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Studies, Repairs and Maintenance

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Objectives

The **International Journal of Heritage Architecture** addresses a wide range of topics related to studies, repairs and maintenance of the built cultural heritage.

Technical issues on the structural integrity of different types of buildings, such as those constructed with materials as varied as iron and steel, concrete, masonry, wood or earth are discussed. Restoration processes require the appropriate characterisation of those materials, the modes of construction and the structural behaviour of the building. Of particular importance are studies related to their dynamic and earthquake behaviour aiming to provide an assessment of the seismic vulnerability of heritage buildings.

The Journal contributions aim to provide the knowledge to facilitate regulating policies. They also address topics related to historical aspects and the reuse of heritage sites.

Of particular interest is the study of Heritage Architecture in Asia, Islamic countries, Native American cultures and vernacular civilizations in Africa and Oceania. An important aim of the Journal is to investigate cross-cultural influences.

The Journal brings together contributions from scientists, architects, engineers, restoration experts, social scientists, planners, and economists dealing with different aspects of heritage buildings.

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PREFACE

This issue comprises selected papers on Studies, Repairs and Maintenance of Heritage Architecture topics that are becoming increasingly important in modern society.

The rapid growth recently experienced in many regions of the world has added a particular urgency to the need to preserve our built cultural heritage. This requires the collaboration of different parties, including not only architects and engineers and scientists but also artists, socio-economic professionals and equally important, all stakeholders to ensure the effective integration of the rehabilitated buildings within the community.

The papers in this issue address a series of topics related to historical aspects and the reuse of heritage architecture, as well as technical issues on the structural integrity of different types of buildings. Restoration processes require the appropriate characterisation of materials, the modes of construction and the structural behaviour of the building. Modern computer simulation can provide accurate results demonstrating the stress state of the building and possible failure mechanisms affecting its stability. Equally important are studies related to their dynamic and earthquake behaviour aiming to provide an assessment of the seismic vulnerability of heritage buildings.

Of particular interest is the need for Heritage Buildings rehabilitation to conform to energy consumption reduction goals framed within climate change initiatives. It is necessary to encourage actions to improve energy efficiency, harmonised with both appropriate amounts of investment and transnational commitments to reduce greenhouse gas emissions.

The contributions are the result of an event hosted by the University of Alicante to which the editors are indebted. The meeting was coorganised by the Wessex Institute.

The editors are also grateful to all authors for their excellent papers and to the reviewers for their help in ensuring the quality of this issue.

The Editors
Alicante, 2017

INITIAL STUDIES OF THE DEFORMATIONS OF VAL D'ARAN CHURCHES

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ABSTRACT

In the region of Val d'Aran, there is an ensemble of Romanesque churches with very particular formal and constructive characteristics. These buildings, most of which were built during the 12th century, have suffered various alterations throughout history. Their capacity to deform in many cases has pushed the balance of the masonry structure to the limit, forcing the introduction of stabilizing elements.

The aim of this investigation is to evaluate the construction and equilibrium conditions of these highly deformed shapes. This article introduces the context of the churches of Val d'Aran from a wide point of view and addresses the formal characteristics of some of the most relevant examples of basilica floor plan constructions.

An assessment of stability is performed in the church of Santa Eulària d'Unha, which has one of these basilica floor plans, with large deformation of the masonry structure. The methodology is based on graphic statics within the theoretical framework of limit analysis.

Keywords: limit analysis, masonry, Unha, Val d'Aran.

1 GEOGRAPHICAL, HISTORICAL AND CULTURAL FRAMEWORK

The Aran Valley, Valle de Arán in Spanish or Val d'Aran in Aranese, the native language, is located in the north of the Pyrenees (province of Lleida, Spain). It is bordered by France (Department of Haute-Garonne) to the north, the region of Ribagorza (province of Huesca) to the southwest and the Catalan regions of Alta Ribagorza and Pallars Sobirà (province of Lleida) to the south and east. The majority of the valley is located in the Atlantic basin. It has an extension of 634 km^2 and 30% of its surface is over 200 m in altitude.

Since ancient times, the human relations, both commercial and cultural, with the north following the natural course of the Garona River have been very intense, especially with the French regions of Comminges (Department of Haute-Garonne) and Couserans (Department of Ariège). Proof exists in the archaeological remains of the prehistoric and Roman times. It was not until the Middle Ages that political relations began with the states located on the southern gradient of the Pyrenees. Between the 11th and the 15th centuries, a large historical process occurred in which in a progressive way it became part of Aragon's kingdom, then part of the principality of Catalonia and, finally, after the vanishing of the Aragonese crown, part of Spain.

This process was opposed by the French monarchy, who on numerous occasions occupied the Aran Valley. The longest and most transcendent of these occupations occurred after the invasion of November 1283. The King of France claimed his rights over the territory, and the Aran Valley belonged to France for more than 15 years. For this reason, a long dispute occurred, and when it was not solved, Aran was left in the hands of the king of Majorca. The Poissy Treaty, on 26 April 1313, ended the conflict, and Philip IV of France restored Aran to the Crown of Aragon. Among these struggles, the Aranese knew how to negotiate and enforce their rights and privileges. Not long after their return to the Aragonese Crown, on 22 August

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1313, King James II of Aragon established the privilege of 'Era Querimònia', which is a written compilation of their usages, rights and customs. However, the Church continued in the French bishopric of Comminges until its disappearance, and in 1804, it was annexed to the diocese of Urgell (Catalonia), to whom it now belongs.

In this context, rich and varied natural and cultural heritages have been preserved, extremely concentrated in the valley of no more than 40 km in length. Thirteen small villages are located in this natural environment, which has a high landscape value, arranged in nine municipalities. It has an interesting ethnological heritage; the traditional stock economy is concentrated in the household as the economic, social and political unit. There are hydraulic flour mills, washing places, and, based on the industrial heritage, lime ovens, wool factories, iron and zinc mines and, most recently, large hydroelectric plants. No less important is its immaterial heritage, which is highlighted by the Aranese language, a variant of the Occitan language, spoken in the Aran Valley, and numerous festivities and traditions.

2 ARCHITECTONIC AND ARTISTIC HERITAGE

The Aran Valley has retained a large and concentrated group of parochial churches and chapels of Romanesque and Gothic style. In addition, ruins of various castles, some of which emerged to protect the parochial churches, and watch and defensive towers can be found.

Unfortunately, there is a lack of historical documentation to date these buildings. Up to now, the chronologies taken as reference are based on the study of the materials, the construction techniques and the style characteristics, comparing them with other monuments. The oldest chronologies date from the beginning of the 20th century and are the result of two scientific expeditions. The first one was led by Lluís Domènech i Muntaner in the year 1904, from the architecture school of Barcelona, the materials of which were published by Granell and Ramon [1], and the second one, in 1907, was the 'Missió arqueològica' of Josep Puig i Cadafalch, Gudiol and company, the materials of which were published by Alcolea [2]. The result from this trip is the synthesis and interpretation of Puig i Cadafalch [3] on the characteristics of the Romanesque Aranese architecture. After, the Aran Valley fell into oblivion, unlike the Vall de Boí, which is easier to access. It was not until the works of Sarrate Forga [4–6] and the encyclopaedic publication *Catalunya Romànica* [7] that a more complete and comprehensive revision of contents was achieved.

Despite these shortcomings, it must be recognized that in the last two decades knowledge about the Aran Valley has significantly increased, with specific studies and the results of several interventions carried out with some movable and immovable goods, which have contributed to the generation of new information on many topics.

During the 11th and 13th centuries, an original and attractive Romanesque art flourished in the valley, far from the main creation centres. It conveys archaic elements with other mid- or even late-Romanesque characteristics. There are signs that relate the origin of this flourishing to the renewal of Comminges during the episcopate of Bertrand de l'Isle (1083–1123). He was canonized in 1308, with his name given to the episcopal Seo of Comminges.

Thirty-five churches whose constructions date from this period are preserved standing or with significant remains. The most antique group is inscribed in the first Romanesque style, although in many cases they are late constructions, fully built in the 12th century, as in the neighbouring Valley of Boí. They are characterized by the use of small ashlars roughed down by hammer; the total absence of sculpt decoration except for toothed frieze, blind arches and pilaster strips; cut tufa stone, which articulates and gives life to the exterior surfaces of the walls, especially in the apses; the absence in some of the construction of vaults; the use of calcareous tufa in arches and vaults; and the simplicity and narrowness of the overtures, both doors and windows.

Santa Maria de Cap d'Aran is a first prototype church, and its construction should have started in the 11th century. After, all the great Romanesque churches in the valley during the 12th and 13th centuries adopted the basilica floor plan with three naves and four structural vanes. The church of Cap d'Aran is the only one with a small crypt. These basilica buildings were covered in the central nave with a barrel vault and in the lateral naves with a quarter of circle vaults. In the late building of St. Andrèu of Salardú, transitioning to Gothic, the coverage of the nave is made with cross vaults. In these buildings of the basilica floor plan, the pilasters that sustain the vaults and divide the naves are usually circular. This is a common characteristic when compared with the Romanesque architecture of the neighbouring Valley of Boí.

During the 12th century, even during the first third of the 13th century, Romanesque buildings were still being built but with better achieves on exterior surfaces, through greater and more regular rigs, set out in horizontal courses, cut regularly and with a smoother surface. Externally, a single-slate roof with double slope covers the three naves. The simultaneous presence of two types of bells is characteristic: a belfry wall in the eastern gable and a robust bell tower are usually attached. However, few cases exist where the tower is Romanesque. Many of the bell towers were completed at a later time, in Gothic style, or even later. The slender pyramidal slate spire that covers them gives considerable uniqueness to these towers.

They have one or two entrances that are usually located in the lateral façades. From the 12th century, these doors became generously sculpted decoration on the tympanums, archivolts and capitals, usually the work of some local artist. Despite the power of the Romanesque tradition in the end of the 13th century and even more in the 14th century, new ideas of Gothic artistic and architectural trends arrived to the valley.

The beginnings of the new style coincided with the French (1283–1295) and Majorca (1295–1313) occupations. The French style is obvious in the bell tower windows of Vilac or in the decoration of the exterior archivolt of the main entrance of the church of St. Miquèu de Vielha, as explained by Español [8]. In addition, in this church, a new type of monumental door is found, in which the longitudinal direction of the pointed arches is superimposed, which is a timid tendency to the disappearance of the tympanum and the use of not only the space of the tympanum but also of the archivolts as a support for an abundant sculpture. Subsequently, a simpler typology devoid of sculptural decoration was adopted. With architectonic solutions from the so-called meridional Gothic, some of the Romanesque buildings were finished or restored. In Salardú, the central nave of the church is covered with crossed vaults, and the western wall is finished with a magnificent ogival window. In many other Romanesque churches, the importance of light in this period forced the opening of wider windows, especially in the western facade. In other cases, larger restorations and extensions were taken on or new buildings were constructed. These new constructions acquired the formula of a unique nave, but maintaining a tripartite sanctuary, a consequence of the deep roots of the basilica floor plan in native builders.

The Aran churches, according to the intense conflicts of the period, became very fortified enclosures defended by a wall flanked with towers in this time. In addition, the church, this enclosure protected some annexed buildings and the cemetery. The bell towers were provided with loopholes and battlements. Between the 15th and early 16th centuries, this evolution of the Aranese bell towers towards a fully military appearance culminated in the Gothic towers of octagonal section of Salardú and Vielha.

3 THE BASILICA FLOOR PLAN CHURCHES OF ARAN VALLEY

The interest in these Romanesque structures took the Escola Técnica Superior de Arquitectura of Rovira i Virgili University to study them in 2012–13 and 2013–14 courses. Three campaigns were conducted. The first occurred in winter (2012), and the church of Santa Maria de Arties was surveyed, where Bassegoda (1972) noticed the large deformations of the structure. In the second campaign in the following spring (2013), Santa Maria d'Arties was surveyed again in greater detail. A third campaign was carried out to survey the churches of Vilamos, Salardú, Bossost and Unha. As a result of these three campaigns, the floor plan and main cross sections of these churches were laid out. The general characteristics are as follows. The churches have a basilica floor plan with three naves, two laterals with similar height and one higher central nave. All the churches, except Vilamos, have a Romanesque apse, and all of them have a bell tower. Finally, the most important characteristic is that all the churches have a central barrel vault and half barrel vault at the lateral naves.

The church of Santa Maria d'Arties can be defined as a rectangular space of approximately 19.60 × 13.8 m until the apsidioles (Fig. 1). This measure is only indicative because the great deformations make it impossible to accurately set the general building measures. The construction is raised with a typical east–west orientation, with a central nave and two collaterals, each with four bays and a span of approximately 5 m.

The central pillars support the former arches and are located under the gathering of the central barrel vault and the lateral half vaults. In the western side of the church, a wooden choir is found over the access bay. The heading is currently finished with a semi-circular apse, reconstructed during the last few years, and the two original apsidioles. All of them are covered with hemispherical domes. The naves present a typical deformation pattern according to the structural arrangement. Vertical supporting elements, especially the pillars, have got out of plumb because of the thrusts of vaults. The deformation has been measured, in degrees (α) at the wall or column base. Arties have 0° in the north wall, one and five in the inner columns, and 4° in the south wall. The horizontal displacement of the upper part of the northern wall measures 0.03 m, and the wall measures 0.98 m in width at the base. If the difference in height of the keystone of the vaults is related with the width of walls and their displacements, Arties is the most deformed church, with a difference of 1.91 m in height (measured at the keystone) between the lateral vault and the central vault. The span of the central vault is 0.21 m larger at the springing than the distance between the supports at the base. The height and width of the

Figure 1: Plan and section of Santa Maria d'Arties [9].

