experts, indicates all three components in equal quantity. We have yet to explain the meaning of this anomaly.

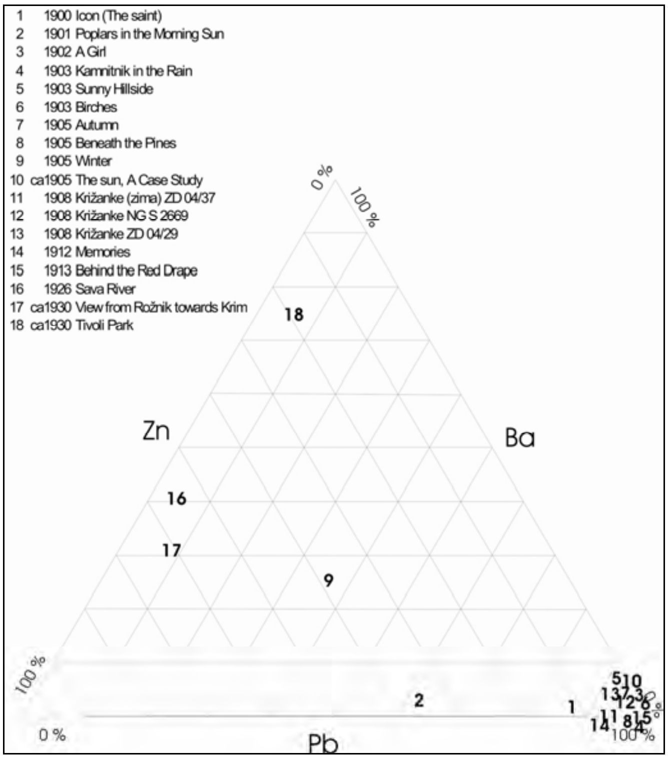

Figure 1

The second troubling case is *Poplars in the Morning Sun* (NG S 1388), dated 1901. The whole pattern shows small differences from the average, while in this case the difference is substantial. The concentration of barium
sets it in early, while zinc white is indicative of late period. The explanation here is quite prosaic: the selection of four points for beaming makes for a less relevant pattern. The pigments are not uniformly distributed through the depth profile and an accidental concentration of zinc surface changes the picture of the pigment composition.

4. 3 Profiles

We have examined four points on three Jakopič paintings by application of the differntial PIXE method. They all fit within the early period between 1900 and 1905. By the decrease of the proton energy we have looked closely at the layers closer to the surface. We found the structure of the paint in cross-section at great variation.

In *The Sun, A Case Study* (NG S 3101), dated ca. 1905, we have directed the beam at the pale yellow centre of the sun-disc and at the dark green edge. The point at the centre showed very little lead, while deeper underneath the lead content soars to 80 weight %. There is barely any calcium on the surface then it increases towards the middle and decreases towards the bottom. Additional investigation by electronic microscope found chrome and baryte as the extender in deeper section. Chrome was not detected by the differential PIXE method because of insufficient quantity.

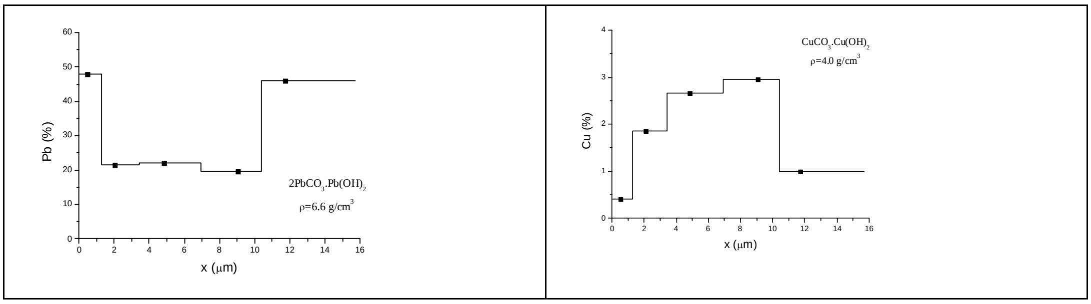

Figure 2

The second point (Figure 2) showed the change of lead and copper share which depended on the depth reached by the beam of protons. The thin upper layer contains a larger share of lead which decreases and then reaches the same share again deeper beneath. The PIXE indicates it happening at the depth of ca. 10 μm. Depths with less lead contain a bigger share of copper which then decreases in depth. A comparison of results with samples analysed by SEM-EDS mapping analysis corroborates the results gathered by PIXE.

In *Poplars in the Morning Sun*, dated 1901 we have investigated the white of the sky by the differential PIXE method. All three methods - the differential PIXE, UVFM in SEM-EDS of cross-sections of paint layers show larger quantities of zinc and lesser content of lead near the surface and a reversed pattern deeper beneath.

The largest number of components was found by the differential PIXE method in the signature of the painting *Kamnitnik in Rain* (NG S 1317), 1903. Upper strata show a mixture of zinc, iron, and calcium pigment. Further on barium quantity increases, while we hit upon lead only at the bottom. SEM-EDS mapping shows a somewhat different picture. Barium and zinc is detected in the upper strata with iron and calcium at the end but with no lead content. In the next layer the lead appears and increases with depth as indicted also with the PIXE.

A comparison of profiles gathered by the differential PIXE method with optical and electronic microscopy of cross-sections taken on the same spots demonstrated a relative incongruence of patterns along the depth axis. The differences can be accounted for in part by the size of the analysed surface. The surface of the beamed spot is approximately 1 mm^2, while in SEM-EDS the analysed surface is ca. 10x10 μm. The proton beam fetches average results of the analysed surface. In SEM-EDS we deal with a point analysis in which the composition can vary between two points distanced only a few μm.

Mathematical and physical model of the data analysis in differential PIXE shows that the proton beam reaches no more than 10-15 μm in depth, which does not correspond to the mapping of component distribution gained from SEM-EDS.

We shall thus attempt to modify the model by more appropriate consideration of density, porosity, quantity of the organic components which should allow us to achieve a greater accuracy in correspondence to the actual condition.

In spite of some uncertainties and shortcomings of the differential PIXE method we can claim that the proton beaming is a reliable tool to generation of a generalized picture of strata composition - stratigraphy.

5. CONCLUSIONS

It is evident that any single method has many limitations. The use of a combination of methods improves reliability. PIXE method's advantage is that it is non-destructive, relatively reliable and suitable for the first step which tell us what to do next to formulate a good answer to our question.

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ON OBTAINING NEW DERIVATIVES OF TRIAZOL WITH BACTERICIDE AND FUNGICIDE ACTION IN THE CONSERVATION OF CULTURAL AND HISTORICAL HERITAGE ITEMS

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ABSTRACT

The paper presents the experimental results concerning the active biologic potential of some pyridine salts of the newly synthesized 1,2,4-triazolic derivatives. An appropriate environment has been developed and optimised for the breeding of three different microorganisms: the fungus species Aspergillus penicilloides and Fusarium and the bacterium species Bacillus subtilis. The three species of microorganisms that were used to test the antimicrobial action of the 2-amino-pyridinium carboxylate of the α-(o-chlorophenoxy) – α-(1,2,4-triazole-1-il) acetic acid were isolated from art objects with organic and inorganic support (polychrome wood, paper, frescos or ceramics).

1. INTRODUCTION

The compounds of the triazole class with antifungal action are used internationally, both in medicine and as a pesticide applicable in different fields.

Triazolic fungicides stand out due to the fact that they have an ample spectrum of action, being used in small, non-polluting doses, with a systematic action. Triazolic fungicides act by inhibiting the biosynthesis of the ergosterol, the main compound of the cell membranes [1,3].

The substances used in preventing and fighting against the fungal and bacterial degradation of works of art must comply with the following requirements: they have to be efficient in preventing and fighting against the biologic attack for as long as possible, by removing the microorganisms in all development stages; they must not modify the aspect of the object; they are to be non-toxic for humans; they should not require special application conditions and have a reasonable price.

The structure of the newly synthesised compound salt, the 2-amino-pyridinium carboxylate of the α-(o-chlorophenoxy) – α-(1,2,4-triazole-1-il) acetic acid, has been determined by analytical and spectral methods (^{1}H and ^{13}C NMR spectra). This structure is presented in Figure 1.

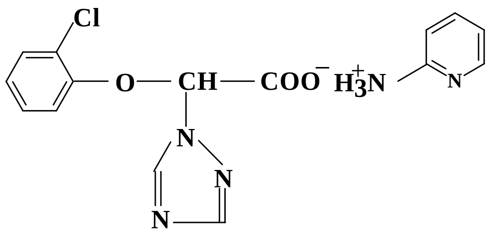

Figure 1 2-amino-pyridinium carboxylate of the α-(o-chlorophenoxy) – α-(1,2,4-triazole-1-il) acetic acid

2. THE EXPERIMENT

The experimental results obtained by testing the pyridine salts of the newly synthesized 1,2,4-triazolic derivatives on several fungal and bacterial species reveal a very good biocidal potential. We will now exemplify the manner in which the optimum composition of the growing environment for one of the species – Aspergillus penicilloides – has been established.

Table 1. Experimentation plan extended with 3 variables for the species Aspergillus penicilloides

Variable	**Code**	**Level of variables**				
		-α-1	-1	0	1	α+1
C source	x_2	- 0,182	1,5	3	4,5	6,182
Organic N source	x_3	- 0,682	1	2	3	4,682
$CaCO_3$	x_7	- 0,818	2,5	5	7,5	9,182

Taking into consideration the influences of the 3 factors, the regression equation that describes the performance of the growing process is [2]:

$$Y = 50.38 - 2.60x_7 - 0.69x_2^2 - 0.53x_3^2 - 0.87x_7^2 + 0.625x_2x_3 + 0.625x_2x_7 + 1.125x_3x_7 \quad (1)$$

The Fisher test confirmed the adequacy of this mathematical model – if $\mathbf{F_{calculated}} = 726.94 > \mathbf{F_{critical}} = \mathbf{4.6}$, the result is that the mathematical model is adequate to the two independent variables x_1, x_2, and there are no errors.

$$F = \frac{(n-1)\sum_{i=1}^{n}\left(Y_{ei} - \overline{Y_e}\right)^2}{(k-1)\sum_{i=1}^{k}\left(Y_{eki} - \overline{Y_{ek}}\right)^2} \tag{2}$$

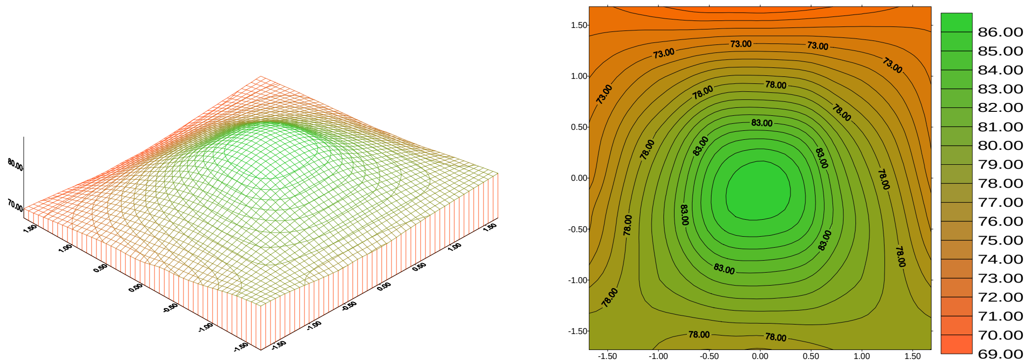

Figure 2 The dependence of Y on the two variables (x_3,x_7) for $x_2 = 0$
a) tridimensional; b) isolines

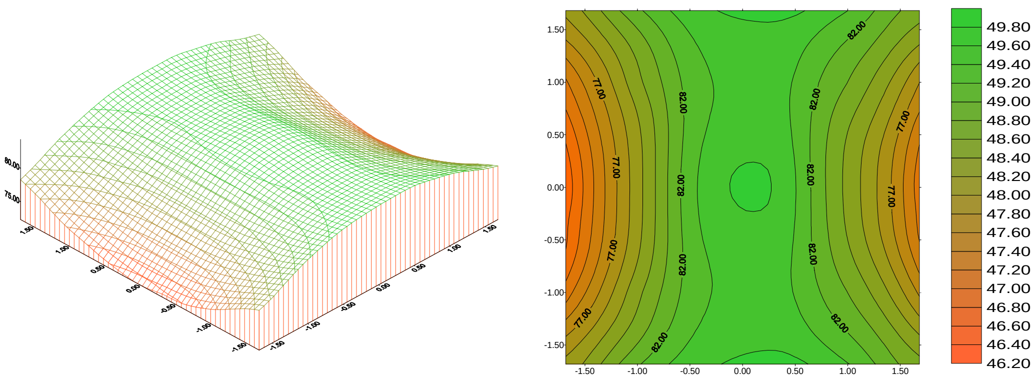

Figure 3 The dependence of Y on the two variables (x_3,x_2) for $x_7 = 0$
a) tridimensional; b) isolines

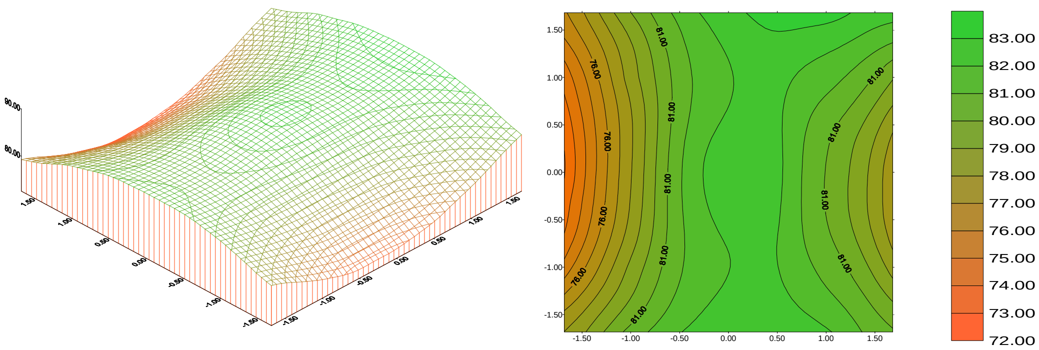

Figure 4 The dependence of Y on the two variables (x_2,x_7) , for $x_3 = 0$
a) tridimensional; b) isolines

Figures 2, 3 and 4 exemplify the dependence of the concentration of culture media (Y) on the anorganic source (x_3) and the concentration of $CaCO_3$ (x_7). The application of the classical optimisation method leads to the conclusion that this function (Y) has the maximum point: $x_2 = 0,718$ $x_3 = 1,04$ $x_7 = 0,57$. Transposed to real variables, these values correspond to a concentration of C source of 4,57 g/l, of organic N source of 3,04 g/l, and of $CaCO_3$ of 10,42 g/l. The same is valid for the gram positive bacteria Bacillus subtilis.

Table 2 Experimentation plan extended with 3 variables
for the species Bacillus subtilis

Variable	**Code**	**Level of variables**				
		$-\alpha$-1	-1	0	1	α+1
C source	x_1	36,68	35	3	39	40,68
Organic N source	x_2	1,74	3,422	2	3,768	5,4
Monopotasic phosphate	x_4	0,822	0,860	5	0,656	2,338

Taking into account the efficiency of the applicability of triazolic derivatives in medicine (internal medicine, dermatology) and agriculture [3], we tested the newly synthesized compound on two types of wood essences frequently used as a support for objects of art. The samples come from pine wood and fir wood. The microorganisms are sown as a 10^{-7} suspension in distilled water with a platinum thread handle. The growth of the fungus, the efficiency of fungicides on wood samples, as well as the results are analysed and interpreted after a 7-day incubation period at 28^{o} C, by optical, microscopic and photographical analysis, using grades according to the standard (STAS 8022/1991). In table 3, the efficiency degree of the antifungic properties of the tested biocide is presented.

Table 3 The characterisation of the 2-amino-pyridinium carboxylate of the α-(o-chlorophenoxy) – α-(1,2,4-triazole-1-il) acetic acid for pine and fir wood.

Fungicide	**Wood essences**	**Development of spores and of the mycelium**	**Degree of development**	**Efficiency of disinfection**
2-amino-pyridinium carboxylate of the α-(p-chlorophenoxy) – α-(1,2,4-triazole-1-il) acetic acid	Pine wood	The mycelia form a very well-defined inhibition area when in contact with the treated test tube	0	Very good
	Fir wood	The treated sample forms an inhibition area between the environment and the mycelium or the spore-free test tube	0	Very good

The results obtained confirm the biologically active potential of the tested compound by the fact that the presence of the microorganism is imperceptible in the culture environment and by the presence of a clear inhibition area around the test tube.

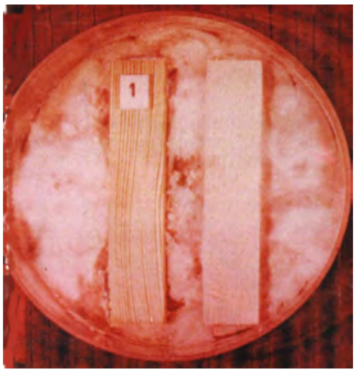

Figure 5 Pine wood treated with 2-amino-pyridinium carboxylate of the α-(o-chlorophenoxy) – α- (1,2,4-triazole-1-il) acetic acid

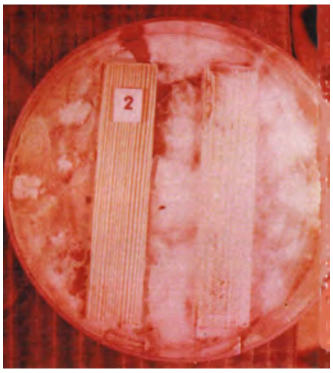

Figure 6 Fir wood treated with 2-amino-pyridinium carboxylate of the α-(o-chlorophenoxy) – α- (1,2,4-triazole-1-il) acetic acid

In order to be able to observe the effect of the solutions on the ancient wood of the heritage objects on treated surfaces (polychrome wood, leather) in ordinary conditions, the analysed biocide was applied with a brush on surfaces within 5 cm on both sides of the icon “Saints Pantelimon, Cosma and Damian”, 1928, painted with tempera on fir wood.

a) b)

Figure 7 “St. Pantelimon, Cosma and Damian” Icon: a) untreated support, b) polychrome layer treated with 2-amino-pyridinium carboxylate of the α-(o-chlorophenoxy) – α- (1,2,4-triazole-1-il) acetic acid

3. CONCLUSIONS

When the biocide was practically applied and tested, the solutions used had the same concentrations as those used experimentally. Regarding the tests performed on the polychrome surface of the icon, the microscopic analysis of the areas treated with biocide revealed no chromatic or dull-spun modifications. No supplementary cracks or creases appeared. The colour tests performed on the reverse were adequate, the tested compound maintains the wood colour.

ACKNOWLEDGEMENTS

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DOCUMENTATION ON PAPER CONSERVATION

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ABSTRACT

Conservation and restoration are actions which are undertaken by the conservator to bring the artifacts to a known previous condition so that it survives longer in its entire life span. The assessment remarks and definitions made in order to choose the most appropriate treatment method is known as examination and recorded in a) Collection Survey and b) Pre-Treatment Report. The details concerning the applied treatment are documented in the Post Treatment Report. A systematical recording of pre and post treatment phases of the entire campaign is called as documentation. The steps described in this paper were employed in a collection survey which has been conducted in Istanbul University, Faculty of Letters Rare Books Library.

1. INTRODUCTION

Paper artifacts, like all other objects, are produced based on their intended functionality. Paper gains certain properties and attributes as a function of the materials used in its production phase. Plant originate paper artifacts undergo deterioration from a variety of sources simultaneously at rates that are dependent on environmental conditions and artifact designs. When paper artifacts from libraries, archives and museums are examined, it is seen that none of them shares the same state and conditions. For this reason, before initiating any treatment, a conservator must firstly examine and identify the extent of deterioration at all levels of organization and the degree of stability remaining in the object. It is only after this that the conservator may suggest a conservation methodology.

2. "A COLLECTION SURVEY" FOR A LIBRARY

Paper artifacts are objects that are generally kept together in places such as libraries. During the examination and documentation phases, this has to be taken into account and a collection survey needs to be filled in to have a notion about the general state of the library.

Books consist of surface elements like front and back covers, bindings, side pages, etc. The changes in the conditions of these outer surface elements and alterations that are monitored in support and media materials need to be recorded. Besides that, bacteria and microorganisms which are products of biological deterioration must be taken into consideration in this phase

While assessing the physical conditions of books, terms such as “excellent”, “good”, “average”, “poor” and “very bad” may be utilized. These adjectives may be accompanied by causes as well (i.e., “very bad” because of inappropriate transportation). Since new books may be added to the survey in future applications it would be wiser to utilize a commercial recording and organizing software during this phase.

The benefits of such a survey strategy are twofold: First of all, the books in a collection may require a varying degree of conservation and restoration. That specific level would be determined at this stage (e.g., 40% of the books are vulnerable to acidity, 10% have been attacked by moth, etc.). Secondly, periodical surveys help the conservator to determine the rate of deterioration which serves as reference point.

3. PRE-TREATMENT REPORT FOR A PAPER ARTIFACT

Based on the results of the Collection Survey, a Pre-Treatment Report is prepared for those books which have been diagnosed as in poor condition and therefore quarantined. This report consists of visual examination results and descriptions of existing characteristics of the paper artifacts that have been revealed by tests and analyses. At the final step, based on the results, treatment suggestions are presented. The pre-treatment report is composed of 6 stages.

3.1. Identification

This section consists of information such as collection title, registration number, owner or custodian’s name, book title, publication date or period, place of manufacture, dimensions, photographic documentation or other visual aids, etc.

3.2. Description

Methods of fabrication, techniques and materials used in the manufacture phase of the artifact are noted for a) the support, b) design media, c) sizing, d) binding.

3.3. Past treatment

The signatures and evidences of past treatments and their locations are recorded.

3.4. Condition

Deteriorations in paper may be surveyed by the help of stereoscopic microscopy and UV-IR radiation techniques as well as visual investigation [1]. Probable causes of deterioration in paper artifacts are quite different from one another and may be listed as follows: environmental factors, fabrication techniques, improper usage, poor treatments. A selective classification of similar causes of deterioration and the usage of common terminology would facilitate the treatment procedure. Description of the physical and visual quality alterations can be parametrically classified as follows:

Strength : Embrittlement, abrasion, thinning

Structural integrity:
Planar distortions : Bulge, cockling, undulation, blocking, draws, adhesion
Local distortions : Wrinkles, creases, folds, scratch, tears, breaks
Overall distortions : Missing pages, media loss, holes, insect damages, burns

Discoloration:
Overall : Darkening, yellowing, blanching, burnishing
Local : Acid burn, watermark, liquid or iron or oil stain, fingerprints, foxing,

Residuals : Microorganisms, bacteria and insects (Figure:1), dust particles

Figure 1 Stereomicroscope image: traces and residues of moth bite

3.5. Testing and analysis

For in depth information which is not possible to obtain by visual and radiative surveys, the following tests and analyses are applied:

Some of the fiber and non-fiber originated materials which are used in the fabrication of paper produce harmful components or may act as nutritive platforms for biological activities due to environmental factors. In order to determine such material, morphological identifications are done under polarized microscope (Figure: 2) or micro chemical testing is applied. Ground wood paper made from lignin containing fiber, produces acidic components which attack cellulose especially when exposed to light. Phloroglucinol, Aniline Sulphate and P-Nitroaniline tests are applied to determine the existence of lignin in fibers [2].

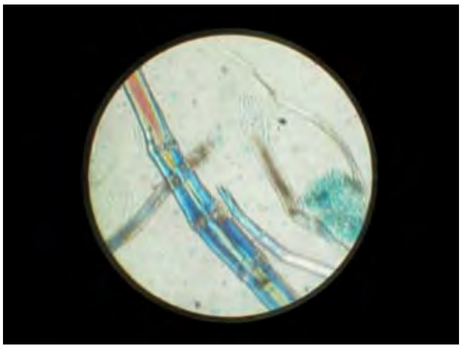

Figure 2 Morphological character of a fiber under polarized microscope

Since the 17th century, alum (aluminum sulfate) is used by paper makers to facilitate sheet formation. Alum-rosin and gelatin sizing with excessive alum added may lead to very high acidity. Aluminon test is applied to reveal alum quantity within paper. Additive materials such as starch, gelatin, rosin, casein or soya form potential nutritive grounds for biological activity. Iodine and C-stain test; Tanin and Hydroxyproline test; Millon test; Ninhydrin, Biuret and C-Stain test; #1 and #2 Raspail test is used to reveal starch, gelatin, casein or soya products, protein and rosin respectively. Any kind of plant resin and starch adhesives cause mold development. While Sudan IV and Sudan Black B tests are applied to detect resin, Iodine Potassium Iodide test is applied to reveal the existence of adhesive starch [3, 4, 5].

Besides the above mentioned tests, a series of tests are applied to the paper artifacts in order to figure out the possible reactions of the object to the treatment materials. These tests also give hints to select appropriate treatment methods.

The object's sensitivity against dry (mechanical) cleaning is tested by strength analysis of media and support material. Ph-meter is used to measure the acidity of the object. The sensitivity of the material against solutions used in wet cleaning such as water testing [5], humidification testing, organic solvent testing, testing bleaches and enzyme testing is carried out. In conservation applications, design and support media bleeding [6] and friability must also be tested.

3.6. Conservation method

At this final stage, the conservation method to be selected must be based on one of the following two distinct approaches:

The first approach involves altering the state of the object through treatments such as mending, cleaning and restoration to bring it to a known previous state. The latter approach requires a less intrusive perspective and focuses more on the the control of the environment in order to stabilize deteriorating materials and structures and prevent developing deterioration processes [7].

In places like libraries where paper artifacts are stored in bulk, the selected conservation methodology should aim to benefit from both approaches mentioned above. In situations where environmental conditions are not improved, conservation treatments lose their healing influence in a short time and the object immediately reenters into a new stage of deterioration

4. CONCLUSIONS

- After Utilization of a common terminology in Collection Survey, Pre and Post-Treatment Reports would facilitate knowledge transfer between groups of conservators.
- A conservation treatment which starts from the conclusions of an accurate diagnosis is hardly prone to failure. Identifying some of the chemical, morphological, biological and mechanical consequences of deterioration can help to overcome most of the challenges presented by a given artefact.
- A proper conservation diagnosis would also furnish the conservator with parameters such as required conservation time, required material, equipment and human resources.
- A paper conservator must start by learning the existing, lost and altered qualities of a given paper artifact a priori to his/her conservation campaign.

We hope that the Turkish Ministry of Culture and Tourism supports the preparation and development of a standardized collection survey form so that the conservators would find a sound basis in their future conservation attempts at any cultural heritage establishments containing paper artifacts. This form would certainly function as an important and invaluable asset in the hands of conservators.

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STUDY CONCERNING EVALUATION OF NEW TYPE OF LEATHER TO BE USED IN THE RESTORATION OF HISTORICAL OBJECTS

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ABSTRACT

It is known that chrome tanned leathers have been shown to be highly durable but this type of leather is generally unacceptable to binders due to its springy nature and failure to tool satisfactorily. On the other hand, vegetable tannins impart the properties required by the binder, but at the same time render it susceptible to deterioration.

The aim of this paper is the evaluation of a new type of leather to be used in restoration of historical leather. The experimental plan involves different organic tanned leathers. The behavior of new leathers has been followed after exposure to atmosphere rich in SO_2 by changes of water vaporous absorption was studied.

1. INTRODUCTION

Leather objects, whether on display or held in store are likely to be exposed to fluctuating climatic conditions of temperature and relative humidity in the immediate environment of the object. Like other organic materials, leather will respond readily to changes in the relative humidity, taking up or losing moisture to the atmosphere. It is the response over a long period of time which is thought to lead to a type of deterioration seen in many collections of historical objects made of vegetable tanned leather. This deterioration, as distinct from that brought about by acidic atmospheric pollutants, takes the form of a progressive hardening of the leather, loss of flexibility, dimensional changes and a darkening of the surface color.

These changes are undesirable, for if the study of the object is to be meaningful, the leather should ideally retain as closely as possible its original appearance and condition.

These changes can also-cause physical damage, especially if the object is restrained from adjusting dimensionally to the climate changes of its surroundings; with the result that internal stress can lead to the development of cracks and breaks. Objects which have lost flexibility are also more at risk from damage due to improper handling. While leather chemists have studied extensively the short term response of leather to changes in relative humidity and temperature during the later stages of leather manufacture, only limited studies have been concerned with the longer term exposure to varying in conditions.

Identification of sulphates and sulphites in the old leather water extract associated with the results of hide substance analysis have revealed the sensitivity of the vegetable tanned leather to the sulphur compounds action, leading to highly deteriorated collagen fibers [1].

In earlier works [2-5] the influence of the exposure time to the damaging agent on the water amount absorbed in the parchment samples is investigated.

2. EXPERIMENTAL

The experimental plan involves three different organically tanned bovine leather:
Leather 1 - Combination of organic and Aluminum tannage / Mimosa retannage
Leather 2 - Dialdehyde tannage/ Mimosa retannage
Leather 3 - Polymeric tannage/ Mimosa retannage and
Control sample - Mimosa tannage
From each of the bovine leather, test samples of 2 × 2 cm were collected and conditioned. Thereafter they were exposed to the damage by SO_2 generated 'in situ' at a level of 0.04 mg/l, in an enclosed room for various times (τ): 2, 4, 6, 8, 10, 12 hours. After the expose to the damaging agent (t), the test samples were tested for the water vapor absorption at different times, as follows: 60, 120, 180, and 240, 300 and 360 minutes.
The water weight absorbed by a leather test piece is given by the formula:

$$\Delta m = m_f - m_i \tag{1}$$

where m_i is the initial test sample weight, and m_f is its final weight.
Then the ratio Q was determined giving information on the relative water amount absorbed by the test sample unit weight.

$$Q = \frac{\Delta m}{m_i} \times 100 \tag{2}$$

3. RESULTS AND DISCUTION

Figures 1 to 4 reveal the relationship between the Q ratio and the exposure time (t) to wet atmosphere for 3 organically tanned leather samples and control sample (vegetable tanned leather), at 0.04 mg/l SO_2 in the atmosphere. The exposure times (τ) to the noxious atmosphere were: 2, 4, 6, 8, 10 and 12 hours.
The plots below show the water amount absorbed by the leather versus time, at an exposure of atmosphere with SO_2 level of 0.04 mg/l.

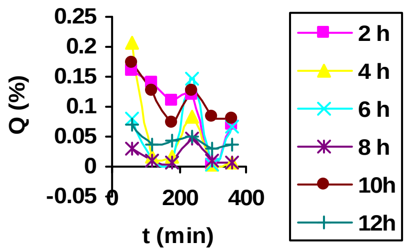

Figure 1. Leather 1

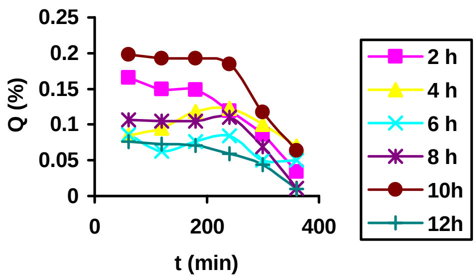

Figure 2. Leather 2

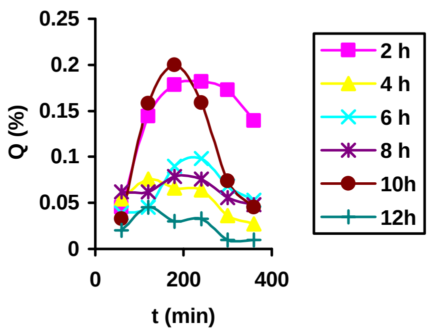

Figure 3. Leather 3

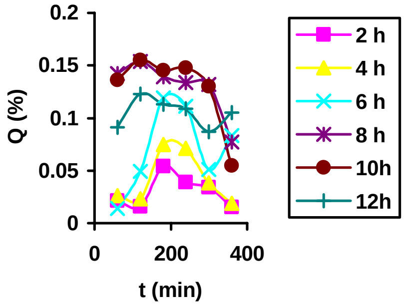

Figure 4. Control sample

Generally, the absorbed water weight (Q) has revealed high changes during the early 150-250 minutes of exposure to the wet atmosphere and SO_2 polluted atmosphere and decreased in time.

SO_2 polluted atmosphere has shown a lower action on the sample 1 and control sample, which has absorbed smaller water amounts (low Q values, less than 0.16 %), because of the tanning process and tanning agent Mimosa employed. The maximum absorbed water has been revealed at exposure times longer than 300 minutes for Leather 2 and 3.

Q ratio increased with the SO_2 exposure time.

Leather 1 had smaller water vaporous absorption.

New leather has been used in the restoration of a book from the Romanian Literature Museum, in Iassy. During the restoration works, sample Leather 1 has been used and was applied the following techniques:

a. Consolidation of deteriorated edges and corners;
b. Intarsia;
c. Consolidation of broken joints.

Presently, the restored work is kept under observation within the Restoration-Conservation Centre of Cultural Heritage in Iassy, and is periodically checked in order to observe the compatibility of the new leather with the original objects.

Figure 5. Bible of Blaj, 1795, Romanian Literature Museum, Iassy;
Aspects before and after restoration.

4. CONCLUSIONS

The decrease in Q value after a water vapor exposure of 300 minutes has revealed the swelling of collagen matrix by the hydrophilic functional groups until the water vapor absorption stops.

The conclusion is that Mimosa tannin and Aluminum used in leather manufacturing to be used in the restoration of historical leathers could provide a good leather fastness to the sulphurous gas polluted environments.

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THE BOND MECHANISM IN STONE OR BRICK TO GROUT INTERFACES

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ABSTRACT

The present work deals with the bond mechanism between in-situ masonry units and grouts. The mechanism of bond is investigated in composite substrate/grout specimens. The grout-to-substrate interfaces are characterized by means of mechanical tests in tension and shear.

1. INTRODUCTION

Grout mixes applied in historic masonries should simultaneously be: (a) physico-chemically compatible with the in situ materials and (b) efficient from the mechanical point of view. The use of hydrated lime and pozzolans in various proportions, with parallel reduction of the cement content of the mix, satisfies the requirement (a) and leads to more durable interventions. Even though the mechanical properties of the grout are reduced, mechanical tests on ungrouted and grouted three leaf stone masonry (summarized in [1]) have proven that the key parameter for the mechanical properties of grouted masonry is not the compressive strength of the grout. The efficiency of grouting depends on the bond properties of grout-to-in situ material interfaces [2]. This is qualitatively confirmed by the totality of available experimental results. However, the design of adequate grout mixes, as well as the prediction of the mechanical properties of a grouted masonry needs to be based on quantified data regarding the bond properties of interfaces. The present study focuses on the bond properties of ternary grouts with existing materials, as grouts of this type satisfy requirement (a), whereas available tests have proven that, when adequately designed, they may also satisfy requirement (b).

Bond between building materials is due to two mechanisms, namely chemical bond (due to chemical reactions between the materials in contact along an interface and mobilized under practically zero slip) and mechanical bond.

Mechanical bond depends on characteristics of the substratum, such as strength, surface porosity and pore size, roughness, aggregate water content and water absorption capacity, as well as on properties of the binding material, namely its strength, and thickness, as well as the applied normal stress at the interface. A very important characteristic of mechanical bond is that part of bond strength is mobilized even at high slip values.

2. EXPERIMENTAL STUDY

2.1.Materials-Testing program

For the investigation of the bond mechanism of the grout-to-substrate interfaces composite specimens were prepared, made of two aggregate pieces connected with a grout layer. Two types of limestone with different porosity and solid bricks were used (Table 1). Travertine is a material of very variable compressive and tensile strength affected by the percentage of pores and the presence of argillaceous discontinuities. Thus, pronounced scatter of experimental results is anticipated in case of travertine.

Table 1. Mechanical properties of stones and bricks

	Compressive strength (MPa)	**Tensile strength (MPa)**	**Apparent porosity (%)**
Dionysos marble [3],[4]	83/70(*)	8.7/-(*)	0.2
Travertine	12.1-95.5	4.0-21.5	16.8-2.9
Brick	12.2		21.4
(*) The two values refer to marble’s strength in the strong and weak direction			

Table 2. Mix proportions, compressive and flexural strength of grouts [MPa]

	G1		**G2**		**G4**	
	C=80%, L=20%		C=30%, L:MK=1:1		C=30%, L:LA=1:2.5	
days	**f_c**	**f_t**	**f_c**	**f_t**	**f_c**	**f_t**
7	13.3	3.7	5.1	1.3	1.0	0.6
28	14.6	3.4	9.9	2.0	3.3	1.7
90	17.9	4.5	13.6	1.0	7.6	1.9
230	-	-	17.9	3.3	7.3	1.7

The materials used for the grouts mixes were: hydrated lime (L), Portland cement CEM I42.5 (C), commercial pozzolan from Milos Island (LA) and commercial metakaolin (MK). The mix proportions of the grouts are given in Table 2. The water to solids ratio was between 0.8-1.1, in order to achieve penetrability to voids smaller than 0.3mm. To increase fluidity, superplasticizer was used. The grouts were prepared by using a mechanical mixer. The compressive and flexural strength of the grouts are given in Table 2. As expected, the cement grout develops its strength within the first weeks after casting, while the pozzolanic activity contributes to the strength of ternary grouts approximately

2-4 weeks after casting. Strength gain continues several months after production of ternary grouts. As for the obtained compressive strength, grout G2 reached in 230 days the same compressive strength as grout G1 in 90 days, thus proving the potential of ternary blends provided the lime to pozzolan ratio is optimized. As for the flexural strength of the ternary grouts, despite some fluctuations, it generally increased or remained constant with time.

Tension and shear tests at ages of 28, 60, 90 and 180 days were carried out. In case of shear tests, the effect of the normal compressive stress, σ, on the interface was also investigated. Three values of σ were considered, namely: 0.1, 0.3, and 0.6 MPa. A total of 111 and 135 composite specimens were tested in tension and shear respectively.

2.2. Experimental Setup

The fragment-test method was used to measure the tensile strength of the interfaces (Figure 1(a)), while the shear tests were performed using a shear box device (Figure 1(b)). Tests were displacement-controlled. Displacements were imposed at mid grout joint level, under constant normal stress. Horizontal displacement, lateral dilatancy and the corresponding resisting shear stress were automatically recorded.