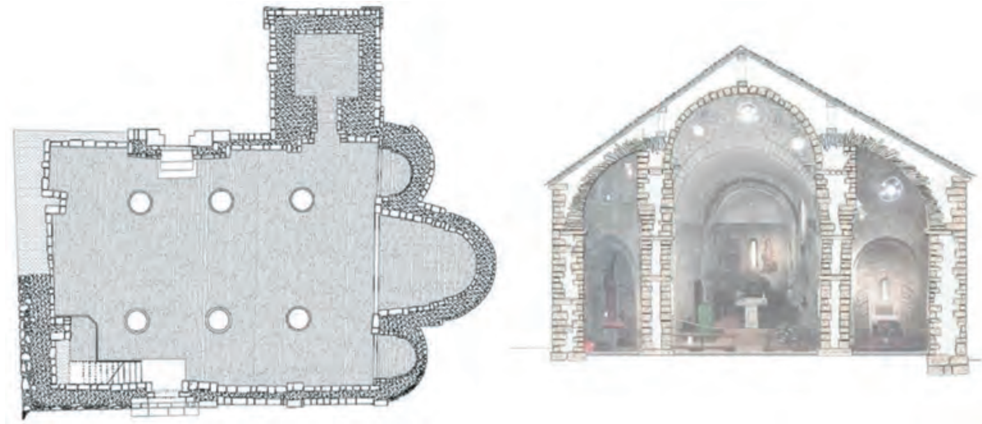

Figure 2: Plan and section of Mair de Diu dera Purificacion of Bossost [10].

church are compared with the maximum deformation. Arties measures 9.76 m in height and 13.86 m in width, and the maximum displacement of the upper part of the walls of the apse measures 0.03 m.

The church of Mair de Diu dera Purificacion of Bossost (Fig. 2) is characterized by a stylistic unity of the 12th century. It was built with a basilica floor plan and three apses. The bell tower is at the northeast facade and the axis of the construction is rotated 15 grades from the typical east–west orientation. The inner space can be defined as a rectangular space of approximately 19.86 × 10.97 m. The church has six circular columns of freestone. Bossost has no relevant deformations detected.

The church of Santa Eulària d'Unha (Fig. 3) is a church with a basilica floor plan with three naves. The apse has a Lombard style. In the northeast, there is a bell tower built in the 18th century. The construction is raised with the typical east–west orientation and the interior measurements are 21.27 × 10.92 m. The displacements of the vertical structure were measured at the base of the walls and columns. Values are expressed in degrees (α). The northern wall of Unha is 2° out of plumb, the inner columns 4° and 3°, and finally, the southern wall has plumbed 4°. The horizontal displacement of the upper part of the northern wall measures 0.09 m, and the wall measures 1.13 m in width at the base. If the difference

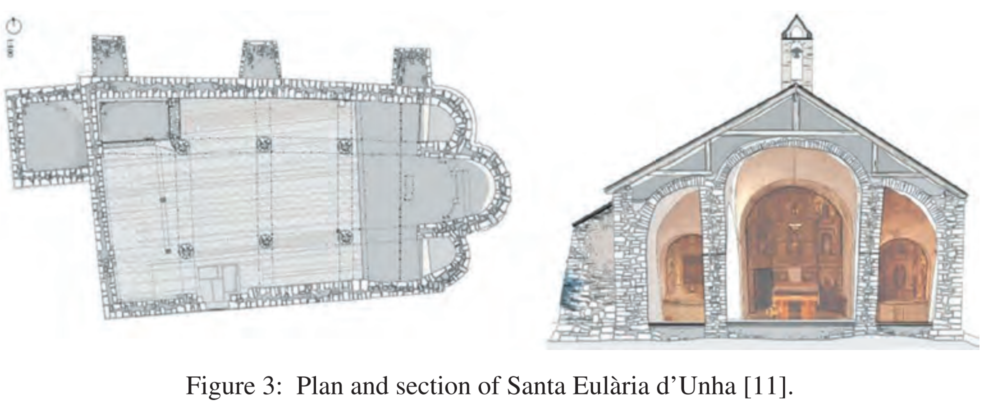

Figure 3: Plan and section of Santa Eulària d'Unha [11].

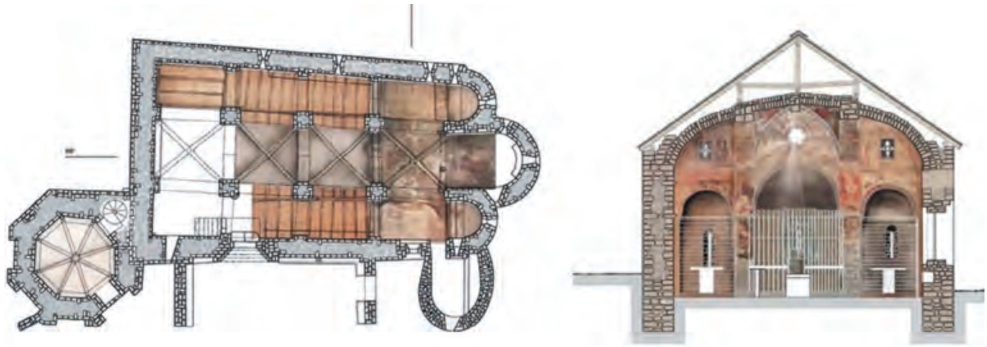

Figure 4: Plan and section of Sant Andrèu of Salardú [12].

in height is related with the width of walls and their displacements, Unha is the second most deformed church. There is a difference of 1.45 m in height (measured at the keystone) between the lateral vault and the central vault, and the span of the central vault is 0.11 m larger at the springing than the distance between the supports at the base. The arch of the presbytery of Unha measures 6.66 m in height and the apse has a width of 10.21 m. The maximum displacement of the upper part of the walls of the apse is 0.09 m.

The church of Sant Andrèu of Salardú (Fig. 4) belongs to late Romanesque (13th century). The construction is raised with an east–west orientation. The interior measures are 24.27 × 11.76 m. In the southeast angle, there is a bell tower from the 15th century with an octagonal floor plan and Gothic vaults. Inside the style of the church is Gothic because the space is covered with ribbed vaults over cruciform columns. The church has no measured deformations.

The church of Santa María de Vilamós (Fig. 5) has a central nave and one of the lateral naves covered with barrel vaults, with the other lateral nave covered with a half barrel vault. The vaults are supported by four circular columns and two cruciform columns. The orientation of the church has a rotation of 15° from the east–west axis. The inner space can be defined as a rectangular space of approximately 24.09 × 9.85 m. Deformations have been measured in degrees (α), taking as reference the bottom part of walls and columns: the northern wall is 2° out of plumb, the inner columns 1° and 3°, and the southern wall 2°. The upper part of the northern wall, which measures 1.66 m in width at the base, has suffered a displacement of 0.011 m. The difference in height of the keystones between the central and

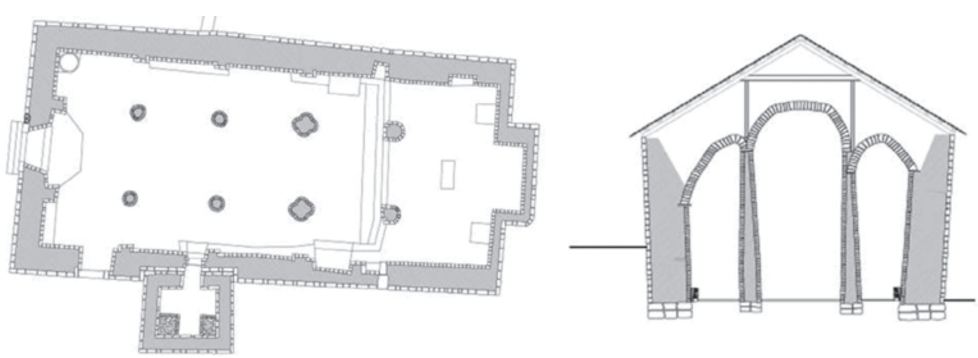

Figure 5: Plan and section of Santa María de Vilamós [13].

lateral vaults is 1.25 m. The northern vault increased its span by 0.34 m, whereas the southern vault increased its span 0.34 m. The church of Vilamos has a height of 6.08 m measured at the central arch of the presbytery, a total width of 9.62 m and maximum displacement of the upper part of the walls of the apse of 0.011 m.

The three main structural criteria are resistance, stiffness and stability [14]. The concept of stability rules masonry constructions. Thus, historical buildings such as the churches of Aran Valley are ruled by this criterion. Those structures have to be assessed considering the overall stability, which is sometimes due to its capacity to assume geometrical deformations.

The theoretical framework for the assessment of masonry structures is currently well developed, according to the principles of limit analysis defined by Heyman [15] and developed by many authors such as Huerta [16] and Block et al. [17]. Those structures are subjected to compression, being far from its mechanical limits, even in the largest buildings. Therefore, they are considered to have infinite resistance to compression. In addition, the tensile strength is considered to be null, and friction prevents sliding between pieces. New methodologies for the assessment of masonry structures based on limit analysis have been developed in recent years. To cite some examples, ref. [18] proposes a methodology that combines integral 3D models and limit analysis structural assessment. Other approximations are based on strategies, such as rigid block limit analysis [19] or the Load Path Method [20] for the assessment of masonry arches. Moreover, refs. [21, 22] developed a 3D funicular analysis, based on limit analysis, for the assessment of masonry vaults. Despite these developments, due to the typology of the structure being analysed, the investigation is based on traditional graphic statics.

4 CASE STUDY: SANTA EULÀRIA D'UNHA

Santa Eulària d'Unha is a Romanesque church built at the end of the 11th century. It is located on top of a rocky hill in the little village of Unha, 9 km from Vielha. Throughout history, it has suffered several transformations, most of them due to the displacement of the masonry. There is very little documental evidence of these changes, but the historical context and the assessment of the masonry make it possible to set a general chronology.

The main access to the building is located in the southern facade, where most of the openings can be found. The northern wall is completely blind, and three large buttresses were built at some time to balance the thrusts of the vaulting. In 1716, the bell tower was built with a total height of 25 m, supported over the west facade of the church. Regarding the roof, the marks on the masonry of almost three different inclinations reveal several changes.

All these modifications have changed the stability conditions of the structure, altering the distribution of loads. These processes, together with the settlement of the masonry through time, have deformed the architectural elements. The measures are not constant, the geometrical forms are irregular and neither pillars nor walls are aligned. Regarding materials, the church is basically built with little stones and lime mortar with low mechanical properties. The roof presents the typical solution with a timber frame and slate tiles, supported over pillars and walls.

5 METHODOLOGY

The assessment of the equilibrium conditions of the structure is based on the widely developed principles of limit analysis, determining possible stable solutions of the structure through lines of thrust. This type of study is especially helpful when visualizing whether the collapse mechanisms of a structure can be activated. The limit analysis enables the characterization of the stability conditions of the current structure. The described strategies are commonly used in the assessment of masonry structures [23–25].

The stability of the structure is assessed by means of two geometrical models: the current shape of the masonry and a theoretical initial shape before deformations occurred. This can be achieved by a drawing restitution process assuming that the supports did not change their position in the ground and were perfectly vertical.

Stability is analysed for both the hypothetical and current shapes of the structure. It evidences the differences between the stability conditions. The most deformed sections obtained from the Total Station survey are analysed for the current state. The specific weight of materials was defined according to usual values. For masonry, it is 25 kN/m^3 weight, and for roofing, it is 1.5 kN/m^3. The supports of the timber structure were placed over the vertical masonry structural elements of the church.

The assessment of the stability of the church is performed for both the initial section and current deformed section. The analysis of the theoretical initial geometry revealed that the stability of the church was already delicate. It is possible to draw a range of possible solutions considering various hypotheses, although they are near the limits of the masonry (Fig. 6). However, according to the principles of limit analysis, if it is possible to find a network of compression forces in equilibrium with the applied loads that fits within the section of the structure, it will be stable and will not collapse. So, if it is possible to find a thrust line within the masonry, the structure will be stable and will not collapse. Moreover, it has to be taken into account that a hinge will appear if the thrust line touches the edge of the structure. An arch with three hinges is stable, but the formation of a fourth hinge will transform the arch into a mechanism and it will collapse [26].

When analysing the current deformed shape, the lines of thrust tended to escape its limits in the base of the pillars. This circumstance leads to the conclusion that an extra load in the upper side of the vaults was dismissed in the hypothesis of the current roofing solution.

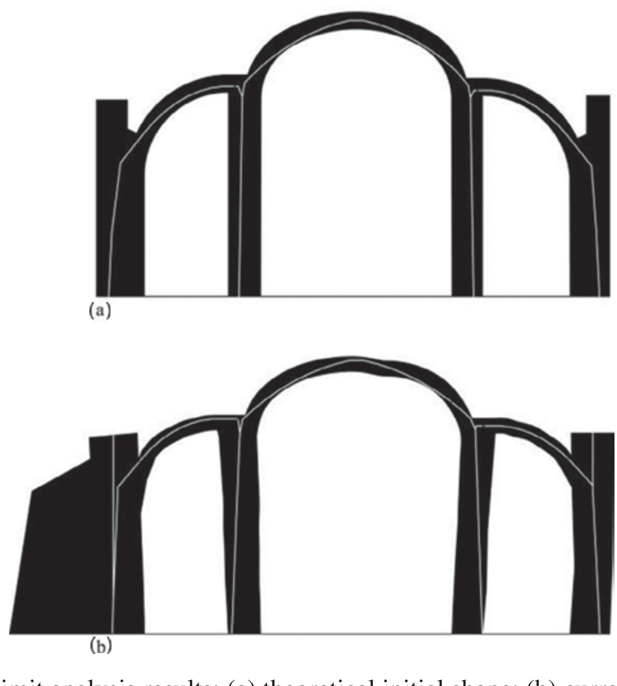

Figure 6: Limit analysis results: (a) theoretical initial shape; (b) current deformed shape.

Increasing the weight of the lateral vaults had a great redirecting effect on the thrust lines (Fig. 6), and it was possible, as in the initial shape, to find a valid range of solutions of thrust lines for the current state of Santa Eulària d'Unha.

Finding thrust lines within the section of the central vault has been particularly challenging because of its lowered geometry. In addition, the slenderness of the pillars was not favourable. The results highlight the importance of the loads applied on the upper side of the lateral half vaults. This set of constructive elements works as a buttressing system for the central lowered vault, counteracting the large horizontal thrusts.

By comparing results of the analysis with the church itself, it can be proven that the zones where the lines of thrust approach the boundaries of the section are traduced into physical cracks.

6 CONCLUSIONS

The survey of the five basilica floor plan churches of Aran Valley allowed us to quantify some of the deformations suffered by these masonry structures. Moreover, the typological assessment evidences the wide variety of geometrical solutions that can be found based on the same floor plan typology.

The results obtained in the limit analysis of Santa Eulària d'Unha revealed that, according to the principles of the procedure, the structure should have been stable. This finding highlights the importance of the loads on the extrados of the lateral half vaults in absorbing the considerable horizontal thrust caused by the lowered geometry of the central vault.

The church, which has large deformations, stands out as an example of a masonry building challenging the boundaries of stability. Like most of the churches in the Aran Valley, it evidences the importance of defining an analysis methodology based on suitable procedures to understand the behaviour of the masonry structure.

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COLONIAL CITY PLANNING IN PENANG WITH A SPECIAL REFERENCE TO THE GOVERNMENT BUILDINGS

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ABSTRACT

Colonial buildings and monuments are the prominent symbolism of the architectural sovereignty over the existing local architecture of the conquered lands. Specifically referring to the British colonialism, the colonial architecture was disseminated to manifest the triumph of the British colonial governance and the thriving monetary economy. In examining the impact of the British colonial influence on the local architecture precisely driven by the British colonial governance and the thriving monetary economy, the study enlisted three case studies of government office buildings located in the city of George Town. These prominent case studies include the Penang Council State Assembly, the Town Hall and the High Court Building. The design coherence of these buildings in regard to the British colonial references became the essential requisite in the selection of these case studies. Analysis on the design elements of these case studies was meticulously undertaken to draw relevant relationship between the colonial design praxis and the local government office buildings. The outcome of the study underscores the profound influence of the classical style in representing the British institutional status and its monetary economic success. Intended to showcasing the grandeur of classical elements, the embodiment of classical orders such as Doric, Ionic, Tuscan and Corinthian columns is evident in abundance of institutional and financial buildings across the Peninsula Malaysia, tracing its design references to the ancient Greeks and Romans. Further stipulation on some of these buildings revealed the adornment of Greek pediments and a series of Roman arches and vaults intended to further uphold the notion of the British colonial success.

1 INTRODUCTION

Colonial buildings and monuments, the emblem to herald the architectural sovereignty over the pre-existing local architecture of the conquered lands, are invariably touted with the triumph of colonial governance and economy [1]. During the Western colonial era, the architectural style became the hallmark to calibrate success, triggering multitudinous construction of the colonial buildings, particularly in the provinces governed by the European nations. Consequently, the style began emanating into different periphery of the colonial worlds, with greater distribution of the style signalling greater success. This echoes the British colonialism, hailed for its major imperial conquest over the New World (America), Africa and Asia. The British imperial power began disseminating the architecture that conjures the image of British Supremacy as described by Morris [1] asserting that the British 'had ruled a quarter of the earth's land surface and nearly a quarter of its people' [2]. He further aggrandized the British colonialism, elaborating that its colony borders from 'tremendous mountains, wide and barren plains, lush pasture-lands, rain forests, and marshlands to palm beaches, bogs, grassy uplands and desert subcontinents'.

2 LITERATURE REVIEW

The architectural styles of colonial buildings and houses were designed in grotesquely dissimilar fashion from one province to another, in response to wide-ranging regions and climate. The British colonialists were responsible in orchestrating the dissemination of the newly

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fashioned architectural style, a product of cultural blend between the Western architectural styles predominantly ingrained to the Western European design attitudes morphed into the lesser pre-existing traditional styles of the subjugated colony [3]. The style typically renders the melange into projecting the overt dominance of the architectural styles of the West, ideally enforcing compliant to European construction standards, coupled with the introduction of newly conceived colonial cutting-edge construction technology. Ultimately, the colonial-style buildings began showcasing the advance construction materials such as steel structure, masonry and stone artwork, which were alien to the locals. Due to the lack of knowledge of these materials, the immediate ramification presented design and constructional challenges to the local builders, a gamut which could be equally juxtaposed to the struggles of the British architects in dealing with local materials particularly timber-based materials prior to constructing the local traditional buildings and houses [4].

2.1 Symbol of democracy

The British imperial architecture had imposed great influence on their conquered lands, a colonial practice which reverberates the design and political praxis introduced by the Romans throughout their empire as argued by Morris [2]. The classical styles which were considered emblematic to the Western ideals of democracy and the capitalist economy became the prominent character to the buildings and monuments. The classical architecture, which predates ancient civilizations, upholds the notion of democratic superiority tracing its design praxis to its ancient Western predecessors, the Greeks and the Romans [5]. The British embraced the classical design, but unlike the Roman imperialism, the British had no intention to implement the classical styles to all buildings, monuments and houses; instead the inherited architectural practices were systematically integrated with the local architecture in the conquered lands. In some of the British colonies like America, Australia, South Africa and New Zealand, the neo-classical style became the dominant architectural influence. Unlike the rest of the conquered colonies, these British dominions were treated by the British as part of their allies. These new territories were given the privilege as permanent settlements for the British emigrants most notably from England, Wales, Scotland and Ireland, who were incessantly endeavouring for new opportunities in the New World. Conversely, nascent to the British colonial establishment, the conquered provinces like Malaysia were only regarded as a temporary settlement, with sole commitment in harnessing the local economic resources.

The decades that followed began to witness the tremendous shift in the British colonial attitudes towards the Peninsular Malaysia, envisioning the province as a prosperous melting pot, an impetus to engender profitable economy by exclusively harnessing its natural and agricultural resources [1]. The province which was previously regarded by the British authorities as remote and exotic ceased to play its function as temporary settlements, establishing a more profound role as the land of the opportunity. The immediate aftermath oversaw grand buildings and lavish monuments deliberately constructed by the British to explicitly signalling their intention for permanent settlement as they began to view the Peninsula Malaysia as their homeland. The construction of grand and aesthetic institutional buildings and monuments gradually sprung across towns and cities in the Peninsula Malaysia, with the classical style dominating the overall composition, a testament to the British institutional status and economic achievement. The embodiment of the British design and aesthetic ideals of their picturesque homeland alongside the Western colonial allegory is physically manifested through the interplay of classical building elements dating back predominantly to the Ancient Greeks and the Ancient Romans. Multitudes of these erected buildings are visually distinguishable by its perfectly symmetrical paragon embroidered with classical pillars typically of Ionic, Doric and Corinthian columns among others. The Greek pediments, a series of Roman arches and reiterated vaults can seldom be seen incorporated into the design of these erected buildings to amplify the symbolism of the colonial triumph [6, 7].

2.2 Symbol of trade

Aside from democracy, the colonial architectural influence is also essentially marked by the triumph of the Western economic influence over the colonized dominions. With the capitalist system became the burgeoning force for the monetary economic achievement in the colonial administration, the repercussion has greatly expedited the rise of multinational financial institutions and commercial companies involved in trades. During the colonial period of the Peninsular Malaysia, the British inaugurated the monetary economic system based on the colonial agricultural products which were uncustomary to local people. Under this system, the newly introduced colonial agricultural commodities such as rubber, cocoa, palm oil and natural resource of tin mining industry began to inadvertently eclipsing the pre-existing traditional rural paddy-growing and fishery activities. The evolution of the port cities became the impetus to trade these commercial products as chronicled by Galantay [8]:

> The colonial towns of pre-industrial societies were founded in response to an enlargement of the mercantile sector which provided the risk capital for the colonising venture. The creation of mining towns and of administrative centres was simply instrumental to the achievement of the main goal of expanding long distance trade. […] into the design of these erected buildings to amplify the symbolism of the colonial triumph.

The British fascination with the monetary system has led to the creation of a more prosperous colonized Peninsula Malaysia, transcending the British colonial economic institution as the monetary system became the chief source of the administration's profit. The outcome of this bountiful economic prosperity inevitably reinforced the position of the British administrative, financial and commercial institutions under the control of British East Indian Company. In return, the British officers received better monthly wages and subsequently improved their living standards and employment status. The immense fortune aligned with economic prosperity of the province had certainly altered the Western long-standing callous perception as they began recognizing the potential of their conquered province to transform into a prosperous Peninsula Malaysia [1]. The port city of George Town, the prominent testament of economic prosperity in the province, developed into the busiest trading centre in the Southeast Asia. The city significantly grew into a major trading centre, where the waterfront areas became the epicentre of the major trading affairs made popular by its bustling commercial activities of import and export of the merchandise goods. The waterfront channels were the most densely built-up areas in the city typified by an agglomeration of administrative offices, financial institutions, warehouses and commercial shop houses due to its direct involvement in trades. Administrative offices like the custom building were strategically nestled within the midst of harbour complexes to figuratively empower the government control over the trading activity.

Historically the City of George Town is the oldest British colonial city in Malaysia as well as in Southeast Asia with the city's name tracing its origin to the infamous English monarch King George III, made notorious for his majestic reign in the era of British colonialism [9]. Today, the historical City of George Town developed to become the second largest city in Malaysia. The city which was established in 1786 was originally a small town resided by a small group of people. Prior to its establishment, the city was initially introduced as the British trading centre in Southeast Asia under the authority of Captain Francis Light [10]. He anticipated the island as an ideal selection to flourish as port city acknowledging the island's strategic geographical location as a trading centre. Over the next few years following the establishment, the port city of George Town underwent a progressive sprawling of warehouses, built primarily to store merchandise goods alongside commercial shop houses acting as the trading offices. The major streets at the waterfront areas were divided into two major trading zones namely the eastern and the western streets. The western part of the street was designed to accommodate the Weld Quay's important buildings while the eastern part, in reverse, is specifically referring to the harbour full of small sailboats to bolster the transfer of merchandise goods from the ship to the warehouses. The warehouses consisted of an extensive array of shop houses are commonly constructed out of bricks and cement as the primary materials. Elaborate classical Roman arches seemingly adjoined each unit of the shop houses allowing the creation of five-foot walkways, windows and doors [11]. During the colonial era, the shop-like warehouses mainly served as offices for the European companies like shipping agents, general importers and tin refiners [7].

The Beach Street which is ideally situated one block away to the west of Weld Quay was a setting of numerous shop houses essentially to house traders and forwarding agents. It was a melting pot for various ethnic communities chiefly the Malay, Chinese, European and Indian traders who provide their expertise in various trading affairs including cargo handlers and shipyard workers. Furthermore, it was the venue for commercial products and merchandise goods to be temporarily stored in several warehouses before they were finally transported to their respective trading destinations. The Beach is also the home of major European financial institutions such as the Standard Chartered Bank, the Algemene Bank Nederland (ABN AMBRO Bank) and the Hong Kong and Shanghai Banking Corporation which are mostly located at the end of the street. The location of the government buildings such as post offices, Penang Council State Assembly, Immigration Building, City and Town Halls, and Magistrate Buildings can be seen standing further to the north.

3 RESEARCH METHODOLOGY AND THE CASE STUDIES

This study is to identify neoclassical elements in portraying image of colonial building in George Town, Penang. Among the significant elements are as follows: (Table 1)

To provide fundamental understanding of the colonial influence, this study enlists three government office buildings in the city of George Town with their neoclassical elements as follows:

a. Penang Council State Assembly
b. Town Hall
c. High Court Building

Table 1: Architectural elements and the definition.

Architectural element	Definition
Arcade	A sequence of arches structures emerging as a covered walkway.
Architrave	A lintel or beam sitting atop capitals of the columns.
Balcony/veranda	A projected floor several feet over the building wall creating a shade beneath it and open door system for natural indoor air movement.
Balustrade	A moulded lathe-built form made out of stone, wood or metal, incorporated on the footing of parapet wall or integrated as the handrail of a staircase.
Bay	An extended division of exterior or interior of a building by an array of windows, vaults, arches, roofs, etc.
Classical column	A column with a round or a square base crowned with Doric, Ionic or Corinthian capital.
Colonnade	A set of reiterated columns joined by an entablature or a beam, in free-standing manner or directly integrated into a building.
Cornice	An arrangement of ornate mouldings fixed to a wall, arch, etc.
Cupola	A minimal size dome structure on top of a building or adorned as a crown topping a larger dome.
Dentil	A pack of rectangular blocks resembling teeth frequently embellished under the soffit of a cornice.
Fan-like window	An upper semicircular or semi-elliptical window often fixed with sash bars resembling a set of fan ribs mostly secured on top of a door or another window.
Keystone	A wedge-shaped stone cast slit into the crest of a masonry vault or arch.
Parapet wall	A low-projected wall runs vertically along the edge of the building/ house particularly in the classical and modern architecture to replace the overhang roof system. There is a roof gutter design behind the parapet wall.
Pedestal	A base of a column constructed slightly bigger than the diameter of its respective column and risen several foot above the ground.
Pediment	The initial design is a triangular wall section fixed above the entablature supported by columns. The design gradually evolved into different shapes most notably semicircular and rectangular section during the neoclassical period.
Pilaster	A slightly protruded column built as integral part of a wall manifesting a rendition of a supporting column.
Pitch roof	A roof with a slope over an angle of 20° defined by Malaysian Uniform Building By-Laws.
Porte-cochere/ portico	A sheltered porch or portico primarily utilized to drop passengers from vehicles or horse carriages (in colonial times) and to provide protection from weather and can be found either on the main or secondary entrance. It is often integrated with open veranda/balcony on its top.

Quoins	A set of masonry blocks arranged vertically at the corner of a wall symbolizing permanence and strength, and reinforcing the immediate impression of structural presence.
Recessed wall	A wall recessed several feet from the building wall to give a shade from direct sunlight and rainwater. Known as 'serambi' in traditional Malay architecture.
Roof overhang	A projected roof design several feet over the building wall creating roof shades from direct sunlight and rainwater.
Round arch	A curve-shaped masonry construction used to span an opening alongside to support the mass on top of it.
Shuttered window	A window with angled horizontal slats to permit indirect sunlight and natural air ventilation, restricting rain and direct sunshine.
Tympanum	A decorative semicircular or triangular wall surface right on top of an entrance encapsulated by a lintel or arch.