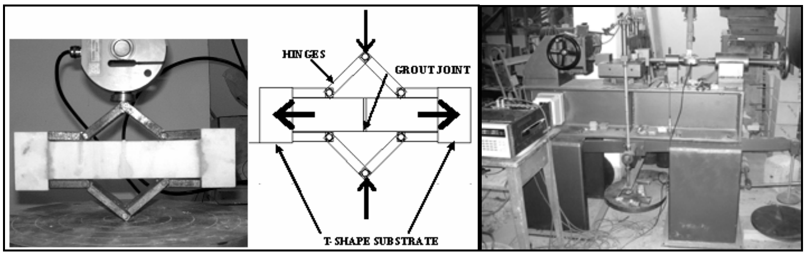

Figure 1.Experimental setup for (a) tension and (b) shear tests

TENSION TESTS: (a) ITZ, (b) Z, (c) G, (d) S SHEAR TESTS: (e) ITZ, (f) Z, (g) S

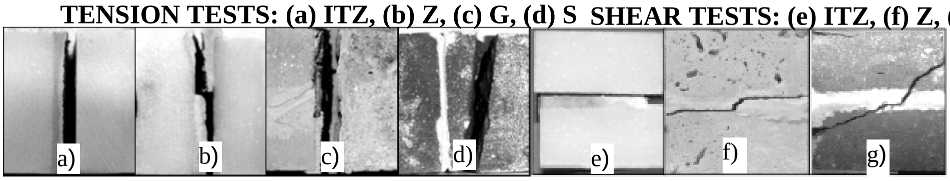

Figure 2. Failure modes

3.EXPERIMENTAL RESULTS AND DISCUSSION

3.1. Failure modes

Specimens subjected to tension exhibited the following failure modes (Figure 2):

i. Mode ITZ: The grout detaches from the substrate along one interface.

ii. Mode Z: Similar to (i). Practically half of the grout joint remains attached to the one substrate prism, whereas the other half remains attached to the second.

iii. Mode G: Failure within the grout (tensile failure of the grout).

iv. Mode S: Failure of the substrate.
Similarly, specimens subjected to shear exhibited one of the failure modes (i), (ii) or (iv), as described previously for tension tests (Figure 2).

3.2. Tension tests

Marble-to-grout interfaces: In Figure 3(a), bond strength of the interfaces between the three grouts and marble substrate are plotted against the age at testing. It is observed that the lowest tensile strengths were measured for the ternary grout G4, whereas the highest tensile strength values were reached in specimens with the metakaolin-based grout G2. As for the in-time development of interface strength, the following can be observed: (i) For grout G1, the tensile strength was more or less stabilized after the age of one month. The observed slight reduction of tensile strength (from 0.93MPa to 0.85MPa) between the 28^{th} and the 90^{th} day lies within the acceptable margins of scatter of experimental results, related to a very sensitive property like tensile strength. (ii) For grout G2, it is assumed (on the basis of XRD observations [5]) that the consumption of portandite crystals and the early formation (at 28^{th} day) of the C-S-H gel, provided the mechanical interlock between marble and grout and led to tensile bond strengths close to (or even larger than) those ensured by the reference grout G1, although both the compressive and the tensile strength of grout G2 are substantially smaller than those of the reference grout G1 (Table 2). On the other hand, after the age of 60 days, the tensile bond strength of G2 to marble interfaces exhibited a reduction. This reduction may be related to a similar reduction of the tensile strength of the grout G2 itself (Table 2). However, until more detailed study of this phenomenon is available, no interpretation of this drop in bond strength is attempted. (iii) For grout G4, a continuous increase of the tensile bond strength was recorded between the 28^{th} and the 180^{th} day (from 0.33MPa to 0.59MPa). This behaviour is attributed to the densification of the interface due to the pozzolanic reaction [6], which is slower with the coarser pozzolan from Milos Island. Due to the slowly developing pozzolanic reaction, grout G4 follows an ascending branch even after 180 days. The better behaviour exhibited by joints with grout G2 is also evidenced by the observed failure modes of the specimens: all specimens with grouts G1 and G4 failed along the interface. For grout G2, some specimens failed in Mode ITZ (27 %). However, Modes Z and G were also observed (in 46 % and 27 % of the cases respectively). The observed failure modes Z and G characterize improved interface properties possibly attributed to the fine metakaolin particles.
Travertine-to-grout interfaces: In Figure 3 (b), bond strength of travertine-to-grout interfaces is plotted against the age at testing for the three alternative grout mixes. One may observe the larger scatter of experimental strength values as compared to the results regarding marble. It is to be reminded that the porosity and the mechanical properties of the travertine itself are very scattered (Table 1). In general, the values of tensile bond strength for grout to travertine interfaces are by more than 50% higher than those obtained for marble interfaces. Since bond is partly due to mechanical interlock (see i.a. [7]), the improved performance of

travertine-to-grout interfaces may be explained by the higher porosity and surface absorption of the travertine substrate, which led to a better interlocking of the binders to the substrate, as well as to a reduction of the water at the interface. The higher values of the tensile bond strength could possibly be explained also by the reduced wall effect due to higher natural surface roughness of this travertine, as compared to marble. If the fact that grouts G1 and G4 develop their bond strength in different rate is disregarded, it is observed that their “final” bond strength is not substantially different, although the mechanical properties of grout G1 are significantly higher than those of grout G4 (Table 2). The similar behaviour of travertine to G1 or G4 interfaces seems to be confirmed by the fact that failure modes Z or ITZ are typically observed. Although grout G2 exhibits for all examined ages higher bond properties than grouts G1 and G4 (the main observed failure mode is of mode G), this difference is not as pronounced as in case of interfaces with marble. This suggests that the properties of the travertine are governing the behaviour of the interfaces.

Brick-to-grout interfaces: In all composite specimens with brick as a substrate, the failure occurred in the brick, irrespectively of the grout composition and the age of the specimen. The mean tensile strength obtained by the specimens was equal to 0.80MPa and can be taken as a measure of the tensile strength of the bricks and a minimum for the bond tensile strength of the interfaces (for the brick and for the grouts tested within this program).

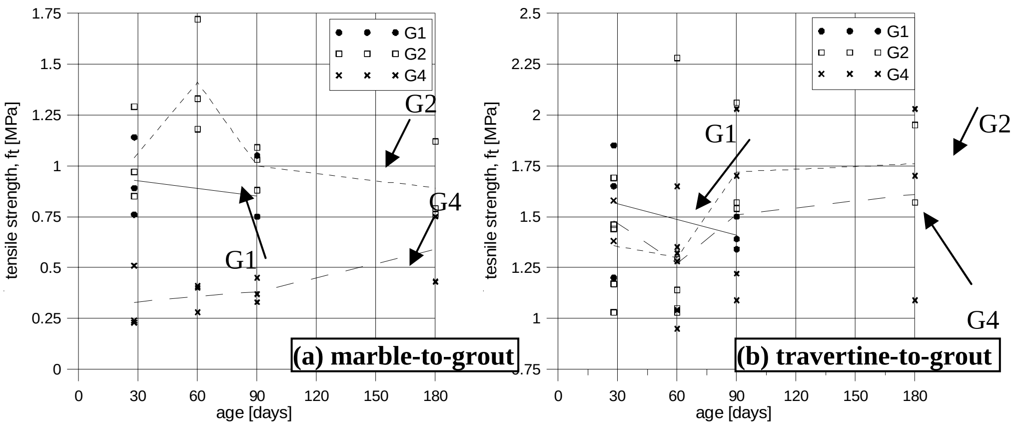

Figure 3. In-time development of bond tensile strength

3.3. Shear tests

Marble-to-grout interfaces: All specimens failed along the grout/substrate interface. Regarding the maximum shear stress mobilized along interfaces, the results (Table 3) seem to be in accordance with the results of tension. In fact, the maximum shear resistance of marble to G1 interfaces exhibits a slight increase (from 0.47MPa to 0.64MPa). On the contrary, marble to G2 interfaces that exhibited a mean value of the maximum shear resistance equal to 0.82MPa at the age of one month, are less resistant at the age of 90 days. In fact, the shear resistance of the interfaces is reduced by 30% approximately, following the similar in-time reduction of the tensile strength of grout G2. In case of grout G4, the maximum shear resistance of the interfaces is continuously increasing with time. It has to be noted, however, that although with increasing age, the maximum mobilized shear resistances seem to be quite similar for the three grout mixes, the behaviour of marble to G2 and G4 interfaces is considered to be better than marble to G1 interfaces taking into account the higher mechanical properties of the cement grout G1 (Table 2). Regarding the mean values of the residual shear strength at the age of three months, it is observed that for grouts G1 and G4, τ_{res} is approximately equal to 0.20 MPa, while it is somehow higher for grout G2 (equal to 0.30MPa). It is interesting to note that independently of the bonding material and the age at testing, the shear slip corresponding to the maximum shear resistance is approximately equal to 0.7mm.

<u>Travertine-to-grout interfaces:</u> The general behaviour of travertine to grout interfaces seems to be in accordance with test results of shear along cracks in concrete (see [8]). As shown in Table 3, the maximum mobilized shear resistance increases for increasing normal compressive stress on the interface, whereas the friction coefficient (expressed as the ratio between maximum shear resistance and applied normal stress) is decreasing with increasing normal compressive stress (Figure 4 (a)). Furthermore, the results obtained from shear tests seem to confirm the improved bonding properties of travertine-to-grout interfaces as compared with those between grout and marble: As shown in Table 3, the maximum shear resistances obtained for travertine are systematically higher than those recorded for marble. The improved bonding properties of ternary grouts G2 and G4 are also confirmed, since they ensure higher shear resistances although they are of lower mechanical properties than the reference grout G1. This is shown also in Figure 4 (b), where the values of friction coefficient are plotted against the applied normal stress normalized to the compressive strength of the respective grout. One may observe that, for the same σ/f_c ratio, grouts G2 and G4 ensure substantially higher friction coefficients μ_{max}. This is more so for the residual friction coefficient, μ_{res}. Regarding the in-time development of shear strength of interfaces, the general trend observed in case of tension tests is observed in case of shear tests as well. However, a substantial decrease of the grout G4/travertine maximum shear resistance was observed at the age of 180 days, attributed to the increase of the carbonation depth of the grout. The strong dependence of the behaviour of travertine-to-grout interfaces on the (quite variable) properties of the substrate is illustrated by the larger scatter of the measured maximum shear resistance (Table 3). This dependence becomes apparent when the failure mode of the specimens is examined: composite specimens with grout G1 failed in mode ITZ at early ages, while at the age of three months failed in mode Z. Specimens with grout G2 failed mainly in mode Z at higher values of the normal stress level and older ages. Finally, travertine to G4 interfaces failed mostly in mode ITZ.

<u>Brick-to-grout interfaces:</u> The specimens with joints filled either with G2 or with G4 fail due to shear failure of the substrate (at a shear stress approximately equal

to 0.85 MPa for σ=0.3 MPa). Thus, similar to the case of tension, one may say that the two grouts provide a shear resistance along the interface larger than 0.85 MPa. This is not the case for specimens where the reference grout G1 is used, whereas a mixed failure mode is observed (mainly an ITZ mode combined in some cases with partial failure of the substrate). In this case, the mean value of the measured shear resistance of the interface is approx. equal to 0.90 MPa (at σ=0.3 MPa). Thus, it is legitimate to assume that, in this case too, the bond ensured by the ternary grouts is higher than that of the cement grout.

Table 3. Summary of shear test results (mean values of two or three specimens)

days	Substrate type	Ref. No of grout	τ_u (MPa) σ=0.1	σ=0.3	σ=0.6	μ_{max} σ=0.1	σ=0.3	σ=0.6
28	marble	G1		0.47			1.57	
		G2		0.82			2.73	
		G4		0.26			0.87	
	travertine	G1	(*)	1.00	1.14	(*)	3.33	1.90
		G2	1.05	1.10	1.12	10.50	3.67	1.87
		G4	0.66	0.45	0.80	6.60	1.50	1.33
60	travertine	G2		1.37			4.56	
		G4		0.64			2.13	
90	marble	G1		0.61			2.03	
		G2		0.54			1.80	
		G4		0.50			1.67	
	travertine	G1	0.61	0.70	0.88	6.10	2.33	1.47
		G2	0.99	0.93	1.14	9.90	3.10	1.90
		G4	1.02	0.95	1.14	10.20	3.20	1.90
180	travertine	G2		0.86			2.87	
		G4		0.65			2.17	
(*) unreliable test results, σ in (MPa)								

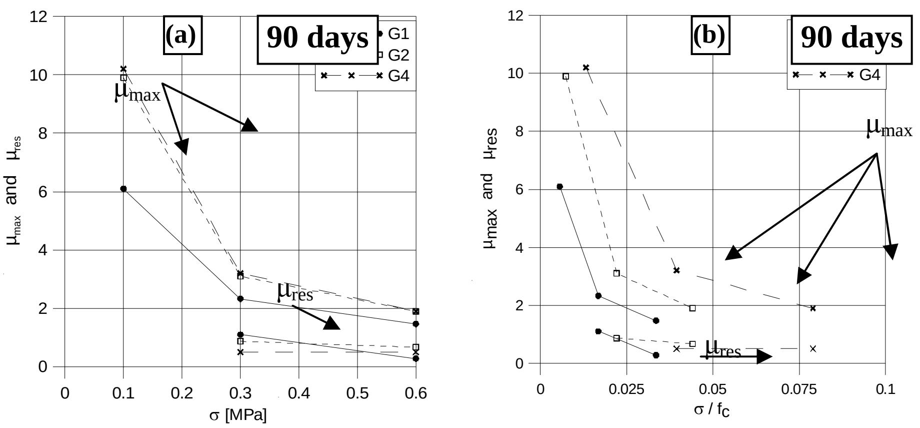

Figure 4. Friction coefficient along travertine-to-grout interfaces: The effect of the a) normal stress, b) normal stress normalized to grout compressive strength

4.CONCLUSIONS

1.) The bonding properties of ternary grouts with reduced cement content (30%-wt) were proven to be satisfactory both in tension and in shear. The bond strength exhibited by ternary grouts to substrate interfaces were equal or higher than the bond strength reached by cement grout to substrate interfaces.
2.) Tests have proven the dependence of the bond properties of the interfaces on the characteristics of the substrate, mainly porosity.
3.) Brick-to-grout interfaces examined within this program were in general stronger than the substrate itself.
4.) Interfaces subjected to shear have exhibited similar behaviour with interfaces within concrete. The beneficial effect of normal compressive stress on the interface was confirmed.

ACKNOWLEDGEMENTS

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FLUIDITY OF HYDRAULIC GROUTS FOR MASONRY – STRENGTHENING

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ABSTRACT

Design of hydraulic grouts for strengthening of masonry historical buildings seems to follow a rather empirical procedure, with all the related uncertainties, both in economical and efficiency terms. This paper is part of a broader attempt to establish a rational methodology for the design of such grouts, based on their discrete injectability characteristics, i.e. (i) Penetrability, (ii) Fluidity and (iii) Stability. The first part of this holistic methodology was published elsewhere [1]. The second part regarding the fluidity of the grouts is the subject of this paper. A new practical fluidity measurement is proposed (the Adjusted Cone Test, ACT); and a "fluidity factor" is defined. It is proved that the follow-up of this factor as a function of the water-to-solids ratio may reveal fundamental characteristics of the grout-composition under design. The influence of the mixing method, and superplasticizer on grout's fluidity are also examined. The paper concludes with a case study to highlight the practical use of the proposed test.

1. INTRODUCTION

The significance of the concept of fluidity becomes apparent through the basic rheological equation under quasi-laminar flow conditions:

$$V = \alpha \cdot \left(\frac{\Delta p}{l} \right)^{\beta} \cdot d_{ch}^{\ \gamma} \cdot \eta^{-\delta} \qquad (1)$$

Where V expresses the velocity of flow, Δp the pressure loss along a length "l", l the total length of the grouted "channel", d_{ch} the equivalent diameter of the “channel” (the void), η the viscosity of the grout and $\alpha,\beta,\gamma,\delta$ constants, depending on the roughness of the walls and the form of the cross section of the channel, as well as on the rheological properties of the grout.

Normally, a maximum grouting pressure ($p_{\max} = \Delta p$) is imposed, depending on the tensile strength of the grouted body; on the other hand, the length “*l*” of flow from each nozzle may be estimated, roughly though. Thus, for a given equivalent diameter “*d*” of the grouted voids, and a practically expected grout discharge, an order of magnitude of required viscosity of the grout could be estimated.

The concept of fluidity, however, cannot be unequivocally expressed by just one parameter such as the viscosity of the grout. Moreover, the constants of Equ.1 can hardly be known – even under well defined industrial conditions. That is why some more practical estimators of fluidity are frequently used, such as the “flow time” through the Marsh cone (ASTM C939-87 or NF P 18-358).

2. THE ADJUSTED CONE TEST

In what follows, an adjusted cone test (ACT) is proposed in order to increase its physical significance. A 2mm nozzle-diameter is used, filled with the normal quantity of grout, equal to 1000cm^3; the flow time t_f is measured for a flow of only $Q = 100\text{cm}^3$ of grout to pass through: Thus, the fluid pressure acting on the nozzle is practically kept constant during this rapid test, and the influence of the roughness of walls is minimised. The advantage of choosing a small grout-volume for reference-flow-time measurements was already indicated by Agullò et al. [2]. The concept of a “fluidity factor” f_l is introduced (Figure 1):

$$f_l = \frac{Q}{A \cdot t_f}$$

where “*A*” denotes the area of the cross section of the nozzle

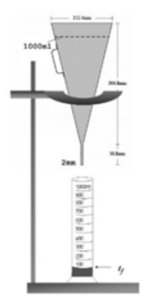


Figure 1: Marsh cone test and equation for calculating fluidity factor values

Thus, “more fluid” grouts are characterized by higher f_l - values (higher “velocities” of flow). Furthermore, for each grout mix, it is strongly suggested to study a broader spectrum of water-to-solids ratio (W/S), in order to counterbalance scattering of measurements, and collect additional rheological information on the grout mix under consideration. Thus, in Figure 2, the following important characteristics may be identified, based on a rough bilinearisation of the experimental findings:

- $(W/S)_o$, the “theoretically” minimum possible water-to-solids ratio.

- $(W/S)_u$, an ultimate value of water-to-solids ratio, which practically results in the maximum possible fluidity factor (for this particular solid phase).
- max f_l, that maximum possible value of the fluidity factor.
- C.I.=$[(W/S)_u - (W/S)_o]$:max f_l, a cohesiveness index, which may be very useful in stability aspects (bleeding, segregation or washout effects).

Figure 3 and Table 1 show the results of the application of the ACT method in the case of grout compositions of a Portland cement (C) with Blaine Specific surface S_A=4,100cm^2/gr, satisfying the penetrability grading rules [1] for a W_{nom} corresponding to the 0.63-1.25mm sand column, plus Santorini Earth (SE), with max d<20μm.

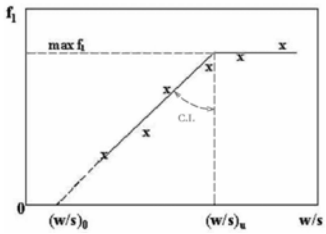


Figure 2: Rheological characteristics of grouts with given composition of solids and various W/S, assessed by means of the ACT method.

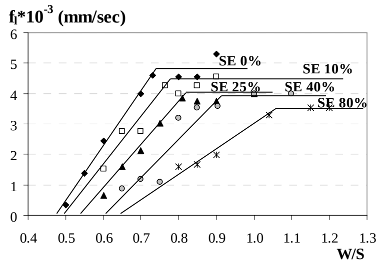


Figure 3: Fluidity factor measurements (ACT method) for several cement-and-Santorini Earth compositions (SP% = 0).

Table 1: Rheological characteristics of cement C and Santorini earth composition (SP%=0), measured by means of the ACT method, and compared to limit W/S-values observed in the sand-column test and in stability tests.

SE %	Fluidity test (ACT)		Penetration in the sand column	max f_l (10^3mm/sec)	C.I. (Fig.2)	Bleeding	Initiation of Segregation
	$(W/S)_o$	$(W/S)_u$	$(W/S)_{sand\ col.}$			$(W/S)_{0-Bl}$	$(W/S)_{segr}$
0	0.47	0.72	0.70	4.6	54	0.55	1.48
10	0.50	0.77	0.75	4.3	62	0.65	1.56
25	0.53	0.82	0.75	3.8	76	0.72	1.67
40	0.58	0.88	0.80	3.6	83	0.80	1.78
80	0.63	1.04	1.10	3.3	124	0.84	2.08

As expected, all rheological characteristics are almost linear functions of the SE-percentage. On Table 1 are also reported the values $(W/S)_{sand\ col}$ for which the grout penetrates easily in the sand column, and the values $(W/S)_{0-Bl}$ and $(W/S)_{segr}$ for which the grout starts to exhibit bleeding and segregation respectively. It is interesting to observe that water-to-solids ratios $(W/S)_u$ leading to the maximum possible fluidity index are somehow comparable to those enabling the grout to penetrate in the sand-column test. This may be considered as another indication of the practical usefulness of the proposed ACT-method.

A similar limit (W/S)-value ("saturation point") was indicated by Khayat & Yahia [3]. Agullò et al. [2] as well have defined the maximum dosage of superplasticizer (SP) in cement pastes, in terms of the saturation point beyond which there is no significant decrease in flow time using the Marsh cone test. The importance of a separate assessment of the cohesion of the grout was reiterated by Lombardi [4], who has also proposed a practical method (the "plate cohesion meter") for the measurement of cohesion. In this connection, the Cohesiveness Index (C.I.) measured by means of the ACT-method (Figure 2) seems to be directly proportional to the critical water-to-solid ratio $(W/S)_{segr}$, initiating segregation. In fact, for the examined grouts we may roughly write:

$$\text{C.I.} \sim 45 \cdot \left(\frac{W}{S}\right)_{segr} \qquad (\pm 20\%) \qquad (2)$$

It is worth to note that the same physically meaningful characteristics of a given mix regarding its fluidity, penetrability and stability can also be recognized and assessed by means of other well established rheological test methods, such as e.g. the coaxial viscosimeter [5]. Figures 4 and 5 indicate that in fact there is a physically significant concept of a critical $(W/S)_u$-ratio, corresponding to a practical upper limit of fluidity, i.e. corresponding to the lowest possible limit of yield stress τ_0 and to the lowest possible limit of viscosity η, in a similar way as it was suggested by the proposed ACT method (Figures 2 and 3). This observation reconfirms the practical importance of the ACT-method.

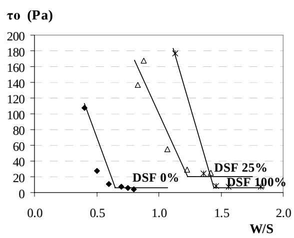


Figure 4: Evolution of yield stress τ_0 as a function of the water content of grouts composed by cement and densified silica fume (DSF) (SP%=0).

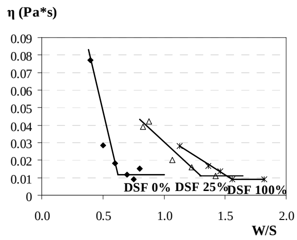
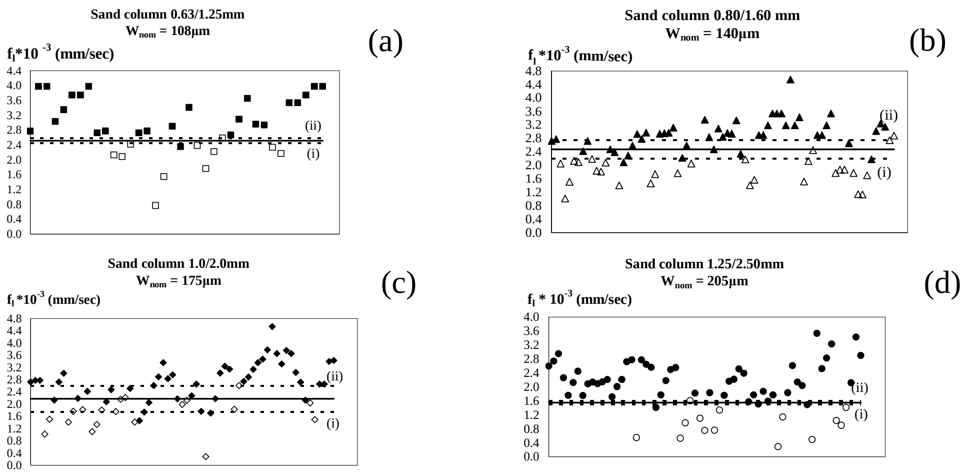


Figure 5: Evolution of plastic viscosity η as a function of the water content of grouts composed by cement and densified silica fume (DSF) (SP%=0).

3. ACCEPTABLE LOWER FLUIDITY FACTOR VALUES

Figures 6 shows the values of the fluidity factor for injectable and non injectable grouts that have been tested both using the ACT method and the sand column test. The compositions of the grouts were selected so that to satisfy the penetrability grading criteria [1] for four different values of W_{nom}: 108μm, 140μm, 175μm and 205μm. A large variety of grout compositions was examined. The solid phase of the grouts consisted either of plain cement/hydraulic lime or of various combinations of cement/hydraulic limes with lime or/and pozzolans. The grouts have been classified in two categories: those that are injectable into the sand columns without difficulties, and those that are not injectable at all. The f_l – threshold is defined as the average of (i) a 5%-fractile level of “injectable” (sand column test) and of (ii) a 5%-fractile level of “non injectable” grouts. From these experimental results, an indicative lower value of the fluidity factor can be derived for each W_{nom}, as presented in Figure 7.



Figures 6: There is a lower fluidity-index-value approximately equal to (a) 2.50 $\cdot 10^3$ mm/s, (b) 2.45 $\cdot 10^3$ mm/s, (c) 2.20 $\cdot 10^3$ mm/s and (d) 1.58 $\cdot 10^3$ mm/s for grout mixes to be injectable through a sand column with nominal value of crack widths equal to (a) 108μm, (b) 140μm, (c) 175μm and (d) 205μm.

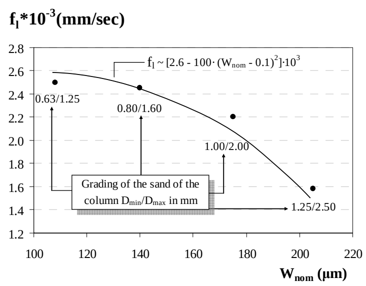


Figure 7: Lower fluidity factor values, for grouts to be injectable through sand - columns of several nominal values of crack widths, W_{nom}.

4. INFLUENCE OF MIXING METHODS AND SUPERPLASTICIZERS

As it is well known, the fluidity of a hydraulic grout may be drastically affected by the mixing procedure. Several mechanical means such as high turbulence (HT) or ultrasound dispersion (US) may “break” the flocs, and establish a considerably better fluidity of the grout [5]. A comparative presentation of US and HT mixing is shown in Figure 8. Both mixing methods were applied on lime/pozzolan/cement (25/45/30) grouts, for various values of water to solids ratio. Apparently, when US mixing was applied, higher values of the fluidity factor were achieved. Nevertheless, there are indications (see Figure 9) that in the case of grouts consisting of hydraulic lime and pozzolan, US mixing does not always give better fluidity of the grout, as compared to HT mixing.

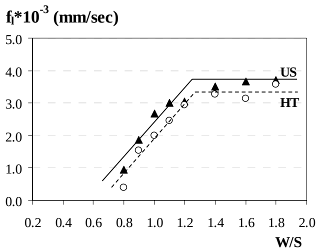


Figure 8: Comparison between US and HT mixing: f_l values of lime /pozzolan/cement (25/45/30) grouts.

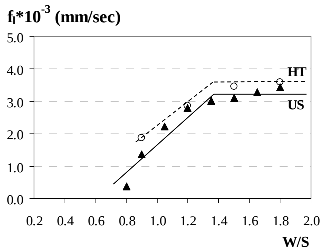


Figure 9: Comparison between US and HT mixing: f_l values of hydraulic lime/ pozzolan (90/10) grouts.

The use of appropriate superplasticizers, resulting in electrostatic repulsive forces and consequently in the dispersion of solid particles, is beneficial for the fluidity of hydraulic grouts. This is also confirmed from the results presented in Figure 10 under the same conditions as those in Figure 8. An increase of fluidity is observed, independently of the mixing method (see mean curves in Figure 11).

(SP% = 1)

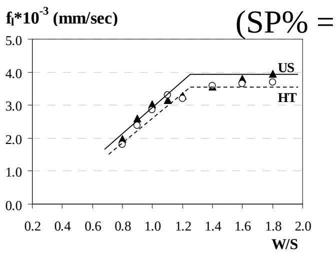


Figure 10: F_l values of lime/ pozzolan/cement (25/45/30) grouts.

(SP% = 0 and 1)

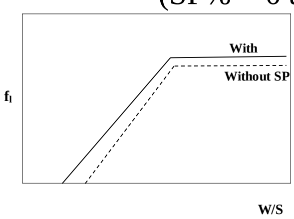


Figure 11: Mean f_l values of lime/pozzolan/cement (25/45/30) grouts.

The study of the several issues of the use of such superplasticizers in grout mix design is beyond the scope of this paper.

5. CASE STUDY OF PRACTICAL USE OF FLUIDITY FACTOR

The eastern and western ranges of cells of the internal yard of Dafni Monastery (World Heritage List of UNESCO) were heavily damaged and injection grouting was implemented for the consolidation of masonry walls. The design of high injectability grouts was performed as presented in [7]. On this basis, after a series of laboratory tests on several mixes, a ternary grout (white cement, lime, pozzolan) was selected, and applied in situ. Fluidity factor measurements were realized, both during the design and the in situ application.

The mix proportions of some of the grout compositions tested, along with penetrability, fluidity and stability characteristics, are summarized in Table 2, for various W/S ratios. The standardized sand column test method (NF P18-891) was applied to check the penetrability and fluidity, along with the standard test for stability (NF P18-359). Flow time was measured using a Marsh cone with a 4.7mm nozzle-diameter (NF P18-358). The fluidity factor was as well estimated by Adjust Cone Test. The following criteria were set for the acceptance of grouts: A time limit of 50 sec for the sand column penetrability test (T_{36}>50sec); a flow time of 500ml of grout less than 45 sec for Marsh cone d=4.7mm ($t_{d=4.7mm}$< 45sec) and a fluidity factor $f_l \geq 1.50 \cdot 10^3$mm/s (corresponding to W_{nom}~205μm); maximum acceptable limit of 5% for the bleeding test [5]. The grout composition $I_{72.5}$ was selected, since it fulfilled simultaneously all the injectability criteria set, and had in the same time the lowest water content (72.5%), which plays a role for strength and durability characteristics.

Table 2: Tested grout compositions – injectability characteristics.

Grout composition weight %	I_{67}	I_{70}	$I_{72.5}$	I_{75}	$II_{72.5}$
White cement	30	30	30	30	30
Lime powder	25	25	25	25	20
Pozzolan	45	45	45	45	50
Superplastisizer	1	1	1	1	1
Water /Solids	0.67	0.70	0.725	0.75	0. 725
Injectability characteristics criteria					
Flow time $t_{d=4.7mm}$ < 45 sec	50	29	25	24	27
Fluidity factor f_l*10^{-3} >1.5 (mm/sec)	0.82	1.29	1.73	2.12	1.33
Sand column T_{36} <50 (sec)	∞	∞	43	26	94
Bleeding <5 (%)	1.5	2.5	3.0	3.5	5.0

Table 2 shows that, although the grouts I_{70}, $I_{72.5}$, I_{75} and $II_{72.5}$ have a different W/S, their flow time is practically the same and fulfil the criterion set (<45 sec). However, only the grouts $I_{72.5}$, and I_{75} are injectable according to the sand column test. On the other hand, the fluidity factor of the above mentioned grouts is not the same and only that of two injectable grouts ($I_{72.5}$ and I_{75}) fulfil the criterion set: $f_l \geq [2.6\text{-}100 \cdot (W_{nom} - 0.1)^2] \cdot 10^3$mm/s ($W_{nom}$ in mm).

This observation highlights the practical importance of the ACT-method, as it can be used, along with stability tests (bleeding and apparent density), not only in the Laboratory but also in the worksite, where the use of sand column tests is not possible. In Table 3 the injectability characteristics measured in situ are presented. In all cases the grout characteristics satisfied the injectabilty design criteria. The observed dispersion in measured values was expected, due to variations of weather and worksite conditions. The grout strength measured on specimens taken in situ, was as well satisfactory, as reported in [7].

Table 3: Injectability characteristics of $I_{72.5}$ grout measured during the project.

Grout $I_{72.5}$	Cement%	Lime%	Pozzolan%	SP%	W/S
	30	25	45	1	0.725
In situ control	1st	2nd	3rd	4th	5th
$t_{d=4.7mm}$ (sec)	23	22	25	23	27
f_l*10^{-3} (mm/sec)	1.90	2.20	1.69	2.27	1.50
Bleeding (%)	3.0	3.5	1.5	3.2	3.1
Bulk density (g/cm^3)	1.44	1.40	1.47	1.41	1.43

6. CONCLUSIONS

In conclusion, fluidity factor measurements seem to be a basic aid in designing grout mixes regarding their minimum and threshold W/S ratios, as well as their necessary cohesiveness against segregation. The ACT-method has a practical importance, as it can be used, along with stability tests (bleeding and apparent density), not only in the Laboratory but also in the worksite, where the use of sand column tests is not possible.

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RESISTANCE OF REPAIR MORTARS OF HISTORIC STRUCTURES TO WETTING-DRYING SALT CYCLES

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ABSTRACT

It is widely accepted that compatibility and durability are the basic requirements for the new repair mortars used for re-pointing the joints of historic masonries as well as for reconstruction of their parts. The present paper focuses on the durability of those new traditional repair mortars to salt cycles. Firstly, a survey is made on the presence of salts that are often found in old mortars concerning the type, the concentration, the crystal form and their distribution in mortar mass. Then, new repair mortars were produced and submitted to salt cycles according to EN 12370:1999. Both air-hardened and hydraulic character mortars were tested and their behaviour was monitoring up to the end of the experiments. Based on the results it seems that mortars present different decay pattern according to the binder system and the porosity structure. An effort is made to explain this different behaviour of each category of repair mortars.

1. INTRODUCTION

The durability of old mortars despite the salt presence into their structure was the subject of many surveys [1] [2] [3] concluding that the salt crystals are formed into pores and openings provoking different decay patterns. Salts may derive from different sources and their presence is closely related to the mortar's characteristics such as the binder system, the porosity and the pore size distribution. The salt presence in old structural mortars results in the softening of the binder matrix while scaling and efflorescence phenomena may also concur [4]. Combined microscopic examination and liquid chromatography analysis of old mortar samples are used for defining the type and content of salts present in the structure as well as the position into which the salts are crystallized and the size of salt crystals. The above mentioned methods were used in order to record the content of ions of chlorites, sulphates and nitrates in over 500 mortar samples of monuments of different historic periods. Evaluating the results confirms that the presence of salts in historic structures is a multi-dimensional phenomenon. From the evaluation of the data it seems that old mortars based on lime and also containing materials with pozzolanic properties into the binding system were characterized by open porosity that ranges between18-38% (Table1). These mortars are rich in sulphates while their content in chlorines is related to their distance from the sea. Nitrates can also be present in special cases according to the usage of the building.

As it is mentioned in the literature the mortar components, the humidity, the neighbouring materials, the distance of the structure from a salt recourse and the location of the mortar sample in relation to the structure seem to play a decisive role to the salt presence[5] [6]. As the presence of salts is closely related to humidity or water movement into the structure, the porosity and the porosity properties such as the pore size distribution and the interconnectivity of the pores are also important factors that determine the location and the formation of salt crystals [7].

Table 1.Anions %b.w. and characteristics of old mortars

Monument	Cl^-	NO^-_3	SO^{2-}_4	Open porosity %	L=lime P=pozolana B-brick dust C=clay
Roman Forum (2nd century A.D)					
Position1 (Near the ground)	0.16	0.57	1.32	14.75	L+P
Position2 (1.5m from the ground)	0.036	0.15	0.48	17.0	L+P
Panagia Acheropiitos (6th centuryA.D)					
Position1 (south wall)	0.27	0.76	0.07	17.9	L+P+B
Position2 (north wall)	0.13	0.1	0.01	19.5	L+P+C
Hagia Aikaterini (14th centuryA.D)					
Position1 (north wall)	0.01	0.014	0.057	23.7	L+C
Position2 (south wall)	0.53	1.02	1.44	18.9	L+P+C
Rhodes – Fortress Hagios Nikolaos (14th century A.D)					
Plaster 1.9m	1.24	0.05	1.26	20.4	L+P
Render 1.2m	0.22	0.07	0.17	39.81	L+P
Hagios Panteleimonas (15th century)					
Position1 (healthy)	0.05	0.017	0.28	18.6	L+P
Position2 (cracks)	0.212	0.75	0.80	20.0	L+P

Studying salts microscopically it is obvious that the salt crystals are larger than the micro crystals of the binder matrix (figure1) as well as the favoured places that salts crystallize are pores and openings into the structure of an old mortar (figure2). As it is seen from table1 lime-based old mortars rarely contain salts more than 2.5-3%b.w. and if that happens it should be under special circumstances (near the sea, ground rich in sulfates).

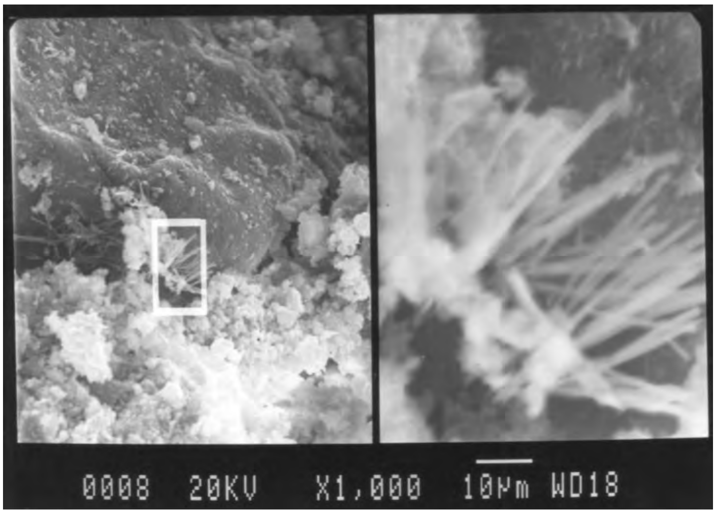

Figure 1. Crystals of gypsum into the binder-aggregate contact zone

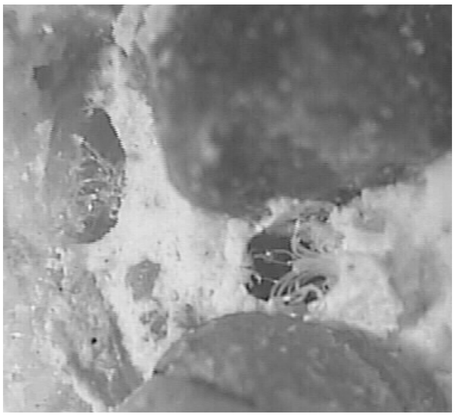

Figure 2. Crystals of salts into the pores of an old mortar (Stereoscope x25).

Taking into account the longevity of old structural mortars it seems that into the mortar structure, salts can be present as minor components and they have reached a kind of equilibrium with the environment and the material itself. Proceeding to the performance of repair mortars is a high cost, detailed and accurate task. In order to apply a compatible mortar many criteria should be taken into account in order to gain compatibility such as mechanical, physical, microstructural characteristics of the authentic mortar, the surrounding materials and the environment under which the new mortar will act [8]. As the presence of salts in the repair mortars seems unavoidable the durability of the new repair mortars should be proven. The behaviour of repair mortars to salt exposure should be predictable. The present paper is a contribution to this effort.

2. EXPERIMENTAL STUDY

Different types of repair mortars were produced and cured according to EN459-2. At the age of 6 months they were subjected to salt cycles according to EN 12370:1999. Three different solutions in salt concentrations were prepared: 1%, 3% and 5%b.w. NaCl and another three of the same concentration in Na_2SO_4. Two types of mortars were tested. Pure lime mortars (L) and lime+ pozolana 1:1 proportion (L+P). River sand 0-4mm, free of salts was used in 1:3 binder: aggregate proportion. The characteristics of the raw materials used are shown in Table2. The workability of all mortars was stable (15±1cm) measured by a flow table. The mechanical and physical characteristics of the mortars before the test performance were recorded in Table3.