3.1 Penang council state assembly

Standing magnificently to the neighbouring historical site of Fort Cornwallis at Sultan Azlan Street, the Penang State Assembly overlooks the refreshing grounds of the Padang Kota Lama. The monument was erected in 1905 at the height of the British colonial era, is placed under the authority of the state government and is presently serving as an Assembly Hall for the Penang State Parliament. The immediate impression of the Assembly Building echoes the influence from the ancient Greek temples most notably the Temple of Concord, the Temple of Poseidon and the glorious Parthenon. Upon closer inspection, the design elements draw similar parallels to the 'Doric Order' of the Greek prostyle temple model plainly visible through the embodiment of six inviting Doric columns at the front of the main buildings to support the roof structure. The main entrance of the State Assembly are chaperoned by two alternative entrances which protruded from the main building further injecting the image of the Greek temples. The facade is embellished with colossal Doric columns with a strikingly modest triangular crown roof resting atop the supporting columns (Fig. 1).

In contrast to typical Greek temples, the State Assembly completely obliterated the solid platform often merged with three large steps (stylobate and stereobate). This is due to their steepness and proportion which makes it uneasy to users to climb these steps. In exchange, a set of three smaller cascading steps made proportional to human scale was constructed a few feet away from the front colonnades to offset the missing design elements. The absence of a platform allowed for the columns to be directly built from the ground and secured by cubicle bases, a construction method with resounding similarity to the typical column system of a traditional Malay house, where the columns are often supported by a base known as the piles. The extended roof is rendered with clay tiles projecting overhangs to pragmatically delivering shades to adapt the thermally demanding tropical climate. The exterior walls are furnished in subtle white complexion encompassing minimal openings of approximately 9–10 feet above the ground floor. The building is festooned with nine wooden entry doors to hasten the access for the state representatives during the state assembly. The solitary rendition of its minimal openings engendered an efficient privacy status an essential requisite to properly function as the State Assembly.

Figure 1: Penang Council State Assembly.

3.2 Town Hall

The Town Hall which was constructed in 1850 had undergone several renovations from 1904 to 1906, and is currently serving as the municipal hall under the supervision of the Penang Municipal Council (MPPP). The majestic rendition of the two-storeyed building using a mixture of white and gold yellowish paints emboldens its colonial reference with vast tendencies towards the neoclassical style. In response to its purely symmetrical plan layout and elevation, the resulting facade expresses design affiliations to the prostyle portico style at the middle and joint by double symmetrically balanced projected bays. On the ground floor, the portico is harmoniously integrated with three open arches, and its apparent dominant central arch is constructed to be slightly taller and wider than the side arches. The portico is articulated with minimally ornate double Tuscan columns on pedestal support in each corner enhanced by two columns at the centre that compose the arches. An indistinct single entrance arch on each side of the portico compliments the Tuscan columns and arches. The upper level is injected with a balcony with the largest single arch spanning at each side of the extended facade. Among the striking traits of this building is the degree of ornamentation that encapsulates the entire facade complexion of the building. It ranges from its meticulously ornate floral motifs on the pediment, a magnificent array of balustrades skirting the unbroken appendage of its cornices and the Tuscan pilasters seemingly dividing the upper and lower levels. The flamboyant melange that ensued is perpetuated by its two immediate bays through the embodiment of moulded arches, decorative keystones and double-leaf glass windows (Fig. 2).

Figure 2: Town Hall.

3.3 High Court Building

The High Court Building which is located at Light Street, in George Town, was constructed in 1905 and is currently placed under the authority of the Federal Government. The facade of the two-storey courthouse is rendered in gold yellowish colour articulated with an alternate of white-coloured stripes legibly manifesting strong design tendencies to the neoclassical architectural style. The symmetrical plan layout of the courthouse divides the building into four sides, with each side carrying a prostyle portico. On the ground floor, the portico is constituted of three bays by a set of double classical columns supporting the delicate glass louvered shutter windows. Each of the rectangular windows is complement by the geometrically moulded balustrade sills. On the first floor, the style evidently reiterated the classical columns in a slightly smaller scale embroidered with contrastingly darker shades of timber louvers in between the columns. The triangular pediment (tympanum) is engraved with letters ‘Mahkamah Tinggi’ a Malay-language expression translating ‘High Court’ punctuating an immediate impression of its prominent function as a courthouse.

The influx of the building’s colonial design traits is also evident from the extensive colonnaded walkways on the ground floor triggered by a row of classical-style columns and the Doric capital supporting the upper floor. The purely geometric nature of its vertically arrayed columns is juxtaposed by the organic presence of the semicircular arches on the upper floor. From the spectacle of the extended bays on the side of the building, each section of the bay is divided by pilasters. Glass louvered shutters are well connected and fixed in each division of the bay. The amalgamation of geometrically simplified classical building configurations of the main facade and the side bays is carefully clung to the core of the building made of octagonal turrets with copulas on all its four corners (Fig. 3).

Figure 3: High Court Building.

4 DISCUSSION

Table 2 shows the result of the colonial design elements identified on the three case studies. The study finds the following:

1. Numerous neoclassical design elements can be found in the case studies of government office buildings with special reference to mostly the classical Greek and Roman styles.
2. Each of the case studies is designed with a porte-cochere or portico as the central facade which engendered facade design with roof shade coherence to the tropical climatic contexts with harsh sunlight and heavy rainfall. Through this method a number of overriding neoclassical design elements can be traced in each of the case studies.
3. In all case studies, the porte-cochere or portico is fundamentally designed with a pedestal as platform to support the classical columns. The supporting columns, which divide the portico into three facade bays, are connected to an unbroken projection of architrave with minimally ornate cornice. Unlike the rest of the case studies, the Case Study 2 (Town Hall) is further adorned in a continuous array of dentils alongside its cornice.
4. Many porte-cochere or portico designs continue to the upper floors and are finally crowned with a pediment in engraved tympanum.
5. The study suggests that round arches can be persistently found in all the case studies that constitute to the design of the classical bays. Keystones can be found attached to the crest of the arches only in Case Study 2.
6. In Case Study 3 (High Court) the round arches form an arcade, a design element which disparate the high court with the other case studies.

7. In Case Studies 2 and 3, the embodiments of classical elements like balustrades, shuttered windows, pilasters and parapet wall are evident, while colonnade and fan-like windows are profoundly utilized in Case Studies 1 and 3.
8. Additionally, unlike Case Studies 1 and 3, the Town Hall facade is decorated with quoins to draw reference to immense structural strength.
9. A set of cupolas can only be found on Case Study 3 and is rendered unavailable to the other case studies.
10. The incorporation of climate-responsive design elements is observable with application of portico/porte-cochere, balcony/veranda, pitch roof, roof overhang, recessed wall, fan-like and shuttered window as a design adjustment to the tropical climate for shades and natural air ventilation to provide thermally comfortable environment.

Table 2: The result of analysis of the architectural elements.

Architectural elements	State Assembly	Town Hall	High Court
Arcade			X
Architrave	X	X	X
Balcony/veranda		X	X
Balustrade		X	X
Bay	X	X	X
Classical column	X	X	X
Colonnade	X		X
Cornice	X	X	X
Cupola			X
Dentil		X	
Fan-like window	X		X
Keystone		X	
Parapet wall		X	X
Pedestal	X	X	X
Pediment	X	X	X
Pilaster		X	X
Pitch roof	X	X	X
Porte-cochere/ Portico	X	X	X
Quoins		X	
Recessed wall	X	X	X
Roof overhang	X		
Round arch	X	X	X
Shuttered window		X	X
Tympanum	X	X	X

5 CONCLUSION

In conclusion, the colonial buildings and monuments are evidently utilized as the insignia of colonial architectural sovereignty over the existing local and expatriate architecture in their overthrown dominions. This praxis is undoubtedly employed to manifest the triumph of the British colonial governance with thriving monetary economy. Retrospectively, the fostered economic prosperity had presumably shifted the erroneous and long-established British perception of the Peninsular Malaysia. The province which was previously regarded as temporary settlement for the British emigrants promptly began to induce profitable monetary economy in agriculture and natural resources signalling economic prosperity. The fruitful province ceased to exist as a remote and exotic terrain at the sight of the British officers. The shift in the British colonial attitudes witnessed the sprawling of grand buildings and monuments indicating their inclination for permanent settlement in the newly conceived land of the opportunity.

Institutional and financial buildings and monuments were built with precise intention in showcasing the grandeur of classical style with adjustment to the local tropical contexts across the towns and cities in the Peninsular Malaysia. The classical style was chosen as the ideal style for representing institutional status and its monetary economic success. The ultimate design ramification observed the embodiment of classical elements profoundly the classical pillars such as Doric, Ionic, Tuscan and Corinthian columns into the colonial buildings and monuments. Some of these buildings revealed the unity of Greek pediments and a series of Roman arches and vaults intended to amplify the notion of the colonial success. Application of portico/porte-cochere, balcony/veranda, pitch roof, roof overhang, recessed wall, fan-like and shuttered window is feasible for shades and natural air ventilation to provide thermally comfortable environment. The design creates a unique hybrid of colonial building that can only be found in this region [13].

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URBAN HERITAGE AND CONSERVATION IN THE HISTORIC CENTRE OF BAGHDAD

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ABSTRACT
Baghdad, one of the leading cultural centres in the Middle East, has been a centre of political and economic operations since it was chosen by Caliph Al-Mansur to be his capital city for the Abbasid Empire in 762 CE. Up to the 21st century, the city has been occupied many times by different groups such as the Ottomans (1638–1917), the British (1917–1932) and the Americans (2003), who have all left their marks in varying degrees. The historic quarter of Old Rusafa is one of the areas of the city where historic buildings going back to the early 13th century have resisted the power of transformation, such as Al Mustansiryia School, The Abbasid Palace and Al Khulafa Mosque. This article will address how the traditional compact urban fabric in Old Rusafa has witnessed irreparable damage because of wars, a weak definition of demands and an ambiguous formulation of what to preserve. These are some of the reasons that the majority of urban conservation plans prepared by different groups for the city centre have not been successful. The article will address revitalizing urban heritage in Old Rusafa as an example of preserving the urban system and its components in historic cities. It will also argue the significance of preserving these historic places and how to promote socio-economic and sustainability aspects. Finally, preserving traditional areas will require implementing efficient and sustainable urban development strategies that drive urban evolution and encourage revitalization of the historic centre.
Keywords: conservation, sustainability, urban conservation, urban fabric, urban pattern.

1 INTRODUCTION

Everard and Pickard [1] mention that conserving the built heritage can protect and promote identity, the significance of place, cultural value, aesthetic value, as well as an economic and commercial value. They suggest, ‘The “psychological and aesthetic value” of the conserved environment is so important that knowledge of peoples’ conscious or subconscious commitment to buildings from the past should play a crucial part in the development of conservation policy and practice’. They also write, ‘There may be “multi-faceted outcomes of conserving the cultural built heritage in terms of the dynamic benefits to society”, and conclude that “the cultural heritage is an economic, tourist, scientific, educational and sustainable asset which needs to be protected by the commitment of the whole community through partnership of public and private sectors”’ [1].

Since policymakers and urban authorities have turned to ‘culture’ as an instrument for urban regeneration, the importance of historic environments has become increasingly evident as part of urban regeneration initiatives [2]. At the same time, ‘Conservation initiatives try to enhance strategies which not only ensure the continuing contribution of heritage to the present and the future through the thoughtful and intelligent management of change responsive to the historic environment and collective needs, but also the preservation of fundamental elements of social environments. Such strategies will lead to more equitable and sustainable solutions to the problems currently faced by the historic quarters’ [3].

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2 CONSERVATION IN THE URBAN CONTEXT

The past century has been one of unprecedented change in terms of impact on the urban environment. The issue of conservation of historic urban areas was seen in a new light in the late 1980s, partly due to the growing concern for the environment and situations of poverty in many countries, as well as disasters and armed conflicts [4]. The main factors driving change in the urban environment are globalization, rapid uncontrolled development, demographic changes and economic pressures, which directly influence the preservation of historic urban environments. Many challenges emerge in the conservation of built heritage but the main one is the original uses are to be changed while preserving the importance of the area and its buildings [5].

The population growth in cities, as Al-Saffar [6] debates, will rise to more than 60% of the world population by 2050, and this increment will lead to increase the pressure in various urban places. He argues that built heritage resources and traditional places are under threat in responding to modern business forces. He asserts that urban conservation can offer new sustainable methods to deal with socio-economic and environmental problems. He adds that urban conservation can develop the historic physical environment, offer new jobs opportunities and improve the quality of life in run-down areas. He states, ‘Conservation policies can play a significant role in promoting, managing and protecting our built heritage in terms of its socio-economic and environmental aspects’ [6].

Conservation is discussed by Ebrahimi in the following terms (2015): ‘In preserving and maintaining the frame and concrete architectural structure; however, the growth of awareness alongside attention to other aspects caused different aspects to be effective in recognizing and evaluating the values’ [7]. In addition, it ‘is the action was taken to prevent decay and manage change dynamically. It embraces all acts that prolong the life of our cultural and natural heritage’ [8]. Conservation policies and measures have changed due to the alteration in the principles of urban conservation. Peerapun [9] has stated according to International Council on Monuments and Sites (ICOMOS) that coherent strategies of socio-economics development and of urban planning at every scale should be a complementary aspect of the conservation of historic urban areas. He has added that one of the essential elements for the success of conservation programmes is public participation [9]. Conservation aims to be a part of broad procedures of promoting the existing physical-built environment and affects all citizens in a community. Glendinning [10] argues that architectural conservation is something that embraces different forms and subjects such as urban design, housing, environmental issues and renewal [10:1].

3 URBAN CONSERVATION

During the 19th century, the infrastructure of land uses, buildings and streets suffered from different issues typically linked with urbanization, for instance, poverty, migration, overpopulation, unemployment and segregation. Improving the quality of urban areas in recent years has become a response to the challenges displayed by citizen’s mobility, which require the physical renewal of declining inner urban spaces in a flexible way. Cities show endless examples of neglect that manifests high rates of decline in their urban fabric. These areas are widely connected with historical layers of urban change during which they have, over time, advanced, declined and sometimes been renovated. The narrow alleys found in Cairo, London, Rome and Athens are representing vibrant models of this. Various actions to conserve these fortunes were framed in combinations of policies that have seen positive results in the recent years [11:14–15].