Table 2. Physical characteristics of raw materials used for the repair mortars

	Specific gravity gr/ml	Pozzol. index MPa	Lime content Ca(OH)2	Soluble salts (%b. w.)		
				Cl^-	NO_3^-	SO_4^{2-}
Lime	2.17	-	75%	0.020	0.040	0.100
Pozzolan	2.22	4.9	-	0.070	0.000	0.030
Sand(0-4mm)	2.65	-	-	0.0006	0.0005	0.002

Table 3. Mechanical and physical characteristics of repair mortars at 6-month age

	Compressive strength MPa	Flexural strength MPa	Open porosity %	Specific gravity
L	1.95	0.52	20.50	1.767
L+P	4.65	1.70	18.85	1.690

The microstructure analysis of the untreated samples showed a loose structure for the lime mortar. Many spherical pores of mean diameter 500μm and open cracks (mean width 20μm) were present. In the case of pozolanic mortars, small pores of mean diameter 300μm were present into the binder and the binder matrix was dense. The difference is due to the crystals that were formed in both cases. As explained in literature in the case of pure lime mortars calcitic plate-like crystals are formed having a loose contact with each other (figure3).

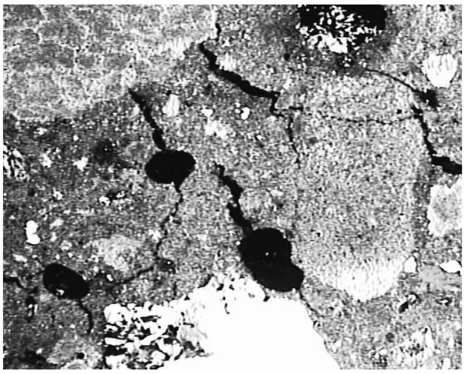

Figure 3. Structure of an old lime mortar (Polarized microscope x65)

On the contrary, in the case of pozolanic mortars a combination of needle-like and plate like crystals is existing in the matrix and a strong cohesion between them is achieved (figure4) [9].

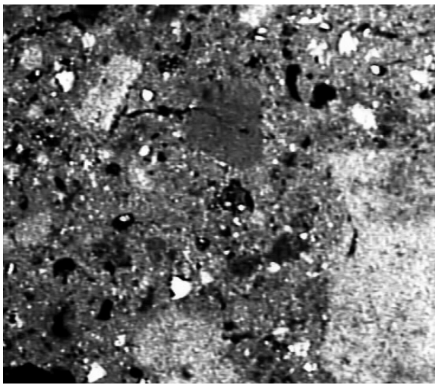

Figure 4. Structure of an old pozolanic mortar (Polarized microscope x65)

Three specimens 4x4x8cm from each mortar type were tested in each case. During each salt cycle, the dry weight of the samples was measured and a photographic documentation was performed. The experiments were ended when the samples collapsed. Diagrams were produced showing the durability of each sample while the type and extent of damage was recorded (figures 5, 6, 7).

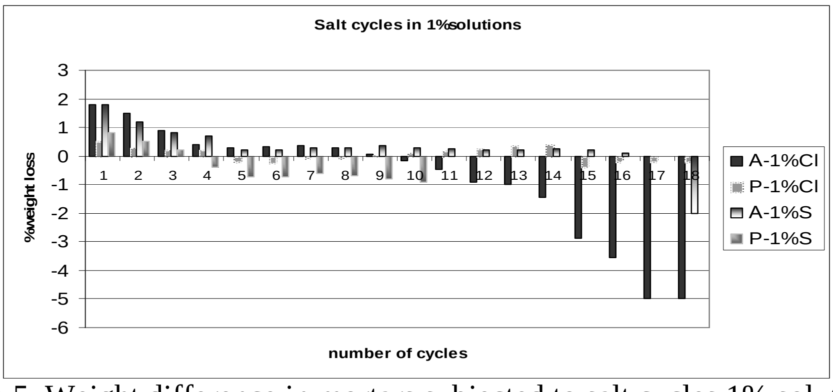

Figure 5. Weight difference in mortars subjected to salt cycles 1% solutions

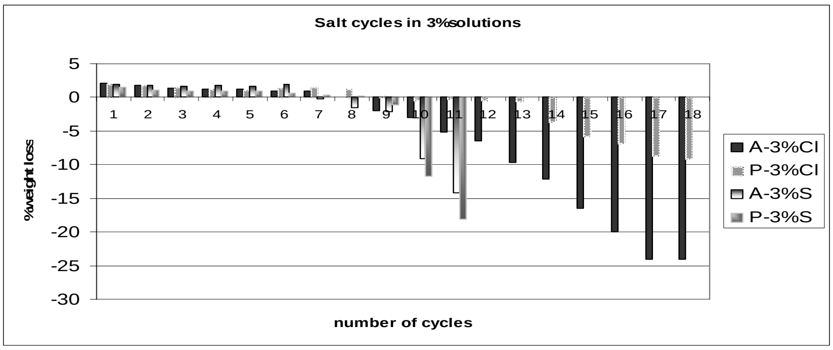

Figure 6. Weight difference in mortars subjected to salt cycles 3% solutions

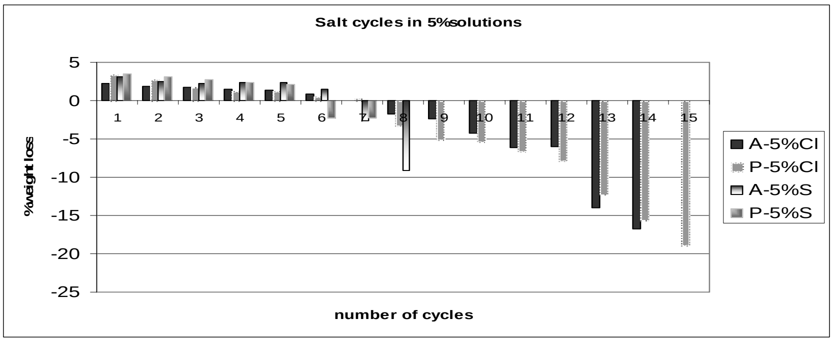

Figure 7. Weight difference in mortars subjected to salt cycles 5% solutions

3. DISCUSSION

According to the results, all mortars increase their eight during the first cycles. Lime mortars subjected to 1%NaCl presented adequate resistance as they presented mass stability up to the 10^{th} cycle and after the 10^{th} cycle gradually there was a material loss (figure5). Scaling phenomena were observed after that period (figure8) and up to the 17^{th} cycle where the material loss was intense (figure 9). The behaviour of lime mortars was almost the same when exposed to 3% and 5% NaCl but in the latter cases the sample decomposed earlier (starting from the 8^{th} cycle) (figure7).

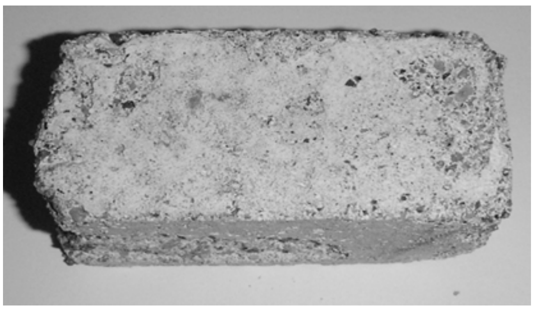

Figure 8. Lime mortar after 10cycles in NaCl solution

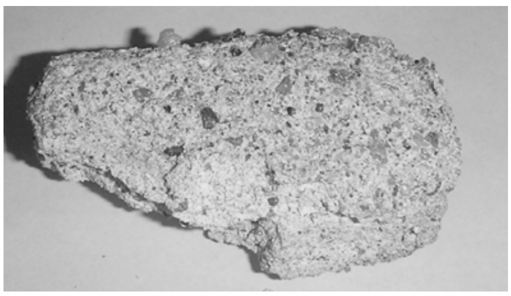

Figure 9.Lime mortar after the 18^{th} cycle in NaCl solution

When lime mortars were subjected to sulfate solutions material loss was also presented but it started from the 15th cycle. As expected, the durability was conversely proportional to the salt content as in solutions containing 3% Na_2SO_4 lime mortars were starting loosing material from the 8th cycle (figure6) while in solutions containing 5% Na_2SO_4 the specimens started loosing material from the 7th cycle (figure7). Pozolanic mortars subjected to chlorine solution resisted up to the 14th cycle in case of 1% solution but they were destroyed on the 8th cycle in case of 3% and 5%NaCl (figures 6, 7). The decay pattern in this case began with material loss from the surface (figure10) of the samples but progressively cracks occurred (figure11). In the case of pozolanic mortars subjected to cycles of Na_2SO_4 solution, they presented cracks from the 7th cycle despite the concentration of the solution.

Performing XRD analysis on the mortar samples at the end of the experiments, in the case of lime mortars subjected to NaCl revealed the presence of calcite, portlandite and halite while those mortars subjected to sulfates the presence of glauberite, gypsum and thermonatrite was recorded.

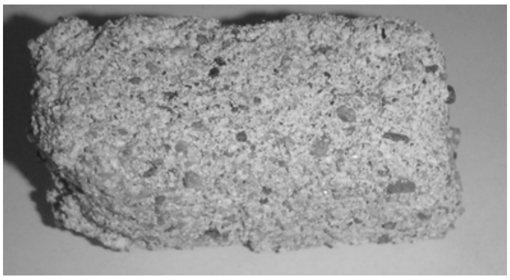

Figure 10. Pozolanic mortar after 5 cycles in NaCl solution

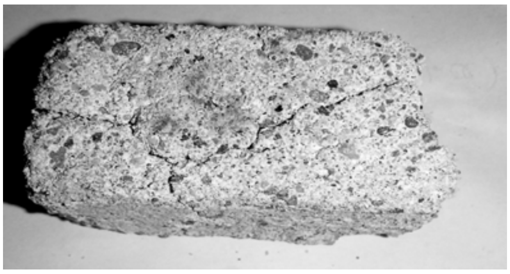

Figure 11. Pozolanic mortar after the 10th cycle in NaCl solution

Similarly, in the case of pozolanic samples subjected to NaCl solutions, halite and hydrohalite were formed while those mortars treated with Na_2SO_4 thenardite, glauberite and anhydrite were found.

4.CONCLUSIONS

Salt cycles are a rather aggressive procedure that decomposes the mortar structure and provoke considerable material loss, create cracks and finally destroys the material's cohesion. Repair mortars are expected to behave differently according to their binding system when subjected to salt solutions. Different decay forms are generated in case of hydrated and hydraulic type mortars as the adhesion of the crystal lattice is different. In the porous structure of a lime mortar exfoliation and material loss is expected after exposition to salt cycles while in the denser structure of a pozolanic mortar cracks are generated and they can provoke a severe damage. Studying the structure of the repair mortars designed for intervention works, information about their behaviour in salt decay can be drowning. In this particular case lime based mortars present a considerable resistance to sulphate solutions while their resistance to chlorine solutions is can be considered significant.

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THE INFLUENCE OF MIXTURE DESIGN PARAMETERS ON THE LONG TERM STRENGTH OF LIME-BASED MORTARS

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ABSTRACT

Lime-based mortars are widely used for re-pointing or for other interventions necessary for the maintenance and consolidation of historic masonries. Their design is based on using traditional binders such as lime, pozolana, brick dust and natural aggregates of different gradation since coarse aggregates were often used for the construction of thick joined masonry.
In the paper the long term mechanical characteristics of an adequate number of repair mortars manufactured with different binding system and binder/aggregate ratio are given. Flexural and compressive strength (according to EN-771) as well as open porosity (according to RILEM CPC 11.3, absorption of water under vacuum) were measured at the age of 3 months, 1, 2 and 5 years. Relationships between ultimate strength development and parameters such as binder type, binder/aggregate ratio are plotted to help the estimation of the influence of each of these parameters on the final quality of the repair mortars.

1. INTRODUCTION

To produce a repair mortar, criteria concerning the selection of the raw materials and the proportions of them in the mortar mixture must be pre-defined. In order to decide upon these parameters an analysis of the authentic old materials with which the new repair mortar will co-operate should be performed [1] [2]. From the analysis, data concerning the type of the binders used for the production of the old mortar, the physical and mechanical properties, the binder/aggregate ratio and the type and granulometry of the aggregates used, are compiled and evaluated properly. Some indicative values concerning characteristics of old mortars coming from different historical periods are given in Table1. Then the proportioning of the new mortar mixture is designed (figure1).

Table1.Characteritics of old mortars

Historic periods	Comp. strength (MPa)	Porosity %	Specific gravity
Roman	2.50-5.50	20.0-25.0	1.65-1.70
Byzantine	2.8-6.5	17.5-22.0	1.68-1.72
Ottoman	1.36-2.50	18.0-27.5	1.50-1.65

Figure1. Reconstruction of an old structure of the Roman period

The new mortar should be compatible to the old one in terms of texture, colour, porosity, strength and thermal dilation [3] [4] [5].At the same time its longevity in time is desirable. That is why it is of great interest to see how the properties of the repair mortars are changed with time.

In order to produce a suitable repair mortar many parameters can be taken into account such as [6]:

- The type of the aggregates. It is advisable to use aggregates of the same origin with that of the old mortar if that is possible (river or quarry) otherwise aggregates of similar nature, granulometry and colour should be used. Natural silica origin sand is usually used after testing its granulometry and its content in harmful components (organic or clayish additives, salts).

- The parameter of binder/aggregate ratio is also important in terms of mechanical and physical characteristics. The proportion of the binder in relation to the aggregate content depends mainly on the type of mortar (structural, rendering, plaster).An estimated value of it could be received by the analysis of old existing mortar. To have an opinion about the importance of these parameters on a repair mortar it is essential to know how they influence the long term strength and other properties.
- The decision about the type and proportion of the binders used in case of mixed type binders constitute a problem since they influence the most important properties of the new mortar such as strength and porosity. Binders such as lime, natural pozolana and brick dust can be used but it is necessary previously to check their reactivity and suitability.

This paper focuses on testing the mechanical characteristics of many series of different types or repair mortars which are often used for restoration works. Diagrams of time-strength, time-porosity relationships were produced after measuring the compressive strength and the open porosity of the repair mortars at the age of 3 months, 1, 2 and 5 years.

Although there are some research works on design and apply repair mortars [7] [8] there is still a gap concerning long term properties of those mortars. Their behaviour with time is not often monitored and there is a missing knowledge on how much these properties of modern repair mortars are changed.

2. EXPERIMENTAL PART

In order to test the long term behaviour of repair mortar mixtures three different binding systems were selected representing the most often found in old mortars [1]. The characteristics of the binders are shown in table 2.

- pure lime (L)
- lime + pozzolana in proportion 1:1 (P)
- lime+ pozzolana+ brick dust in proportion 1:0.5:0.5 (B)

Table2. Physical characteristics of the binders

	Specific gravity	Lime content Ca(OH)2 %	Pozzolanicity index (MPa)
Lime	1.961	75	-
Pozzolan	2.220	-	4.9
Brick dust	2.279	-	1.2

The sand was siliceous of natural origin (river), 0-4mm and the binder/aggregate ratio was:

- 1/1 (R1),
- 1/ 2 (R2) and
- 1/3 (R3)

The water demand was controlled by a flow table in order to produce mixtures of the same consistency (DIN 85555). A number of twenty four specimens of each mortar type were manufactured. The fresh mixtures were mould in prisms (4x4x16cm) and compacted by hand. The specimens produced were properly cured up to the age of 3 months (EN 196-5) and then they were exposed to indoor conditions where the temperature changes from 18-25^{o}C and the relative humidity from 75-80%. However in some periods very low relative humidity such as 55% have been recorded. Flexural and compressive strength were measured as well as porosity by water absorption under vacuum (RILEM CPC11.3) at the age of 3 months, 1, 2 and 5 years. All tests performed under the same conditions as the rate of loading, the temperature and the humidity are concerned. At each age, 3 samples (4x4x16cm) were tested under flexure and compression while 3 specimens (4x4x8cm) were subjected to porosity measurements. The average value was calculated and used in the following diagrams. All raw materials were tested in the laboratory for their reactivity, clearness and their suitability according to the relevant regulations (EN 196-5) (ASTM C87-69).

The produced mortars are shown in table3. The measurements of the main characteristics of them at different ages are indicated in the Table4.

Table3. Composition of mortar samples (parts by weight)

CODE Nr	Lime	Pozolana	Brick dust	Sand	Water/Binder
LR1	1	-	-	1	0.678
LR2	1	-	-	2	0.926
LR3	1	-	-	3	0.996
PR1	1	1	-	1	0.638
PR2	1	1	-	2	0.760
PR3	1	1		3	0.816
BR1	1	0.5	0.5	1	1.490
BR2	1	0.5	0.5	2	1.506
BR3	1	0.5	0.5	3	1.534

Table4. Compressive strength and porosity evolution by time

	3months		1year		2years		5years	
	Compr. strength MPa	Porosity %	Compr. strength MPa	Porosity %	Compr. strength MPa	Porosity %	Compr. strength MPa	Porosity %
LR1	0.67	21.57	1.51	21.48	2.65	21.56	3.2	21.0
LR2	0.95	20.4	2.8	19.39	3.5	19.41	2.86	19.01
LR3	0.56	19.8	1.4	17.75	1.9	17.6	1.7	17.5
PR1	6.64	22.94	7.6	22.09	8.5	20.89	8.23	20.59
PR2	3.0	18.3	3.1	17.76	4.5	16.95	6.96	15.55
PR3	4.0	21.2	4.05	17.84	5.22	17.55	8.0	17.2
BR1	5.6	20.43	5.8	18.39	6.0	19.5	5.4	19.37
BR2	2.63	19.2	2.85	17.43	2.8	17.15	2.7	16.92
BR3	3.05	17.81	3.5	16.0	3.13	15.37	3.6	15.7

In the figures 2, 3 and 4 strength and porosity evolution have been plotted for each series of mortar under testing.

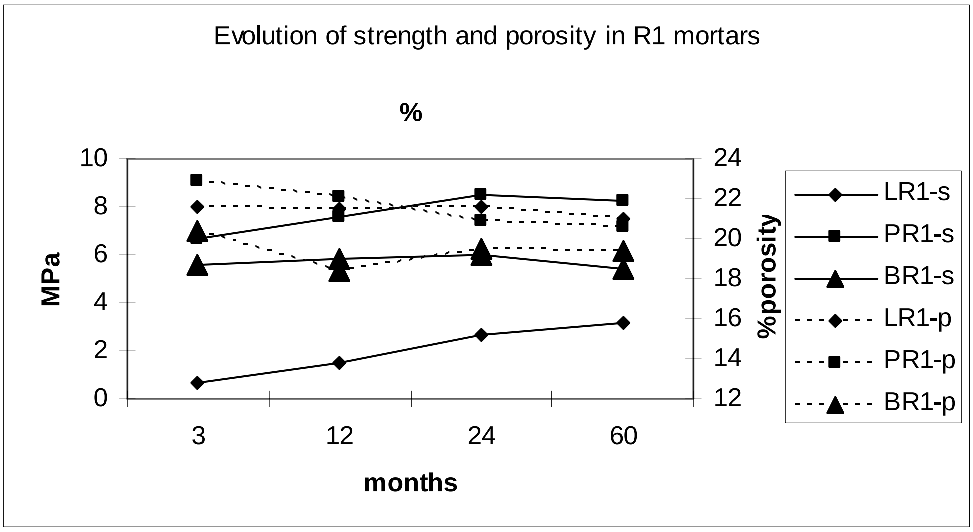

Figure2. Evolution of compressive strength (-s) and porosity (-p) in mortars of binder/aggregate ratio 1/1(R1).

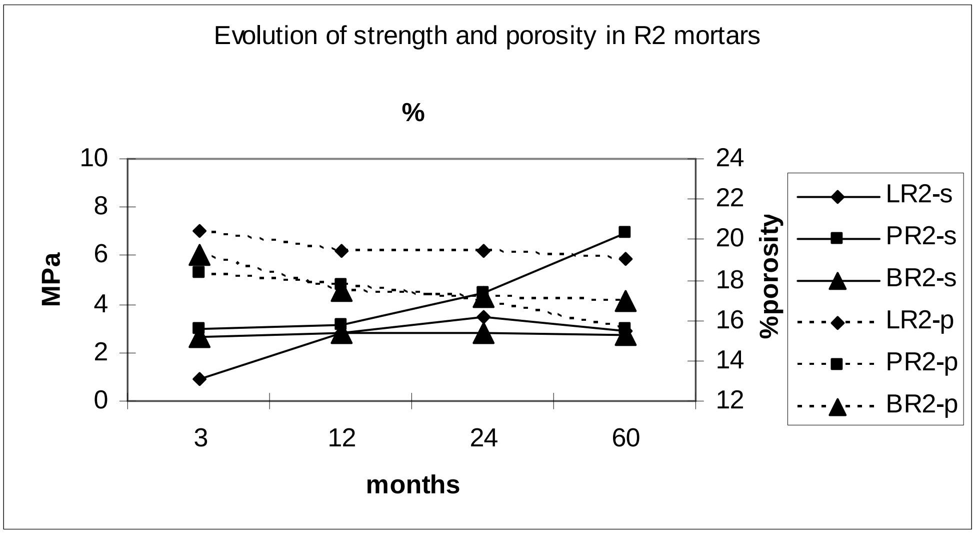

Figure3. Evolution of compressive strength (-s) and porosity (-p) in mortars of binder/aggregate ratio 1 /2 (R2).

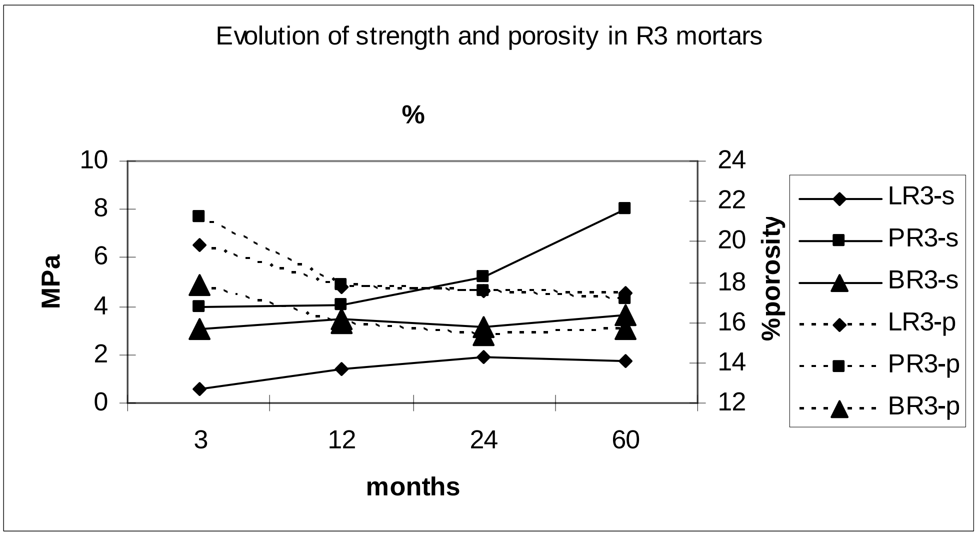

Figure4. Evolution of compressive strength (-s) and porosity (-p) in mortars of binder/aggregate ratio 1/3 (R3).

3. RESULTS AND DISCUSSION

The parameters changed in the nine series of the mortar mixtures tested, are the binding system and the binder: aggregate ratio. Considering test results it could be said that:

- Pure lime mortars develop the lowest final strength which ranges from 2.0 to 3.0MPa (figure 2). The strength increases from 3-month age up to 2-year age and afterwards it remains unchanged or it is slightly reduced. This means that under the curing regime followed, the carbonation is finished at the 2-year age and then the ageing effects are activated. Among LR1, LR2, LR3 series the highest strength was developed by the mortar mixtures with 1:1 binder: aggregate (R1). Regarding the porosity values it seems that they decrease slightly, approximately 10%, up to 2-year age and then remain unchangeable.

- The lime-pozzolan mortars exhibit the higher among the mixture series final strength, around 8.0MPa (figure 3). The rate of strength development for PR2 and PR3 is increased up to the age of 5 years showing that this binding system is reactive for longer time than lime carbonation. The decrease of the porosity with time is relatively higher (10-18%).
- In the case of lime-pozzolan-brick dust mortar mixtures where part of pozzolan was replaced by brick dust, the achieved final strength ranges from 3.0 to 5.0MPa(figure4). The strength development after the 3-month age is actually zero and the relevant curves almost horizontal. The change in porosity after the 3-month age of the BR1, BR2 BR3 mixtures as also low but the porosity values remain lower than the corresponding ones of the lime-pozzolan mixtures.

4. CONCLUSIONS

The binding system influences the final long term strength of the lime-based mortar mixtures. As expected the lime-pozzolan system is more and longer reactive and presents the higher strength. In the case of pure lime mortars the maximum strength is developed at 2-year age while in the lime-pozzolan system the 70-75% of the final maximum strength is achieved.

The brick dust used in the binding system acts rather like filler. It reduces the porosity but the strength evolution curve remains between those corresponding to the lime and lime-pozzolan systems. The strength of lime-pozzolan- brick dust system seems to be improved in comparison with the lime system and reduced in relation to lime-pozzolan system. These relationships, concerning strength-porosity-time and basic binding systems used in the past, are useful for designing a new repair mortar.

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DURABILITY OF HISTORICAL MASONRY REGARDING JOINT REPAIRING MEASURES – PREDICTION BY MEANS OF NUMERICAL AND ENGINEERING MODELS

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ABSTRACT

When repointing historic masonry, it is the quality of the bond between mortar and stones that decides on the durability of the structure. Once the composite system or the mortar start cracking, moisture can penetrate into the masonry and destroy the system. What mortar to use for what kind of masonry is normally an empirical decision. But in how far the mortar eventually selected is really suited for the purpose in question will not turn out until several years later. It is with this knowledge in mind that a simple engineering model has been developed, which is easy to use and which is to permit the likelihood of cracks to be assessed quantitatively. The model is based on calculations made for stresses occurring on the surface of the masonry and only requires a few material parameters. A combined, complex research model is being developed, which is to provide for exact structural analysis. For this model, the temperature and moisture transport is calculated by means of an FDM program. The temperature and moisture fields thus determined are then transferred to an FEM program which uses the material models of *Rots (1997)*, *Lourenço (1996)* and *Van Zijl (2000)* for stress and deformation calculation.

1. INTRODUCTION

Conservation of historic structures normally involves rehabilitation of joints, and the jointing mortar has the function of providing weathering protection. In particular in case of in-depht-measures, the mortar also has to be able to transmit forces. An essential condition for the durability of such repair measures is that the bond between stone and joint mortar is of a good quality and does not show any cracks.

The decision as to what kind of mortar to use for joint repair measures in natural stone masonry of historic buildings is usually a question of experience, while trying to give due regard to preservation requirements. Whether or not the masonry mortar or joint mortar chosen is actually suited for the given kind of masonry often does not show until it has been in place for several years. A major criterion is the weather protection of the masonry, i.e. protection against weathering of the stones and mortar destruction, which depends in particular on the crack-free bond between stone and joint mortar.

Even if a joint mortar itself has good weather protection properties, the mortar/stone flank bond region is a critical weak spot for the durability of masonry. Since the stones and the mortar in new joints tend to differ in their deformation behaviour (which is the result of differences in their thermal, hygral and mechanical properties), cracks are likely to occur between stones and mortar, or in the mortar itself. Material qualification tests alone do not suffice to predict the occurrence of cracks in the composite stone / mortar system.

In order to assess the risk of cracking, a large number of tests have to be performed on composite stone / mortar elements. Since historic buildings are made from a variety of different stones (normally natural stones whose properties tend to vary considerably), the bond characteristics would have to be examined separately for each structure requiring rehabilitation. This would not only be very costly, but also rather time-consuming. Another aspect is that different kinds of mortar are generally used in a particular structure. Mortar in the base region will not be the same as that in the rising masonry or on inclined surfaces. This large number of factors would increase the test requirements considerably.

However, if it should be possible to use models to predict the durability of new joints in historic masonry for defined boundary conditions, such costly and time consuming tests could be either limited or be avoided altogether. Broadly based parameter analyses made before starting any rehabilitation measures will then allow the suitability of a mortar to be reviewed for the application in question. Should the mortar be found to be inadequate, the properties of the mortar can be varied to decide what changes need to be made to produce a joint that is free from cracks.

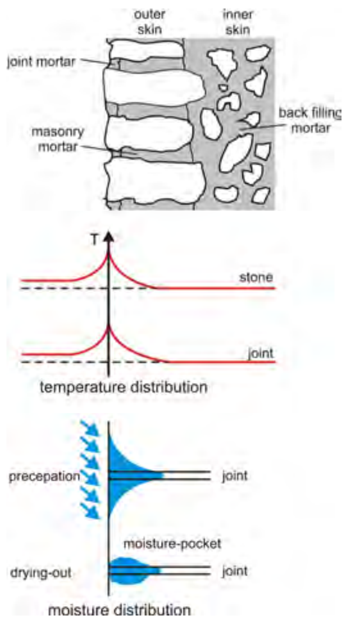
2. CAUSES OF CRACKS

For the development of the composite structure models below, the cause for cracking must be known. The criteria primarily considered as a first step in developing the model are the mechanical/physical material properties and the residual and the restraint stress resulting from such properties. Stones and mortar are characterised by specific thermal and hygral behaviour. Irregular temperature and moisture distribution (see Fig. 1), which itself is the result of atmospheric conditions, produces constrained thermal and hygric strains.

Fig. 2 is a schematic representation of the thermal strains in natural stones at the surface of the masonry, which are produced by changes in ambient temperatures. During summer months, the surface of the natural stone facade heats up considerably due to its exposure to direct sunlight during the day. At night, the surface of the facade cools down to the temperature level of the ambient air. Temperature differences of up to 50 °C at the surface are therefore quite normal. This difference in temperature produces strains in the stones and the mortar, which because of the mutual deformation restraint in turn gives rise to restraint stress. In winter, the entire facade cools down to very low temperatures. The result are tensile stresses in the mortar and in the stones, and adhesive tensile stress in the bond region.

Stresses acting on the bond primarily in near-surface regions of the masonry are hence a function of moisture and temperature fields and they are subject to stress relaxation. This means they depend from location and time as well.

The consequence of restrained deformation normal to the joint flank can be flank failure. Deformation along the joints is limited by internal constraints. The results are residual stresses which can make the mortar crack transverse to the joint. The bond resistance R is determined by the tensile strength of the stone $f_{t,St}$ and of the mortar $f_{t,Mo}$, and by the adhesive tensile strength $f_{t,a}$. The lowest value is always the decisive one. The tensile strength is determined by the moisture level and, in the case of the mortar, also by the time.



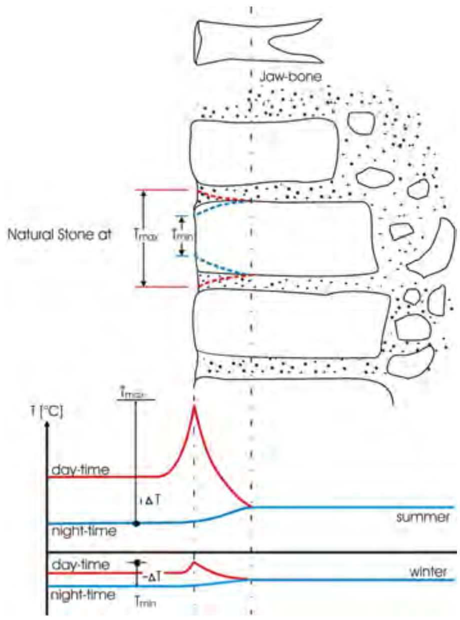


Figure 1: Thermal and hygric exposure of historical masonry

Deformation of natural stones in histo- sonry as a result of thermal elongation

3. MODELS FOR CRACKING IN NEW JOINTS

3.1. Engineering model

The engineering model for the durability of the composite system natural stone / mortar joint in connection with repointing of historic masonry developed by *Schmidt-Döhl and Rosásy* (*2000*) is used as a simple means of modelling the bond behaviour. The engineering model starts from the assumption that stress that can lead to cracks is the result of irregular temperature and moisture distribution across the masonry cross section. Thermal and hygral strain at the surface is restrained by the inner masonry structure. The basic function of the model is to calculate stresses at the surface, starting from the simplifying assumption of a fully constrained composite stone / mortar element and maximum temperature difference:

$$\varepsilon_T + \varepsilon_S - \varepsilon_{el,pl} - \varepsilon_C = 0 \tag{1}$$

where ε_T = thermal strain, ε_S = shrinkage strain, $\varepsilon_{el,pl}$ = elastic-plastic strain and ε_C = creep strain

Under conditions of full constraint, the sum total of all strain components has to be 0 at the surface. For the cases flank cracking (crack in parallel with the joint, Fig. 3) and mortar cracking (crack normal to the longitudinal direction of the joint, Fig. 4) the different strain components are examined more closely.

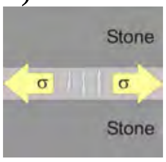


Figure 3: Cracking parallel to joint

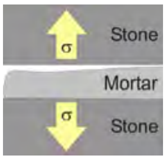


Figure 4: Cracking normal to the joint

Crack initiation parallel to joint (side cracks)

The *thermal strain* ε_T is calculated by means of the coefficient of thermal expansion α_T of mortar and stone, the maximum temperature difference $\Delta T_{\max}$ occurring between mortar and stone or the constraining action of the inside of the masonry (cf. Figs. 1 and 2), and the percentage of area l_0 taken up by mortar and stone:

$$\varepsilon_T = \alpha_{T,Mo} \cdot \Delta T_{\max,Mo} \cdot l_{0,Mo} + \alpha_{T,St} \cdot \Delta T_{\max,St} \cdot (1 - l_{0,Mo}) \tag{2}$$

The *shrinkage strain* ε_S is calculated by means of the final degree of shrinkage $\varepsilon_{S,\infty}$ of mortar and stone, and the area percentage l_0 of mortar and stone. The final degree of shrinkage is used for simplification, because it is expected that the relative moisture in the mortar and stone surfaces decisive for cracking will follow very soon any changes in the relative moisture of the ambient air and that the constraint-induced shrinkage strain will be produced at the surface:

$$\varepsilon_S = \varepsilon_{S,\infty,Mo} \cdot l_{0,Mo} + \varepsilon_{S,\infty,St} \cdot (1 - l_{0,Mo}) \tag{3}$$

The *elastic-plastic strain* $\varepsilon_{el,pl}$ is the result of the actual stress σ_t and the secant modulus $E_{\sec}$ of mortar and stone, and of the area percentage l_0 of mortar and stone in the composite stone / mortar system. Respecting flank failure, the model starts from series arranged mortar and stone:

$$\varepsilon_{el,pl} = \frac{\sigma_t}{E_{\sec,Mo} \cdot \left(l_{0,Mo} + (1 - l_{0,Mo}) \cdot \frac{E_{\sec,Mo}}{E_{\sec,St}}\right)} \qquad \varepsilon_C = \sigma_t \cdot \left(\frac{C_{t,Mo} \cdot l_{0,Mo}}{E_{Mo}} + \frac{C_{t,st} \cdot (1 - l_{0,Mo})}{E_{st}}\right) \tag{4+5}$$

The *creep strain* ε_C is calculated from the actual stress σ_t, the creep coefficients C_t of mortar and stone, the modulus of elasticity E of mortar and stone, as well as the area percentage l_0 of mortar and stone.

Plugging equations 2 to 5 into eq. 1 and solving the equation for the maximum stress the composite stone / mortar system can take, or for the modulus of elasticity of the mortar, yields equations 6 and 7:

$$\sigma_t = \frac{l_{0,Mo} \cdot (\alpha_T \cdot \Delta T_{\max,Mo} + \varepsilon_{S,\infty,Mo}) + l_{0,St} \cdot (\alpha_{T,St} \cdot \Delta T_{\max,St} + \varepsilon_{S,\infty,St})}{\frac{l_{0,Mo} + l_{0,St} \cdot E_{\sec,Mo} \cdot 1/E_{\sec,St}}{E_{\sec,Mo}} + C_{t,Mo} \cdot l_{0,Mo}/E_{Mo} + C_{t,St} \cdot l_{0,St}/E_{St}} \tag{6}$$

$$E_{Mö} = \frac{1}{\frac{\frac{(l_{0,Mo} \cdot (\alpha_{T,Mo} \cdot \Delta T_{\max,Mo} + \varepsilon_{S,\infty,Mo}) + l_{0,St} \cdot (\alpha_{T,St} \cdot \Delta T_{\max,St} + \varepsilon_{S,\infty,St})}{\sigma_t} - C_{t,St} \cdot l_{0,St}/E_{St} - l_{0,St}/E_{\sec,St}}{l_{0,Mö} + C_{t,Mö} \cdot l_{0,Mö}}} \tag{7}$$

Crack initiation normal to joint (mortar cracks)

The risk of crack propagation perpendicular to the joint is assessed by connecting mortar and stones in parallel rather than in series. When compared with the residual stress in the mortar, the influence of the stones on crack propagation in the mortar is insignificant. This is why in this case the engineering model is restricted to the mortar and does not consider a composite stone / mortar system. Again, considerations start from a fully restrained system and the maximum temperature difference.

The *thermal strain* is calculated with the aid of the thermal coefficient of expansion α_T of the mortar and the maximum difference in temperature $\Delta T_{\max}$ between mortar and the restraining masonry:

$$\varepsilon_T = \alpha_{T,Mo} \cdot \Delta T_{\max,Mo} \qquad \varepsilon_S = \varepsilon_{S,\infty,Mo} \tag{8+9}$$

The *shrinkage strain* corresponds to the relevant final degree of shrinkage $\varepsilon_{S,\infty}$ of the mortar.The elastic-plastic strain follows from the actual stress σ_t and the secant modulus $E_{\sec}$ of the mortar

$$\varepsilon_{el,pl} = \frac{\sigma_t}{E_{\sec,Mo}} \qquad \varepsilon_C = \frac{\sigma_t \cdot C_{t,Mo}}{E_{Mo}} \tag{10+11}$$

The *creep strain* ε_C can be calculated from the actual stress σ_t, the creep coefficient C_t of the mortar, and the modulus of elasticity E of the mortar.

Plugging equations 8 to 11 into eq. 1 and solving the equation for the maximum stress the mortar can take, or for the modulus of elasticity of the mortar E_{Mo}, yields equations 12 and 13.

$$\sigma_t = E_{Mo} \cdot \frac{\alpha_{T,Mo} \cdot \Delta T_{\max,Mo} + \varepsilon_{S,\infty,Mo}}{1 + C_{t,Mo}} \qquad E_{Mo} = \frac{\sigma_t \cdot (1 + C_{t,Mo})}{\alpha_{T,Mo} \cdot \Delta T_{\max,Mo} + \varepsilon_{S,\infty,Mo}} \tag{12+13}$$

Implementation and application of the engineering model

Equations 6 and 7, as well as 12 and 13, form the kernel of the engineering model which is based on a *Microsoft Access®* database. It has been developed a graphical user interface using mortar and stone data available from literature and data compiled from our own investigations and analyses. This database can be used for rough parameter studies to be able to select mortars that promise to be a good choice for a given masonry, and it can alternatively be used to determine the requirements the intended mortar has to meet.

Even though the model starts from linear-elastic material behaviour (while considering time-specific deformation), experimentally determined results could be shown with a high degree of approximation. But the accuracy of the model is limited. Because it has so far been formulated as a deterministic model, it does, for instance, not account for the considerable variation of properties of natural stone. Much effort is at the moment being given to the possibility of automated parameter studies. These would also account for the variation of the mortar and stone properties, provided they have been stored in the database. Another aspect which is at the moment not included in the calculation is the bond shear strength, which is why shear stress perpendicular to the crack front is not accounted for. Neither does the model at the moment consider any chemical degradation processes and frost-induced processes, such as the degradation of mortar properties as a result of weathering.

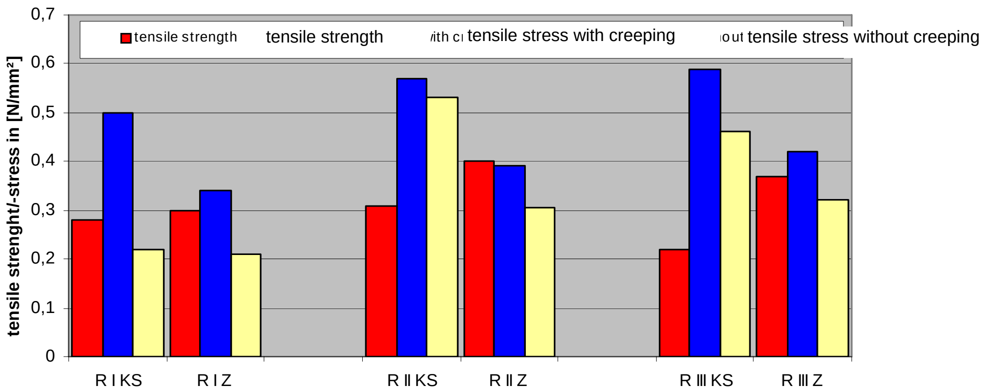


Figure 5: Calculation of flank cracking of three different gypsum-lime-mortars and two different bricks (results) Fig. 5 shows the results of comparative calculations using the engineering model for flank failure due to the temperature load case ΔT=5K. In this case, the bond between three different gypsum-lime mortars and calcareous sandstone or highly absorbent bricks is considered. Once the maximum stresses exceed the measured bond strength, the flanks will fail. It is evident that the stress-reducing effect of the creep deformation of gypsum mortar has been considered in a very realistic manner. Masonry samples exposed to this temperature load case showed flank failure in the same specimens as it had been forecasted in the model.

3.2. Research model

The research model is to serve as a basis for extensive and effective analyses before starting rehabilitation measures, while allowing the number of pre-rehabilitation tests to be reduced substantially. Quantitative determination of the deformation and stress components, sensitivity analyses etc. give more detailed insight into the possible cause of cracks. The research model also permits the moisture distribution to be assessed for the entire cross section as a function of time.

For the time being no model is available that would be able to describe both heat and moisture transport, and the complex material behaviour of masonry (shrinkage, thermal strain, creep, relaxation, failure patterns) with a high degree of precision. One reason is the highly complex dependence of the material behaviour on moisture and temperature. This dependence pattern produces coupled differential equations that have so far not been solved satisfactorily with the FEM method (*Van Zijl (2000)*). In the following a complex research model is presented, which offers the consideration of such effects. Up to the point at which cracking starts, hygral and thermal transport can be assumed to be a process that is independent of the mechanical condition of the system. This is why a model has been developed which combines the detailed submodels.

The program *DELPHIN*®, based on the finite difference method (FDM), provides the possibility to determine the transport processes realisticaly including effects of solar radiation, driving rain and of course variable time-dependent climatic conditions. Especially to simulate experimental outdoor test, measured data from the climate gauging station can be prepared and used as realistic occured boundary conditions in the transport calculation.

Results of the time-specific thermal and moisture fields are transmitted to a developed interface-programm. This interface transformes data from the FDM-mesh to a FEM-mesh, which is generated from the FEM-program *DIANA*® using the material models of *Rots (1997), Lourenço (1996)* and *Van Zijl (2000)* to calculate the resultant deformations, stresses, and cracking, due regard being given to viscous and plastic material behaviour.

So far, the model has been used to describe two-stone bodies (see Fig. 6), in which heat and moisture transport processes were still simulated separately by making use of the symmetry.

Figs. 7 and 8 show the results of moisture distribution, stress distribution and deformations for a two-stone body when dried for 100 days (initial situation: masonry with 90 % rel. air humidity; air with 50 % rel. air humidity). The expected cracking pattern as a result of intensive dryness could be approximated with a high degree of precision, a result which measurements during test programmes cannot achieve. Another advantage is that climatic conditions can be simulated at random and that the numerical model can be used for probabilistic analyses. In this way it can also be determined under what conditions the bond between mortar and stone is particularly likely to fail.

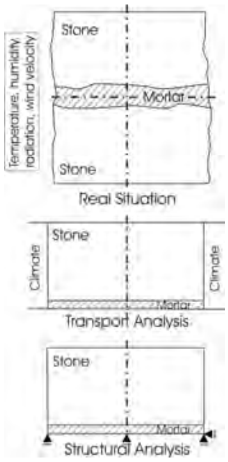


Figure 6:
Geometric modell and deformation conditions in the research model

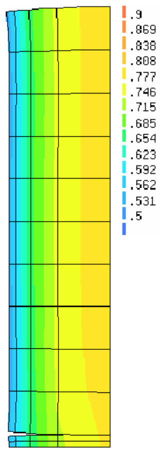


Figure 7:
Moisture content and deformation pattern across the cross section

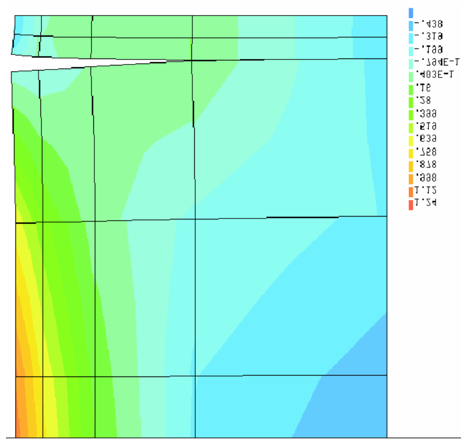


Figure 8:
Detail stone-joint: resulting stress in y-direction and deformation pattern

CONCLUSIONS

The simple engineering model offers a tool that permits the likelihood of cracks in new joints to be assessed in a realistic manner. There is good agreement between the results calculated with the engineering model and the results of experimental tests. On the whole, the cracking pattern was forecast correctly. First coupled calculations using the more complex research model also produce plausible results. Model development aims at providing an instrument that permits a better understanding of the failure mechanisms in the bond between natural stone and mortar joint. More broadly based experiments are essential for verification of both models.

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DESIGN AND EVALUATION OF HYDRAULIC LIME GROUTS FOR THE STRENGTHENING OF STONE MASONRY HISTORIC STRUCTURES

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ABSTRACT

The present paper discusses an experimental procedure realized in order to design adequate hydraulic lime based grouts for the strengthening of stone masonry historic structures. With the aim to minimize compatibility problems between the original materials and grouts, a series of natural hydraulic lime based grouts, as well as a ternary lime-pozzolan-cement grout with low cement content, have been studied. The selection of the most suitable grouts was performed based on their injectability, their mechanical and durability characteristics. The selected grouts were subsequently injected into cylindrical specimens that simulate the infill of three-leaf stone masonry. The experimental results obtained from mechanical tests carried out on the injected cylinders demonstrated the efficiency of all the studied grouts in strengthening the infill material. Finally, an empirical formula was developed to predict the compressive strength of the injected infill, as a function of the mechanical properties of grouts.

1. INTRODUCTION

Grouting constitutes one of the most common techniques applied for the repair and strengthening of masonry structures or fissured architectural members, when interconnected voids in adequate percentage are present. It has the advantage to retrieve the continuity, cohesion and strength of the damaged structures without altering their morphology and load-bearing system. Given that it is an irreversible intervention, the design of the grout as well as the method of its application to historic structures must satisfy a series of performance requirements, comprising that of retreatability. These requirements are set on the basis of an overall approach of the structure to be repaired (morphology, materials, dimensions, distribution and nominal width of voids, etc.) and involve all the injectability, strength and durability aspects.

Although hydraulic lime-based grouts (hydraulic lime with or without a pozzolanic material) offer a promising alternative to the ternary grouts (with low cement content) due to their similarity with the in situ materials and their mechanical efficiency, only few studies have been devoted to them so far [1].

The present research considers some of the most important parameters that influence the performance of hydraulic lime based grouts, namely injectability, durability characteristics and mechanical properties of the grouts. Furthermore, specimens that simulate the infill material of three-leaf stone masonry, strengthened by the selected grouts were tested.

2. GROUT DESIGN

In this project, the design of hydraulic lime-based grouts was performed in order to ensure high injectability under low pressure, even in cracks of width of two tenths of millimetre (W_{nom}~200 μm). To this purpose, the penetrability, fluidity and stability characteristics of the suspensions were fully examined for various water/solids ratios, with or without using additives [2]. The standardized sand column test method (NF P18-891) was applied to check the penetrability and fluidity along with the standard apparatus for testing the fluidity and the stability of the suspension (NF P18-358 & P18-359). Additionally, a ternary grout [composed of low cement percentage (30%, Danish white cement), lime (25%), pozzolan (45%) and superplasticizer (1%)] was examined. An ultrasound dispersion mixer, assisted by a mechanical device of low turbulence, was used throughout the program. The mixing time was 3 minutes for the hydraulic lime-based grouts and 6 minutes for the ternary grout (2 min/solid component).

The following limit values were set for the acceptance of grouts: A time limit of 50 sec for the sand column penetrability test (T_{36}); an efflux time of 500ml of grout less than 45 sec (Marsh cone d=4.7mm fluidity test-$t_{d=4.7mm}$) and fluidity factor higher than $1.5x10^3$mm/sec, [3]; maximum acceptable limit of 5% for the bleeding test.

Four natural hydraulic limes (NHL5 of St. Astier, Chaux Blanche of Lafarge, Calx Romana of IAR and Albaria Calce Albazzana of Degussa), as well as a premixed grouting material with binder based on natural hydraulic lime (Unilit B Fluid 0/0 of Unilit), have been considered. The diameter of the 85% and 99% of the solid phase of the hydraulic lime grouts was <40 μm (<W_{nom}/5) and <100μm (<W_{nom}/2) respectively, as obtained from the laser grain size analysis, fulfilled the granularity criteria to penetrate in voids and cracks of W_{nom}~200 μm [4].

Evaluation of the grouts capacity was performed based on their injectability (fluidity, penetrability, stability), their behavior to salt decay and their mechanical characteristics (compressive and flexural strength).

Table 3: Optimum grout compositions and evolution of their strength.

TERNARY GROUT										
White Danish cement	Lime (powder)	Pozzolan (d_{max}<75μm)	SP1 *	Water *	Compressive and flexural strength (MPa)					
					Age (days)					
					28		90		180	
					f_{gc}	f_{gt}	f_{gc}	f_{gt}	f_{gc}	f_{gt}
G1: 30	25	45	1	80	4.08	2.11	8.16	2.29	10.6	3.13
HYDRAULIC LIME-BASED GROUTS										
NHL5 (St Astier)		SP2		Water						
G2:	100	1		80	2.82	1.90	4.50	2.52	6.36	3.87
G3:	100			80	2.06	1.10	4.88	1.75	6.00	2.70
Chaux Blanche		SP3								
G4:	100	0.7		80	3.10	1.65	4.67	2.19	6.72	1.05
Calx Romana										
G5:	100			70	2.25	1.51	3.04	1.39	2.88	1.08
Albaria Calce Albazzana										
G6:	100			70	1.69	1.02	2.60	0.88	2.49	0.65
Unilit B Fluid 0										
G7:	100			70	1.53	1.27	2.56	1.53	2.53	0.98
* % of the solid phase of the grout. SP1, SP2 and SP3 superplasticizers based on naphtalenesulfonate polymer, lignonaphthalene salts and polycarboxylic ether, respectively										

The compressive strength of the selected grouts generally increased with time or remained approximately constant (for grouts G5, G6 and G7). The flexural strength (measured by three-point bending test) showed a decrease in the obtained values for grouts G5, G6 and G7. This flexural strength reduction can be attributed to the carbonation (note that for G5, G6 and G7, significant carbonation was observed between the age of 90 and 180 days, by applying phenolphthalein) that leads to microcracking [5]. It should be noted, however, that such carbonation is not expected to occur within the mass of masonry.

On the basis of their compressive (f_{gc}) strength (at 6 months), the selected grouts (Table 3) can be classified in three categories: a) ternary grout (W/S=0.8), having f_{gc}=10.6 MPa and f_{gt}=3.1 MPa, b) hydraulic lime-based grouts (W/S=0.8), having f_{gc} of 6–6.7 MPa and f_{gt} of 1.0–3.9 MPa and c) hydraulic lime-based grouts (W/S=0.7), having f_{gc} of 2.5–2.9 MPa and f_{gt} of 0.6–1.1 MPa,.

Salt durability tests were carried out (following a procedure based on [6]): At ambient temperature (20 °C) grout specimens (at the age of 9 months) are impregnated with mirabilite saturated solutions and dried for 6 cycles. After the sixth cycle, half of the specimens were dried at 20 °C and the others at 50 °C until constant mass was reached. Table 4 summarizes the results of the salt decay tests.

Table 4: Mass changes (%) and damage pattern during salt durability tests

GROUT	Mass changes (%) until the 6th cycle (up to)	Mass changes (%) from 7th to 11th cycle. Drying at 20°C and high RH (up to)	Mass changes (%) from 7th to 9th cycle. Drying at 50 °C and low RH (up to)
G1	33%	7% (edge rounding)	8% (fracturing)
G2	21%	-1.6% (edge rounding)	-4% (edge rounding)
G4	29%	-6.3% (extended delamination)	-4% (severe edge rounding)
G5	13%	3.4% (edge rounding)	collapsed into pieces
G6	18%	4.6% (edge rounding)	collapsed into pieces

Table 5: Injectability characteristics of the optimum grout compositions

GROUT	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**
T_{36} (sec) – Sand column 1.25/2.50 mm (voids ~0.2-0.4 mm)	19	18	37	26	17	12	22
$t_{d=4.7mm}$ (sec) - 500ml of grout	21	22	26	24	22	23	22
Bleeding	2%	2%	1%	1%	1%	1%	<1%
Fluidity factor (x10^3mm/sec)	2.58	2.23	1.72	1.82	2.34	2.24	2.23

After characterization was completed, optimum grout formulations of similar injectability characteristics (see Table 5), were injected at low pressure into cylindrical specimens that simulate the infill material of three-leaf stone masonry.

3. MECHANICAL PROPERTIES OF FILLING MATERIAL BEFORE AND AFTER GROUTING

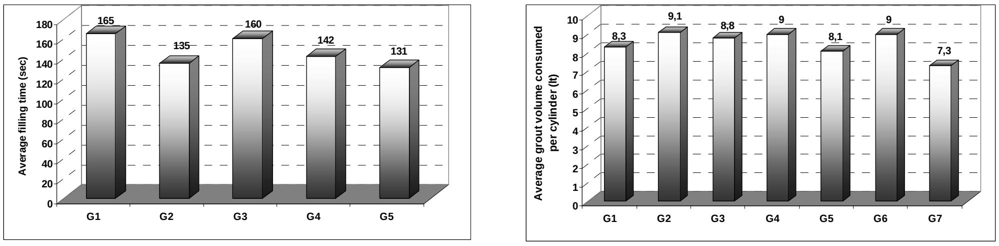
Cylindrical specimens (D=25 cm, L=50cm) were made by filling plastic moulds with lime/pozzolan mortar and pieces of travertine stone (size: 20 to 50 mm), in order to achieve a percentage of voids of 40% approximately. The whole procedure for the preparation of specimens was similar with that described in [2].


(a) (b) (c)

Figure 1: (a) Ungrouted cylinder, (b) and (c) injecting the cylinders

As shown in Table 6, only three (out of twenty eight) cylinders were tested in compression before grouting, although initially, all cylinders were planned to be tested ungrouted as well. However, as (a) large deformations (lateral dilatancy) encountered by the cylinders during testing would not allow the moulds to be re-used for the procedure of grouting and (b) vertical strains could not be measured in a reliable way, since measuring devices could not be easily fixed on the ungrouted cylinders [Figure 1(a)], testing of ungrouted cylinders was limited to a number of three specimens. A mean compressive strength of 0,15N/mm^2 was measured for the ungrouted filling material.

The specimens (placed in their moulds) were injected at constant pressure of ~0.75bar, using special manufactured equipment. The injections performed from the bottom of the moulds; whereas the time needed for filling each cylinder and the consumed volume of grout were recorded. After 180 days of curing, the grouted cylinders were tested in compression.



(a) (b)

Figure 2: (a) Time for filling of the cylinders, (b) Average grout volume consumed per cylinder

Table 6 summarizes the results of testing the grouted cylinders, whereas typical stress-strain curves are given in Figure 3. The failure mode of cylinders was characterized by the formation of almost vertical cracks (Figure 4).

Table 6: Summary of the experimental results obtained from mechanical tests carried on cylindrical specimens

Mechanical properties of:						
	Ungrouted cylinders	**Grout**		**Grouted cylinders**		
	f_c (MPa)	**f_{gc} (MPa)**	**f_{gt} (MPa)**	**$f_{c,in}$ (MPa)**	**E_{in} (GPa)**	**λ_f**
G1	0.15	10.58	3.13	3.04	1.662	20.3
G2	0.15	6.36	3.87	2.79	1.683	18.6
G3	0.15	6.00	2.70	3.26	1.556	21.7
G4		6.72	1.05	3.25	2.097	
G5		2.88	1.08	2.65	1.928	
G6		2.49	0.65	2.26	1.355	
G7		2.53	0.98	2.01	0.618	
Average percentage of voids: G1 (7 cylinders)= 39.5%, G2 (5 cylinders)= 42.2%, G3 (6cylinders)= 41.30%, G4 (3 cylinders)= 42.2%, G5 (3 cylinders)= 38.1%, G6 (2 cylinders)= 42.2%, G7 (2 cylinders)= 35.5%						
f_c, E: Compressive strength and modulus of elasticity of ungrouted cylinders f_{gc} και f_{gt}: Compressive and flexural strength of grout $f_{c,in}$ και E_{in}: Compressive strength and modulus of elasticity of grouted cylinders λ_f= $f_{c,in}$/ f_c,,						

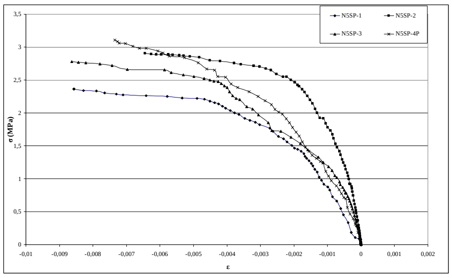


Figure 3: Typical stress-strain curves

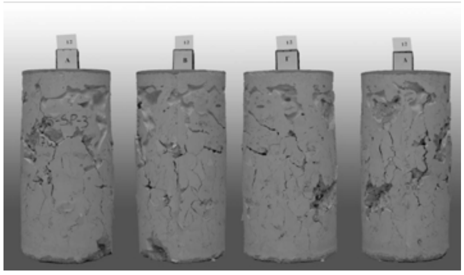


Figure 4: Typical failure mode

One may observe (Figure 5) that, in general, the strain corresponding to the compressive strength of grouted cylinders is smaller for higher compressive strength of the injected grout: As shown in Figure 5, although the scatter of the measured strain values is rather high, there is a tendency of stronger grouts to produce a stiffer grouted filling material. This is confirmed by the data of Figure 6, where the modulus of elasticity of grouted cylinders (at a compressive stress equal to 1/3 of the compressive strength) is plotted against the compressive strength of the injected grout, as well as by the data of Figure 7, where the ratio between the strain at strength and the respective compressive strength of grouted cylinders is plotted against the compressive strength of the cylinders.

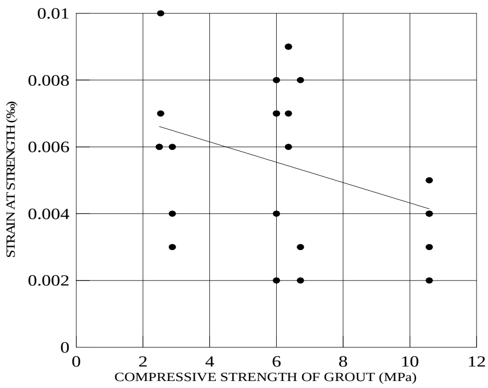


Figure 5: Relationship between the strain at strength and the compressive strength of the grout

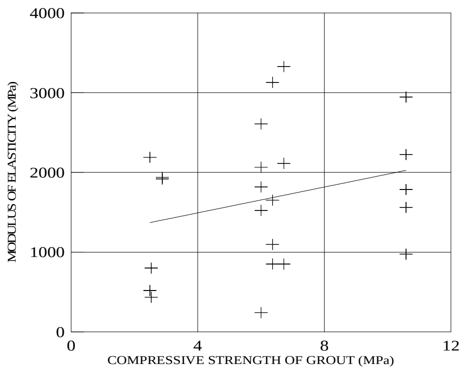


Figure 6: Modulus of elasticity of grouted cylinders as a function of the compressive strength of the injected grout

Nevertheless, the measured differences in moduli of elasticity are not very large: For a compressive strength varying roughly between 2 and 10 MPa, moduli of elasticity between 600 and 2000 MPa were measured (Figure 6).

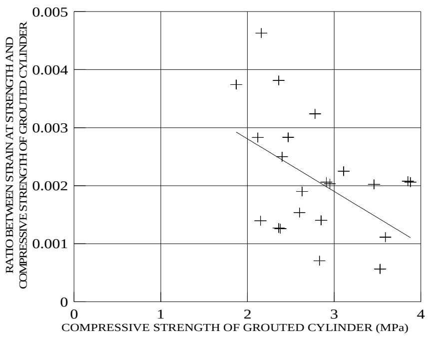


Figure 7: Ratio between the strain at strength and the respective compressive strength of grouted cylinders against the compressive strength of the cylinders

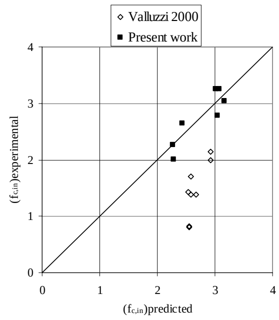


Figure 8: Comparison of predicted $f_{c,in}$ and experimental values using Equ. (2)

4. ESTIMATION OF THE COMPRESSIVE STRENGTH OF GROUTED CYLINDERS

In Vintzileou et al. [7], a simple formula is developed, allowing for the calculation of the compressive strength of three-leaf masonry after grouting. The development of the formula is based on the assumption that grouting significantly affects the mechanical properties of the filling material mainly. Furthermore, based on the results obtained from testing three-leaf masonry wallettes before and after grouting [8], Vintzileou et al. [9] concluded that the strength enhancement of the filling material due to grouting (and, hence, the strength enhancement of the masonry as a whole) is proportional to the tensile strength of the grout.

Valluzzi [1], on the basis of the results obtained from testing cylinders made of filling material and grouted with hydraulic lime based grouts, proposed the following empirical formula for the prediction of the compressive strength of the grouted infill material:

$$f_{c,in} = 0.31 f_{gr,c}^{1.18} \quad , R^2=0.57 \qquad (1)$$

In the present research the attempt to correlate the compressive strength of the injected infill with the compressive strength of the grout led to the following formula (see Figure 8):

$$f_{c,in} = 3{,}18 * (1 - e^{-0{,}5 f_{gr,c}}) \quad , R^2= 0.79 \qquad (2)$$

However, the use of Equations (1) and (2) in the formula proposed by Vintzileou et al [9] leads, in most cases, to calculated compressive strength of grouted three-leaf masonry significantly higher than the experimentally obtained values [8], [9]. This confirms that the failure type obtained from testing three-leaf masonry wallettes is governed by the tensile strength of the materials rather than by their compressive strength.

CONCLUSIONS

The experimental results obtained from mechanical tests carried out on injected cylinders have demonstrated the efficiency of all the studied grouts in strengthening the infill material, despite of the differences in their mechanical properties. In fact, for compressive strength of the grouts varying between 2 and 10 MPa, the compressive strength of the injected cylinders varies between 2 and 3.3 MPa approximately. The moduli of elasticity vary from 0.6 to 2 GPa, shown good agreement with relative published data for such type of grouts [1]. Experimental data show that significant strengthening of the filling material is reached even with grouts of low to medium compressive strength. Therefore, the decisive properties for the improvement of the mechanical properties of masonry are mainly the grout tensile strength, as well as its bonding properties with the in situ materials.

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EVALUATION OF HISTORIC STRUCTURES: TWO CASE STUDIES

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ABSTRACT

Historic structures are in public spotlight and valued as a symbol of their communities. Historic structures are subject to deterioration both due to effects of time as well as exposure from visitors. Protection and rehabilitation of historic structures gain importance as our cultural heritage ages.

This paper discusses condition assessment, testing and evaluation techniques as they apply to assessment and rehabilitation of historic structures. Two unique engineering case studies in rehabilitation of historic structures are discussed. The two structures are; historic masonry structure which served as an armory and historic cast iron stairs of the Cape Hatteras Lighthouse.

The first structure is a historic masonry building and was undergoing restoration of the exterior brick masonry walls. An engineering evaluation was requested to identify if the masonry rehabilitation met the project specification requirements. The evaluation consisted of visual evaluations, sounding, Windsor Probe determinations, petrographic evaluations, and ultrasonic pulse velocity testing at selected areas. The second part of the article discusses a structural evaluation using a load test designed to test and also protect the deteriorated historic stairs of the Cape Hatteras Lighthouse, which were closed to public due to concerns about safety.

1. INTRODUCTION

This article discusses condition assessment, testing and evaluation techniques as they apply to assessment and rehabilitation of historic structures. Two unique engineering case studies in assessment of historic structures are discussed. The two structures are; historic masonry structure which served as an armory and historic cast iron stairs of the Cape Hatteras Lighthouse.

2. EVALUATION OF HISTORIC MASONRY REHABILITATION

The subject structure is a historic masonry building and was undergoing restoration of the exterior masonry walls (Figure 1). The walls consisted of 3 wyhtes of brick with two grouted collar (vertical) joints between wythes and had arches over window openings. Because of the deteriorated condition of the structure and the deterioration in the structural load bearing walls, the masonry restoration involved removal and cleaning of the original brick and partial re-construction of the walls using new masonry mortar. Following concerns on quality of work, cracking and appearance deviating from the original historic texture of the structure (Figure 1) the work was stopped. An engineering evaluation was requested to identify if the masonry construction met the project specification requirements with properly filled and consolidated collar joints for load bearing capacity. The evaluation consisted of visual evaluations, sounding, Windsor Probe determinations, petrographic evaluations, and ultrasonic pulse velocity testing at selected areas.

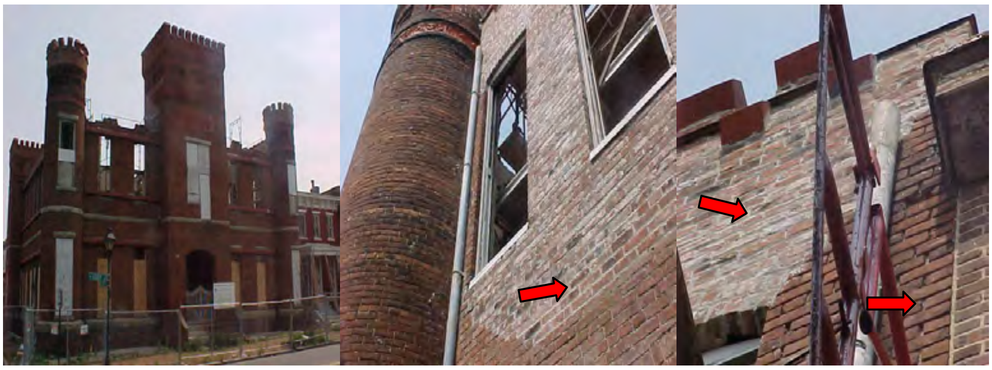

Figure 1:Overview of the building difference in appearance in rehab areas

2.1 Forensic Engineering Assessment of Deficiencies & Issues

Construction of Masonry Arches: Construction of the new segmental arches did not meet the intent of the project to restore the structure to it's original condition. The old arches were terminated in a manner that can be described as "wedged" between the sides of the window opening, enabling the entire arch to remain under compression . Figure 2 shows the construction of new arches with smaller radius, containing double curvature and developing tension, compared to the single curvature of the old segmental arches. Figure 2 also shows cracking in the unreinforced new arches with double curvature.

Mortar Joints: Figure 1 shows the distinct difference in appearance of new mortar joints. The original structure contained a recessed tooled joint. The rehab joints consisted of a flush trowel struck finish. This type of joint is not recommended for exterior exposure by Brick Industry Association [1]. The trowel struck flush finish not only stains the brick surface (note difference in appearance) but also omits the required compacting of the exposed outside layer of mortar against the adjacent brick surfaces which would likely lead to poor waterproofing performance and separation from brick surfaces(Figure 3).

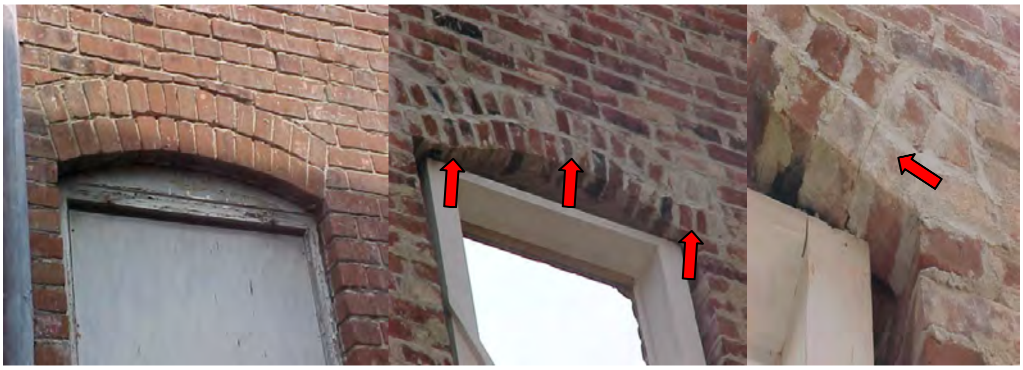

Figure 2: Construction of arches and cracking in area of double curvature

ASTM C856 Petrographic Evaluation for Possible Frost Exposure: Concerns were raised due to bricklaying during low temperatures. The suspect areas were identified based on weather data and petrographic evaluation of mortar samples was performed per ASTM C856 Standard Practice for Petrographic Examination of Hardened Concrete. Petrographic/microscopic evaluations of masonry mortar indicated frost related distress and ice crystal formation in fresh mortar limited to the outermost ½ inch of the suspect areas.

Type of Masonry Mortar: Project specifications required a mortar complying with type O (medium-low strength 350 psi/2.4Mpa) mortar requirements. A low strength mortar was selected to ensure any cracking to occur in the mortar rather than the brick, by selecting a mortar weaker than the expected strength of the historic brick. A pre-bagged mix was used in the field which was likely Type N (medium strength 750 psi/5.17 MPa). Instances of cracking brick were noted in new work (Figure 3).

Chemical analysis results of mortar per ASTM C1324 Standard Test Method for Examination and Analysis of Hardened Masonry Mortar were variable but indicated higher cement contents compared to expected cement content of a type O mortar. It appeared that the soluble silica content, therefore the cement content was high for a type O mortar, which would mean higher strengths. Windsor probe penetration resistance determinations in masonry joints per ASTM C803 Standard Test Method for Penetration Resistance of Hardened Concrete (Figure 3) to confirm this finding indicated highly variable in-situ mortar strengths ranging from 180 psi to 2900 psi.

Construction of Collar joints: Sounding of the masonry walls was performed by lightly impacting with a hammer. Sounding provided an indication of lack of grouted vertical collar joints based on the difference or contrast in sound. Incomplete collar joints were indicated at several areas. Figure 4 shows non-destructive testing in general accordance with ASTM C 597 Standard Test Method for Pulse Velocity Through Concreteat one of these areas. This area was approximately 3 to 4 courses high and was indicated to have a hollow collar joint.

Through wall pulse velocity measurements were performed starting with the center and continuing 4 courses of brick above and below the starting point. The lower pulse velocity results indicated a masonry area of lower quality within the boundary indicated by sounding.

Figure 3:Cracking in brick, windsor probes and separation in new joints

Moving away from the indicated hollow area, the pulse velocities increased in magnitude approaching typical expected pulse velocity values for 3 wythes of brick and two full collar joints. Subsequent removal in the hollow area confirmed NDE findings (Figure 4). The collar joint was incomplete and only poorly consolidated head and bed joints existed at three courses.

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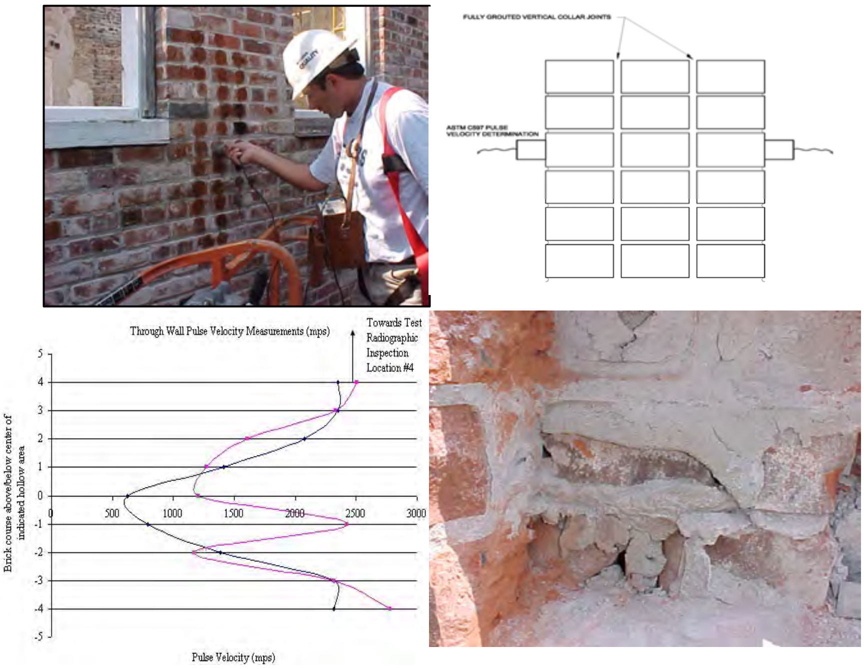

Figure 4: NDE of hollow collar joints and demo verification of findings
Based on the findings of the evaluation, the defective areas
of rehabilitation were removed and reconstructed

3. EVALUATION OF THE HISTORIC STAIRS BY LOAD TESTING

The Cape Hatteras Lighthouse was built in 1869-1870. The cast iron stairs are original to the lighthouse and spiral up the brick shaft (Figure 5) in 8 flights for a total of 52 meters in height. A couple pieces of the stairs approximately 5 cm by 1.3 cm by 7.6 cm dislodged and fell inside the brick structure. The lighthouse was closed to visitors and a 3 phase engineering assessment of the in-situ load carrying capacity of the deteriorated stairs was initiated [2].

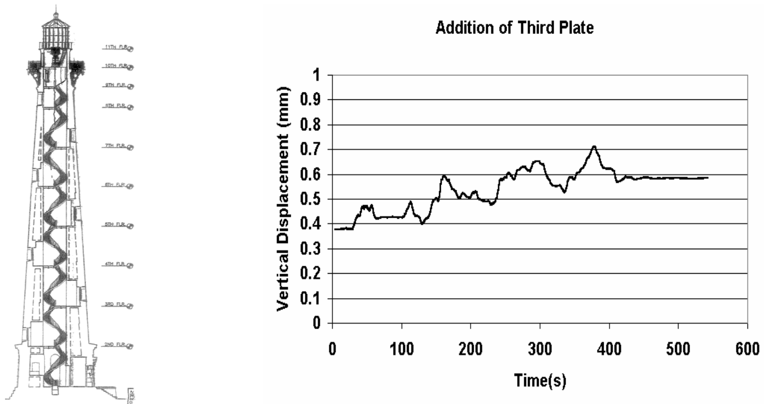

Figure 5 Stairs of the Hatteras Lighthouse

3.1 Phase I: Condition Survey of the Cast Iron Stairs

A tread-by-tread survey of the distresses was performed for each flight of stairs, to document the current condition. The results were compared to a previous study from 1988 for progression of distresses. The distresses had generally increased in number compared to the 1988 survey. Cracks in the treads, risers, support brackets (Figure 6) and railing posts were noted, as well as a qualitative evaluation of the extent of corrosion. The close proximity of lighthouses to the ocean and associated salt exposure, humid weather as well as perspiration from climbers makes their stairs susceptible to corrosion. Approximately 61,500 people climb Hatteras during peak summer months

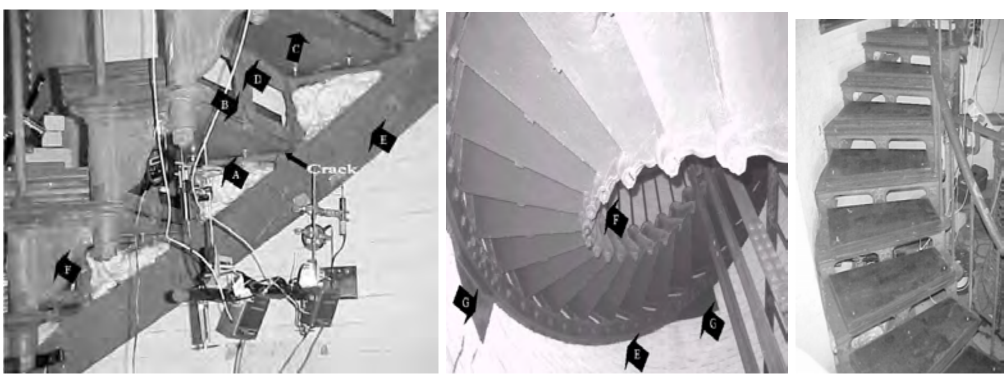

Figure 6. Monitoring Gages, Structural Configuration of Stairs and Load Plates.
A Bracket, B Tongue/Tab, C Tread, D Riser, E Ext. Stringer, F Int. Stringer

3.2 Phase II: Development of the Load Test Program and Review of Statistical Data

A load test would verify the load carrying capacity of the stairs, and serve as a proof test to protect the public. The code required live load for public egress stairs is 488 kg/m^2 (100 psf) [3]. A load test would require the structure to withstand twice the service live load without failure or excessive or permanent deflections [3]. Several options were considered for continued safe use of the stairs including: removal and replacement (Option A), load testing to the full code required live load and enforcing no limits on climbers, (Option B), load testing to a reduced live load with minor limits on climbers (Option C), and no load testing with severe limits on climbers (Option D).