Urban conservation, as Cohen [12] points out, is a cultural necessity ‘due to the increasing tendency of city dwellers to move back into historic centers, urban conservation is becoming an ever more urgent issue’ [12:9]. Albrecht [13] has stated that ‘urban conservation’ was used by others more broadly to include environmental factors as well as socio-physical and socio-cultural issues. Moreover, he defined urban conservation as 'protecting and managing the valuable ecological spaces and species in and around cities, as well as the ecosystem services that they provide' [13]. Pendlebury and Strange [14] debate that the power in shaping the planning of the contemporary city is the practice of conservation of the historic environment [14]. Su [15] has stated that over the last three decades urban conservation has become a substantial element to promote urban competitiveness in the global economy, asserting that one of the main purposes of urban conservation is to promote the historical physical environment and ensure its continuity as an attractive place to live [15]. Al-Saffar [6] mentions, 'Since policymakers and urban authorities have turned to "culture" as an instrument for urban regeneration, the importance of historic environments has become increasingly evident as part of urban regeneration initiatives' [6]. Puren and Jordaan [16] suggest, 'A shift in how urban conservation is viewed in the sense that it should move from preserving heritage resources as isolated objects towards a more integrated view where heritage resources are proactively integrated into the contemporary uses and future development of cities to ensure the continued existence of these assets' [16]. Therefore, urban conservation, as Koramaz and Gulersoy [17], mention, will require comprehensive spatial analyses and investigations devoted to the evaluation of urban historic areas [17].

3.1 Urban conservation and society

In recent years, governments, practitioners, experts, academics and international organizations have considered urban heritage as urban areas rather than single monuments. They moved towards utilizing citizen participation in order to preserve, manage and control urban conservation plans. The bottom-up approach has become an essential factor in cultural heritage issues creating new opportunities for citizens' participation in the decision-making process of urban conservation. Sarvarzadeh and Abidin [18] point out that citizen participation has the ability to improve the practice of urban conservation and assist policymakers in identifying opportunities and challenges [18]. Stakeholders were expected to have various knowledge and experience, and interest in, cultural heritage resources. However, governments and professionals considered citizen's participation in forming and responding to the social needs of societies [19]. Al-Saffar [6] mentions, 'There is an interaction between what people build and what they believe, mentioning that people structure their environment and are influenced by it in their attitudes as a result of interaction with it over time'[6].

In Old Rusafa nowadays, enhancing the concept of identity and developing the traditional social values are a new tendency. The historic centre is represented by the important role of culture, religion and the most significant element social structure. The physical and social situations are depressed in this traditional area; however, it is still the source of cultural inspiration for citizens, and people still prefer to go back and live in the traditional neighbourhoods where they grew up. This area has community representatives who could participate and promote conservation processes more than the official administrative body in such areas [20]. One of the significant elements to advance the urban conservation plan is to create a cooperation between the city's stakeholders and urban designing experts. Pieri [21] argues, 'In the case of Baghdad, a city in which there were so many urban and architectural additions throughout the twentieth century, preserving a "continuity" does not only imply the formal level, but also the practical appropriation of the urban space. Baghdad's renaissance should not depend on arbitrary external criteria deciding what is beautiful or ugly, good or bad, but on a cautious analysis of the physical needs and the mental representations of its inhabitants, balancing between objective, subjective and even symbolic data' [21].

3.2 Urban conservation and economic

Yung and Chan [5] have argued, ‘Conservation of historic buildings and places contributes to a higher degree of creativity and economic development as well as a better quality of life and the social well-being of different groups. However, a key issue in heritage conservation is the use of the heritage and its vital interface with both culture and identity’ [5].

Economics is the most important element that might enhance and encourage governments to plan a new strategy for developing the traditional cores in historic cities. The majority of historic centres in Iraq are concentrations of local industries that are the main source of traditional and cultural goods and services, not only for local residents but also for visitors and the whole population in the country. Urban conservation of historic areas has the ability to motivate these traditional industries, generating incomes and employment for local citizens and businesses. This will lead to increasing the rate of internal and external tourism that might be one of the fundamental elements of significant revenue; tourists are usually attracted by the traditional areas that represent cultural identity. This will form a new and essential commercial area for the traditional products of the city. If these historic centres are ignored or demolished, the city will lose these advantages [22].

Old Rusafa has strong economic bases and contains many significant commercial markets such as Shorja Suq which has a national role. This area is considered as the main commercial centre of Baghdad and showed the characteristic division of trade, goods and crafts (Fig. 1).

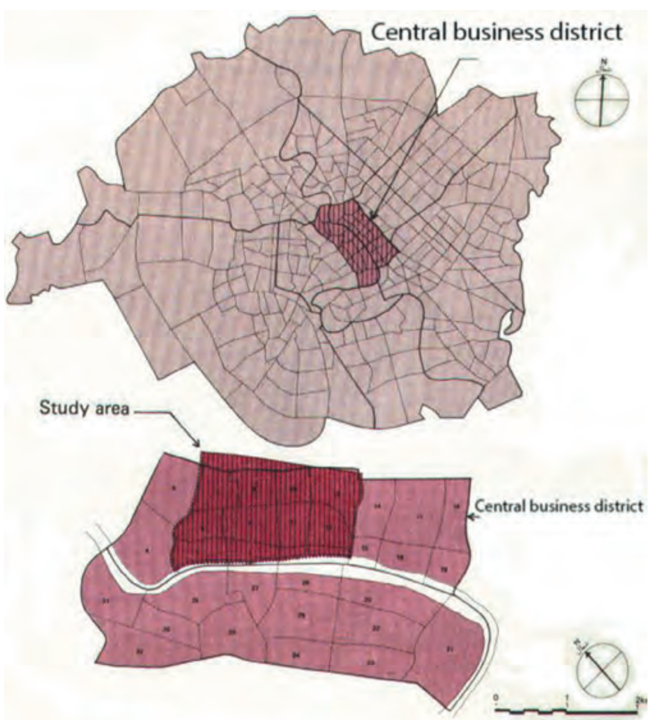

Figure 1: Old Rusafa as part of the Central Business District in Baghdad (CBD). Source: [28].

These markets or suqs are located in a particular place that is usually connected with its adjacent specialized suq. Sarai Suq, for example, is close to Mutanabi Street, the first one specializes in books and stationery, and the second specializes in print works, libraries and book storage. A second example is Sarafin Suq, which is occupied by moneylenders and exchange, but is just located near a modern street of banks. Furniture, car repair, metalworking and textiles are the significant industries in Old Rusafa. Various challenges and problems have faced the national economy such as ongoing conflict, no access to adequate private investment and lack of official promotion of popular interest in urban conservation. In addition, the land around the commercial centre has witnessed an increase in its price, and the nature of materials and high standards of craftsmanship that are needed to preserve this area are very expensive [20].

3.3 Urban conservation and sustainability

In the last few years, we have seen plenty of research on the urban conservation of traditional areas. The consequences of these literatures have endeavoured to find a connection between urban conservation and the ability of cities to transform to a sustainable future. Shwartz et al. [23] clarify that 'researchers, advocates, and policymakers have proposed urban conservation as an emerging, integrative discipline that can contribute to sustainable cities by delivering co-benefits to human and non-human components of biodiversity' [23]. Hiu and Hon (2012) state that 'built heritage is extremely difficult to survive in a city if they are not conserved in a sustainable way'. Preserving traditional fabric and enhancing the character of a place are not the main concern of urban conservation nowadays, but how would urban conservation be sustainable. To move to this stage it demands the involvement of the environmental, social and economic issues in urban conservation in order to promote the quality of life for all citizens and to create a better place to live and work. Social equity, inclusiveness and action are consistent with the concerns of built heritage conservation as part of sustainable development [5]. Sustainable city planning is an essential issue in historic cities that seek to create liveable places for public, green areas and perfect physical environment that is required for a better society life [24]. Heritage and sustainability in the 21st century share the widest common base when both are preserved first as being ongoing processes rather than immediate end products, and second as being people-centred (culturally as well as socially) rather than object-oriented [25:20].

Cities nowadays, as Al-Saffar [6] debates, are facing many fundamental challenges in terms of developing sustainable urbanism. He indicates, 'One of these challenges is how to solve problems of unsustainable geographical expansion patterns and ineffective urban designing and planning methods that have increased the number of slums areas, unsuitable delivery of basic services and inefficient resource use, and poverty'. He confirms, 'Previous studies have not illustrated a clear vision for dealing with the assets of urban heritage and their relationship with environmental, social, and economic issues, especially in an age of such significant transformation. Therefore, an evaluation of urban heritage conservation under the light of sustainable urban design is required to regenerate urban form and fabric'. In terms of Old Rusafa, he says that the organic traditional urban fabric was the first stage for sustainable thinking. He asserts, 'The compact area of narrow alleys and traditional Baghdadi houses are oriented in a defensive posture against the wind-borne dust, and the direction of the sun must be determined for all hours of the day at all seasons along with the direction of the prevailing winds, especially during the hot season'. He states, 'The features of the old urban fabric represent the main principles of environmental sustainability and shows how individuals in the past built a sustainable environment to face the tough climate' [6].

4 URBAN HERITAGE CONSERVATION IN HISTORIC CITIES

In the last five decades, various projects, research and proposals have been produced to preserve historic cities in the world and especially in the Arab world. Cultural heritage has contributed to promoting the economic, social and cultural life of cities in the developing countries. We can find the heritage in the historic core of alleys and traditional buildings that have resisted the power of modernism. The significance of preserving these iconic historic buildings and areas is to obtain economic, social and cultural goals. Hence, policymakers, architects and urban designers require the creation of a new approach that connects the architectural and cultural functions of heritage in the urban spaces. In several historic cities in developing countries, the long-term methods of urban evolution have bypassed quarters where alleys, patterns, urban fabric, social and heritage activities have been kept unchanged for many centuries [22].

Historic cities have transformed into paths of cultural activity by using appropriate urban conservation, which is not only preserving some significant building but is a compressive approach to protecting and conserving the whole historic urban structure [12:9, 11]. Bianca [26] argued that the Industrial Age has affected the dynamics of the socio-economic issues and has helped them to find their physical term in the substantial transformation of historic cities, while changes in the architectural fabric through former centuries had usually happened as part of a natural evolutionary process [26:174]. Shin [27] observes that due to local entrepreneurialism, cities have employed different strategies in order to compete for increasingly footloose capital and citizens. Conservation of historic areas has played a fundamental role in promoting economic development in cities. Consequently, urban historic centres, and plenty of significant monument and architectural heritage, have gained renewed interests in the last few decades for their socio-economic value [27].

5 URBAN CONSERVATION IN HISTORIC CENTER OF BAGHDAD (OLD RUSAFA)

Old Rusafa is the historic centre of Baghdad and has a long history going back to thousand years. This old core has become a complex urban organism as Al-Saffar [6] says. He shows, 'The area of Old Rusafa once enclosed within the old wall is approximately 5.4 square kilometers, has a population of about 203,000 (1980), and contains nearly 15,700 buildings. Currently, Rusafa forms a contracting mixture of dense irregular traditional fabric and gridiron modern developments often conflicting with each other in form, scale, and function'. He asserts, 'The importance of Old Rusafa is of not only local but also regional and national dimensions. It contains the biggest concentrations of traditional suqs and workshops and some of the most significant mosques and government and administrative buildings in Iraq'. He also adds, 'Old Rusafa contains several significant historic buildings: 132 monuments are listed, twenty-one monuments of which belong to the Abbasid Empire (762–1258) and the rest to Ottoman Period (1638–1917). Therefore, it is considered as an important heritage that demands emergency protection for its historic identity'. He illustrates that the historic core has suffered from many problems such as destruction of many buildings and deterioration of the traditional urban fabric [6].

One of the significant comprehensive urban conservation master plans for Old Rusafa was submitted by Japan planners, Architects and consulting engineering (JCP) in 1984. Urban conservation and redevelopment of the traditional core were the main aims of this scheme. This project proposed a buffer zone around the old centre by promoting the advancement of a Central Business District. This master plan was only partly implemented due to the political condition from 1990 until now. The proposed conservation scheme designates conservation places and monuments to ensure their protection. It also offers solutions that minimize the damage as much as possible be the removal of eyesores, development control, incentives for restoration and by environmental rehabilitation and revitalization. JCP plan [28] designates conservation places within Old Rusafa, identifies building by building, their typology and architectural interests, and suggests diverse criteria for intervention, restoration, urban repair, infill or substitution. A methodological approach for such intervention and a corresponding 'manual' for the use of The Municipality of Baghdad are proposed in order to permit it to control ongoing growth. They assert that conservation and development in the historic core should be implemented in the progressive stage and can succeed only when other equally necessary legal, administrative and financial tools are provided. The importance of this plan is not envisaged as merely a passive protection of the existing historic centre. In addition to proposing the conservation, restoration or rehabilitation of significant portions of the historic centre, the structure plan and urban design schemes aim for an active development of the historic fabric. This includes the retrieval of many fundamental parts which, if realized, would greatly improve the image of Old Rusafa (Fig. 2) [28].

In recent years, to conserve the historic part of Baghdad, many initiatives and projects have been prepared by The Municipality of Baghdad to protect the historical physical environment of Old Rusafa and display the socio-economic and environmental problems. However, these plans have concentrated on demolishing big parts of the traditional urban spaces or on simulating the Western countries' methods of urban growth. Furthermore, these initiatives did not consider citizens' participation as a main element in making decisions (Fig. 3) [20].

Figure 2: Goal image of Rusafa historic centre. Source: [28].

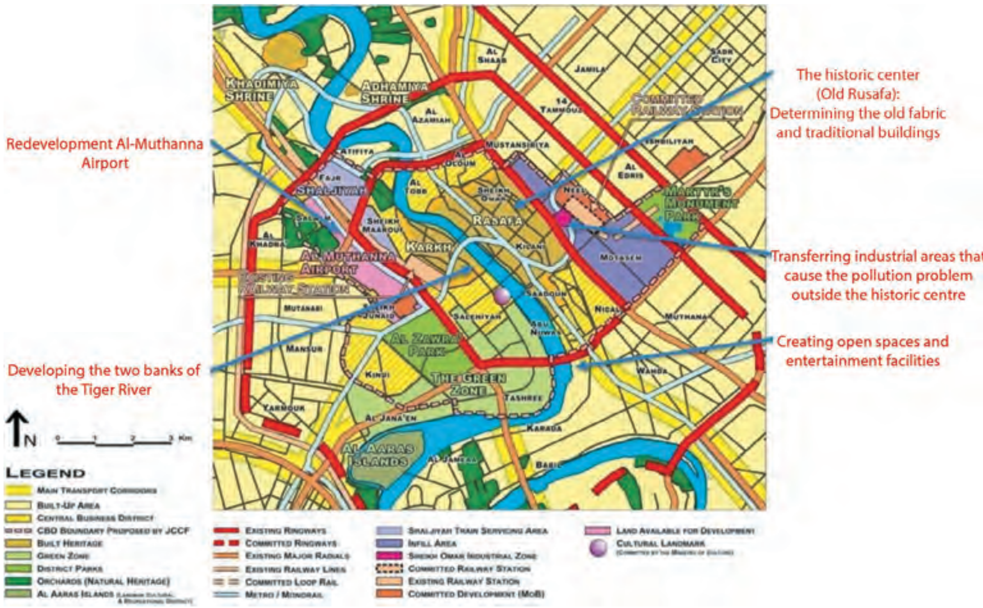

Figure 3: Short-term development strategy for the central business. Source: Author [6] according to The Municipality of Baghdad.

6 REVITALIZING URBAN HERITAGE IN OLD RUSAFA IN TERMS OF ITS URBAN PATTERN AND URBAN FABRIC

The beginning of the modernization in Old Rusafa started in 1869 when the Ottoman demolished the old city walls that were built during the Seljuk rule (1052–1152 AD) and constructed the first residential extensions. The layout of the old city did not change much between the Seljuk period and the end of the 19th century. Many problems have led to the deterioration of the structures of the historic centre that were constructed of brick and timber and had to be rebuilt periodically due to frequent flood damage and fire. One of the main problems was the opening of four major roads between 1914 and 1956 which linked the northern and southern limits that had led to the dissection of the continuous urban fabric into isolated fragments (Fig. 4). The second problem was the rehabilitation of the disrupted urban form on both sides of these new roads that were given over to wholesale redevelopment, huge areas of old urban fabric been demolished and the rest of the traditional urban fabric was ignored. The method of transforming the city centre from the traditional to the modern was another problem, which has been affected not only physically, but also socially, by the departure of the original people of Old Rusafa into new modern areas. A new community from rural areas in search of employment and a better life filled the social vacuum in the old city by renting the traditional houses, usually one family per room. Furthermore, property owners were not interested anymore in preserving their properties. These circumstances have led to acceleration of the physical deterioration.

Four main types of urban form were identified in Old Rusafa by JCP planers. The first type was the traditional homogeneous places located mostly between Khulafa Street and Kifah Street. The second type was the traditional fabrics built between the two World Wars, including Rashid and Kifah Street. Modern fabric blocks was the third type starting in banks District Khulafa street in 1950s, and finally, the Shikh Omar area developed in the early 1940s consisting mostly of large, one-storey garages, stores and services workshops. JCP planers tried to achieve compatibility between these different urban forms in Old Rusafa; conservation

Figure 4: Old Rusafa from 1854, overlapped with the new urban system. Source: [26:251].

and urban design plans are approached as complementing each other. Therefore, to attain this aim they suggest that The Municipality of Baghdad should apply development control in two stages: First, by passive control with guidelines and regulations to control private growth in conformity with plans. Secondly, through active control by assisting or initiating comprehensive development projects to assist the implementation of the overall concept. Several focal places in the historic centre were selected by JCP planers to illustrate these approaches such as the riverfront, Rashid Street, historical spines suq system and Sheikh Omar zone [28].

Bianca [26] argued that the traditional urban fabric in Baghdad required a new scheme to solve the broken structure of the urban system, before producing a comprehensive plan for the historic centre that might propose a total redevelopment including the conservation of a few isolated historic buildings. He also suggested relinking the current components of the urban system in order to integrate the remains of the traditional urban fabric and precious urban characteristics [26:250–256]. Therefore, to create an efficient urban conservation in Old Rusafa, we should consider and improve all socio-economic issues and produce a holistic approach to revitalizing urban components of the urban system in the city centre of Baghdad.

6.1 Urban pattern

Population growth is the main reason for current urban development in various urban areas worldwide. This has shown a great concern about a reduced quality of urban patterns and the quality of life of the urban resident. In other words, the lack in quality of urban patterns will result in a reduction in the quality of life of the urban resident. Hence, huge efforts are made to evolve new procedures for improving the socio-economic and environmental condition that might transform current urban patterns towards a higher quality. Wissen Hayek et al. [29] say, 'Urban areas are highly interlinked systems with human agencies and urban patterns, both affecting socio-economic and ecological processes at various spatial scales' [29].

Cohen [12] point out that the concept of the best urban pattern should have the basis for sustainable life and has the ability to encourage the present towards self-preservation without ignoring the new one. He asserted that this concept would require implementing a few general conditions. Firstly, one must consider the idea of the whole in relation to the size and the character of the city. This method will clarify the structure and allow us to make decisions more quickly and control the non-essential mistakes. In this case, the new pattern will have the ability to accommodate itself in a well-identified framework with the past. Secondly, one should determine the fundamental elements that constitute urban patterns including building style and spaces that define human actions in such an area. Lastly, the main components in the urban fabric should have the capability to affect local elements in order to improve relationships and overcome what is usually detrimental [12:19].

In the past decades, Baghdad city has experienced extremely great changes in its urban patterns. Many new buildings and modern road facilities were built in the historic city centre. The new type of urban area and modernism movements has affected the identity of the existing traditional urban fabric, which has led to the creation new urban pattern within the old one (Fig. 5). Al-Hasani [30] argued that the conflict between various patterns could be solved by defining the area between them and developing it in a better way to use it between diverse users and functions. He also debated, 'The self-organized urban form was interrupted by a planned and planted one. The result was two different space languages competing against each other. Those new added urban elements have created an interrupted urban pattern, which

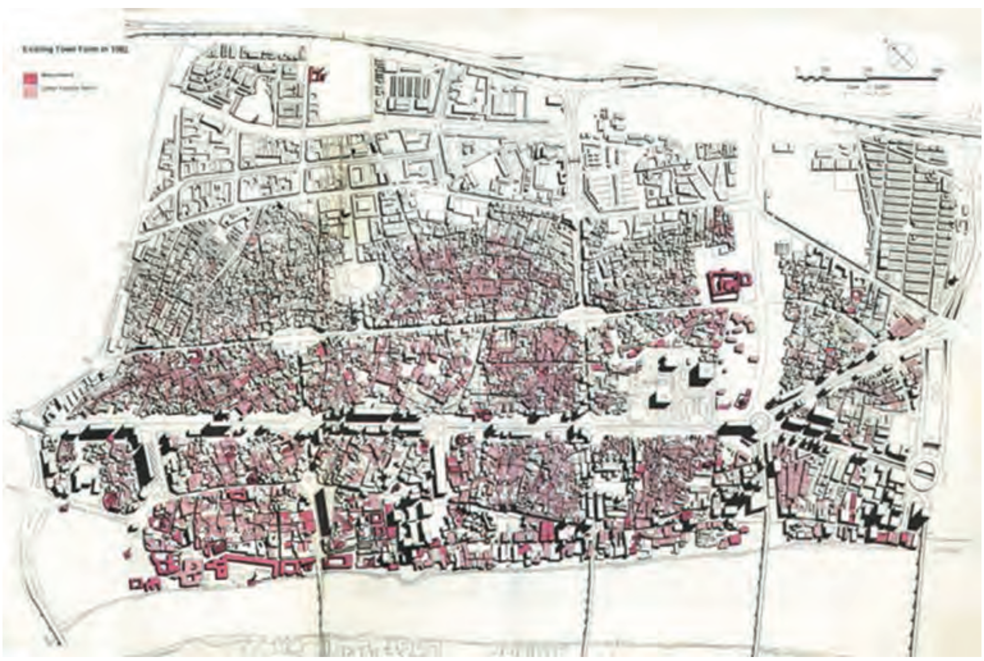

Figure 5: The new urban pattern within the old fabric (Old Rusafa). Source: [28].

was so far from having continuity, coherence, and integrity with the surroundings. The quality, use and nature of the urban space in Baghdad is based on different spatial concepts, urban patterns and building typologies' [30]. However, the historic urban area in a city centre has a high mixed land use pattern and still contains many essential features from the past; further, it not only represents the concentrated residential area but also the commercial, political and cultural centre of Baghdad city.

6.2 Urban fabric

Old Rusafa is the historic centre of Baghdad city, and due to that, its fabric has been under pressure from modern development and has suffered tremendous losses in its traditional form. However, there is still an opportunity to preserve the rest of the unique fabric by promoting these areas with new facilities and fixing the broken structure. The historic centre has witnessed some conservation by the Municipality of Baghdad in its fundamental buildings and street such as the Al-Mustansyria school, the Baghdadi Museum, Khan Merjan, Al-Rashid Street, the historic castle which is used as the Ministry of Defense, and many tombs, mosques, houses, cafes and squares (Fig. 6) [20]. Al-Saffar [6] debates, 'There are many elements that emphasize the unique urban fabric that makes the Old Rusafa so special such as traditional suqs, Rashid Street, khans, churches, and significant mosques. Conserving these archaeological and cultural features will promote heritage values in Baghdad'. He emphasizes, 'Rescuing the Old Rusafa by regenerating its urban fabric, the five historical spines, and Baghdadi courtyard houses will enhance the quality of life and achieve equity'. He clarifies, 'Traditional urban fabric needs a green and new urban infrastructure that helps to reach environmental and health standards' [6].

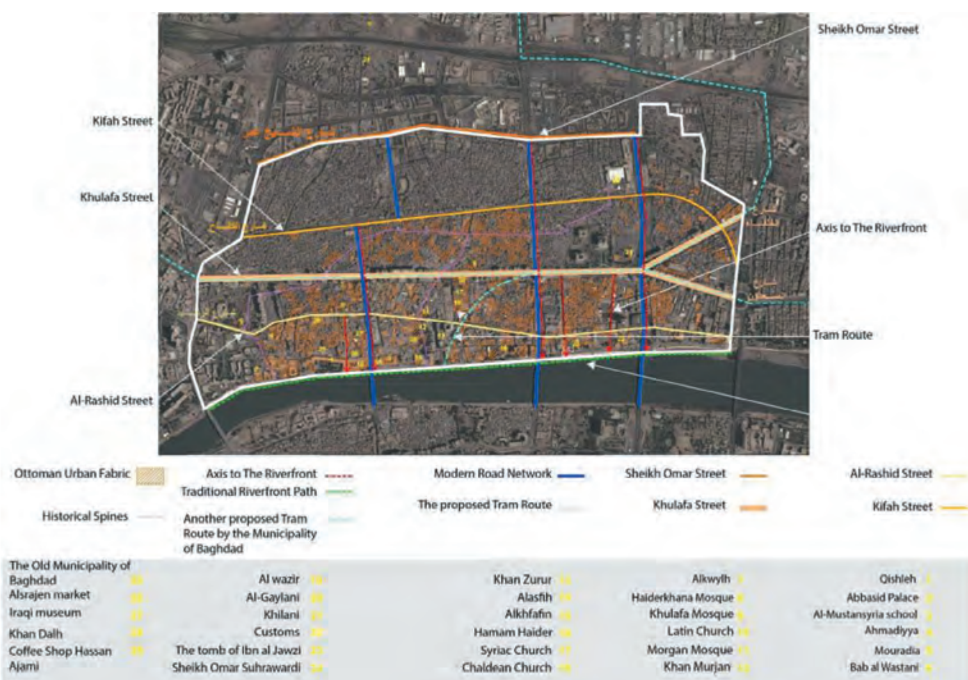

Figure 6: Urban conservation strategy in old Rusafa. Source: Author [6] according to The Municipality of Baghdad.

7 CONCLUSION

This article debates the literature review around the subjects of conservation in the urban context, urban conservation and socio-economic and sustainability aspects. It has asserted that conserving historic centres are significant in protecting cities identity, character and contributing in their economic development. The argumentation of this research concentrates on urban conservation and planning in Old Rusafa and indicates that the traditional urban fabric in Old Rusafa has witnessed an irreparable damage because of the weak definition of demands and an ambiguous formulation of what to preserve. It has also indicated that The Municipality of Baghdad is suffering from lack of clear vision and regulations in terms of urban conservation and this usually creates many obstacles when they want to prepare a plan for conserving traditional areas. As a result, the majority of urban conservation plans prepared by different groups for the city centre have been unsuccessful. Therefore, to create an effective urban conservation in Old Rusafa, we should enhance socio-economic environmental aspects and produce a comprehensive method to revitalizing urban components of the urban system in the city centre of Baghdad.

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A METHODOLOGY FOR THE CONSERVATION OF SMALL ANATOLIAN CITIES PLANNED BETWEEN 1920 AND 1960

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ABSTRACT
Beginning from the 1960s, cities in Turkey continue dealing with a constant and rapid transformation which causes great pressure particularly for the 20th century and Modernist architectural heritage in those cities. Threat of rapid urbanization is not limited to big cities but also valid for those Anatolian cities planned in between the 1920s and 1960s. The main risk is the limited understanding of integrity and authenticity concepts by decision-makers and planners. For those cities which are visually and aesthetically disowned of a numerous historic layers, they require a careful management of change. The integration of historic preservation with general urban planning decisions is substantial and should aim for the preservation of fundamental, spatial, environmental and social balances. Small Anatolian cities planned between 1920 and 1960 have a significant urban layer dating back to the early 20th century, which forms an integral part of public and urban memory, and the perception of the place. The lack of a systematic legislation and capital based approach supported by authorities especially cause the loss of Modernist architectural heritage. This article aims to propose a methodology for a holistic preservation approach for three cities in west Anatolia, Akhisar, Alaşehir and Tire, where existing features of modern planning period is a part of their authentic character.
Keywords: Anatolian cities, conservation, modern architecture, urban planning.