Option A was not preferred due to the historic value of the stairs, cost of removal and replacement, and long down time. Options B and C required the team to determine the current safe load capacity of the in-situ stairs using a load test. A reliable analytical approach was not possible due to unknown extent of distress, non-uniform material properties of old cast iron and the complex geometry of the stairs. Option D proposed a severe limit on the number of climbers without any further testing. The proposed visitor limits were to be based on the visitor statistical records.

***3.2.1 Review of Visitor Data and Live Load for Options B and C*:** A load test procedure for unrestricted use (option B) would utilize a test load of 976 kg/m^2 (200 psf), twice the code required live load of 488 kg/m^2 (100 psf). Based on a 0.232 m2 (2.5 sf) tread area, this option would require a test load of 226.8 kg (500 lbs) for each of the 31 treads, therefore 7030 kg (15,500 lbs) for each flight. Given the relatively narrow width of the spiral stairs, service loads based on a live load of 488 kg/m^2 (100 psf) or 113.4 kg (250 lbs) per tread seemed unlikely even in the peak usage times. Additionally, the team was concerned that the required test load based on the prescribed full live load amount could potentially permanently damage the stairs.

Given the unique and historic nature of the cast iron stairs, the engineering team had the added objective of designing a load test without exposing the historic stairs to unnecessary risk of failure or permanent damage due to excessive loading. The visitor statistical data indicated that a limit of 160 climbers in the lighthouse at one time was exceeded only about 10 days during peak season. Based on this “ten day limit” of 160 climbers and an average visitor weight of 77 kgs (170 lbs), this would amount to 1540 kgs (3400 lbs) for each of the eight flights. This load exposure information review lead to the development of option C with a reduced test load while still permitting realistic load exposure limits. Option C required load testing of the stairs utilizing a reduced live load of 244 kg/m^2 (50 psf) thus limiting the potential for permanent damage, while permitting almost unrestricted use.

Based on a reduced live load of 244 kg/m^2 (50 psf), the corresponding test load would be 488 kg/m^2 (100 psf) or 113.4 kg (250 lbs) per tread. The corresponding test load on a flight of 31 steps would therefore be 3515 kg (7750 lbs). This test load amount would still be greater than twice the 1540 kg (3400 lbs) per flight estimated for service exposure based on climber statistics and a "ten day limit" of 160 climbers in the lighthouse at one time. Successful completion of the load test and repairs would allow the stairs to be rated for a live load of 244 kg/m^2 (50 psf) and to be returned back to service with almost unrestricted use of the stairs, with a 160 person limit. Option C using the reduced load exposure was selected

3.3 Phase III: Load Testing of the Stairs

3.3.1 Stairs: Each flight of stairs consists of 31 treads. The locations of the landings alternate between north and south sides (Figure 5). During the condition survey phase, an inventory of visible distresses was developed for the stairs. A tabulation of the observed distresses was performed and the flights were ranked starting from the flight with the most observed distresses. Flights 1, 5 and 7 with the highest extent of distresses were selected for load testing. By testing the 3 most severely distressed flights, the cost and time of the evaluation was reduced. If the 3 most severely distressed flights passed the load test, the remaining 5 flights would also be considered adequate.

3.3.2 Test Load and Material: The test load was set at 113.4 kg (250 lbs) per tread or 3515 kg (7750 lbs) per flight. The test load was applied using steel plates. The use of steel plates enabled application of the required load in a short timeframe and minimized the volume of load testing material, compared to other loading material options such as sand or water.

Steel plates with a thickness of 12.5 mm (½ in.) and a surface area of about 0.232 m2 (2.5 sf) and matching the shape of the treads were manufactured (Figure 6). Each of these plates weighed 22.7 kg (50 lbs). This enabled application of the full test load in five stages by manually stacking the plates on top of each other. Steel plates fitted to the treads allowed the testing staff to walk up and down the flight safely during loading and unloading with the plates in place.

3.3.3 Load Testing of Stairs: Load tests were performed on one flight of stairs at a time. Emergency shoring was installed below each flight to be tested. Shoring was installed with a gap of 12.5 mm (½ in.) between the underside of the risers to provide support in case of excessive deflections or failure. Each flight was loaded in 5 increments. The load was held for a minimum of 20 minutes for each increment and deflections were measured. The final load was held for 2 hours. After unloading, the residual deflections were measured.

Ten monitoring points were set up in pairs located along matching points on the interior and exterior stringers (Figure 6). Data acquisition and recording of deflections was performed using Linear Variable Displacement Transducers (LVDT) linked to a field computer located at an upper landing. LVDTs were placed on temporary supports installed on the lighthouse wall, under the monitoring locations. Backup dial gauges with sensitivity of 0.025 mm (0.001 in.) were installed, in case of power or data acquisition failure (Figure. 6).

Real-time vertical deflections were monitored for safety during loading (Figure 5) enabling monitoring for any sudden increases in deflections. Displacements were recorded using data acquisition software and associated hardware capable of sampling at variable rates up to 100 Hertz.

3.4 Results of Load Testing:

Maximum deflections were encountered on the interior stringer that clear-spans between the landings. The three flights of stairs that were load tested satisfactorily passed the load test. Maximum deflections observed were 1.85 mm (0.07 in.) or less. The observed deflections were well below code service load deflection limit which would apply to these stairs. The rebound of the stairs after load removal exceeded the code required minimum 75% recovery. Failures or significant permanent deflections that would make slope of the treads unsafe or uncomfortable were not encountered.

Upon successful completion of the load tests, the stairs were placed under a rehabilitation program. The repairs included removal and replacement or reinforcing of a number of distressed elements and repainting of the stairs. The historic Cape Hatteras Lighthouse was reopened to the public, following repairs, with an in-place restriction on the number of climbers.

4. CONCLUSIONS

The two case studies outlined here provide unique diagnosis, evaluation and testing methods applicable to historic structures. This article should be of value to researchers as well as practicing engineers and consultants involved in historical structure assessment and appraisal and monitoring techniques.

This article also discusses the use of load testing in evaluation of historic structures. In the deteriorated historic stairs, the code required load level was modified to design a load test without exposing the historic stairs to unnecessary risk of failure. The engineering team reviewed the statistical visitor data to determine a realistic load level representing service conditions which also would not expose the stairs to risk of additional damage.

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THE EFFECT OF RH CHANGES ON SALT DAMAGE: THE CASE STUDY OF THE “WAAG” BUILDING IN AMSTERDAM

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ABSTRACT

Hygroscopic salts present in building materials can cause severe damage if they undergo frequent dissolution/crystallization cycles because of RH changes of the air. This phenomenon has been observed in the *Waag* building in Amsterdam. The high content of hygroscopic salts (chlorides and nitrates mainly) in the masterpieces of the masons guild, in combination with RH changes of the air, was shown to be the cause of severe salt decay.

1. INTRODUCTION

Salt crystallization can cause severe damage to porous building materials. Salt, crystallizing in the pores, creates pressures which weaken and finally damage the material. Repeated dissolution/crystallization cycles of the salts increase the risk of damage. Most of the salts commonly found in masonry are hygroscopic, i.e. they adsorb moisture from the air if the RH of the air is higher than their RH of equilibrium (RH_{equ}) [1]. If the adsorbed moisture is enough, the salts (partially) dissolve, and then re-crystallize once the RH of the air decreases again below the RH_{equ}. Depending on the climate conditions and on the kinetic of the specific salts (dissolution and crystallization can occur rapidly or very slowly [2, 3], cycles of crystallization/dissolution may take place leading to severe damage [5, 7].

In the following sections the case of the Waag building is discussed in which the climate conditions are shown to play a crucial role in the development of salt decay.

2.THE WAAG BUILDING: HISTORY AND STATE OF CONSERVATION

The Waag building in Amsterdam is a remnant of the former city walls (1481-1492); originally it was one of the city gates. When in the late 16th century the city expanded, the wall was torn down and the gate lost its function. The defensive canal and palisade around the gate was turned into a market square. The upper floors housed four guilds for some time, namely those of the smiths, painters, masons and surgeons. Each guild had its own entrance tower. The main object of this research is the tower belonging to the masons' guild. In the tower master proofs of the masons' guild are located whose curved shapes, often in perspective, (Fig. 1) are testimonies of the high mathematical and technical skills reached by the master masons. After the guilds were dissolved around 1795, the building served numerous purposes, later housing a fire brigade and two museums before it was handed over in 1990 to an ICT research foundation working in the social and cultural domain.

Severe crystallization damage affects the master proofs in the masons' tower. The bricks show powdering, and in some cases, scaling of the outer surface (Fig. 2). The very thin mortar joints are powdering and, at some locations, they are completely gone. There is no clear pattern in the decay: damage is present both in the lower and in the upper part of the tower. At some locations the damage seems to start at the joint and to develop then into the brick, whereas in some other locations the mortar is still sound while the brick is completely powdered. The natural stone, used at the door-entrance on the first and 2nd floor, shows damage too.

3. SAMPLING AND INVESTIGATION METHODS

3.1 Sampling

Three sampling campaigns were performed: in November 2004, in February 2006 and in July 2006. The following samples were taken:

- 21 (in the 1st campaign), 44 (in the 2nd campaign) and 21 (in the 3rd campaign) powder samples were collected for the investigation of moisture and salt. Brick, stone and mortar samples were collected at several locations and at different depth at the ground, 1st and 2nd floor of the tower.
- 2 efflorescence samples scratched from the surface of two bricks.
- Scales from the surface of the brick and of the mortar joint.

3.2 Laboratory analyses

The actual and hygroscopic moisture content at 80% (HMC_{80}) and at 96% RH (HMC_{96}) of the powder samples was determined gravimetrically [6]. The HMC gives an indication of the amount of salt present. If the HMC measurements are performed at different RH, an indication of the type of salts can be obtained too [4].

Ion chromatography (IC) was performed by Dionex ICS 90 chromatographer on 9 powder samples, in order to determine the type and amount of ions.

XRD analyses were performed (by means of Philips PW3020 X-ray diffractometer) on the efflorescences scratched from the surface of the brick.

The ESEM observations on brick and mortar scales have been performed by means of a Tungsten XL 30 Environmental Scanning Electron Microscope (ESEM) of FEI, equipped with an Energy Dispersive X-ray (EDX) system of EDAX. ESEM investigations have been carried out mainly by the use of a Back Scattered Electron (BSE) detector. EDX analyses and mapping of Cl, Na, Ca, Si, Mg and S ions have been performed to identify the salts and the material components.

3.3 Environmental monitoring

The indoor climate in the tower has been monitored for a period of about one year, in order to study the effect of the environmental conditions on the salt damage. Data on the temperature (T) and Relative Humidity (RH) of the air have been collected by means of ESCORT sensors placed at different locations: in the tower at the ground, 1st and 2nd floor and in the "*gildekamer*" on the 1st floor.

3.3 Adsorption experiment

The experiment consisted in storing the sample on a balance in a climatic cabinet and to record its weight variation when increasing the RH. The weight of the sample is recorded continuously: when the sample has reached the constant weight the RH is increased. The temperature in the climatic cabinet is kept constant at 23°C, while the RH is increased step by step from 28% to 96%. The experiment has been performed on 2 powder samples (1b and 36b) to get an indication of the RH at which hygroscopic adsorption starts in this masonry contaminated with a salt mixture. In fact, while the RH of equilibrium of a single salt is well known, the RH of salt mixtures is difficult to be calculated.

4. RESULTS

4.1 Actual (MC) and hygroscopic moisture content (HMC)

Regarding the MC (Table 1) the following conclusions can be drawn:

- All the samples, with exception of sample 8b collected above the entrance door, show a low MC; the MC is always lower than the HMC.
- The moisture distribution as found in the pillar at the ground floor (samples 36-46a) excludes rising damp as a relevant source of moisture.
- No significant differences in MC have been observed between samples from external and internal walls. This excludes rain penetration from the possible moisture sources. Only in the case of sample 8b, rain penetration may be present.
- The MC is generally higher in the samples collected in the winter, when the RH in the not-heated spaces showed to be higher, than in the ones collected in the summer, when the RH was lower. This, together with the fact that the samples with a high MC generally also have a high HMC, makes suppose that the MC is mainly due to hygroscopicity.

Regarding the HMC the following conclusions can be drawn:

- The HMC_{96} is high; this is a clear indication for the presence of hygroscopic salts. Also the HMC_{80} is high, indicating that the salts are very hygroscopic.
- The HMC may extremely vary from one sampling location to another.

Table 1 Location, material, MC and HMC of the samples

Sample code	MC	HMC at 96%	HMC at 80%	Sample code	MC	HMC at 96%	HMC at 80%	Sample code	MC	HMC at 96%	HMC at 80%
36aB$_{0,0-1}$	3.0	30.4		**36bM$_{0,1-5}$**	3.7	45.7	27.2	**35bS$_{2,0-1}$**	0.2	30.0	18.6
37aB$_{0,1-5}$	3.4	32.4		**37bM$_{0,5-10}$**	3.2	35.5	22.0	**34bS$_{2,1-5}$**	0.2	10.5	5.8
38aB$_{0,10-15}$	4.1	46.2		**41bB$_{0,0-1}$**	1.1	8.0	4.6	**1NbB$_{2,10-15}$**			7.6
39aB$_{0,0-1}$	2.8	36.9		**42bB$_{0,1-5}$**	0.5	7.9	4.2	**2NbB$_{2,5-10}$**			5.5
40aB$_{0,1-5}$	2.7	34.4		**43bB$_{0,5-10}$**	1.9	9.3	3.7	**3NbB$_{2,0-5}$**			5.7
41aB$_{0,10-15}$	3.8	35.2		**44bB$_{0,0-1}$**	3.4	20.7	6.9	**4NbM$_{2,10-15}$**			24.1
42aB$_{0,0-1}$	1.5	23.1		**45bB$_{0,0-1}$**	2.6	10.5	2.6	**5NbM$_{2,5-10}$**			28.9
43aB$_{0,1-5}$	2	25.5		**13bB$_{1,0-1}$**	0.7	4.1	1.7	**6NbM$_{2,0-5}$**			18.9
44aB$_{0,0-1}$	0.7	20.6		**12bB$_{1,1-5}$**	0.4	2.4	1.0	**39cB$_{1,0-1}$**	0.0	23.3	14.4
45aB$_{0,1-5}$	1.6	34.6		**11bB$_{1,5-10}$**	0.9	2.7	1.2	**40cB$_{1,1-5}$**	0.0	15.6	10.5
46aB$_{0,10-15}$	1	42.1		**10bM$_{1,10-15}$**	1.1	4.9	2.2	**41cB$_{1,5-10}$**	0.0	11.6	7.6
47aB$_{0,0-1}$	2.9	32.9		**16bB$_{1,0-1}$**	1.2	4.3	2.1	**42cB$_{1,10-15}$**	0.0	33.3	16.7
48aB$_{0,1-5}$	3.4	37.6		**15bB$_{1,1-5}$**	0.2	3.0	1.2	**43cB$_{1,0-1}$**	0.0	3.9	3.9
49aB$_{0,0-1}$	2.1	32.4		**14bB$_{1,5-10}$**	0.9	1.8	0.0	**44cB$_{1,1-5}$**	0.0	3.6	2.7
50aB$_{0,1-5}$	2.2	25.7		**20bB$_{1,0-1}$**	1.8	10.6	4.7	**45cB$_{1,5-10}$**	0.0	3.6	2.7
51aM$_{0,0-1}$	5.8	33.3		**19bB$_{1,1-5}$**	0.6	9.8	5.3	**46cBM$_{1,10-15}$**	0.0	9.5	7.1
52aM$_{1,0-2}$	1.5	93.1		**18bB$_{1,5-10}$**	1.7	9.8	4.0	**47cS$_{1,0-1}$**	0.0	10.4	6.7
53aM$_{1,2-5}$	0	54.0		**17bB$_{1,10-15}$**	1.9	10.4	4.7	**48cS$_{1,1-5}$**	0.0	7.6	4.7
54aB$_{1,0-1}$	0	12.6		**24bB$_{1,0-1}$**	1.0	5.3	1.9	**49cS$_{1,5-10}$**	0.0	5.0	3.0
55aB$_{1,1-5}$	0	10.3		**23bB$_{1,1-5}$**	0.7	5.1	2.1	**50cM$_{2,0-1}$**	0.1	22.9	15.0
6bB$_{0,2-5}$	4.2	22.2	14.0	**22bB$_{1,5-10}$**	0.8	5.0	1.5	**51cB$_{2,0-1}$**	0.0	22.1	15.0
7bM$_{0,2-5}$	4.1	33.4	20.5	**21bB$_{1,10-15}$**	0.6	5.2	2.1	**52cB$_{2,0-1}$**	0.0	27.9	20.2
8bM$_{0,0-1}$	14.6	36.6	19.5	**29bB$_{2,0-1}$**	1.2	22.5	11.9	**53cB$_{2,1-5}$**	0.0	19.9	17.5
9bBM$_{0,0-1}$	4.3	32.2	17.8	**28bB$_{2,1-5}$**	1.0	13.5	6.0	**54cB$_{2,5-10}$**	0.0	19.3	14.0
5bB$_{0,0-1}$	0.0	10.4	4.5	**27bB$_{2,5-10}$**	0.2	11.3	5.9	**55cM$_{2,0-2}$**	0.0	9.0	7.0
4bB$_{0,1-5}$	1.6	16.9	9.1	**26bB$_{2,10-15}$**	0.0	8.2	3.3	**56cM$_{2,0-2}$**	0.0	7.5	5.5
3bM$_{0,5-10}$	2.0	27.4	13.7	**33bB$_{2,0-1}$**	0.7	13.6	8.1	**57cB$_{2,0-1}$**	0.0	2.2	0.7
38bB$_{0,0-1}$	0.8	7.1	3.3	**32bB$_{2,1-5}$**	0.2	8.4	4.3	**58cB$_{2,1-5}$**	0.0	1.2	0.6
39bB$_{0,1-5}$	0.9	7.3	4.1	**31bB$_{2,5-10}$**	0.2	8.2	3.9	**59cB$_{2,5-10}$**	0.0	2.1	1.1
40bB$_{0,5-10}$	2.1	13.5	6.2	**30bB$_{2,10-15}$**	0.2	4.8	2.0				
1bB$_{0,0-1}$	3.0	37.9	21.2	**25bM$_{2,0-2}$**	2.0	13.1	8.4				

$nxY_{z,j-k}$ n = sample number
x = sampling campaign (a=winter 2004; b = winter 2006; c = summer 2006)
Y = material (B = brick; M = mortar; S = natural stone)
$_z$ = floor (0 = ground floor; 1 = 1st floor; 2 = 2nd floor)
$_{j-k}$ = depth of sampling in cm

 

Figure 1 (left) Columns of the master proofs. Figure 2 (right) Powdering of the brick.

4.2 Ion chromatography

The results of the ion chromatography (IC) are reported in Fig. 3 On the basis of the obtained results it can be concluded that:

- NaCl is the main salt present. Na and Cl iones have been detected in all the samples analyzed by IC. The Na/Cl molar ratio of about 1 indicates the presence of NaCl.
- Apart from chlorides, nitrates are present too. Chlorides and nitrates are very hygroscopic salts, which start adsorbing moisture at a low RH (RH_{equ} at 20°C: NaCl = 75.5%; NaNO3 = 75.4%). This explains the high HMC_{80} values.
- Sulfates are present in large quantities in samples 36b, 10b, 44b and 45b. It can be reasonably supposed that in samples 20b, 44b and 45b they are mainly present combined into gypsum ($CaSO_4$ $2H_2O$). Gypsum is not very hygroscopic: this explains the low HMC measured in these samples in spite of their high sulfate content. The hypothesis of the presence of gypsum is also supported by the XRD analyses performed on the efflorescences (§ 4.3).
- No clear differences have been detected in salt type and content between mortar and brick samples.

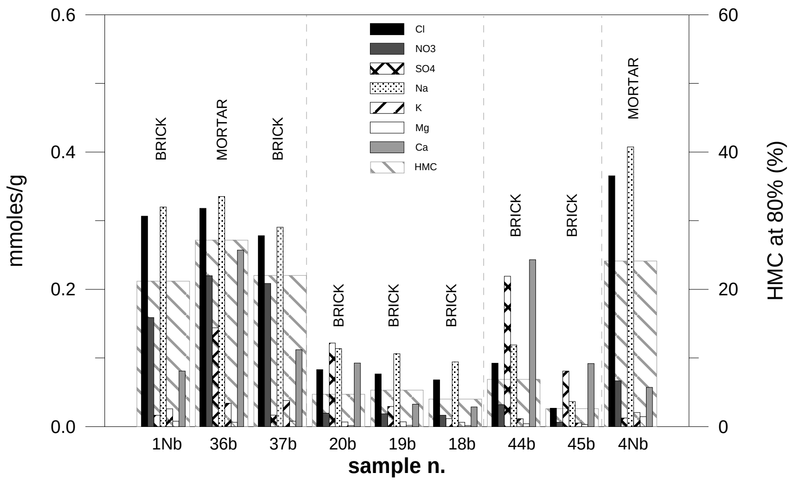

Figure 3 Results of IC performed on powder samples.

4.3 XRD analyses

The XRD analyses results show large amounts of silica (SiO_2) and calcite ($CaCO_3$), components of the brick and the mortar. Also gypsum ($CaSO_4 \cdot 2H_2O$) is present in a significant quantity; low amounts of NaCl have been detected in one of the samples. These results are related to the detection limit of the XRD technique: only compounds present in a percentage higher than 3-5% can be identified.

4.4 ESEM study

The ESEM observations performed on a brick flake show the presence of salt crystals which have been identified, by EDX mapping, to be NaCl (Fig. 4a). Similar results have been obtained on the mortar sample (Fig. 4b).

4.5 Environmental monitoring

From the elaboration of the environmental data (Fig. 5) it emerges that in the not heated spaces (staircase, ground level and 1st floor) the RH varies between 60 and 90% RH in the winter and between 40 and 70% RH in the summer months. In the heated spaces (*gildekamer* and 2nd floor) the RH can recede below 30% in the winter. While the *gildekamer* is continuously heated, the small room on the second floor is only intermittently heated: this causes there fast RH changes between 20 and 60% RH. In the winter large differences exists between the high RH values of the not heated and the heated spaces. The differences between the three locations disappear in the summer when the RH varies between 40 and 70% in all locations.

4.6 Adsorption experiments

The results of the adsorption experiment are reported in Fig. 6.

The adsorption curve of sample 36 shows a clear increase in the hygroscopic moisture uptake between 70 and 76%RH, which corresponds to the RH_{equ} of NaCl, the salt present in a large quantity in this sample (see IC results). Some moisture adsorption is present also at lower RH. This can be due to the presence of other salts (the ion chromatography indicated the presence of nitrates).

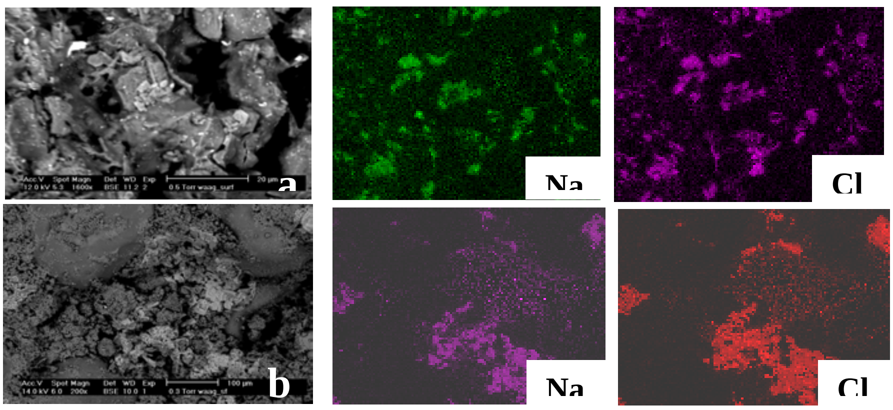

Figure 4 Na and Cl mapping performed by EDX on brick (a) and mortar (b) samples

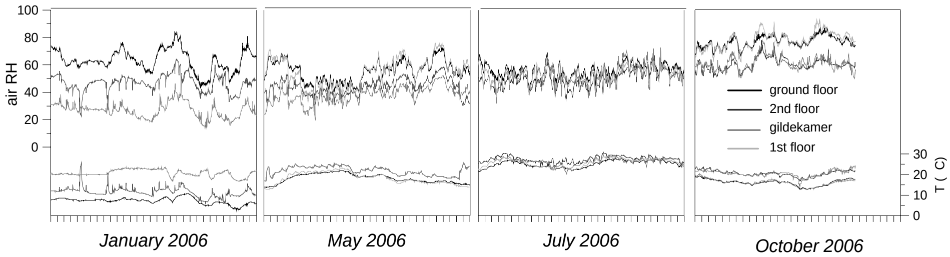

Figure 5 Temperature and RH at different locations in the building

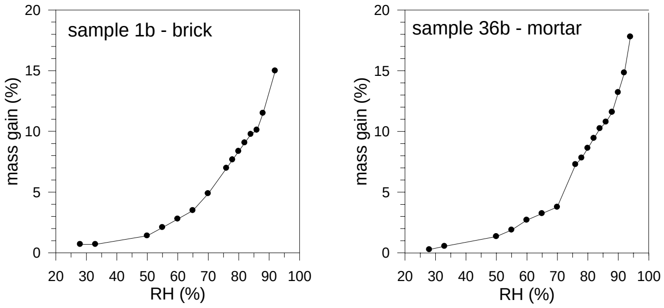

Figure 6 Adsorption curves of sample 1b (left) and 36b (right)

The adsorption curve for sample 1 does not show any clear step; it can be observed that the slope of the adsorption curve increases at 50% and then again at 70% RH. Also is this case, the presence of a salt mix is responsible for this behaviour.

It can therefore be concluded that the hygroscopic moisture uptake already starts at 50% RH and becomes more relevant for RH higher than 65%. This confirms that frequent RH changes through these values enhance the development of the damage by causing dissolution/crystallization cycles of the salt present in the masonry.

5. DISCUSSION AND CONCLUSIONS

From the research performed it can be concluded that the damage in the Waag building is due to the presence of hygroscopic salts in the masonry in combination with variations of the air RH.

The IC, EDX and XRD analyses show that chlorides and nitrates are present in the masonry: these salts are very hygroscopic, i.e. adsorb moisture from the air at relatively low RH. The adsorption experiment has shown that the salt contaminated material starts adsorbing moisture from the air already at 50%RH and, in a larger amount, at 65-70% RH. Monitoring of the indoor climate in de Waag building revealed that the RH often varies across these RH values. This means that the salts present in the wall will adsorb moisture from the air and dissolve when the RH increases above these values and re-crystallize when the RH decreases. These cycles are more frequent on the ground and 1st floor than in the *gildekamer* and on the 2nd floor: these differences explain why the decay is more severe on the walls of the staircase than on the second floor or in the *gildekamer*, even if no clear differences in salt content have been measured between the different locations.

The origin of the salts present in the wall is difficult to assess. NaCl can not be present originally in the brick, since it would have been eliminated during the firing process. The hypothesis that NaCl comes from the mortar seems not probable because of: (i) the quantity of material of the very thin joints being unable to provide so a high NaCl amount as the one found in the masonry and (ii) the salt distribution which does not show any clear difference in salt content between mortar and brick. Therefore, it is more reasonable to suppose that NaCl has reached the masonry after its construction, but its source remains still unclear.

On the basis of the results obtained, an advice for the conservation of the masonry master proofs can be formulated. In order to limit the damage development two options are foreseen: eliminate or reduce the salt amount by desalinating the wall and/or control the RH of the air in order to limit dissolution/crystallization cycles. Hygroscopic moisture adsorption starts already at a low RH (50%), therefore controlling the climate in order to keep the RH always lower than 50% does not seem the best option. This would require a system of air conditioning (the RH is high also in the summer) implying measures (sealing of doors, window etc.) that can be considered quite invasive from the point of view of conservation of the building. The hypothesis of maintaining the RH always higher than the RH of crystallization of the salt mix is not considered realistic, because it would be uncomfortable for the people working in the building and have a high risk of indoor mould growth and/or surface condensation. Desalination seems therefore the best option in this case. Reducing the salt amount in the outer centimeters of the masonry would probably slow down the development of the damage. In fact the salts located near the surface are most susceptible to the RH changes of the air.

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THE EXPERIMENTAL METHODS EXAMINED FOR THE DETERIORATION OF HISTORICAL BUILDINGS WHICH EXPOSED TO THE EFFECTS OF THERMAL WATER: BURSA BATIK (BEKARLAR) BATH CASE STUDY

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ABSTRACT

The paper describes an experimental study aimed at the deterioration of Bursa Bekarlar (Batık) Bath which was exposed to the thermal water. Experimental studies were carried out for the determination of the hazards at the Bath by physical and mechanical properties of the materials.

1. INTRODUCTION

Bursa City has highly rich from its thermal baths and resorts since 6th century in Justinianus period. The thermal water sources come to the surface in Bademli Bahçe and Çekirge Region. Hot water that appears in Uludag’s North foots contains sulphur, iron, magnesium, various minerals and salts. The temperature of the thermal water depends on their sources and between 46-78°C.

There is no exact knowledge about its constructed date. It is understood that the Bath was constructed in Roman Period according to the building materials and construction techniques. The thermal water temperature in the Bath is 51,5°C, water flow 1 lt/sn and thermal capacity is 59400 kcal/hour.

Historian K.Baykal stated that it was used until 1950 but nowadays the bath is in a bad condition because of the abandonment and negligence.

2. ARCHITECTURAL ASPECTS

Batık Bath has two lengthwise rectangular plan, extending along axis in the north-south direction. The first rectangular plan that has a single space is shown as No:1. The other rectangular plan that has two spaces are shown as No:2 frigidarium and No:3 calderium (Figure:1,2).

The entrance of the No:1 space is from the east of the structure with a brick arched door(Figure:3). This place is at the level of -2.80. Its interior dimensions are 5.0x8.5 m. The constructional materials of the bath are ruble stone, brick and timber in the masonry system. The exterior walls are 80 cm. in thickness. The hole on the west door was opened later for passing through the No:3 space. It has barrel vaulted sections on two sides in 3.70m. height from the ground level. The barrel vault was strengthened by two arches in east-west direction. There are three holes used as lighting and installating(Figure:4). It has niches at different sizes on the walls(Figure:5). The thermal water which has a 50°C temperature appears from two place from the ground of this space.

The west side of the entrance facade was later plastered by a cement mortar. There are timber beam holes on the exterior walls. Horizantal timber beams are used in the construction of the wall. And perpendicular timber beams are used along the thickness of the wall to combine the horizantal timber beams.

The entrance to the No:2 is fom the west side of the contruction(Figure:6). This space is called as soyunmalık. Its interior dimensions are 4.95x4.97 m. There are structural cracks on the walls and the vault. It has barrel vault on two sides in 3.40m. height from the ground level. There is one hole on the barrel vault used as lighting and installating. There is the loss of material on the exterior walls.

The No: 3 is on the southwest of the bath at a level of -2.70. The entrance is from the No: 2 from a brick arched door. Its interior dimensions are 3.07x5.25 m. The constructional materials of the bath are ruble Stone, brick and timber in the masonry system. The exterior walls are 80 cm. in thickness. It has barrel vaulted sections on two sides in 4.00m. height from the ground level. The interior walls are plastered by Horasan mortar in Ottoman period. There are two holes on the barrel vault used as lighting and ınstallating. There are signs of *kurna* (fountain) on the east, west and south walls. There is also a sign of window closed later on the west side of the structure.

There are big cracks on the walls and the vault(Figure:7). The thermal water which has a 50°C temperature appears from two place from the ground of this space.

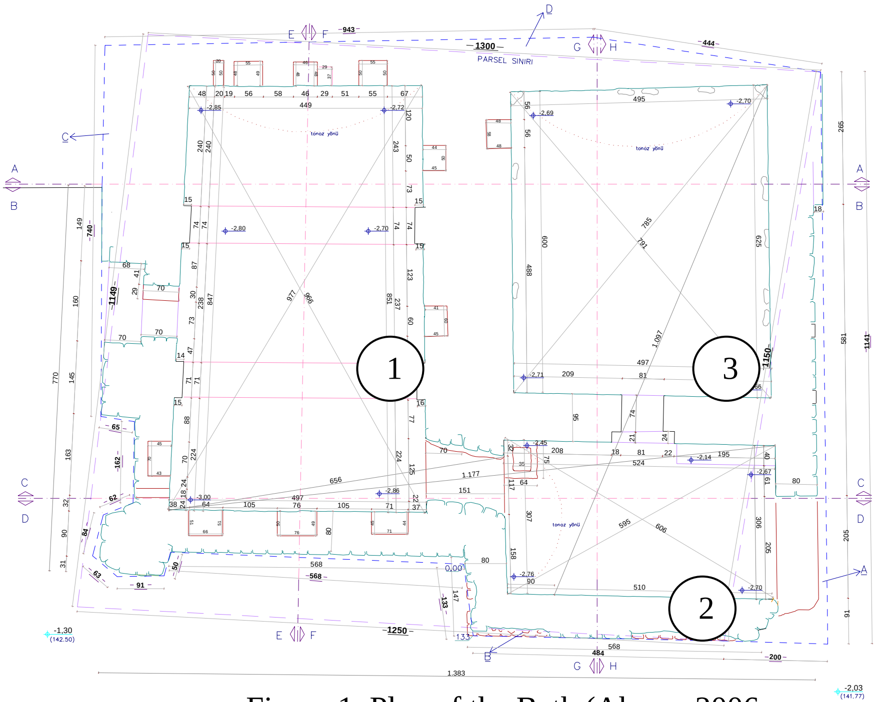

Figure 1. Plan of the Bath (Aksoy, 2006

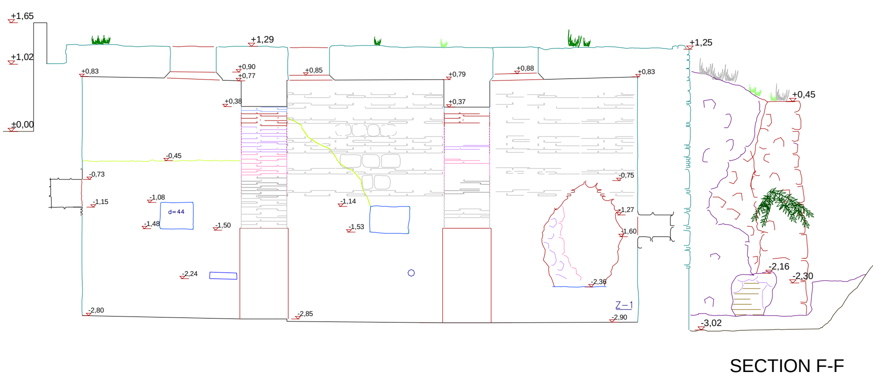

Figure 2. Longitutional section of the Bath (Aksoy, 2006)

Figure 3. East elevation of the Bath

Figure 4. General view of the vault (Space No:1)

Figure 5. Inside of the Bath (Space No:1)

Figure 6. West elevation of the Bath

Figure 7. Cracks on the vaults and lightning holes (Space No:2)

3. CHARACTERIZATION OF CONSTRUCTION MATERIALS

The foundation of the bath was built with ruble stone. The exterior and interior walls were built with ruble stone bonding as ruble stone / large pieces of bricks in the joints. Brick pieces in the ruble stone bond were placed into the lime mortar filling the emptiness among ruble stones parallel to the horizontal joints on the surface and in the thickness of the walls.

The vaults were constructed from brick, lime stone and lime mortar. In the Ottoman period the inside of the Bath was plastered with horasan mortar with a thickness of 2 cm.

The physical and mechanical properties of the materials used in the Bath are determined by taking pyrismatical samples. By using this pyrismatical samples, physical properties as capillary coefficient (C, $gr/m^2\sqrt{min}$.) is given Graph 1, volume density (β, g/cm^3), specific density (γ, g/cm^3), porosity (p,%), mass of water absorption (Ks1,%) and volumetric water absorption (Hs1,%) were

Mass of water absorption and volumetric water absorption also determined in for all types of materials in boiling water and given at Table 2 (Ks2,Hs2).

Figure 8. Samples taken from the Bath

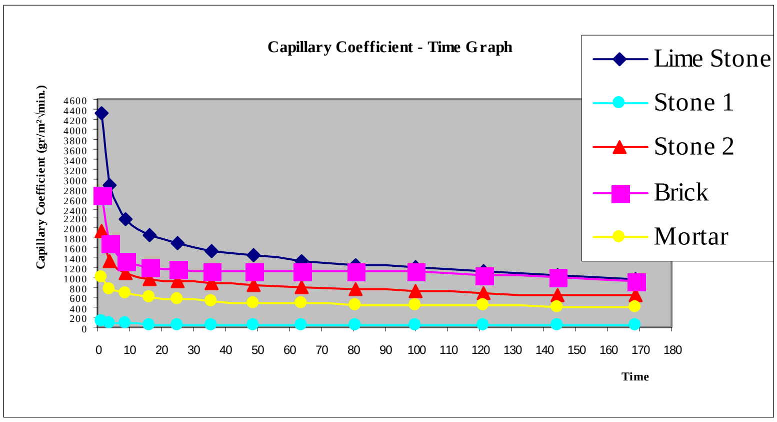

Figure 9. Capillary Coefficient-Time Graph of Bath

Table 1: Physical Properties of Materials of Bath

Materials	β (g/cm³)	γ (g/cm³)	p (%)	Ks1 (%)	Ks2 (%)	Hs1 (%)	Hs2 (%)
Lime Stone	1,87	2,68	30,12	11,89	13,98	21,96	25,02
Stone 1	2,64	2,71	2,41	0,32	0,39	0,86	1,01
Stone 2	2,16	2,67	18,97	4,38	6,19	9,45	13,22
Brick	1,69	2,78	39,15	9,97	15,44	16,97	28,54
Mortar	1,74	2,60	32,96	7,37	9,88	12,79	16,68

After the physical tests, the same materials used for determination of mechanical properties of Batık Bath. The Module of Elasticity (E, N/mm²) is determined as a result of the equation (1), where V is pulse velocity and β is the volume density.

$$E = 10^4 \cdot \frac{V^2}{9,81} \cdot \beta \qquad (1)$$

The Bending Strength (fb, N/mm²) is determined as a result of the equation (2), where Pk is the applied Force, L is the length between axes (100mm), b is the with and h is the height of sample.

$$fb = \frac{(3xPkxL)}{(2xbxh^2)} \qquad (2)$$

The Compressive Strength (fc, N/mm²) is determined as a result of equation (3), where P is the compression Force, A is the sectional area of samples.

$$fc = \frac{P}{A} \qquad (3)$$

Table 2 Mechanical Properties of Bath

Materials	**Ultra. Time (µsec.)**	**Elasticity Modulus E (N/mm²)**	**Bending Strength fb (N/mm²)**	**Compressive Strength fc (N/mm²)**
Lime Stone	48,83	21276,65	2,32	6,12
Stone 1	27,90	60336,80	10,83	116,70
Stone 2	59,00	15261,60	5,89	47,21
Brick	47,93	16804,88	11,14	29,46
Mortar	44,15	8643,17	1,14	9,14

Figure 10. Ultrasound pulse velocity test

Figure 11. Compression test

4. CONCLUSIONS

The following concluding remarks are obtained:

1- It can be stated that the thermal water in the bath mostly affected the limestone material. The limestone material taken from the walls and vaults has high water absorption and the less compression strength. These results are mostly due to the the big gaps in it and because of the deteriorations from hot water.
2- The thermal water gave big hazardous effects to the foundation of the Bath. Almost there have no undamaged stone materials in the foundation. Undamaged samples for testing can only be taken from the walls and vaults.
3- There are a lot of continuous cracks on the walls and on the vaults. These cracks are especially seen in the caldarium because of the hot water that caused the settling down of the foundation.