1 INTRODUCTION

By the end of the 20th century, modern architecture has been accepted as a significant component of the architectural heritage, yet its conservation is still problematic since this heritage is considered to be particularly vulnerable as a result of weak legal protection and low appreciation among the general public including preservation institutions [1]. The story of international acceptance of the modernist era as heritage goes back to the end of 1980s when DOCOMOMO, the international committee for the documentation and conservation of buildings, sites and neighbourhoods of the modern movement, was founded in 1988 on the belief that the preservation of modern architecture presented an urgent worldwide challenge, one that required the fostering of immediate interaction and collaboration across boundaries. Following the foundation of DOCOMOMO International with Eindhoven Statement in 1990, its subsequent expansions like ICOMOS seminars on 20th-century heritage held in Helsinki and Mexico in 1995 and 1996, and International Day for Monuments and Sites of 2002 dedicated to the 20th-century heritage can be considered as first steps to create an academic awareness on international level.

More recent international documents including the DOCOMOMO Constitution as well as the idea of the *spirit of place* or *genius loci* first put forward at the ICOMOS General Assembly Meeting in Quebec in 2008, and the ensuing Valetta Principles for the Safeguarding and Management of Historic Cities, Towns and Urban Areas in 2011 by International Specialists Committee on Historic Towns and Villages of ICOMOS (CIVVIH) incorporate a set of multi-faceted principles and criteria. These principles include both tangible and intangible elements and show a multidisciplinary approach to the historic towns and areas.

As a concurrent contribution to these international documents, the Madrid Document adopted in 2011 again by ICOMOS 20th Century Specialists Committee underlines the

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importance of the modern era as a physical record of its time, place and use as well as its intangible values such as historic, social, scientific or spiritual associations, or creative genius.

At the national level, in Turkey, the heritage protection is regulated with the Law on the Conservation of Cultural and Natural Property, No. 2863/1983, amended several times, that defines cultural property as 'those immovable properties that have been subject to social life in a historic period and has scientific and cultural authentic value' and historic site as 'towns, remnants of towns and those places where cultural properties are concentrated and have been the scene for any kind of social life and/or important historic events, that are the products of various civilizations from the prehistoric period to our day which reflect the social, economic, architectural characteristics of their period', art. 3, amended with Act No. 5226/2004. Hence, there is nothing against the designation of the 20th-century architecture.

The main obstacle against the listing and conservation of 20th-century architecture concerns the criteria of designation. The law includes those buildings constructed 'until the end of the 19th-century' or 'after this date but to be conserved due to their importance and characteristics' according to the Ministry, 'located within a designated site' and 'those buildings and sites which have been the locality of important historic events during the War of Independence and the foundation of the Turkish Republic, and are hence to be documented and registered for their importance in our national history', art. 6. High Council, Principle Decision No. 662/1999, incorporated works built after 1923, clarifying such indecisive and problematic articles, including 'those public buildings used by public institutions and that reflect the architectural characteristics of their period of construction, and those constructed during the first decades of the Republic of Turkey'.

The major legal texts on the conservation of cultural property in Turkey still accept age as an important criterion for national designation. On the contrary, as it can be seen in the international texts, the age value loses its effectiveness as criteria for the evaluation of modern architecture as cultural property. Current approaches in the field of conservation theory suggest not only the preservation of the iconic or singular examples of modern architectural heritage but also the protection of modern implementations as an urban layer. However, most of the buildings and places dating back to recent past are being demolished due to the lack of recognition during urban planning practices, or are at risk of being demolished.

2 CITY PLANNING PRACTICES IN THE PERIOD 1920–1960

Spatial organization strategies of the young Turkish Republic can be considered on two levels. First level is the national level, which aims to transform the country into a nation-state, and the second is the reorganization of the cities as the place of modernity. Spatial strategy developed on the national level includes three main elements: leaving Istanbul and constructing Ankara as the new capital city, construction of a railway network expanding to Anatolia and industrial planning for small Anatolian cities which were connected to this railway network [2].

These urban renovation practices in the early years of Turkish Republic were directed by Turkish government as a part of a modernization programme and many legal arrangements were made relating to municipal organizations in cities. Considering the importance of railway network for these redeveloping cities, train stations gained importance in the general urban layout. So the railway stations and the main roads, all of them named *İstasyon Caddesi*, connecting the stations to city centres were of concern as a primary issue in the new planning decisions and activities.

In 1924, it was defined that each urban settlement needs to establish a municipal government. In the same year, some additions were made to the applicable legislation with the aim of solving planning issues in Anatolian cities affected by fires. Also in the same period, there were the first attempts to compile a planning literature in Turkish. The first urbanism and municipality journal, *Istanbul Şehremaneti Mecmuası*, was first published in 1924, and in 1926 Camillo Sitte's book, *Der Städtebau nach seinen künstlerischen Grundsätzen*, was translated into Turkish [3]. In 1931, Zeki Sayar, Abidin Mortaş and Abdullah Ziya Kozanoğlu started publishing *Arkitekt Magazine*. Three years later, in 1934, the Ministry published the first issue of *Public Works Journal*. In 1935, Osman Nuri Ergin's conference on urbanism in the Institute of Economics and Internal Medicine, which was established in Istanbul University's Faculty of Law, was published as a book called *Urbanism in Turkey*. This book can be considered as the first thesis produced against the urban models of the West. Publications related to architecture and urban planning that had increased in number by the 1930s have led the discussions in those areas.

In spite of new regulations in the early 1920s, planning activities were far away from being the output of a holistic view. In 1933, it was mandatory to make a city plan within 5 years for every municipality in accordance to the Law on Building and Roads No. 2290 (Fig. 1). The law remained in force till 1956 and gave way to the Building Law No. 6785, with the rapid urban population growth that began in the 1950s and gained momentum in the 1960s [4].

Since Modernism is based on the classification of uses and on the possibility of covering the optimal prerogatives of the principal urban functions both separately and collectively, city

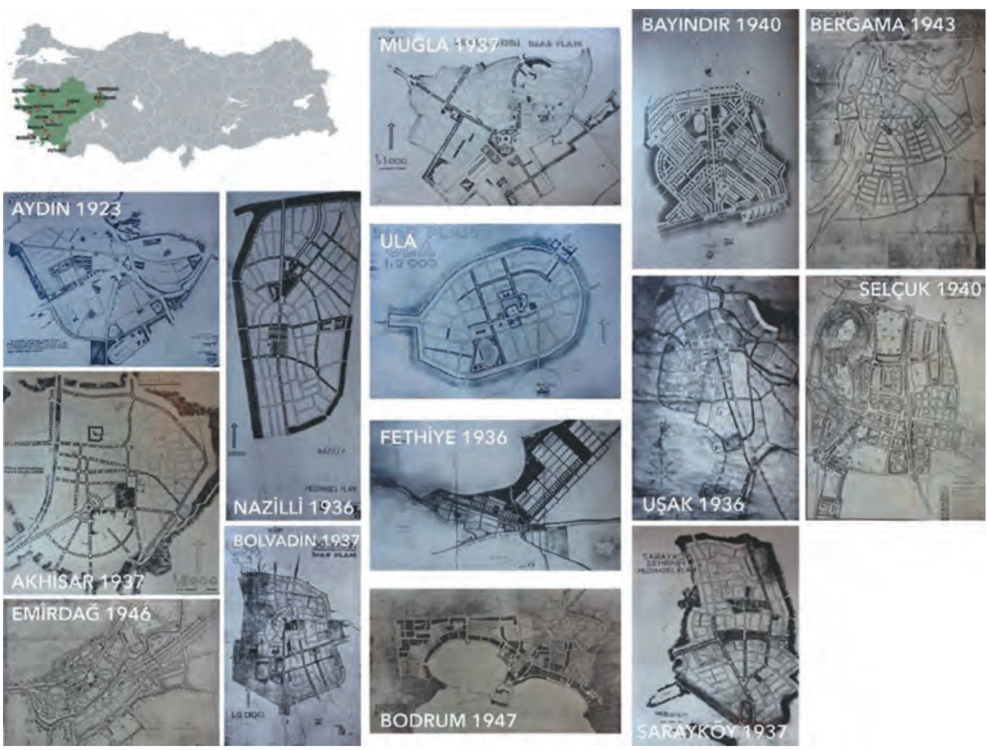

Figure 1: City plans drawn after 1933 in west Anatolia *(Bayındırlık İşleri Dergisi)*.

plans prepared after the 1930s mainly aim for an economic and social development as well as creation of modern city spaces. Recreational areas such as city parks, sport fields and wide roads, open spaces, garden and governmental buildings with new functions appropriate to modern city life were tools used to achieve extensive development. In this period, city planning is based on the creation and development of the public spaces in an environment that was to be shaped with the modern life style: public buildings and spaces became the most important elements defining the cities [5].

Importation of modernism in the urban scale via urban planning and urban planners from central Europe to Turkey in the periphery can be clearly seen in the city plans developed after the 1930s, where many European city planners prepared plans for some cities in Turkey. However, the new plans for small Anatolian cities included in this paper were developed by Turkish planners following the same main approach of 'modern urban planning'.

Urban planning activities in the early republican years in Turkey follow the basis created by topographical engineers, who prepared city maps at the end of 19th century during the Ottoman Empire. These planning studies were primarily experienced on areas affected by fires with the general attitude of creating a grid system and the widening of streets.

After the War of Independence, 1919–1922, the population was drastically diminished in the Aegean region and many cities were severely damaged by fires. So planning activities in Alaşehir, Akhisar and Tire were mostly focused on replanning both depicted areas and those affected by fires. In all the above-mentioned cities, the development plans prepared after 1923 stand at a certain distance from existing fabric. With improvements in the idea of functional urban development, needs of a modern society were tried to be satisfied by urban design. So public recreational and cultural places, such as municipality parks, public squares, sport fields, movie theatres, libraries and community halls, were the new urban forms added to the planning knowledge acquired from the Ottoman Empire.

3 CASE STUDIES

3.1 Alaşehir and Akhisar/Manisa

Alaşehir and Akhisar are both districts of the Manisa Province. Alaşehir, known as Philadephia in Antiquity and in the Middle Ages, situated at the southeast part of Manisa, has a history dating back to the 2nd century BC. In the following periods, as an Ottoman city, mud brick and wooden houses formed the urban character. Galip Bey was the first known mayor of Alaşehir who stayed on task between 1919 and 1923 [6]. In the early years of Republic, after 1923, planning of the areas affected by fire was the main concern of Alaşehir Municipality. Topographical engineers, Sait Erer and Cemalettin, prepared the first urban development plan for Alaşehir in 1924 [7]. This plan mainly focused on the partial widening of roads and settlement of the immigrants of the population exchange between Greece and Turkey [8] (Fig. 2). Because the city was severely damaged by the great fire of Alaşehir in 3–4 September 1922, almost all of urban land was planned in 1924. According to Sungur [9], there were only 6,000 people, 100 houses, 2 mosques and 3 shops left behind from a city of 4,500 houses and with a population of 38,000.

Akhisar is the biggest district of Manisa and is situated at the northern part of the city. The old town of Akhisar is established in a fertile plain of the same name. Even though the municipal council of Akhisar was founded in 1884, the first attempts at urban planning were limited to the construction of immigrant houses in 1924 [10]. At the same period, the municipality was also busy settling the victims of fire that occurred in Manisa. As a result of new needs of modern life, after the proclamation of the Republic, many educational buildings and public spaces for recreation and entertainment were designed (Fig. 3).

Figure 2: Alaşehir city plan produced from 1/1000 scale city map.

Figure 3: General view of Akhisar between 1930 and 1940s *(Anonymous)*.

Between 1923 and 1933, two primary schools, *Misak-ı Milli* and *Gazi*, a library, *Zeynelzade*, a movie theatre, *Tayyare Sineması*, a butcher market, *Kasap Hali*, a hotel, *Florya*, the municipal garden and many shops were built [11].

The city map prepared by Sait Erer in 1934, and approved three years later in 1937, was covering an area of 180 ha. The urban development plan, on the other hand, was prepared and approved the same year by the Urban Planning Scientific Committee within the Ministry of Public Works [12]. The urban development plan predicts an expansion of city boundaries to the west and south.

Figure 4: (a) Plan of Akhisar by Sait Erer; (b) Traditional housing pattern of Akhisar.

The urban fabric that remains at the eastern part of Akhisar, mostly consisting of houses, is preserved with its street pattern (Fig. 4). Monuments like public baths and mosques dating back to the Ottoman Empire are preserved as well. The urban development plan does not include the reorganization or rehabilitation of the old centre, but it proposes a new parcelling in the mainly agricultural areas.

3.2 Tire/Izmir

Tire is a district of the Izmir Province and is located at the southeast border of the city. The old town of Tire leans adjacent to the Güme Mountains in the south and against the Küçük Menderes Basin in the north. The town is planned along two main axes: Selçuk-Ödemiş highway on the east-west direction and Izmir-Bayındır-Ödemiş highway on the north-south direction. The urban pattern and architectural character of the area remaining at the southern part of Selçuk-Ödemiş highway mainly represents a typical west Anatolian city with traditional houses, while the area on the northern side was mainly planned after 1920s.

Throughout history, many earthquakes and fires have occurred in Tire that shaped its urban morphology. The earthquakes that had destructive effects for the city are the ones that happened in 23 February 1653, 1850, 1880 and 31 March 1928 [13]. The fire that occurred on 2 July 1916 affected the city centre severely with a complete loss of 2,000 houses and 450 shops [14].

The first urban planning attempts in Tire starts in the 1910s: according to the local newspapers, two French engineers, called Aleko and Ikar, prepared the first city plan in 1912. However, the commercial centre consisting of perpendicular roads and a grid plan scheme, gains its urban fabric after the big fire of 1916 with the reconstruction of the damaged area (Fig. 5). There is no information on any planning work after the fire. However, it is known that many public buildings have been constructed since the first years of the Republic.