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THE USE OF RADAR TECHNIQUE AND BOROSCOPY IN INVESTIGATING HISTORIC MASONRY: APPLICATION OF THE TECHNIQUES IN BYZANTINE MONUMENTS IN GREECE

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ABSTRACT

This paper summarizes the results obtained from the application of two investigation techniques, namely radar and boroscopy, in the masonry of three Byzantine Monuments in Greece. The techniques were applied to investigate the type of construction and the presence of timber ties in the masonry. The application of the two techniques proved to be efficient, as their results provided reliable information regarding both the thickness of stones, and the presence and the state of timber ties. In the paper, problems encountered and constraints related to the application of the techniques are commented upon.

1. INTRODUCTION

Dafni Monastery and Osios Loucas Monastery (UNESCO World Heritage Monuments) as well as the church of Panagia Krina are monuments of high architectural and artistic value (Figure 1).

Figure 1: The Katholikon of Dafni Monastery, the Church of Panagia Krina and the Katholikon of Osios Loucas Monastery.

The three monuments built in the period of 11^{th}-12^{th} centuries AD, decorated with marble works as well as mosaics and frescoes, have suffered severe damages during their lifetime, due also to earthquakes. The decision been taken by the Hellenic Ministry of Culture to intervene with the aim to repair damages and to improve the seismic behaviour of the monuments, one of the steps taken was the in situ investigation of the construction type of three-leaf masonry. Information about the construction type of masonry is of paramount importance both for the assessment of the mechanical properties of masonry in the actual state, as well as for the stage of decision-making regarding interventions to be applied. The aim of in situ investigations, using radar technique and boroscopy, was (a) to detect the thickness of stones from both faces of masonry and that of the intermediate filling material, (b) to check whether there are stones connecting the external leaves of masonry, and (c) to check whether there are timber ties within masonry, as well as to check the state thereof.

2. APPLICATION OF TECHNIQUES- PROBLEMS ENCOUNTERED

2.1.Results obtained by radar technique

Radar technique, first applied in the field of geophysical investigation, is based on the theory of electromagnetic signals. It is a non-desctructive technique, therefore adequate for structures of high architectural value. The radar technique is applicable to masonry provided that the conditions mentioned hereafter are satisfied:

(a) An antenna of adequate frequency is used, as the accuracy of the picture obtained through radar depends on the frequency of the emitted signal [3]: Higher frequency signals result to rather limited penetrability, however, the obtained picture is more clear for the limited depth that is investigated.

(b) Since the antenna is moved on the surface of the wall, for this movement to be smooth and for the contact of the antenna with the medium to be continuous, the surface of masonry has to be free of protruding and recessing parts.

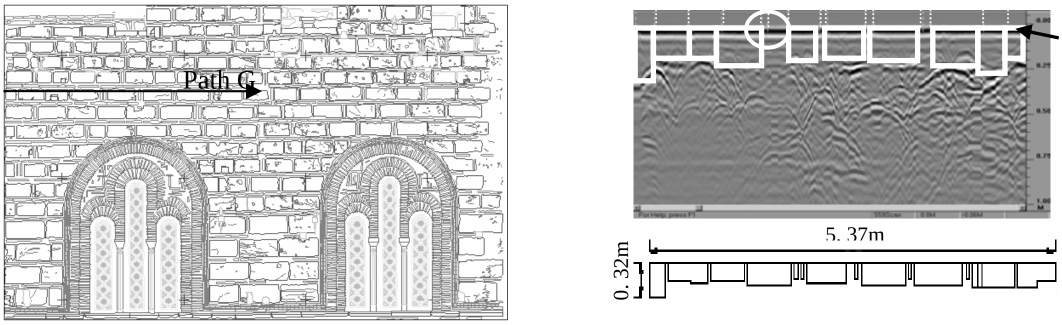
(c) The application of the radar technique is not quite efficient in case of brick masonry, as clay affects the accuracy of the emitted and received signal, because of the attenuation of the signal [3].

(d) Unplastered masonry surface is preferred for two reasons: (i) When the length of stones and the thickness of the mortar joints are known, the interpretation of the results is facilitated, and (ii) the clarity of the results is affected by the nature of the materials the plaster or the mosaic bed is made of [5].

In the profiles obtained by the radar technique, the in-depth dimension is expressed in time units (ns). It expresses the two-way travel time (to and from the target). Using the dielectric constant of the investigated medium, the time is converted to length, so that the depth at which the emitted pulse is reflected can be read on the profile. Figure 2 shows the typical form of presenting data. The location of the path scanned with the antenna is shown on a drawing; the arrow shows the direction of movement of the antenna. Figure 2b shows the data of Path

G, after elaboration, using the software accompanying the equipment. The vertical white dotted lines in the upper part of the picture (two of them are marked with a circle) show the location of mortar joints between consecutive stones. This piece of information is manually introduced and it allows for easier interpretation of the results, as one of the dimensions of the stones appears on the profile. The continuous dark gray line (indicated by the black arrow) constitutes the reflection of the surface of masonry. On the graph, one can distinguish a zone of disturbance at a depth of approximately equal to 0.25m. This zone corresponds to the end face of stones scanned along path G. The findings are presented in a sketch showing the length and the thickness of the stones.

Due to the fact that as mentioned previously, a relatively high frequency antenna was used, with the aim to obtain as accurate as possible results regarding the thickness of stones, the data corresponding to the part of masonry deeper than the back face of the first row of stones are not liable to evaluation (Figure 2).



(a) (b)

Figure 2: (a) Location of Path G (radar). (b) Presentation of radar raw data and of the results in a drawing (horizontal section of masonry).

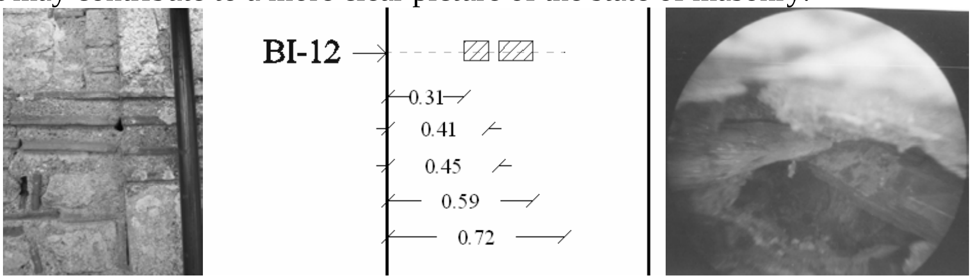
2.2. Results obtained by boroscopy

Boroscopy, first applied in medicine, is a slightly destructive method. Small diameter holes are drilled in masonry, and the application of this technique is acceptable even in case of structures of high architectural value. In any case, after the completion of the investigation, the holes that have been drilled should be adequately sealed.

In places where boroscopy was applied, the following difficulties were faced: (i) To allow for observation along the drilled holes, meticulous cleaning was needed, (ii) In several cases, due to the large thickness of mortar compared to the diameter of the hole, it was not possible to detect the ends of the adjacent stones, or the position of the drilled hole was not the one needed for the timber-tie to be located. Finally, (iii) In some places, drilling was limited to a depth smaller than the predetermined one, when the drilling device met a stone that could not be pierced or, in some cases, metallic objects.

The way the results of observation using the boroscope are presented is shown in Figure 3: The location of the drilled hole is indicated, together with a sketch based on the visual inspection by the observer. The presentation is completed with pictures taken by the observer at various depths.

The observation through boroscope offers, thanks to the direct visual contact of the observer with the inside of masonry, the possibility of detecting discontinuities and holes, as well as to obtain qualitative information about the state of materials that may contribute to a more clear picture of the state of masonry.



(a) (b) (c)

Figure 3: (a) The construction system of Panagia Krina and location of the drilled hole, (b) Sketch based on visual inspection; location of timber elements, (c) Photo of the interior

3. CONCLUSIONS REGARDING THE MASONRY OF THE INVESTIGATED MONUMENTS

Katholikon of Dafni Monastery

It has to be mentioned that the applicability of the radar technique in Dafni Monastery was investigated, during a preliminary stage, by the specialized staff of LCPC-France [1] and gave promising results.

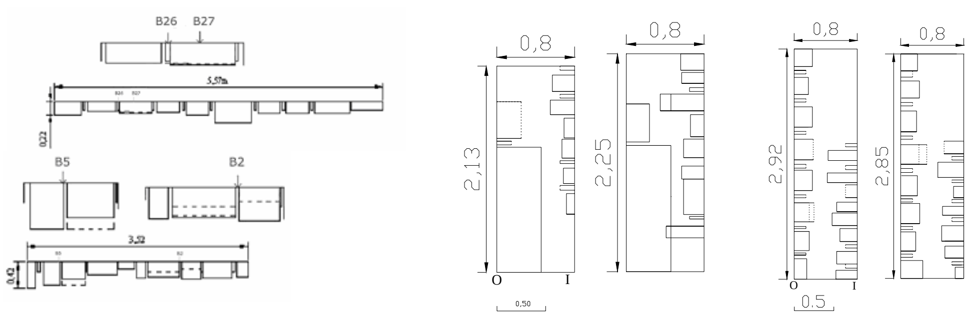
The application of radar technique included several parts of the perimeter walls of the monuments: A total length of more than 200m was investigated along horizontal and vertical paths. Those paths were selected respecting various constraints, namely: (i) Accessibility (locations to be reached by scaffoldings), (ii) the geometry of the monument (accessibility of the same part of masonry both from the exterior and the interior; that this would be desirable in order to gather information about the complete in-depth geometry of masonry), (iii) the existence on the interior surface of masonry of plaster or mosaics, (iv) for the application of boroscopy, holes should not be drilled to regions with mosaics or with original Byzantine mortar.

In this case, boroscopy was applied in positions where the results obtained by the radar technique were not liable. In general, the results of boroscopy are considered to be more accurate, since they are based on visual inspection. Thus, where needed, the pictures taken by radar measurements are corrected accordingly. Nevertheless, in some cases, inspection through boroscope was proven to be inconclusive.

The results of both techniques were re-evaluated and the most reliable ones were selected as final. Even the disagreement between the two methods does not lead to significantly altered basic geometry of masonry in its depth (Figure 4a).

Taking into account the practical purpose of this investigation, it may be assumed that the construction type of masonry was identified in a satisfactory way. All measurements taken by the radar, evaluated and adequately corrected on the basis of the results obtained by boroscopy were plotted on horizontal and vertical sections of masonry.

Two different construction types of masonry are distinguished in the exterior face of the vertical elements. There is a lower zone (from foundation level to the first row of windows), built with large dimension stones, with their length placed horizontally or vertically, to form crosses. In the space between the large stones there are smaller cut stones, as well as solid bricks in the perimeter of stones. In the upper part of the walls, masonry is constructed with smaller stones. Here again, solid bricks are used both within the horizontal and several vertical mortar joints. Horizontal and vertical sections, representing the type of construction of masonry of both zones, are shown in Figure 4.



(a) (b)

Figure 4: (a) Comparison of results obtained by radar and boroscope. Dotted lines indicate the results of boroscopy. (b) Vertical sections of masonry.

A general remark valid for both the lower and the upper zone of masonry is that the construction type is much more complex than that of a masonry consisting of three leaves of practically constant thickness both horizontally and vertically. In fact, in masonry of the Katholikon in Dafni Monastery, the use of stones varying in thickness, both in-length and in-height of masonry leads to increased interface between external leaves and filling material. Thus, a positive effect of the geometry on the mechanical properties of masonry was expected; this was confirmed by mechanical tests [7].

Church of Panagia Krina

The bearing system of the monument consists of three-leaf masonry that presents a variety of construction types in different positions. The external leaves are made of ceramic bricks or stones, with the most frequent type being that of brick masonry in the outer face. A peculiar construction type (with the bricks recessed by almost 20mm from the surface, every second row - Figure 3a) results to a non-planar surface. Only in the lower part of the walls, in limited areas there is rubble stone masonry.

It was known that timber ties are arranged within masonry. However, both their exact location and their state were to be investigated. Timber-ties play a significant role in improving the structural behaviour of historic buildings. In fact, they confine masonry, thus improving its mechanical properties, they provide connection between external leaves and filling material within the thickness of masonry, they improve the shear and the out-of-plane flexural behaviour of walls, etc. Their degradation, however, becomes a source of weakness, as their structural effect is diminished or even cancelled, whereas the cross sectional dimensions of masonry are significantly reduced. In addition, replacement or substitution of degraded or completely destroyed timber ties is a difficult intervention that needs to be based on a good knowledge of both the geometry and the state of original timber ties.

Because of the geometry of the outer face of masonry, the radar technique could be applied only in the plane surface of the internal face of the walls. Nevertheless, the results of this method proved to be unclear and, therefore, inconclusive: As the interior face of masonry is covered with frescoes, it was not possible to identify the type of masonry (brick or stone masonry) under the frescoes. Furthermore, the difficulties in applying the radar technique in case of brick masonry, the effect of the type of mortar/plaster on the reliability of results, as well as the numerous interfaces (between bricks and stones, between masonry leaf and filling material, voids in places of degraded timber ties, etc) the signal meets when passing through masonry, led to a very limited applicability of the technique.

Thus, information about the construction type of masonry was collected in regions of severe damages (by direct visual inspection or by boroscopy). Boroscopy was applied in a systematic way in order to locate timber ties and assess the state thereof. For this purpose, existing holes within the thickness of masonry were used. In areas without holes, or where the existing ones were not sufficient for the investigation, new holes were drilled. Their positions were chosen carefully, so that: (a) to drill only the absolute necessary holes; and (b) to avoid drilling in regions of old mortars or frescoes in the interior of the Church.

The mapping of the timber ties system in the Church of Panagia Krina was based on the results of investigation through boroscope in almost 100 positions. The mapping was completed by recording also the apparent timber elements of the monument (e.g. lintels, base of the cupola, timber ties of the pier-walls, etc - Figure 5).

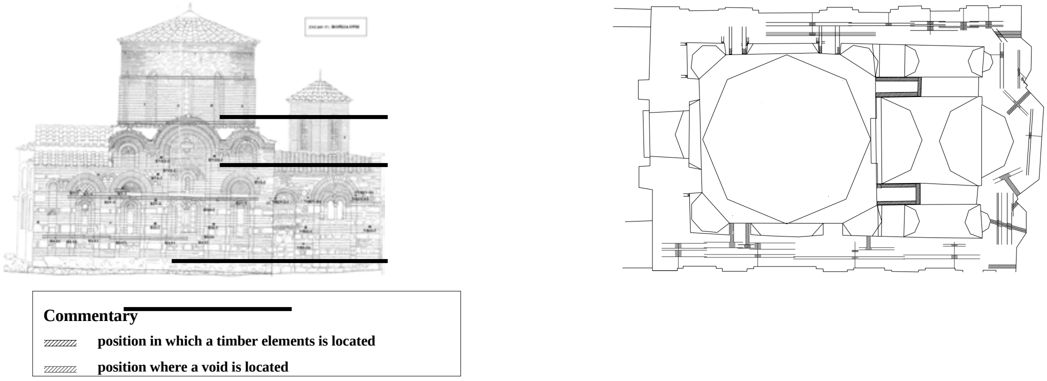


Figure 5: Mapping of the timber ties system (north face and first level plan).

Katholikon of Osios Loucas Monastery

The in situ investigations in the Katholikon of Osios Loucas Monastery are still in progress. Preliminary investigations, necessary for planning the entire program were carried out.

The three-leaf masonry of the Katholikon in Osios Loucas Monastery consists of two zones, namely, the lower zone made of bigger stones, and the upper built with smaller stones (Figure 6). In the outer leaf of the walls, which is unplastered, trial measurements were made in regions where the geometry of the stones is known (e.g. in the corners of the walls). The results were satisfactory, and allowed for adequate calibration of the radar.

The interior face of masonry is covered either with marble, or with mosaics, frescoes or plaster. The accuracy of radar measurements is significantly affected. Thus, systematic application of boroscopy is planned, respecting, of course, the constraints resulting from the importance of the monument and its components.

(a) (b)

Figure 6: (a) Lower zone of masonry, (b) Upper zone of masonry.

4. CONCLUSIONS

On the basis of the data presented in this paper, one may conclude that

(a) The application of radar techniques to masonry can yield reliable results regarding the in-depth geometry of unplastered masonry. For this purpose, rather high frequency antennas should be used; thus, the depth for which the results are accurate enough is limited to part of masonry thickness. The effect of unavoidable

local inaccuracies in estimating the thickness of individual stones is not significant, since the mechanical properties of masonry are rather insensitive to the local geometry.
(b) Nevertheless, when masonry is plastered or covered with frescoes or mosaics or it has a non-planar surface, the information gathered by means of radar measurements may be inconclusive or ambiguous. Therefore, the technique should be applied with caution. It should preferably be applied by personnel familiar not only with the technique but also with the examined monument as well; this is a prerequisite for adequate interpretation of measurements.
(c) In any case, the combination of this non-destructive technique with the boroscopy may enhance the accuracy of the results. In addition, boroscopy may provide information regarding the nature and the state of materials inside masonry.

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EVALUATION OF SEISMIC BEHAVIOR OF HISTORICAL MONUMENTS

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ABSTRACT

Presented in this paper are the results obtained by experimental testing of historical monuments dating from the Ottoman Empire period. Seven mosques and two churches have been selected for investigation and have been tested experimentally applying the ambient vibration testing method to obtain their dynamic characteristics: natural frequencies, mode shapes of vibration and damping coefficients. For determination of material properties of the constitutive materials - stone, brick and mortar, studies on site as well as laboratory testing of samples has been performed.

1. INTRODUCTION

To evaluate the seismic behavior of historical monuments (most of which have been damaged and restored in the past) one of several important aspects that should be considered is definition of the actual state of the monuments, i.e. obtaining of their dynamic characteristics such as natural frequencies, mode shapes of vibration, damping coefficients as well as mechanical characteristics of the constitutive material such as shear modulus, compressive strength, tensile strength, modulus of elasticity etc.

In the frames of the bi-lateral Turkey-Macedonia cooperative project entitled "Evaluation of Seismic Safety of Historical Masonry Monuments", realized by the following institutions: Yildiz University-Faculty of Civil Engineering and Architecture, Istanbul and University "Ss. Cyril and Methodius"- Institute of Earthquake Engineering and Engineering Seismology-Skopje, experimentally tested were nine monuments - mosques and churches in Turkey and Macedonia. The experimental testing of the monuments consisted of two main phases: in-situ testing of dynamic characteristics applying ambient vibration testing method and testing of material properties on site and in laboratory conditions.

2. SELECTED MONUMENTS FOR EXPERIMENTAL TESTING

According to the program of investigation, for testing selected were nine representative historical monuments - seven mosques and two churches.
For all the monuments characteristic is that the structural system consists of massive facade walls (thickness up to 200 cm), constructed of stones or stones and bricks in lime mortar in both directions. The vaulted elements and domes rest on these walls and on columns. All monuments are very impressive structures. Some of the monuments have been damaged during the earthquakes in the past and for some of them extensive reconstruction has been carried out.

Five mosques in Istanbul have been selected as representative monuments:

1. Atik Ali Mosque, 2. Mihrimah Mosque, 3. Bayezit Mosque,
4. Cerrah Mehmet Pasha Mosque and 5. Valide Sultan Mosque

In Macedonia, two mosques and two churches have been selected for testing:

1. Mustafa Pasha Mosque in Skopje, 2. Yeni Mosque in Bitola, 3. St. Nikola Church in the village of Psaca, Kriva Palanka and 4. St. Petar and Pavle Church in the village of Mesheista, Ohrid

The appearance of the monuments is presented on Figs. 1-4.

Figure 1. Atik Ali Mosque and Mihrimah Mosque, Istanbul

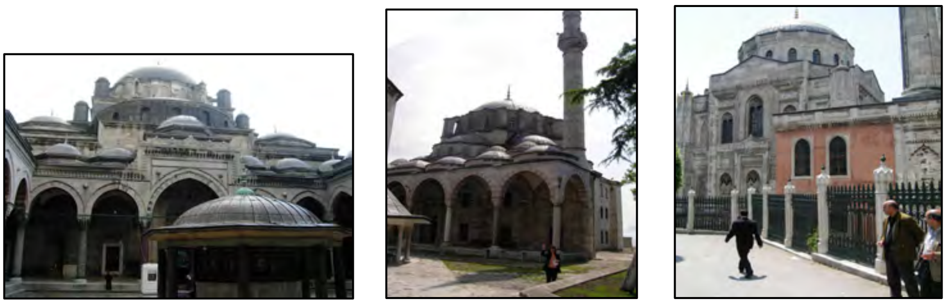

Figure 2. Bayezit Mosque, Cerrah Mehmet Pasa Mosque,Valide Mosque, Istanbul

Figure 3. Mustafa Pasha Mosque, Skopje and Yeni Mosque, Bitola

Figure 4. St. Nikola Church, Psaca and St. Petar and Pavle Church, Mesheista

3. EXPERIMENTAL IN-SITU DYNAMIC TESTING

In-situ experimental testing of dynamic characteristics of the monuments was performed applying the ambient vibration method. The appropriate testing equipment used for the measurements is presented on Fig. 5. To measure wind exited vibrations, three 'Ranger' type seismometers, SS-1 model, manufactured by Kinemetrics, USA were used (a). The signal conditioner (b) model SC-1, also manufactured by Kinemetrics was used for both amplification and simultaneous control of the seismometers. The records were processed by two channel Spectrum Analyzer model 3582A, HP product (c). The processing technique is digital - fast Fourier transform of the signals in frequency domain.

In order to define the dynamic behaviour of the monuments, the following dynamic properties were measured: natural frequencies, mode shapes and damping coefficients. The natural frequencies were evaluated from the Fourier amplitude spectra (FAS), plotted using a small x-y plotter (d) for both translational directions (1-1 and 2-2) and for torsion. Table 1 shows the resonant (natural) frequencies for the measured monuments, clearly selected for all monuments. The mode shapes were derived from the peak amplitudes of the FAS at corresponding measuring points along the height of the structures.

The representative Fourier amplitude spectra for the monuments are given on Figs. 6-14, together with the vertical mode shapes of translational vibrations.

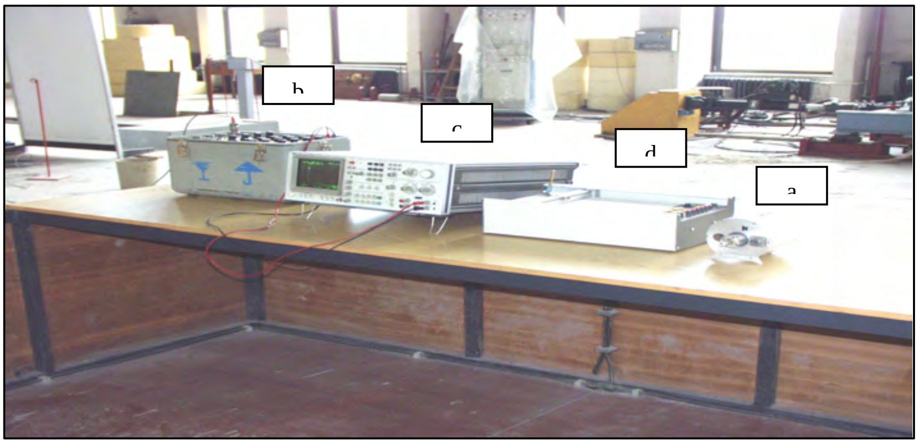

Figure 5. Equipment used for ambient vibration measurements

Table 1: Resonant frequencies and damping coefficients for the monuments

Monument	**Resonant frequency (Hz)**			
	Direct. 1-1	Direct. 2-2	Torsion	Minaret
Atik Ali Mosque	3.0/10	3.4 /11.6	4.8/10	-
Mihrimah Sultan Mosque	2.0/16	2.4/12.6	3.2/11	1.12/13
Bayezit Mosque	2.6/16	2.6/13.5	4.0/6.3	0.96/15
Cerrah Mehmet Pasha mosque	3.2/12.5	3.4/12.5	5.2/7	1.4/20
Valide Sultan Mosque	4.4/6.8	4.0/9.1	8.6/7.1	1.12/25
Mustafa Pasa Mosque	3.0/10	3.2/8.3	5.4/6.5	1.04/16
Yeni Mosque	4.6/5.7	4.2/4.2	6.4/4.2	-
St. Nikola Church	4.0/8.3	5.4/6.5	6.4/5.2	-
St. Petar and Pavle Church	3.8/4	6.6/5.7	4.2/4.2	-

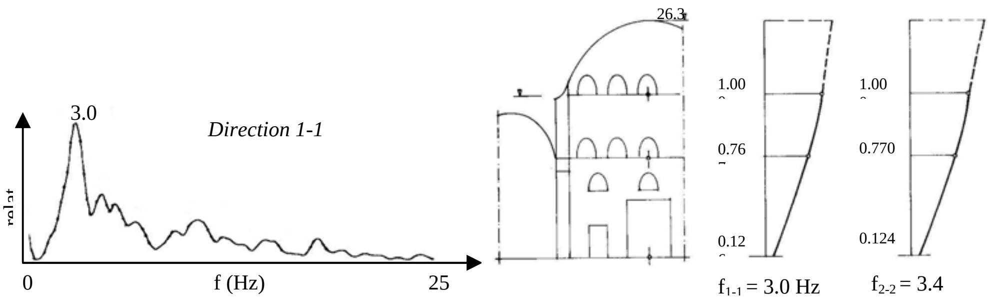

Figure 6. FAS in 1-1 direction and mode shapes of vibration - Atik Ali Mosque

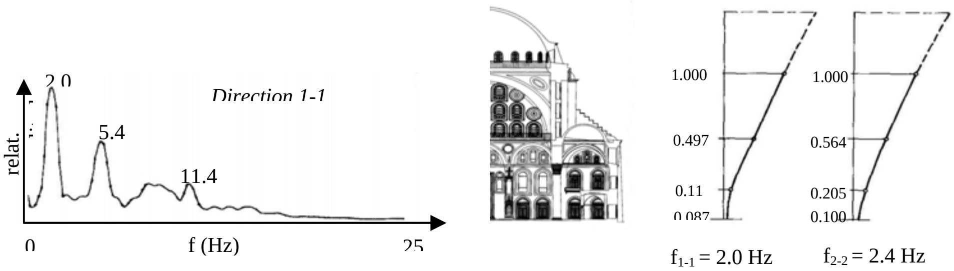

Figure 7. FAS in 1-1 direction and mode shapes of vibration - Mihrimah Mosque

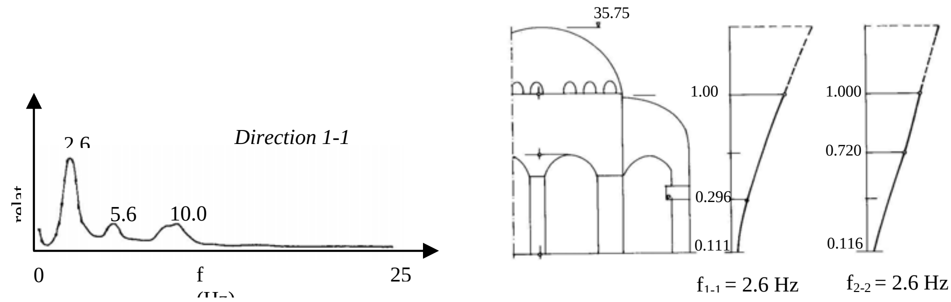

Figure 8. FAS in 1-1 direction and mode shapes of vibration - Bayezit Mosque

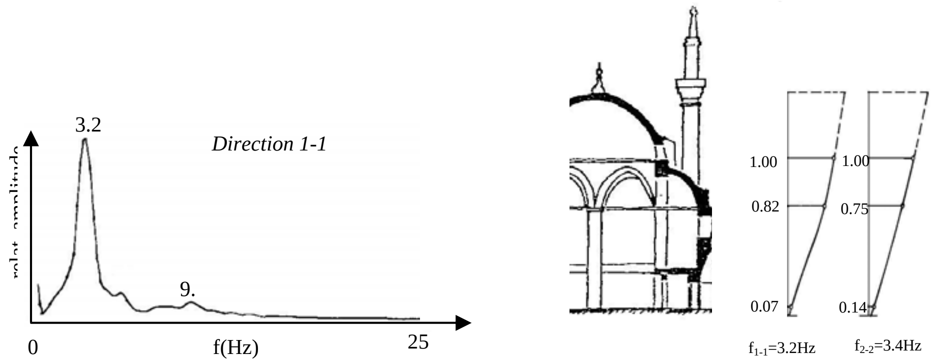

Figure 9. FAS and mode shapes of vibration - Cerrah Mehmet Pasha Mosque

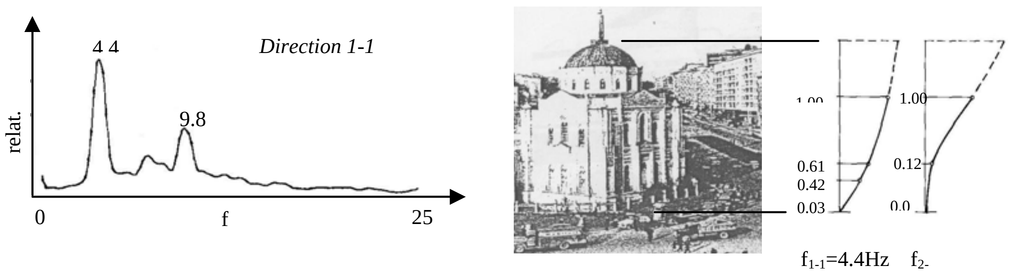

Figure 10. FAS in 1-1 direction and mode shapes of vibration - Valide Mosque

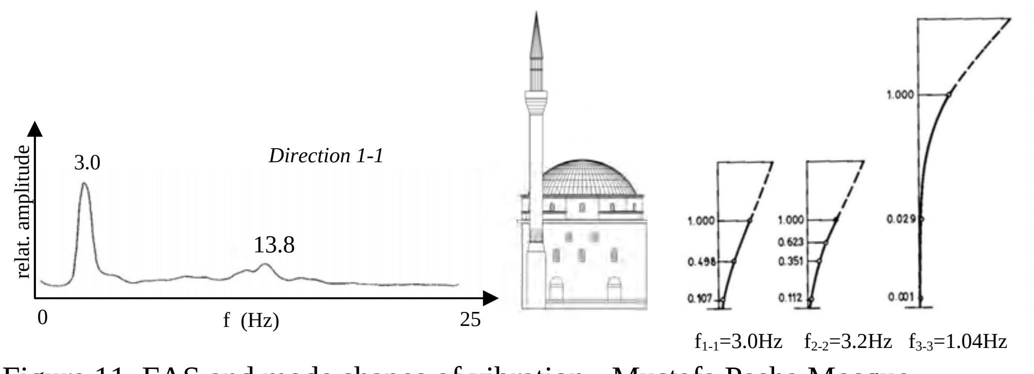

Figure 11. FAS and mode shapes of vibration - Mustafa Pasha Mosque

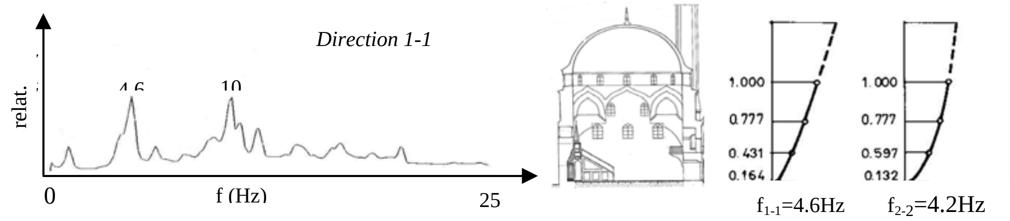

Figure 12. FAS in 1-1 direction and mode shapes of vibration - Yeni Mosque

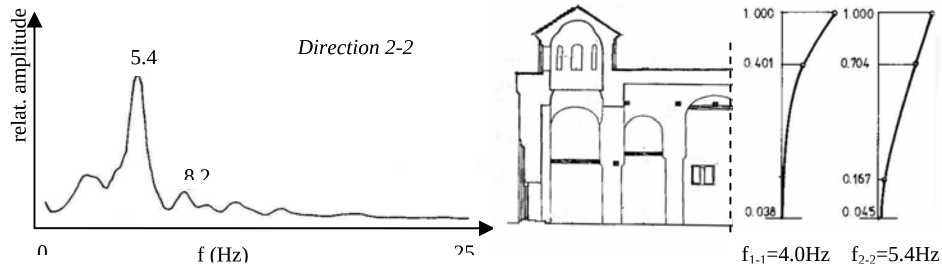

Figure 13. FAS in direction 2-2 and mode shapes of vibration - St Nikola Church

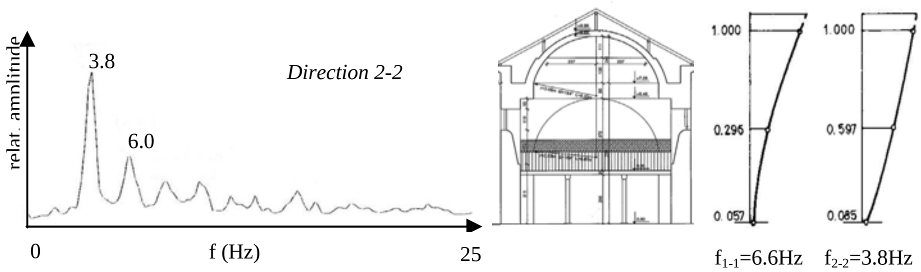

Figure 14. FAS and mode shapes of vibration - St Petar and Pavle Church

4. DETERMINATION OF MATERIAL PROPERTIES

4.1. Studies on site

For each monument temperature and relative humidity of the surfaces were measured by using protimeter survaymaster type measurement device. Surface hardness was determined by using P type Schmidt hammer, Fig. 15.

Figure 15. P type Schmidt hammer test and ultrasonic pulse time measurement

Ultrasonic pulse time was measured according to ASTM C597-BS 1881 by using PUNDIT type pulse device having frequency of 55 kHz at specified length. Indirect transmission was applied, as can be seen in Fig.15

Core samples having nominal diameter of 50 mm were drilled from the specified zones after the non destructive tests were completed, Fig. 16. In order to determine the compressive stress in specified zones, flat jack measurements were carried out according to ASTM C 1196-92.

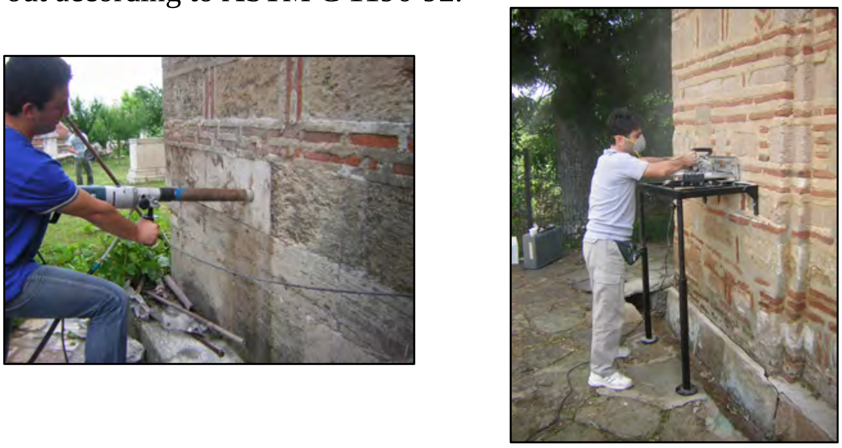

Figure 16. Core drilling and flat-jack application

Mortar and brick samples were also taken out after the flat-jack application. Mechanical and physical experiments were carried out on these samples in Building Materials Laboratory.

4.2 Studies in laboratory

Uni-axial compression test was carried out on stone specimens using load controlled device having capacity of 35 tons and compressive strength was determined. Equivalent cube compressive strength of core samples was calculated by taking drilling effect and size effect into account.

Brick samples were prepared for mechanical tests according to the related standards. Uni-axial compression test is applied as 5-6 kgf/cm^2/s and compressive strength (f_b, N/mm²) is calculated.

Figure 17: Compression test in brick samples

In Table 2, 3 and 4 presented are the results obtained for the material characteristics for the monuments.

Table 2: Mechanical properties of natural stones

Name of the monument	**f_{cube} (N/mm^2)**	**E_s (N/mm^2)**
Mustafa Pasha Mosque	19,6	15467
St. Nikola Church	14,7	11710
Yeni Mosque	108,7	84215
St. Petar and Pavle Church	76,4	59353
AtikAli Mosque	28,3	15530
Cerah Mehmet Pasha Mosque	16,4	14897
Mihrimah Sultan Mosque	12,7	9353
Bayezit Mosque	22,8	14830
Valide Sultan Mosque	21,9	17070

Table 3: Flat-jack Test Results

Name of the monument	**h*(m)**	**In-situ compression stress (MPa)**
Mustafa Paşa Mosque	2,60	1,10
Saint Nicola Church	1,49	0,24
Yeni Mosque	1,20	1,63
St. Petar and Pavle Church	1,15	0,71

Table 4: Physical and Mechanical Properties of Bricks

Name of the monument	**. (g/cm^3)**	**f_b (N/mm^2)**	**E_s (N/mm^2)**
St. Nikola Church	1.8	14,7	11710
Yeni Mosque	1.7	6,8	5640

5. CONCLUSIONS

Historical monuments dating from the Ottoman Empire represent structures for which seismic analysis cannot be performed by using the seismic design codes for modern buildings. Obtaining of the dynamic characteristics of the monuments as well as mechanical characteristics of the constitutive material, are ones of several important tasks for appropriate estimation of the seismic resistance. The results obtained from the experimental testing as well as performed numerical analyses are good qualitative base for developing and application of an appropriate strengthening methodology, if necessary.

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STRUCTURAL FEATURES OF GOTHIC STYLE CHURCHES IN THE EARTHQUAKE PRONE MEDITERRANEAN AREA

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ABSTRACT

This paper focuses on the dynamic behaviour of Gothic churches and in particular of the Fossanova Abbey's church (Latina, ITALY), which represents a magnificent example of pre-Gothic style church. Based on a specific survey, it is shown that this structural typology is largely present in the Mediterranean area, especially in many European Countries characterized by a high-medium seismic hazard. Therefore, detailed investigations have been carried out on the Fossanova church to identify the main constructional parts as well as the mechanical and physics features of the constituting materials. Then, both ambient vibration tests and numerical modal identification analyses by finite element method have been applied, allowing the detection of the main dynamic response. In the whole the present study has to be intended as a preliminary activity of a more comprehensive research work devoted to assess the seismic vulnerability of Gothic style churches.

1. INTRODUCTION

Gothic architecture spread since the 12th Century and broke out during the Middle Ages in the cultural and religious area of the Christianity of Western Europe, with some trespasses in the Middle East and in the Slavic-Byzantine Europe. Many important abbeys were built in those areas, providing a key impulse to the regional economy and contributing to a general social, economic and cultural development. The most interested areas sprawl from the northern Countries (England) to those facing the Mediterranean Basin (Italy), but also spread out from the Western (Portugal) to the Eastern Countries, as Poland and Hungary (see Figure 1). Monastic orders and in particular the Cistercian one, with its monasteries, had an important role for broaden the new architectonic message, adapting to the local traditions the technical and formal heritage received by the Gothic style [1, 2, 3]. Under the architectural point of view, Gothic churches were characterized by an astonishing vertical tendency towards the heaven, which provided a peculiar structural slenderness [4, 5]. For these reason, Gothic churches may result particularly sensitive to earthquake loading. Therefore, within the European research project “Earthquake Protection of Historical Buildings by Reversible Mixed Technologies” (PROHITECH), this structural typology is going to be investigated by means shaking table tests on large scale models [6]. Based on a preliminary study devoted to define typological schemes and geometry which could be assumed as representative of many cases largely present in the seismic prone Mediterranean Countries, the Fossanova church, which belongs to the Cistercian abbatial complex built in a small village in the central part of Italy, close to the city of Priverno (LT), has been selected as an interesting example of pre-Gothic style church [7].

2. GOTHIC CHURCHES IN THE MEDITERRANEAN AREA

In Figure 1, the geographical location of the main Gothic churches and the map of the seismic risk in Europe are overlapped, allowing the presence of Gothic churches in areas characterized by a high seismic hazard to be identified. It is apparent that areas with intense seismic activity, such as the southwest zone of the Iberian peninsula, the Pyrenean chain, large part of the Italian peninsula, the Croatian coasts and some areas of the Hungarian and Rumanian territories, were not spared from the construction of Gothic churches in the Middle Ages. On the other hand, it should be stated that that Gothic churches were undoubtedly limited in the seismic prone regions in terms of both number of examples and the dimensional grandeur that usually characterizes this architectural style. In the following, some of the most important Gothic churches located in high seismic intensity areas have been selected, trying to identify the structural peculiarities and possible architectonical similarities.

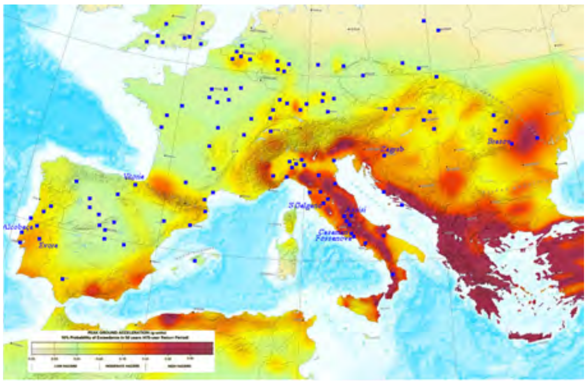


Figure 1: European seismic hazard map and location of main Gothic churches

The cathedrals of Alçobaca (Fig. 2a) and Evora (Fig. 2b) are situated in Portugal. The former is the integral part of an abbey founded in 1152 by the

Cistercian monks. The west body of the church is constituted by three naves and twelve spans and it ends with a transept. On the main façade there are two bell towers. The main characteristic of the Portuguese Gothic architecture is the unusual inclination towards a predomination of decoration. These aspects are clearly present in the Evora cathedral, which was founded between 1184 and 1204. It is characterized by as a Latin cross plan, with three aisles, a triforium and an apse with three chapels. In the Basque provinces, the cathedral of St. Maria Vieja in Vitoria (Fig. 2c) was built in the 14th century. The interior of the church is developed on three levels (arcades, triforium, claristorio) with quadripartite ribbed vaults. Outside, the structure shows flying buttresses (added in a second time) and a bell tower (added in the late Renaissance period) [8].

a) The Alçobaca cathedral

b) The Evora cathedral

c) The Vitoria cathedral

Figure 2: Gothic churches in the Iberian peninsula

Gothic churches are spread in the Italian peninsula and especially in its central regions. The Saint Galgano is a Cistercian church built between 1201 and 1218 near Siena (Fig. 3a). It is partially destroyed, but the Latin cross plan with a nave and two aisles, the seven spans delimiting the western part of the church, a transept and the quadrangular board can be recognized. According to the Cistercian tradition, simple buttresses leaning against the walls of the structure are present. The Casamari Abbey is one of the most important Italian monasteries in Gothic Cistercian architecture, built in 1203 (Fig. 3b). It is another important expression of the Gothic style wanted by the Cistercian Benedictine order, which is characterized by a Latin cross plan with a nave and two aisles, constituted by seven spans, a transept and rectangular apse, lined with chapels. It has many architectonic and structural similarities with the Fossanova abbey (Fig. 3c).

a) The Saint Galgano church

b) The Casamari abbey

c) The Fossanova abbey

Figure 3: Gothic churches in the Italian peninsula

The Basilica of St Francis in Assisi, which was built in the 13th century, is very different from the Cistercian tradition: it is made by two churches, with the upper "Gothic" over the lower "Romanic" (Fig. 4a), has only one nave and a transept.

The nave has strong buttresses (like semicircular towers) and massive flying buttresses (Figs 4b and 4c). Important earthquakes occurred along its life, but the lack of maintenance and a large volume of fill in the springier zones (Fig. 4e), accumulated over centuries of roof repairing, brought to the great damages arisen with the earthquake of Sept. 1997. Two nave vault spans collapsed: the first close to the façade (Fig. 4d,e) and the other close to the transept (Fig. 4f). Moreover a portion of the left transept tympanum failed, producing large cracks and permanent deformation all over the survived vault spans [9].

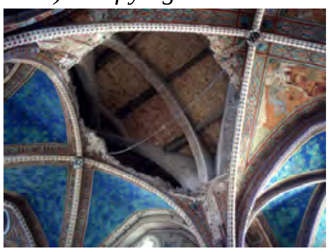
a) the double Basilica

b) the tower shape buttresses

c) one flying buttresses

d) the first span collapse

e) the filling over the first span



f) the span close to the transept

Figure 4: The St Francis Basilica in Assisi

3. THE FOSSANOVA CHURCH

3.1 Geometrical Features

The Fossanova Abbey was built in the XII century and opened in 1208. The architectural complex was probably designed and realized by French and local monks workers. The church shows the aesthetics ideas of St. Bernard with a floor scheme composed of three rectangular aisles, with seven bays, transept and rectangular apse. Between the main bay and the transept raises the skylight turret with a bell tower (Figure 5). The main dimensions are 69.85 m (length), 20.05 m (height), and 23.20 m (width). The nave, the aisles, the transept and the apse are covered by ogival cross vaults.

The previously mentioned vaulted system does not present ribs, but only ogival arches transversally oriented respect to the span and ogival arches placed on the confining walls. The ridge-poles of the covering wood structure is supported by masonry columns placed on the boss of the transversal arches of the nave and apse. The crossing between the main bay and the transept is covered by a wide ogival cross vault with diagonal ribs sustained by four cross shaped columns delimiting a span with the dimensions of 9.15x8.85m. On the extrados of the vault there is a circular opening that enables a link between the inside of the church and the bell tower (Figure 6). The main structural elements constituting the central nave and the aisles are four longitudinal walls (west-east direction). The walls delimiting the nave are sustained by seven couples of cross-shaped piers (with dimensions of 1.80x1.80 m) with small columns laying on them and linked to the arches. The bays are delimited inside the church by columns with adjacent elements having a capital at the top. The columns-capital system supports the transversal arches of the nave. The external of the clearstory walls are delimited by the presence of buttresses with a hat on the top that reaches the height of 17.90 m. The walls of the clearstory present large splayed windows and oval openings that give access to the garret of the aisles. Also the walls that close the aisles present seven coupled column-buttresses systems reaching the height of 6.87 m and further splayed windows.

During the centuries, the complex suffered some esthetical modifications respect to the initial scheme. In particular, during the second twenty years of the XIII century the main prospect has been modified, eliminating the narthex and installing an elaborate portal with a large rose-window. In 1595, due to the damages caused by a thunder, a part of the roof and of the lantern were rebuilt, introducing a Baroque style skylight turret. Finally, in the XX century, additional modifications on the roofing of the church were applied, firstly with the reduction of the slope of pitches and then with the restoration of the same slope as in the original form.

Figure 5: The fossanova church - general view and main façade

Figure 6: Internal view – the nave vaults

3.2 Experimental investigations

Based on visual examination, the basic material constituting the constructional elements of the church is a very compact sedimentary limestone. In particular, columns and buttresses are made of plain stones with fine mortar joints (thickness less than 1 cm). The lateral walls (total thickness 120 cm) consist of two outer skins of good coursed ashlar (the skins being 30 cm thick) with an internal cavity with random rubble and mortar mixture fill. In order to determine the actual geometry and the mechanical features of the main constructional elements, an accurate experimental activity has been developed. In particular, both in situ inspection and laboratory tests have been carried out. In order to inspect the hidden parts of the constituting structural elements, endoscope tests have been executed on the right and left columns of the first bay, on the third buttress of the right aisle, on the wall of the main prospect and at the end on the filling of the vault covering the fourth bay of the nave. The test on the columns, the buttress and the wall (drilling depth of 99 cm), relieving a total lack of internal vacuum, with the predominant presence of limestone connected with continuum joints of mortar (Figure 7,8). The test made on the extrados of the vault, with a drilling depth of 100 cm, allowed a first layer of 7 cm made of light concrete and then a filling layer of irregular stones and mortar with the average thickness of 10 cm to be identified.

Figure 7: Endoscope tests on the buttress

Figure 8: Mortar joint

In order to define the mechanical features of the material, original blocks of stone were taken from the church and submitted to compression tests. In total, 10 different specimens having different sizes have been tested, giving rise to an average ultimate strength of about 140,00 MPa and an average density g_m=1700 kg/m^3. Besides, based on the results obtained for three different specimens, the Young's modulus equal to 42.600 MPa has been assessed, while the Poisson's ratio n_m has been estimated equal to 0.35.

Also, mortar specimens were extracted from the first column placed on the left of the first bay, from the wall of the aisle on the right and from the wall on the northern side of the transept. The specimens were catalogued as belonging to either the external joints (external mortar) or to the filling material (internal mortar). Compression tests have been carried out according to the UNI EN 1926:2001 provisions, relieving a noticeable reduction of the average compressive strength for the specimens belonging to the external mortar (R_m 3.33 MPa) with respect to the internal ones (R_m 10.30 MPa). Besides, the Young's modulus has been determined on three different mortar specimens, according to the UNI EN 1015-11:2001 provisions, providing values ranging from 8.33 MPa to 12.16 MPa.

Chemical and petrography analyses have been also performed on the mortar specimens. In particular, chemical tests were made by X rays diffractometer analysis, according to the UNI 11088:2003 provisions. The prevalence of three material, namely, quartz crystal SiO_2, crystallized calcium carbonate $CACO_3$ and some traces of felspate, was noticed. Also, a petrography study on thin sections of mortar specimens have been done by using two electronic microscopes, according to the UNI EN 932-3:1998 provisions. The analysis relieved the presence of quartz crystal sand end felspate, without any significant presence of crystallized calcium carbonate. The binding was quantified with a percentage of 60% of the total volume.

Finally, the dynamic features of the whole church have been estimated by ambient vibration (e.g. human activity at or near the surface of the earth, wind, running water, etc.) tests, by measurements on several points of the façade, vaults, aisles and main nave. The tests were performed in cooperation with the Institute of Earthquake Engineering in Skopje, by using 3 Ranger seismometers SS-1 (Kinemetrics production), 4 channels signal conditioner system and two-channels frequency analyzer Hewlet Packard for processing recorded time histories of ambient vibrations in frequency domain and to obtain Fourier amplitude spectra [9]. The total number of measuring points was 25, of which 24 recorded on different points of the church, while one point on the bell tower. Using the well know Peak Picking technique and assuming low damping and well separated modes, several modal frequencies were determined. As evidenced by the obtained Fourier amplitude spectra, along the transversal direction the first peak of the vibration response was at the frequency value f = 3.8 Hz (first transversal mode). Instead, by the longitudinal direction the first peak of the response was at the value f = 4.6 Hz (first longitudinal mode). While, both longitudinal and transversal tests indicated the first torsion mode at the value f = 6.6 ÷ 6.8 Hz.

Based on the results of the above experimental investigation, a detailed numerical FEM model of the whole church (in full scale) has been set up, completely reproducing the geometry of the complex and paying particular attention to the modeling of the main structural elements. The results allowed the assessment of the actual seismic vulnerability of the church, finding that the available seismic capacity is significantly lower that the expected seismic demand for the relevant site [9].

4. CONCLUSIONS

In this paper the dynamic features of the Fossanova church have been identified by experimental (including ambient vibration tests) investigations. The performed analyses showed that the middle part of the church (three central bays) presents higher values of the modal displacements, putting into evidence that it could represent a vulnerable part in case of seismic event. Therefore, the dynamic response of this part has been investigated in a more accurate detail, it representing the prototype to be tested on a shaking table in a reduced scale (1-to-5.5) physical model. Eventually, it should be noted that the study referred in the paper is part of a more extensive research aimed at evaluating the seismic behavior and vulnerability of Gothic churches and developing sustainable intervention methodologies based on the use of innovative reversible mixed technologies.

ACKNOWLEDGEMENTS

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SEISMIC RESPONSE OF THE ENDLESS COLUMN

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ABSTRACT

The paper presents the results obtained on the shaking table of INCERC Iasi where a reduced model of the Endless Column, scaled at 1:20, was tested in real time. The same physical model was tested before in the wind tunnel of Yokohama National University. As input excitations the accelerations of real earthquake Vrancea'77 and those of a sliding sine with sweeping frequencies were used. The seismic response of the model was recorded at its top. The results are useful for a further theoretical study regarding the global safety of this outstanding monument.

1. INTRODUCTION

The Endless Column is a memorial built up 70 years ago by the French sculptor of Romanian origin Constantin Brancusi (1876-1957). It is located on a large and open platform of the Romanian town Targu Jiu located at the foot of Southern Carpathians. The Endless Column together with the Gate of the Kiss, the Alignment of Stools and the Table of Silence, placed along the Road of Heroes, are drawing up an Architectural Ensemble devoted to the Unknown Soldier who disappeared during the First World War on 1914-1918. Since in this Ensemble of Modern Art each group of sculptures has been endowed with a precise function it was also ascribed with a stylisation according to the archetypes of Megalithic Culture. Indeed, the Endless Column was identified with a vertical row of Menhirs, the Gate of the Kiss with a Dolmen, the Alignment of Stools with a horizontal row of Menhirs and the Table of the Silence with its twelve Stools with a Cromlech like the existing vestiges in Carnac, France, Stonehenge, Great Britain and Sarmisegetuza, Romania. It was for the first time in History when the Modern Sculpture at such large scale reflected so faithfully the Ancient Art expressed by stone not only in shape, but mainly in the meaning of their messages [8].

There are known many memorials dedicated to the braves. In Rome, for instance, at Forum Trajane, there is a column of 38m erected in the memory of the Emperor Trajan. In Paris, at Place Vendôme, La Colonne de la Grand Armée of 40m was dedicated to Napoleon. In London, at Trafalgar Square, the Column of Admiral Nelson reaches 56m. In Brussels, at Place de Congrès, the column of King Léopold 1st of 47m was dedicated since 1922 to the Unknown Soldier. All the columns mentioned above are massive and robust, have more than 35 meters in height and support the statues of some personalities. The Column at Targu Jiu is essentially different. It has a modular conception, is flexible and slender, and was raised only to the height of 29.35m without supporting any statue on its top. However, it is the only column in the World called by its author in Paris *sans fin*. Often, during the years its endlessness was perceived by art critics as infinite [7]. Leaving this philosophical meaning aside in 2001, after 64 years since its creation, it was demonstrated that topologically Brancusi's Column is indeed rigorously endless [6]. Then, at beginning of the year 2007, the Architectural Ensemble in Targu Jiu was formally declared by UNESCO an asset of the European Cultural Heritage.

Undoubtedly, the Endless Column is a peerless masterpiece of inestimable value. Since, unfortunately, it is not also everlasting the Column should be carefully maintained and preserved. Beside its safety the serviceability of the Column should be kept under a strict control. According to the Mathematical Theory of Reliability the durability of Column structure is in inverse ratio to its risk factors like: 1) steel corrosion and resistance, 2) foundation bearing capacity, 3) soil stability, 4) temperature gradients, 5) wind action, 6) seismic response and 7) maintenance. Since 2004 six of the seven risk factors, except the seismic response, were already assessed. INCERC Bucharest was involved in four factors [1, 2]. Wind action was examined either theoretically [4, 5] or by using the experimental data supplied by the wind tunnels in Italy and Yokohama, Japan [3, 9, 10, 11, 12]. It is now the turn of seismic risk to be checked out knowing that in Romania the seismic hazard is increasing. Indeed, according to the Code of seismic protection P100:2006 now in force the PGA of Column location in Targu Jiu, calculated for a returning period of 100 years, is 0.12g. By considering a larger returning period of 475 years the design acceleration for the same location will assume a higher value of 0.16g or even 0.20g what is worth of concern.

2. TECHNICAL DATA

The physical model of the Endless Column was scaled at 1:20 (Figure: 1). It consists in a squared steel rod with the sides of 14mm, not 17 mm as it is shown below in the figure 2, according to the original design. Along the rod, used as a supporting core, the decahedral modules made of a light synthetic material, were aligned like bids. The geometric and dynamic parameters of the physical model are comparatively shown below, in table 1, with the corresponding parameters of the Endless Column that was chosen as prototype.

Table 1. Geometric and dynamic parameters

	Prototype: the Endless Column	Elastic model	Similitude criteria
Height H	29.35m	1,467.5mm	1/20
Base of steel core B	0.42m	14mm	1/30
Aspect-ratio H/B	70	105	1/0.67
Inertia radius (average) i	0.17m	4mm	1/42.5
Buckling length 2H	58.70m	2,935mm	120
Slenderness λ=2H/i	345	734	1/0.47
Total mass M (without base)	29,173kg	3.0kg	1/9724
Distributed mass (average) q	994kg/m	2.04kg/m	1/272
Natural frequency ν	0.515Hz	2.5Hz	1/0.21
Period of the first mode T	1.94s	0.40s	1/4.85
Percent of critical damping δ	2%	0.7%	1/2.86
Elastic constant k (equivalent)	304kN/m	740N/m	1/411

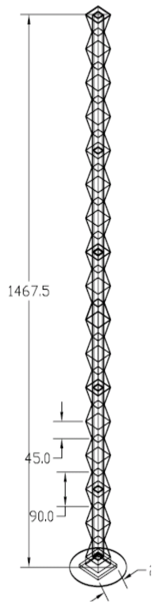

Figure1. Model's view

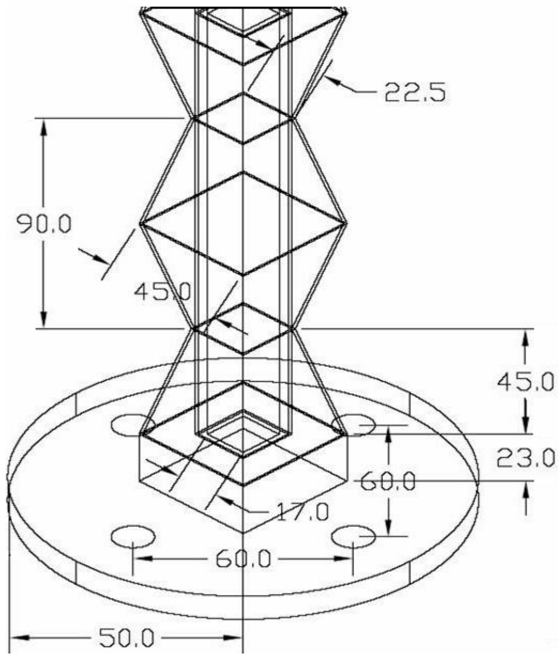

Figure 2. Axonometric view of model's base

3. TEST PROGRAM

Although the physical model of the Endless Column reproduces the geometry and composition of the prototype with high fidelity all geometric and dynamic parameters are much different between them. This is why for the test program the model was regarded independently of its protoype and submitted to real, unscaled, actions: the tectonic earthquake that occurred in Vrancea on 4 March 1977 and a virtual excitation as a sliding sine with sweeping frequencies.

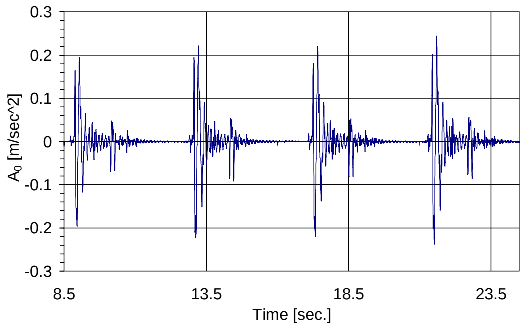

Figure 3. Vrancea'77 N-S;
base induced acceleration

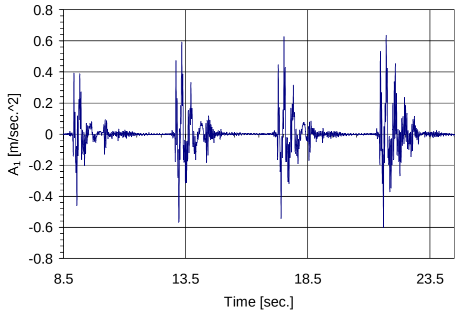

Figure 4. Vrancea'77 N-S;
top response acceleration

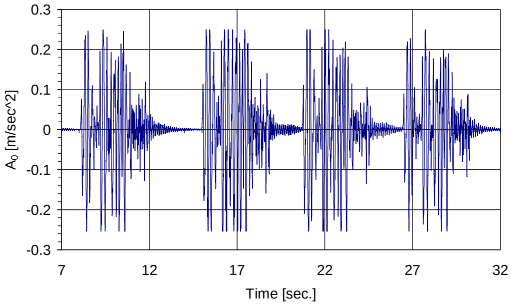

Figure 5. Vrancea'77 E-W;
base induced acceleration

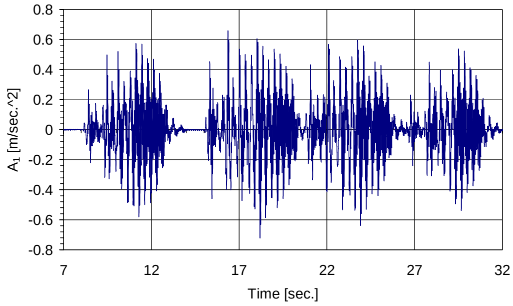

Figure 6. Vrancea'77 E-W;
top response acceleration

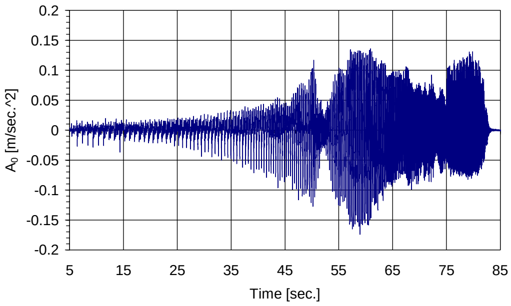

Fig. 7. Sliding sine swept in frequency;
base induced acceleration

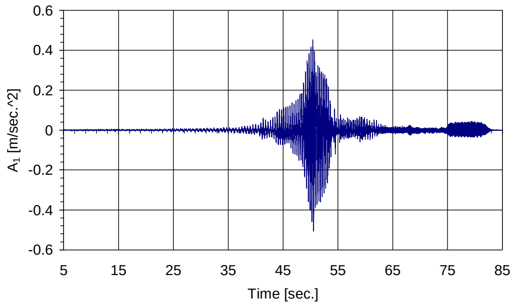

Fig. 8. Sliding sine swept in frequency;
top response acceleration

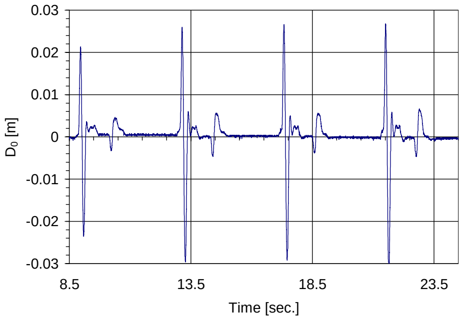

Figure 9. Vrancea'77 N-S;
base induced displacement

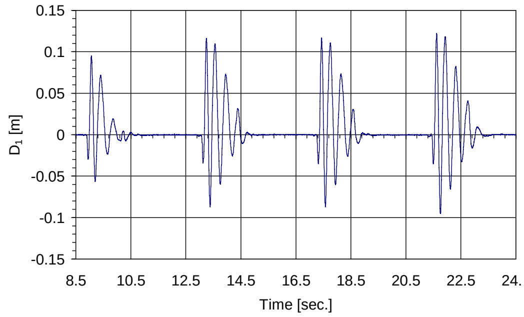

Figure 10. Vrancea'77 N-S;
top response displacement

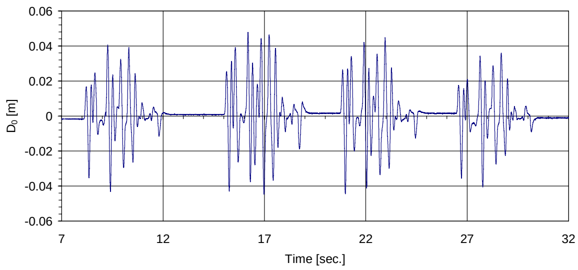

Figure11. Vrancea'77 E-W;
base induced displacement

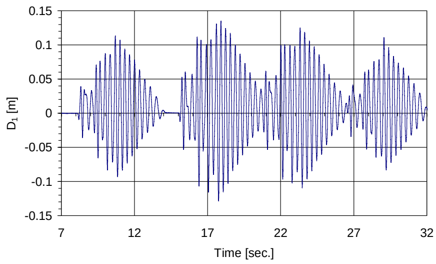

Figure 12. Vrancea'77 E-W;
top response displacement

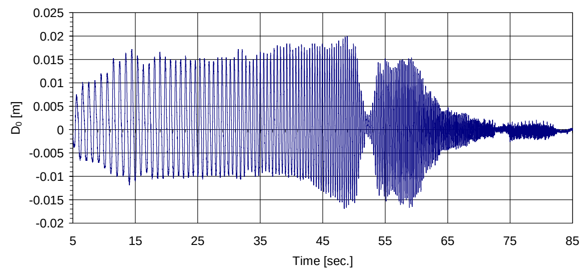

Fig.13. Sliding sine swept in frequency;
base induced displacement

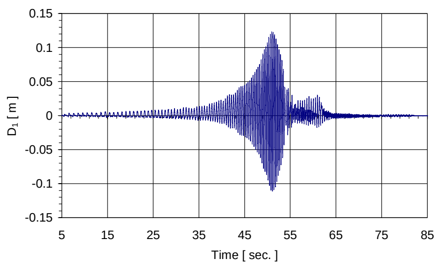

Fig.14. Sliding sine swept in frequency;
top response displacement

In the first series of tests the inputs were successively induced through the base of model by table's platform. For the sake of accuracy each Vrancea input was induced in four successive cycles. The sliding sine excitation was induced randomly with a slow increase at the beginning followed by a sudden decrease and again an increment. The corresponding seismic responses of the model to the first series of excitations were recorded at its top. For an easy comparative examination the input and output diagrams are presented in parallel (Figures: 3-8).

The second series of tests followed the same logical scheme like that used for the first series. However, the inputs were sharper for Vrancea earthquake and much stronger for the sliding sine (Figures: 9-14).

4. TEST RESULTS

The little shaking table was specially prepared for this test in order to avoid mass influence. It has one degree of freedom, namely the horizontal displacement in the input direction (Figure: 15).

Figure15. Two different views of the physical model on the shaking table

Qualitatively, the seismic response of the physical model is suggestively displayed by comparing the input and output diagrams. Due to the influence of elastic forces all the response diagrams preserves the main outline features of the excitation diagrams. However, even weaker the influence of inertial forces excludes a perfect mirroring of the two types of diagrams. Both responses, in accelerations and displacements, are reflecting by their shapes the shapes of inputs, but in a more equilibrated and therefore improved behaviour.

Table 2. Dynamic amplification in accelerations

	Input $\mathbf{A_{base}(m/s^2)}$	**Output** $\mathbf{A_{top}(m/s^2)}$	**Ratio** $\mathbf{A_{top}/A_{base}}$
Vrancea'77: N-S	0.243 0.234	0.619 0.602	2.55 2.57
Vrancea'77: E-W	0.249 0.253	0.650 0.722	2.61 2.85
Sliding sine in frequency	0.140 0.180	0.466 0.505	3.33 2.81

Quantitatively, the seismic response of the physical model is precisely defined by the factors of dynamic amplification. The amplification in acceleration assumes values between 2.55 and 2.85 for Vrancea inputs while for sliding sine the values are a little larger namely, 2.81 and 3.33 (Table 2). Similarly, the amplification in displacements assumes values between 2.80 and 4.53 for Vrancea inputs while for sliding sine the values are much larger namely, 6.42 and 6.75 but correspond to the elastic domain of the steel core (Table 3).

Table 3. Dynamic amplification in displacements

	Input D_{base} **(m)**	**Output** D_{top} **(m)**	**Ratio** D_{top}/D_{base}
Vrancea'77: N-S	0.0267 0.0316	0.121 0.095	4.53 3.00
Vrancea'77: E-W	0.0472 0.0430	0.132 0.126	2.80 2.93
Sliding sine in frequency	0.019 0.016	0.122 0.108	6.42 6.75

Never during those 16 cycles of Vrancea excitations nor of the 2 sliding sine excitations with sweeping frequencies the values of outputs exceeded the input values. Although the ratio of critical damping is rather small all seismic responses were attenuated without displaying any tendency of instability. The homogeneity, symmetry and uniformity of the model would not justify an instable behaviour.

5. CONCLUSION

The main outcome of the test program on the shaking table is that all dynamic parameters of the physical model, its natural frequency including, were confirmed. Therefore from the perspective of d'Alembert Principle the model is a linear structure governed by the elastic forces while the prototype is governed by the inertial ones. This is why the use of similitude methods for this purpose does not seem appropriate. The seismic behaviour of the Endless Column should be further studied with the aid of some theoretical methods. It was also confirmed that for the existing seismic actions the danger of resonance through absorption of the induced energy during earthquakes is less probable. However, in the perspective of increasing the PGA in Targu Jiu some resistance problems of Column's core may arise. Finally, the aging of steel molecular structure should be also considered in analysis.

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SHEAR STRENGTH OF HISTORIC MASONRY WALLS

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ABSTRACT

The paper presents the result of a series of tests consisting of triplet and walls made of historic masonry subjected to combined compression and shear. It appears that the shear strength increases with the increase of pre-compression to a limit. The shear strengths of unreinforced historic masonry obtained from triplet and wall tests are higher compared to the Euro code.

1. INTRODUCTION

The preservation of the architectural heritage presents one of the important challenges in civil engineering due to the complexity of the geometry of the structures, the variability of the materials used and the loading history of the buildings. Further, majority of un-reinforced historic masonry structures are in seismic zones. Although, these historic masonry structures are not considered to be resistant to earthquake loading, many have resisted the effect of seismic action without any damage. Of those that suffered in the past, the most common cause of damage was due to shear. The shear strength and behaviour of modern masonry has been thoroughly investigated with vary shear test methods [1-13], but very little is known about the historic masonry subjected to combined compression and shear [14-17]. The knowledge of strength and behaviour of the historic un-reinforced masonry (HURM) becomes essential for assessing the safety of the structure or for the planning of structurally compatible and economic conservation programme. It was decided to do two types of tests to study the behaviour and strength of HURM [17]:

i) RILEM triplet test [18];

ii) Wall test, since seismic action can be reasonably represented by in-plane horizontal actions [18,19].

2. EXPERIMENTAL INVESTIGATION

To have the meaningful results, it was essential to have similar materials as used in the HURM. Luckily, a few full-scale solid bricks became available during the renovation of a 18th century Italian building, hence test specimens were built in 1/3rd scale utilizing these.

2.1. Triplet Test

RILEM [18] recommends the use of triplet to obtain the shear strength of masonry. The dimensions of the model bricks were 100x50x17mm obtained from sawing the full-scale bricks. The average compressive strength of the model bricks was 34.3 N/mm^2. 1:1:5 (cement: lime: sand) mortar was used for the construction of specimens. The average compressive strength of mortar varied from 2.5 to 4.6 N/mm^2. Figure 1 shows the experimental set up to carry out triplets test. Two independent jacks connected to separate pumps applied pre-compression and shear loads. The pre-compression was applied by jack placed horizontally monitored by a load cell. The pre-compression was kept constant during each test.

(a) (b)

Figure 1 – (a) Experimental apparatus; (b) triplet specimen

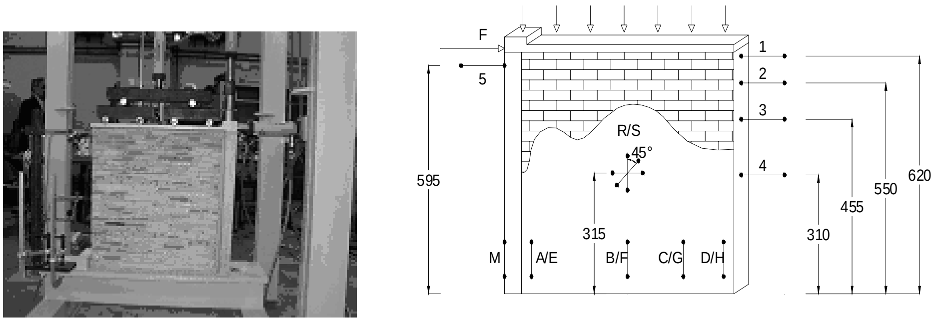
The shear load was applied by the jack placed vertically as shown in Figure 1. The load was measured by a load cell. The applied shear load was increased at stages up to failure.

2.2. Shear Tests on HURM Wall Models

Seven single storey structures designated as W1-W6 were built and tested in a special frame (Fig. 2a). A series of preliminary tests were done on small wallet specimens of HURM to obtain the compressive strength and the modulus of elasticity in two orthogonal directions for theoretical analysis (Tab.1). The flange of the T-section was made from mortar. A steel plate was used as a slab on the top of the wall. The flange and the steel plate on the top of wall were glued with epoxy resin. This was done to avoid failure at the interface of slab and the wall. The historic model test structure is shown in Figure 2(a) and (b).

Table 1- Mechanical values of HURM by compression tests

Average values (N/mm^2)	Direction of test	**Strength Young's modulus**
f_y E_y	Normal to mortar joint	**13.5** **8.76**$\cdot 10^3$
$\mathbf{f_x}$ $\mathbf{E_x}$	Parallel to mortar joint	**10.4** **6.90**$\cdot 10^3$



(a) (b)

Figure 2 – (a) Wall model and apparatus; (b) dimensions and point of measure.

Three load cells measured the applied loads. Before the application of shear load, the pre-compression was applied to both the web and flange of the wall and kept constant throughout the test. The shear load was applied at stages till the failure and deflections and strains were also measured at various levels. In Figure 2(b) the instrumentation to measure deflections in five points (1...5) and strain gauges (M; A/E;B/F;C/G;D/H – Rosetta: R/S) in the middle of panel are shown.

3. EXPERIMENTAL RESULTS

The test results of triplets are shown in Table 2. A different behaviour between the specimens relative to the pre-compression value may be noted [17]. At low pre-compression the failure was at the interface between brick and mortar while at high pre-compression the brick failed.

Table 2- Results of triplet test

Triplet	**T12**	**T1 T2**	**T3**	**T9**	**T4**	**T10**	**T5 T11**	**T7**	**T6**	**T8**
Specimens	2	4	2	2	2	2	3	1	2	2
$\boldsymbol{\sigma_v}$(N/mm^2)	0.0	0.29	0.75	1.0	1.13	1.5	2.0	2.24	2.3	2.87
$\boldsymbol{\tau_u}$(N/mm^2)	0.30	0.46	0.62	0.83	0.90	1.21	1.60	1.62	1.80	2.15

Table 3 – Experimental shear strength by racking tests

Wall	W1	W2	W3	W4	W5	W6
σ_v (N/mm^2)	0.50	0.75	0.30	1.15	2.25	3.00
τ_u (N/mm^2)	0.66	0.68	0.54	1.43	1.90	1.90

The shear test results on the walls are summarised in Table 3. The experimental lateral load, F, vs deflection diagrams for point 1 on the top of unloaded side of the walls are shown in the Figure 3. Figure 3 shows different shear response of walls (W1: σ_v= **0.50** N/mm^2; W3**:** σ_v= **0.30** N/mm^2; W6: σ_v= **3.00** N/mm^2) subjected to varying degree of pre-compression. As can be seen from Figure 3, the load-deflection relation is non linear and it also appears that stiffness increases with the increase of pre-compression.

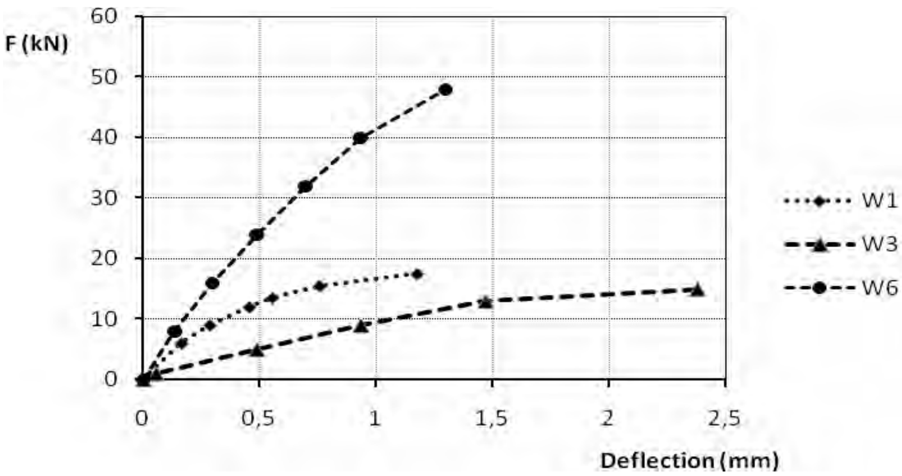


Figure 3 – Experimental horizontal force F vs displacement at the top of walls.

3.1. Comparison between experimental results

As recommended by RILEM, a normal linear regression between shear and pre-compression was done with the data obtained from triplet tests. Accordingly, the values work out to be: the initial shear strength τ_u = 0.21N/mm^2 and the coefficient of friction equal to 0.72 with co-relation coefficient of 99%.

Doing similar exercise with shear tests on walls ignoring the result of Wall 6, the values are: the initial shear strength τ_u = 0.31N/mm^2 and the coefficient of friction equal to 0.74. The result of Wall 6 was ignored from the regression because shear strength remained constant between pre-compression of 2.25 and 3.0N/mm^2. Both tests give the similar value for the coefficient of friction, but the initial shear strength for triplet is much lower than from the wall tests. The triplet test, being a single joint tests may not actually reflect the strength of the wall. At high pre-compression, the shear strength of wall remains constant which is difficult to detect in the triplet tests. The results of triplet and shear tests are compared in

Figure 4. The results of wall test are also compared (Fig.5) with the criterion of EC6 [19]. It appears that the EC6 underestimates the shear strength of the historic masonry of this type.

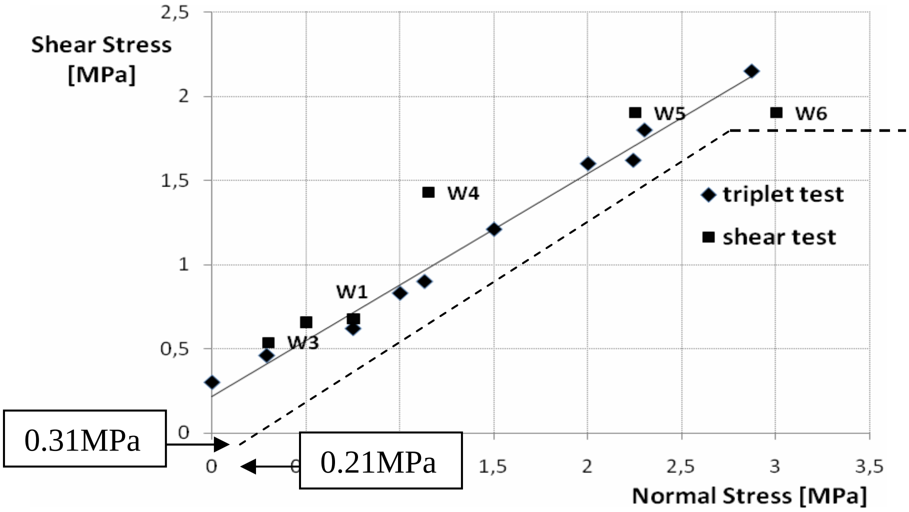


Figure 4 – Comparison of triplet results with shear test results

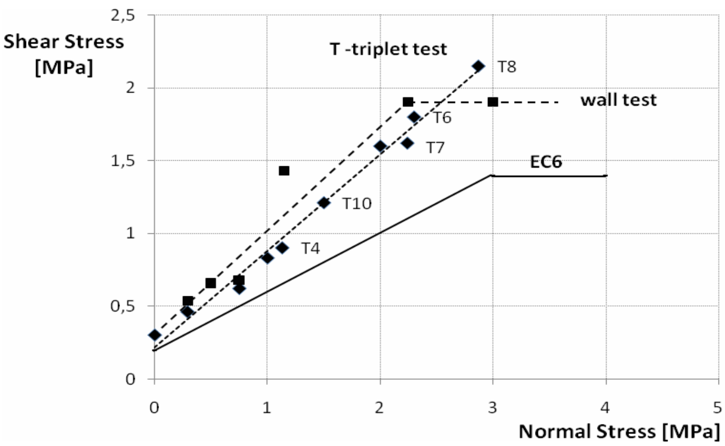


Figure 5 – Comparison of experimental results on shear walls with EC6 criterion.

4. CONCLUSIONS

On the basis of the tests following conclusions can be drawn:

- The shear strength obtained by the triplet tests is lower than obtained by shear tests on walls. Also, the triplet test may not actually reflect the strength at high pre-compression.
- The EC6 underestimates shear strength of HURM of the type tested.

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PRELIMINARY STRUCTURAL MONITORING AND 3D MODELLING OF NEMRUD MONUMENTS, TURKEY

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ABSTRACT

Nemrud is an archaeological site in Adiyaman, located in the eastern part of Turkey, noted with the large-size monumental statues (8 to 10 m tall, having approximately 3.5 m x 3.5 m base area) which are more than two thousand years old. The site is located at 2150 meters altitude and composed of two main terraces in the East and West of a central tumulus where the monuments lined up one next to the other. The monuments, which are composed of big limestone blocks, placed on the East and West terraces show considerable differences in terms of physical integrity. In this paper, the authors tried to introduce the structural studies carries out so far in the site as well as to summarize the future studies.

1.INTRODUCTION

The host archaeological site to Nemrud monuments belongs to an ancient kingdom called 'Commagene' and is located at the top of Mount Nemrud (2150 m). This sacred place, built by the King Antiochos I, is the accommodation of many monumental sculptures and reliefs lined up on the east and west sides of a central tumulus, thought to be the monumental grave of the king Antiochos. Each statue, except that of Antiochos I himself, represents a god or goddess corresponding to the same Greek and Persian sacred figures. Therefore, the site is also important as being the meeting point of two mythologies belonging to two different civilizations. In fact, the presence of a great altar underlines the religious importance of the site. Due to the inscriptions located at the back side of the

statues, the site is also important for having written documents of ancient times [1].
The bodies of the statues are composed of about 7 layers of big stone blocks, probably simply put on top of each other without any physical binder or mechanical connection like mortar or metal clamps; the heads are made of a single piece of stone. The statues are made of limestone, while reliefs are of sandstone, which are readily available materials in the area. Moreover, the statues on the east and west terraces are almost identical. In spite of these similarities, those in the east terrace are in good structural condition, while those located on the west terrace are not. The west terrace statues were tore down towards west and now in the appearance of stone blocks rubble distributed over the ground, while the statues on the east side have a better physical integrity and yet the heads have all detached from their bodies and fallen down. The collapse of heads and statues are thought to have happened during a previous earthquake since the region is located at a highly seismic zone. The difference of structural condition in west and east terrace monuments is being investigated and may also be probably due to heavy snow accumulation difference between the east and west terraces by high winds.
Different material deterioration and abrasion phenomena were observed, which are due to biological factors, and physical – mechanical inducements of environment such as wind, serious seasonal and daily temperature variations, precipitations, freezing and thawing cycles, sun exposure etc.

2.MONITORING STUDIES

Environmental monitoring and assessment studies on the Nemrud monuments have started to investigate the damage pattern, snow and wind loadings, and structural condition of the monuments within the framework of Nemrud project supported by the Turkish Ministry of Culture, World Monument Fund, and TUBITAK. The studies on assessment, monitoring, and diagnosis of the monuments are intended to follow an integrated approach from structural, material, and environmental points of view. For this reason, an interdisciplinary team was formed and various studies are currently being carried out in different branches. In the 2006 campaign, the material investigations have begun through visual inspection and some in-situ measurements, e.g. ultrasonic velocity. In addition, an in-situ system to monitor changing temperature and humidity values was placed on site which is connected to two temperature and humidity sensors. A solar panel was utilized to charge the battery during day time which would continuously provide electricity for the system. Remote communication with the datalogger was established via a GSM modem which was also integrated to the monitoring system. First readings were obtained indicating precipitation in the form of rain and snow as a function of the environment temperature (Figure 1). Using the limited amount of collected data, a general relationship between environment temperature and humidity was observed (Figure 2).

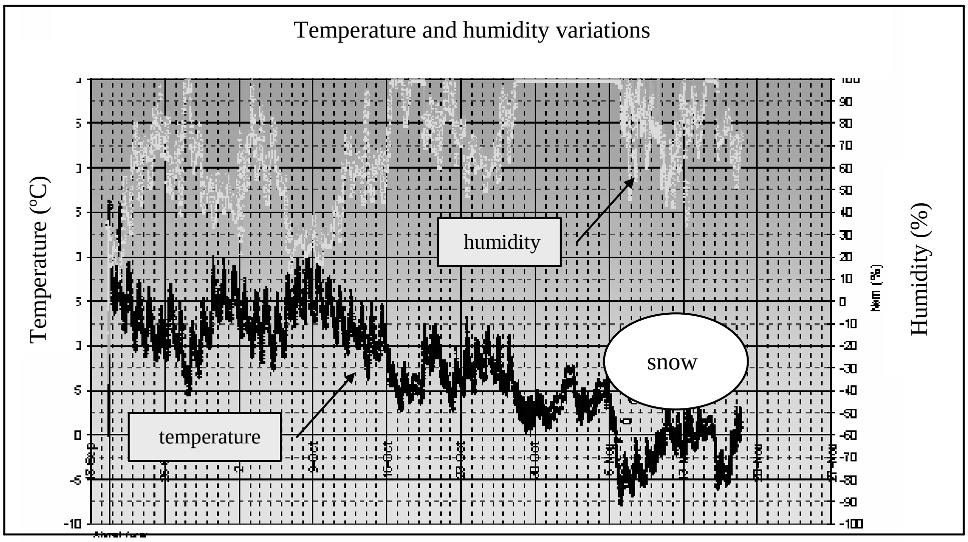

Figure 1: Typical temperature-humidity data belonging to one and a half months

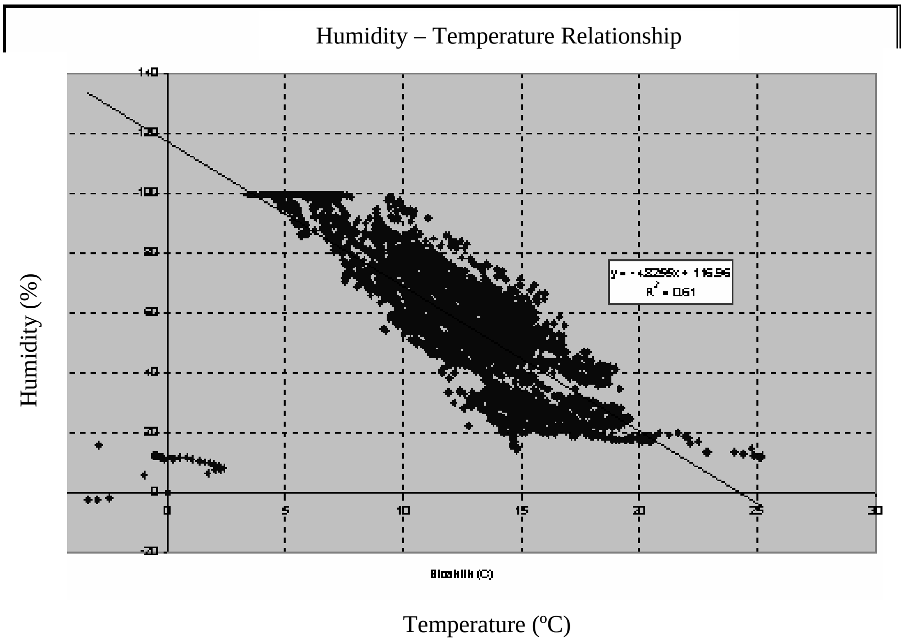

Figure 2: Humidity – temperature relationship derived by humidity and temperature data of approximately a month

Through temperature and humidity monitoring, it was understood that there were a day and night temperature difference of 7-8 ºC, which decreases as humidity gets higher, as a main trend for the period of the measurements. As seen in Figure 1, snow precipitation started in the beginning of November. The temperature and humidity data were collected continuously without any problem for approximately 60 days until the wireless GSM connection was lost making it impossible to remotely download the data. The possible reasons for communication failure could be (1) GSM antenna dismantled from its magnet restrained position due to high winds and/or snow accumulation, (2) solar panel and GSM antenna buried by snow, which might have accumulated more than 3 meters in height, (3) metallic pole, where the solar panel and the sensors were connected, might have been struck by a lightening, (4) vandalism. The team waits for the end of the winter to visit the site to examine the conditions of the sensors, data acquisition system, and antenna.

3.ANALYTICAL STUDIES

The preliminary FEM of a typical Nemrud statue (according to the geometry given at the Nemrud Dag 2002 pilot project and mobilization report) was constructed using 9204 solid elements and with about 34 000 degrees of freedom. A modal analysis was carried out to obtain the range of first natural frequencies and pertinent mode shapes. The initial modal results (mode shapes and frequencies) indicate that the dominant mode periods are close to the zero second of the response spectrum. On the other hand, basic equilibrium analysis indicates that the heads would be vulnerable to lateral earthquake loading especially since tensile stresses cannot be tolerated at the neck level (Figure 3, 4). Frequencies belonging to first 15 modes are listed in Table 1.

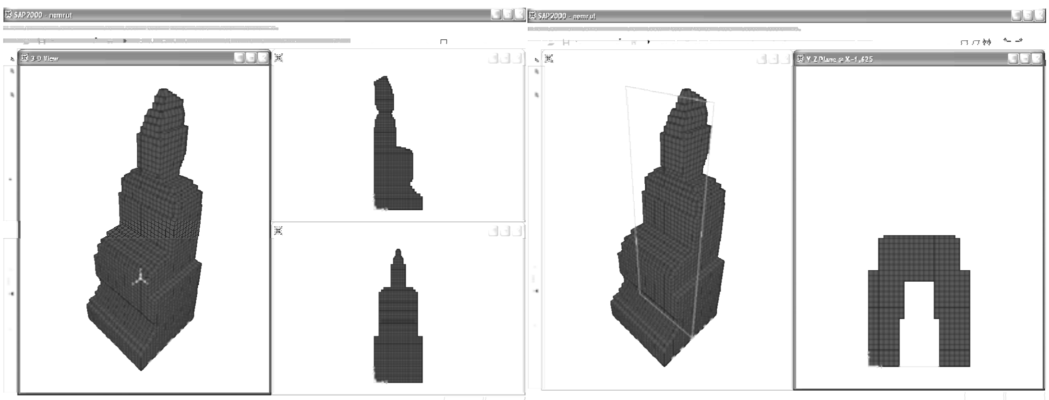

Figure 3: 3D model of a typical Nemrud monument with the internal cavity

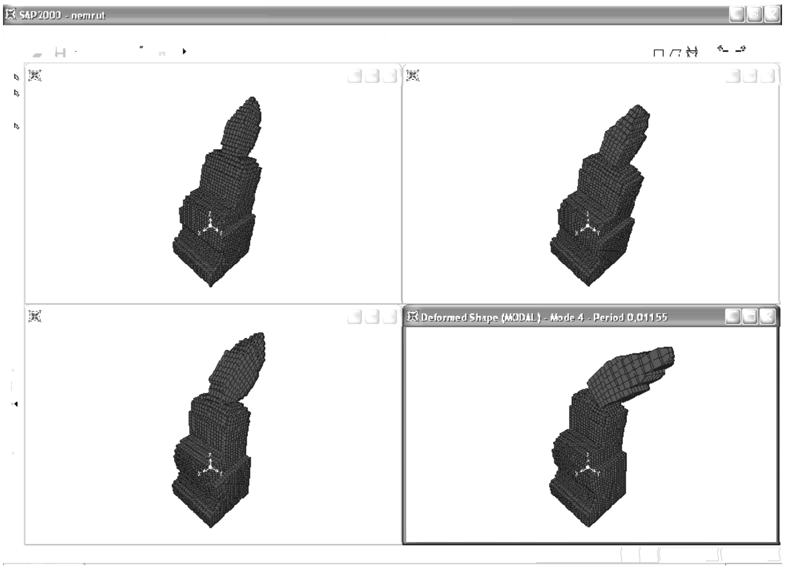

Figure 4: First four mode shapes

Table 1: Period and frequency values belonging to first fifteen modes

WITH HEAD			**WITHOUT HEAD**		
Mode	**Period** sec	**Frequency** cycle/sec	**Mode**	**Period** sec	**Frequency** cycle/sec
1	0.0299	33.42	1	0.0223	44.84
2	0.0240	41.67	2	0.0193	51.87
3	0.0139	71.89	3	0.0090	110.62
4	0.0116	86.58	4	0.0079	127.07
5	0.0092	108.58	5	0.0072	139.08
6	0.0071	140.25	6	0.0065	153.61
7	0.0071	141.24	7	0.0047	212.77
8	0.0067	149.03	8	0.0042	236.41
9	0.0054	184.84	9	0.0035	285.71
10	0.0043	230.95	10	0.0030	334.45
11	0.0042	238.66	11	0.0028	359.71
12	0.0036	277.78	12	0.0027	364.96
13	0.0034	290.70	13	0.0027	367.65
14	0.0030	333.33	14	0.0026	389.11
15	0.0030	334.45	15	0.0025	396.83

Furthermore, a synthetic random burst lateral excitation data at 0.002 sec interval with 1024 data points followed by 2048 data points with zero excitation for free vibration was created along X and Y directions, as seen in Figure 5. The last part of the excitation data was used to simulate the free vibration of the monument to the random burst excitation, which equally excited all frequencies. The Fast Fourier Transform (FFT) of the free vibration responses (Figure 6) obtained from different nodes of the analytical model (Figure 7) revealed that although different nodes were used in the zero to 250 Hz range, it is difficult to obtain the higher modes except for the first bending modes in x and y directions.

The analytical model simulations are very important to guide the testing in real in-situ conditions since the expected range of frequencies dictate the accelerometer and dynamic data acquisition system characteristics. The analytical study indicates the difficulty of obtaining higher mode shapes and frequencies although instruments are selected to measure at 500 Hz measurement speed.

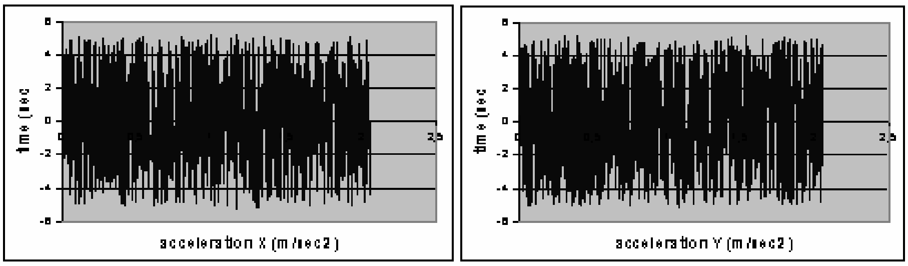

Figure 5: The synthetic EQ data in the x and y directions, respectively.

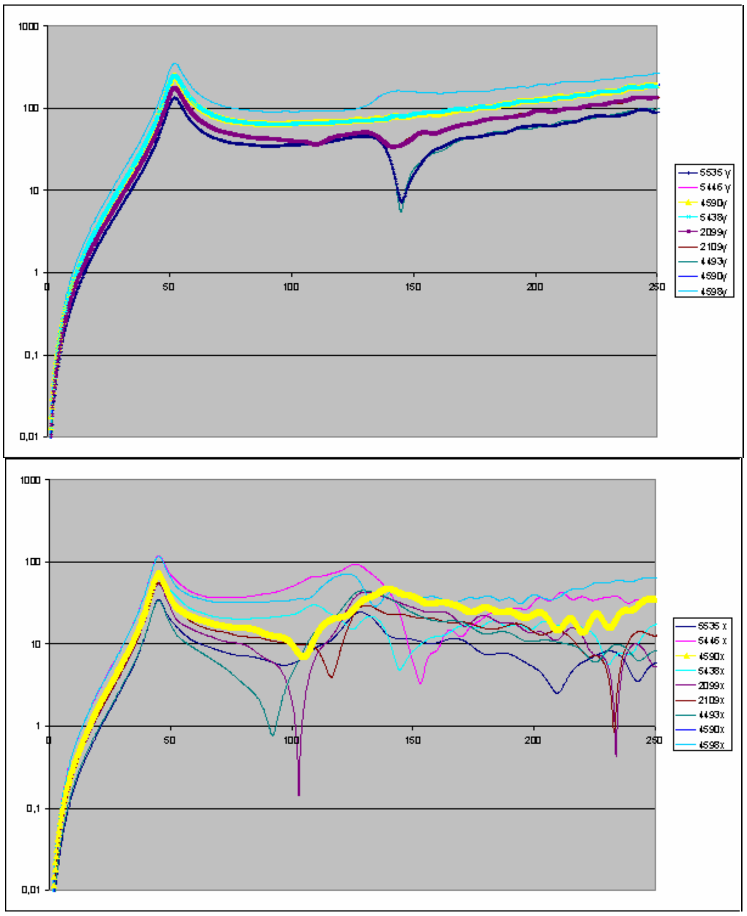

Figure 6: The frequency response functions obtained for the random burst excitation using 8 different nodal points (1% damping, x and y directions, respectively).

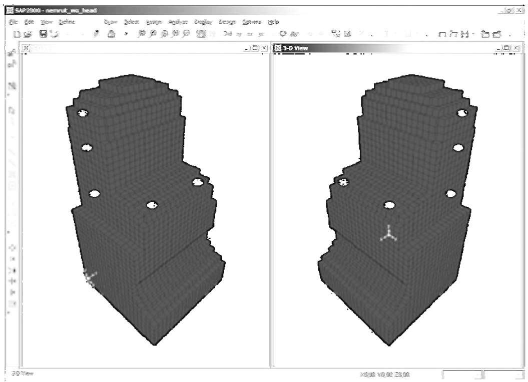

Figure 7: The possible accelerometer locations for capturing the dynamic response of the monuments

4.CURRENT STUDIES

The exact geometry of each monument and the topographical features of the area are currently being examined by using available drawings and photogrammetric tools. The harsh winter conditions would not permit access to the site, which necessitated site visit by March of 2007. During the site visit, additional studies will be conducted to locate the positions of stone blocks on the west terrace in an attempt to reverse engineer the causes of such collapse. Different earthquake records will be used to conduct nonlinear time-history analyses to see if similar collapse patterns may be obtained.

The integrity difference between east and west terraces is though to be possibly caused by the accumulation of snow, by means of wind, to the west terraces. For this reason, additional wind velocity and direction sensors, as well as those to measure snow height will be located at each terrace. Moreover, additional satellite and aerial photographs will be made use of to evaluate the snow distribution and accumulation in the area.

Crack width changes are also planned to be monitored by means of manual measurements. The vulnerability of the standing statues also depends on the crack development of base stones, since a crack initiation at the base stone might cause brittle collapse as the footing cavities exist at various locations.

Dynamic tests will be conducted to obtain the natural vibration frequencies of the standing statues. The 3D-FE model will be updated using field measured dynamic data to conduct structural identification (St-Id). The short term dynamic measurements and long term monitoring results will be combined to understand the behavior of the statues. The calibrated analytical model will be used to simulate possible earthquake loading and pertinent damage scenarios.

Nemrud is a unique site with major monitoring difficulties. Extremely harsh environmental conditions at high altitude would make the site access impossible during winters. Finding suitable sensors to function at very low temperatures (in the range of -40 C^{o}) is another difficulty. Recent experience with the remote communication showed that GSM coverage, antenna properties, instrumentation connection details should all be solved. In addition, the site is located at the top of a mountain, far from urban areas, which brings additional difficulties such as easy access to the area, accommodation, lack of electricity, and security concerns.

5.CONCLUSION

In this paper, the authors aimed to summarize the structural studies carried out so far on the Nemrud monuments in Adıyaman, Turkey. The studies included solid 3D-FE modeling of a typical Nemrud statue and its random burst excitation and free vibration analysis. The results invigorated the possibility that the heads have fallen down during a major earthquake. The preliminary modeling and analysis have shown that the first major modes of vibration are expected to be in the 30 Hz to 50 Hz range, while the higher modes would be difficult to capture due to the bulky nature of the statues.

In the future, the structural investigation will be continued by using more detailed calibrated linear and non-linear FE models, conducting recorded earthquake simulations, and formation of retrospective damage scenarios. If the original positions of the fallen heads can be found through archive document studies, then the possible earthquake which might have caused such a motion may be obtained after a series of simulations. The material studies conducted on the samples by other team members will also be used to update the analytical models' material properties such as unit mass, elastic modulus, etc.

The results of the studies are expected to guide and help the decision makers for planning the conservative and restorative interventions such as putting the heads back to their original places on the statues or keeping them on ground. Snow and wind loading studies might lead to placing temporary supports behind the west terrace statues to relieve lateral forces. The multi/interdisciplinary approach, taking into account the basic principles of minimum intervention, compatibility, and reversibility would set a good example for studies on preservation of cultural heritage.

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PERIMETER WALL REINFORCEMENT IN "ARCHIBISHOPS PALACE", SIRACUSA, SICILY, BY USE STONE ARCH

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ABSTRACT

This case study consists of an experimental and theoretical investigation on the static and dynamic structural behaviour of a important architectural complex in Siracusa, Sicily, named the "Archibishops Palace". There were two modifications that have a substantial import on the building : the first, in 1745, the enlargement of a passage way between the two courtyards to allow the transit of carriages which cut off some Swabian vault; the second, the addition of another level to the transverse building in order to construct a new chapel, following air raids of 1943. These last modifications created the actual conditions of the buildings extreme structural vulnerability. The basis of the experimental work has been the characterization of the local state of stress and the most relevant properties of the employed materials. the procedures have been based on the visual inspections and measurements and on flat jack (single e double) and endoscopic reliefs. Numerical models, suited for static analysis, have been done on the basis of such data constructed and roughly calibrated. The results obtained evidence the potential structural damage aspects. After the intervention, the state of tension diminishes in the whole structure.

1. THE "ARCHBISHOP'S PALACE" IN SIRACUSA

The complex of buildings commonly called the "Archbishop's Palace", delimits the east side of the cathedral square in Siracusa. It was constructed and grew adjacent to an ancient Greek temple, which today is the cathedral. It has complex articulations and layers indicated in the diagram below, of the first level:

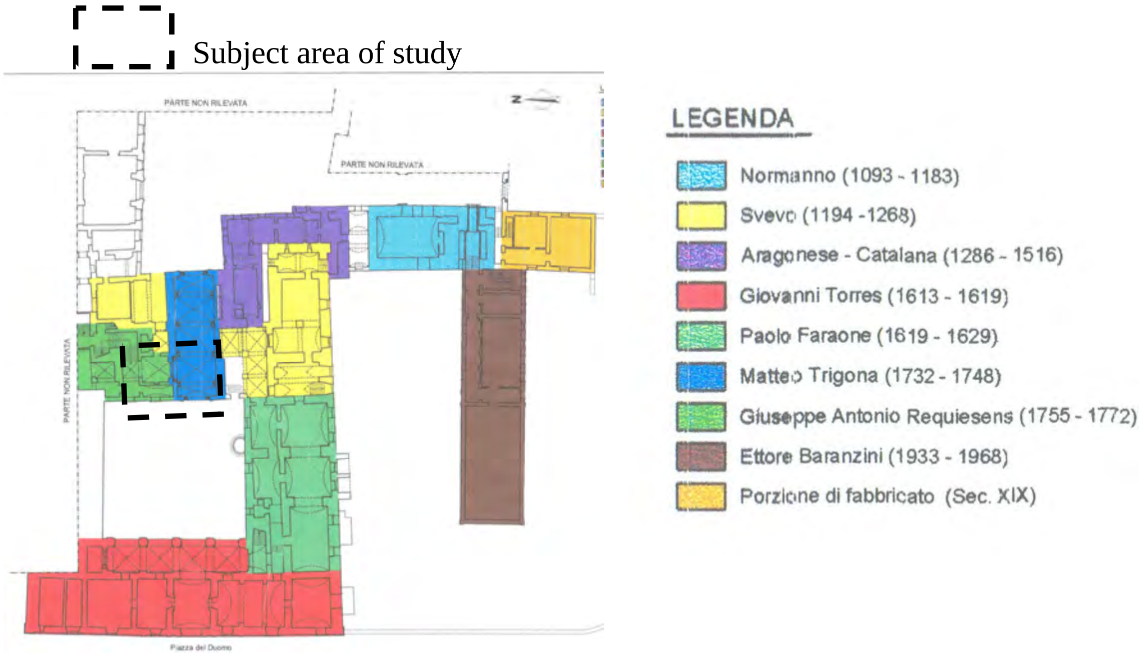
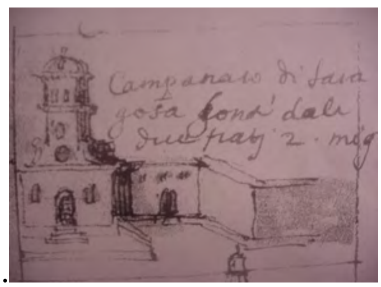


Figure 1

Of the long evolutionary process of the “Palace”, we will only indicate the principal events regarding the buildings of the complex which delimit, on two opposing sides, the first courtyard, (specifically, the building looking on the cathedral square, called “Quarto Torres”) and the building that separates the two courtyards, subject of the present document.

In recorded evidence relative to the damage provoked by the earthquake of 1542, the collapse of the medieval bell tower is always remembered. Nevertheless, thanks to the reconstructed bell tower, one has the possibility of knowing this most antique façade of the cathedral and the “Palace”, sketched in 1578 by Tiburzio Spannocchi. In the design (fig. 2,) the façade of the Archbishop’s Palace is far more recessed with respect to that of the cathedral.


.
Figure 2

This configuration persists until the end of the 1500s, when the Bishop Giovanni Torres changed the appearance of the ancient “Palace”, constructing a new building that radically modified the proceeding iconography. The comparison with Spanocchi's sketch (in fig. 3), shows the intent to close off the area in front of the ancient entrance door.

Figure 3

The ancient façade, closed off by the new building wing, called "Quarto Torres" becomes the element of separation between the two courtyards. On this complex of buildings the seismic events of 1693 weighed heavily. A lengthy notary act dated March 25, 1745, regarding the reconstruction work, describes the enlargement of the passage way between the two courtyards to allow the transit of carriages which cut off some Swabian vault. Successively, in 1762, on the plans of Dumontier, the *Dead Covers* of the Quarto Torres, are rebuilt as a real and proper additional upper level (last level in fig. 3) and just a few decades later, the Quarto Torres begins to show signs of damages. The problem was tackled by consolidation the foundations. During the air raids of 1943 the archbishops palace sustained damage to two areas: the "Quarto Torres" and a house named "Ferrini house", situated at the corner of via della Conciliazione and via Torres. The need of rebuilding the small residential house became an occasion for two projects whose work (1948-1958) weighed heavily on the aspect of the Palace. Of the two projects, the construction of a new chapel . The latter one was built on the building that separates the two courtyards (fig. 4).

Figure 4

The new chapel, which floor is a slab of reinforced concrete with parallel beams of height 70 cm., constitutes the additional upper level of the building. The acting pathologies of the palace are strictly linked to the numerous modifications. Some of them significantly altered the original structure, and varied the static configurations. In light of this, one can see how the two constructions of additional upper levels previously described have produced failures and problems of a different nature. One construction being that of the Quarto Torres, a work of Dumontier (1762) and the other, that of the building that separates the two courtyards (1948- 1958). The first, in fact, caused the settlement of the foundations; the second, caused ruptures in compression of the carrying masonry.

2. CASE STUDIE

In the building the separates the two courtyards, one observes numerous fractures of the stone elements. It is noteworthy, through archival research, the measures taken to correct the damage caused by the first of the two aforementioned additional upper levels. The intervention undertaken by the additional upper level of the building that separates the two courtyards, instead belongs to a project, in a phase of execution, and constitutes occasion and premise for this study.

The mechanical behaviour under stress of the perimeter walls of the building, facing the first courtyard, was investigated, subordinate only to its own weight**,** projects load and seismic effects.

The analysis of the current status is useful toward a goal of determining the characteristics of the consolidating interventions most opportune, that in this case consist essentially in the formation of a discharge arch that allows a proper redistribution of the tensions; and in the closure of a passage on the same façade, with a goal of reducing the tension at the basis of the facade.

3. CAMPAIGN OF INVESTIGATIONS

The principal mechanical characteristics of the building, the level of maintenance of the supporting walls have been deduced from the information furnished from on a series of experimental tests. These tests incuded measurments of tension and elasticity of masonry, using the flat jack edoscopic reliefs.

Once the characteristic parameters of the material were appraised, and the degradation evaluated in qualitative terms, it was possible to calculate the tensional state of the façade walls subject to various conditions of load that are of interest to the project, using F.E.M. ending with a plain model able to simulate the global behaviour of the facing wall[2].

4. FINITE ELEMENTS MODEL

To simulate the mechanical behaviour of the carrying structures of the building, it is possible to resort to the methods of the mechanics of continuity, that allow one to eliminate the difficulties associated with the geometry of the problem.

Although considering the walls (in and of themselves not homogenous), as a continuous homogeneous mean, this alters the physical nature of the problem. Nevertheless this method provides acceptable answers from a qualitative point of view.
The constitutive bond of the material, could be deduced by experimental tests and it is possible to use a constitutive bond of simple formulation that allows us to gather only the fundamental aspects.
A by–dimensional mathematical model of finite elements has been developed. The same model is used for static analysis under all the significant load conditions, as for dynamic analysis.
This model permits the investigation of the tensional and deformative state at every point of the modelled structure.
A numerical model of finite elements of the whole body of construction facing the first courtyard using three - dimensional isoparametric elements of three and four nodes "shell-type" , was developed.
The dimensions of the elements were determined by the relief of executed detail.
The analysis is developed in the hypothesis of small deformations, small movement and the constitutive bonds of the material of linear elastic type.
The calculation of the characteristics of tension uses a failure criterion studied for the masonry structures (material not homogeneous and not linear) [7].
AMV Studio Software-Ronchi of the Legionari (GO) – Italy was used as a solver.

5. CURRENT STATUS

5.1 Mechanical characteristics of the masonry

The mechanical characteristics of the masonry were formulated on the basis of the results of the campaign of experimental tests with flat jack and some general information found in technical literature regarding the materials and the technologies of specific construction of the place [3] [4].
The coefficient of Poisson average was assumed equal to $\nu = 0,15$. The choice of elastic form of the masonry was deduced of the flat jack campaign. In our case were used values equals to
Flat Jack 1: $\sigma = 7$ Kg/cm^2; $\varepsilon = 0.448 / 403.046$ mm; $E = \sigma/\varepsilon = 6297$ Kg/cm^2
Flat Jack 2: $\sigma = 14.7$ Kg/cm2; $\varepsilon = 0.271 / 402.532$ mm; $E = \sigma/\varepsilon = 21834$ Kg/cm2
Flat Jack 9 $\sigma = 7.1$ Kg/cm2; $\varepsilon = 0.770 / 402.576$ mm; $E = \sigma/\varepsilon = 3712$ Kg/cm2

5.2 Characteristics of the ground and scheme foundations.

The characteristics of the ground have been deduced by a campaign of geognostic tests. The terrestrial – structure interaction was simulated binding all the nodes to earth in foundation simply.

5.3 Load analysis

The considered proper weight of the masonry was calculated considering a medium density equal to $\gamma = 1900$ Kg/m3.

They were analysed two conditions of stress:
1) Earthquake Total: dead load + 0.33 x live load + earthquake **x**
2) Total: dead load + live load

5.4 Dynamic modal seismic analysis

The dynamic seismic analysis was developed with the spectral response method using the same model previously used for the static analysis.
The effects of the three wais of vibration considered, were combined according to the SRSS method, where every component of stress resulting from the combination is the result of the square root of the sum of the squares of each single component [1], [6].

6. RESULTS OF THE NUMERICAL ANALYSIS

6.1 The masonry

The key to the normal stress, according to the crack criterion adopted, is reported on the color map in relation to the intensity of the stress.
From the examination of the dynamic behaviour of the structure, the peaks of the increment-decrement stress values, that caused the crisis of some stone elements, are circumscribed in proximity of the access arch (about 1.2 N/mmq.).
One observes that:
At the upper levels, the maximum values of the compression tensions are well under the limits of resistance of the masonry (0.265 N/mmq);
At the lower levels, the stress of compression reaches levels (1.2 N/mmq).

7. NUMERIC AND EXPERIMENTAL RESULTS

From the comparison between values gotten from experimental tests and those deduced from the mathematical model, one realizes that the numerical model employed is sufficiently representative of the structural behaviour of the façade wall**.**

7.1 Color mapping of the actual state of stress

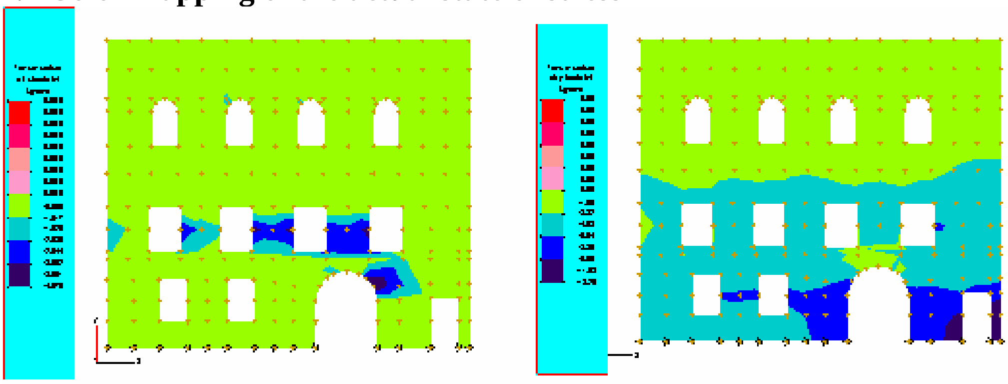


Figure 6

8. F.E.M. ANALYSIS OF THE PROJECT HYPOTHESIS

The interventions for the structural improvement were defined following experimental tests in situ and successive numerical investigations. A localized façade wall consolidation, attained by inserting a large discharge stone arch and increasing the discharge surface of the load by way closing a passageway at ground level, led to determination of the safety level.
A further analysis was executed for the simulation of the project hypothesis which keeps in mind the projected structural configuration.

8.1 Color Mapping Of The Project State

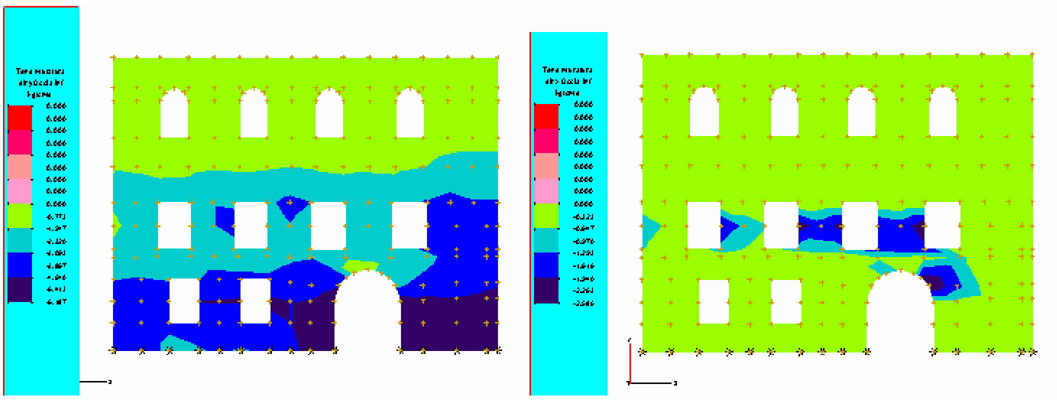


Figure 7

9. CONCLUSIONS

Seven shell elements were chosen, the discretizzazione total of the façade wall among those components, and the values of the two models were contrasted.

Table 2 ($\sigma_{id}^{superiore}$)

Element	Before	After
1/12	9.380	4.437
1/43	6.243	4.254
1/45	4.409	4.538
2/8	3.237	1.801
2/23	3.789	2.453
3/8	2.295	0.86
3/23	2.516	0.81

One observes that the maximum values of the sterss of compression are well under the limits of resistance of the masonry:
The maximum value is 4.437 versus 9.38 Kg/cmq obtained in the preceding analysis [5].
The proposed structural improvement, beyond having greatly reduced the maximum compression value, have permitted a more equal distribution of the stress, greatly reducing the localized peak values. One observes that the tensil strength are completely disregardable. The examination of the dynamic seismic behaviour, demonstrates that the peaks of values of increment-decrement of the stress circumscribed to exiguous values. From a global point of view, in no case does one reach stress values that brings the compression of the material to a crisis point.

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