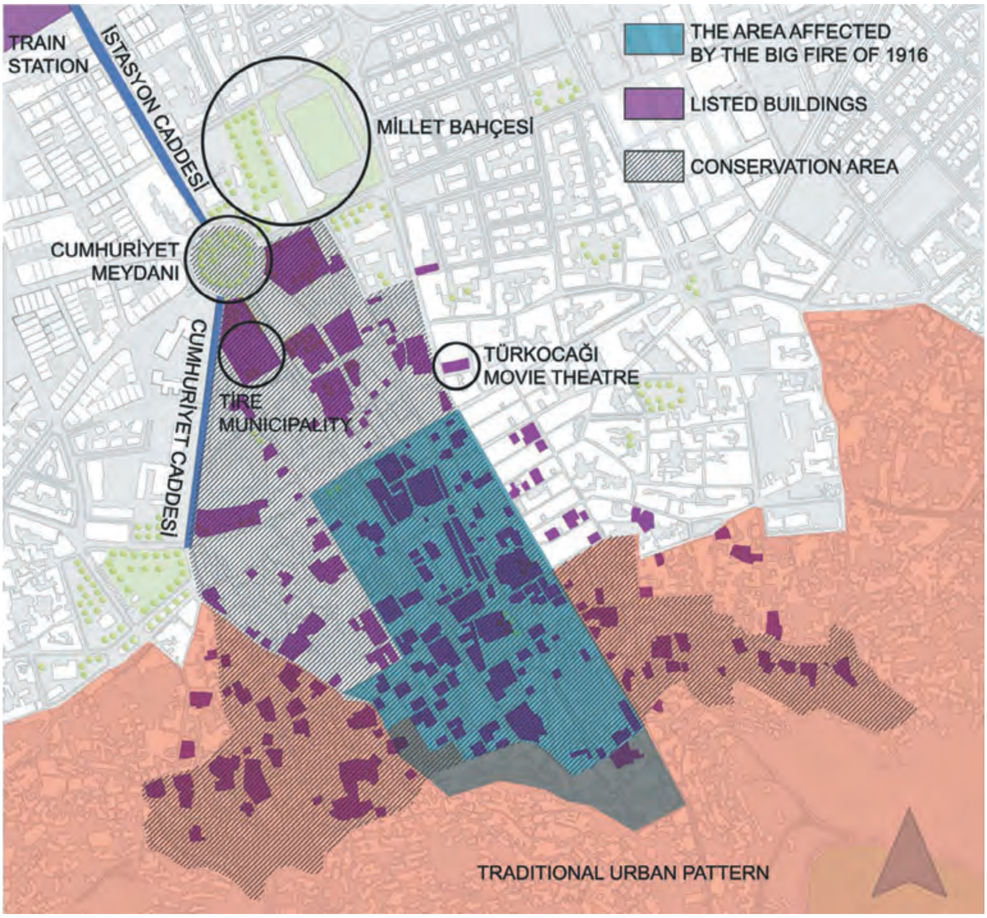

Figure 5: Tire city plan produced from 1/1000 scale city map.

In 1927, the first movie theatre was built by *Türkocağı Association* and came into service the same year. In 1930, a public recreational area, *Millet Bahçesi*, was planned in the backyard of Girls' Vocational School and in 1933, the government office was built at the core of Tire. Between 1934 and 1940, many urban open spaces serving modern city life were organized. The park within train station, the main public square called *Cumhuriyet Meydanı* and the wide boulevard connecting the old Tire to the train station, *İstasyon Caddesi,* were opened in this period.

Vedat Erer prepared the first urban development plan for Tire in 1950. Using the grid scheme, Erer's plan consisted of wide boulevards and reorganized the urban pattern. The development plan was implemented under the supervision of Can Egeli, who worked in Tire Municipality between 1952 and 1955, and was also the architect of many public buildings and projects that were realized in the same period [15]. The plan included rehabilitation of certain areas and new construction activities.

Considering the existing character of the city, the plan proposed three different interventions for the city such as new parcelling for the area at the northern side of public square and for some areas in *İstasyon* and *Cumhuriyet* streets; preservation of residential fabric on both

Figure 6: Tire urban development plan of Vedat Erer *(Beş Yılda Tire: 1950–1955)*.

the sides of the commercial centre; and the demolition and rebuilding of some existing structures in the commercial centre (Fig. 6).

4 CURRENT SITUATION AND THREATS

Three small Anatolian cities Akhisar, Alaşehir and Tire, studied in this article, still have considerably important physical features of modernist period including urban pattern and open spaces besides public and residential buildings. However, the current planning practices in these cities appear as a serious risk for the recent past (Fig. 7). The main problem for preservation is the legal acceptance of modern heritage. Unfortunately, conservation plans do not consider the historical importance and preservation values of the areas planned between 1920 and 1960 (Fig. 8).

In Alaşehir, the only conservation plan is prepared for the ancient city of Philadelphia in 2014, yet, there is no conservation plan developed for the city centre.

The conservation plan of Akhisar was approved in 28 October 2011 by Izmir No II Regional Commission on the Conservation of Cultural and Natural Property (RCCCNP). However, this plan does not have a holistic view for the urban features of modernist period of the city, but considers some of the iconic examples of that period such as the movie theatre, *Tayyare Sineması,* or butchers' market, *Kasap Hali,* as properties to be preserved.

In the case of Tire, urban preservation site borders are defined by Izmir RCCCNP No II in 2009 and the conservation plan was approved by the same commission in 2010. The buildings of the modernist period were not even included in the historical development chapter of the plan report. The residential buildings and commercial areas constructed after the plan in 1950 were misclassified as examples of an architectural period between 1940 and 1950.

All the case studies briefly discussed within this study have urban patterns formed in the period following the foundation of the Turkish Republic up to the 1950s. The urban layers of

Figure 7: (a) View of commercial centre of Alaşehir, 2014; (b) Akhisar city centre, 2013.

Figure 8: (a) Market building of 1950s, Tire; (b) The same building demolished in 2014.

this recent past have a range of values such as, design value, memory value, historical value and social value contributing to the historical character of the site.

5 CONCLUSION

It is clear that the concepts of modernism have had an indisputable impact on the image and structure of the cities all over the world. One of the main reasons of cursing the modernist period of the historical settlements is the so-called destructive planning approach of the period which caused major or partial transformations in the urban pattern. However, with the acceptance of the modern architectural heritage values and expanded redefinition of authenticity and integrity, many international texts today underline the importance of preserving all historical layers, considering both tangible and intangible values.

According to Valletta Principles, the tangible elements include 'the urban structure, architectural elements, the landscapes within and around the town, archaeological remains, panoramas, skylines, view-lines and landmark sites' and the intangible 'activities, symbolic and historic functions, cultural practices, traditions, memories, and cultural references that constitute the substance of their historic value'.

As a recent international instrument, the Madrid Document [16] states that the integrity of the architectural heritage of the 20th century should not be impacted by unsympathetic interventions and the value of significant layers of change and the patina of age should be respected. Undoubtedly, this remark should also be considered for urban scale preservation practices.

In Turkey, the ongoing loss of modern layers bases on both the lack of integrated conservation approach in which conservation planning is accepted as an integrated part of urban planning activity, and the disapproval of the 20th century and modern architectural heritage as an integral part of historical urban layers to be preserved [17]. As the recognition of different preservation values of an urban fabric is a must for a successful urban conservation [18], it is crucial that the significant modern architectural layer should be included in urban conservation planning.

Today, the concept of planning is enlarged into 'management', which includes all related 'legislative, financial, administrative and conservation documents as well as conservation and monitoring plans', embracing the idea of transformation and proposing to make use of it for improving 'the quality' of cultural and architectural heritage. Thus, the methodology for such multi-layered urban areas can only be based on legal recognition and acceptance of all layers. The content of current legislation for the preservation of cultural heritage should be updated to include internationally and scientifically approved heritage values, concepts and time frames. Unless then an entire documentation that is a critical tool for heritage conservation and legal designation of modern heritage depending on scientific evaluation can be possible.

On the other hand, considering the power of public memory and communal value, the replacement of top-down planning approach with a bottom-up format which allows the participation of local bodies and non-governmental organizations will have a constructive effect on the public awareness and acceptance of the cultural heritage values of our recent past.

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ANTI-SEISMIC PRESIDIA IN THE HISTORICAL BUILDING OF L'AQUILA: THE ROLE OF THE WOODEN ELEMENTS

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ABSTRACT

The earthquake of 2009 has brought to light different anti-seismic presidia implemented over the centuries, in the aftermath of repeated earthquakes occurred in the city of L'Aquila, which represent the result of a knowledge and a constructive culture linked to a direct observation of the damage, the intuitive interpretation of the seismic response and the possible countermeasures experimentation.

An important role is attributed to the wooden elements that have different functions and are used in the context of standard and palace building.

The integration of the wooden elements can become a real system and be extended to the entire building unit, as in the case of the adoption of the 'hut' system (sistema baraccato). Alternatively, it can be used only for single and specific building elements, such as the use of 'wooden roots' (radiciamenti lignei) in the walls and vaults or wooden elements used for the construction systems of the roofing.

This article aims to contribute to the knowledge of these anti-seismic systems, framed within a broader constructive culture linked to the pre-modern building.

Keywords: anti-seismic presidia, construction techniques historic building, local seismic culture.

1 INTRODUCTION

The damage of the last earthquake that struck L'Aquila in 2009 and the subsequent reconstruction work have shown, inside the historic building network, the widespread use of wooden elements as anti-seismic presidia, applied and tested over the centuries following repeated telluric events, according to individual or collective structure needs.

This is the case of the wooden roots inside the masonry embedded with the function of wooden chains, improvement of the scarves near the masonry and cantonal hammers (martelli murari e cantonali) or correction of irregular masonry. Similar wooden elements can be found into the structure of the masonry vaults with the role of countering the thrust and improve the box-like behaviour of the walls.

The use of additional wooden elements is the key feature of the design concepts of the roofing. In other cases, the adoption of the 'hut' system involves the entire constructive unit in new buildings or, on the contrary, part of it in the partial reconstruction activities.

This study aims at understanding whether the anti-seismic measures, linked to the local building culture, represented a field of experimentation and anticipation of the official technical culture expressed in journalism history or if, on the contrary, they have assimilated knowledge from experience and practices already codified. Therefore, the methodology of the study envisaged the analysis of direct sources along with the analysis of indirect sources present in the historical treatises and manuals and the first anti-seismic norms and regulations implemented after the major earthquakes of the 17th and 18th centuries.

Indeed, the methodological approach has allowed defining, in terms of time, the comparison between the implementation of different measures involving the use of wooden elements and their presence in the technical publications in order to evaluate the experimental nature and, in analytical terms, the consideration of similarities rather than of differences compared to the codified practices.

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2 LOCAL SEISMIC CULTURE AND THE WOODEN ROOTS

The different processes of reconstruction involving the city of L'Aquila hit by several earthquakes, among the most relevant in terms of intensity and level of damage, those occurred in 1315, 1349, 1461 and 1703, are often connected to significant realignment of the urban structure. With the transformation of the basic building types and the redefinition of the architecture of the fronts, it implies a progressive alteration of the building rules for the construction of walls and a wise use of technical controls to secure a construction consistent with the rules of art and to reduce the possible critical conditions related to recurrent earthquakes.

The rationality and regularity of the medieval urban structure, organized on regular parcels of 4 × 7.5 rods, with the presence of buildings in the 50% of the area, and the building skill of masonry characterized by the 'apparecchio aquilano' (Gavini [1]) attributable to the Angevin construction site, is lost in the urgency of the city's reconstruction after several earthquakes. Starting from the 15th century, a process of transformation of the urban structure begins and leads to an extension of the built environment, achieved through the re-appropriation of basic building types and the progressive occupation of gardens, along with an increase in the number of floors.

These particular circumstances led to an improved focus on rules and precautions that, based on the recurring damage, are used in a preventive manner both in the activity of rebuilding from scratch and for the restoration of damaged buildings. In this way, they can be effectively treated as real pre-modern anti-seismic measures.

By looking at the historical building structure, it is possible to detect a widespread ability to put in place a series of constructive solutions aimed at increasing the building resistance to the earthquake. They represent the feature of a complex and articulated 'local seismic culture' (Pierotti, Ulivieri [2]). Such culture has been continuously used and tested in a fairly long period of time supporting the 15th- and 18th-century reconstructions, through a building practice based on a profound knowledge of the wall structure and on a perfect creation of the artefacts.

The precepts of art ensure 'stability and durability of the building' also 'where the most frequent natural disasters occur' (Cavalieri San Bertolo [3]) and the description of the building techniques provides anti-seismic indications. All of them are mainly focused on the connection of building elements: 'the frames are to be connected with frames, and they will all be strengthened in the most appropriate manner with nerves and ligaments; so that the sequence of frames, connected together, is able to resist alone, even in case of failure of any other element' (Alberti [4]).

In the peculiar structure of the building fabric of L'Aquila, both from the perspective of the standard building and the palace building, an important role, as 'ligament', is attributable to the presence of wooden roots. According to different criteria and technical procedures, they integrate, primarily in the form of beams, walls and vaulted horizontal elements, or define more specifically the design concepts of 'staked' floors and roofs.

The use of wooden elements in the walls, probably already known in the Middle Ages defensive architecture even in the Abruzzo area, gradually becomes part of building practices as a result of the earthquakes of the mid-15th century.

During the reconstruction period, after the earthquake of 1703, the use of wooden roots was significantly extended to the entire building structure and, with specific improvements, becomes 'a real building methodology, neither sporadic, nor random' (Bramanti [5]). In addition, it was fully recognized by the 19th-century journalism technique: 'In civil buildings there are generally, within the thickness of the walls, hidden oak beams which are placed horizontally in the upper parts of each plan and conveniently joint with iron straps, where two following rafters are found one after the other or where the joists are placed in a wall and meet those located in other walls, serve to keep all the walls well concatenated and to partially eliminate the effects of horizontal thrusts' (Curioni [6]).

2.1 Animated masonry

L'Aquila's wooden beams walls are placed lengthways and embedded within their thickness with the aim of improving the meshing of the wall. In fact, the lack of well-meshed orthostats, due to a masonry predominantly made of little stone material, had shown a poor resistance. The 'roots' also called 'dead keys' or 'dead beams' are embedded in the masonry as a real armour that, by resorting to the wood's tensile strength, is capable of ensuring higher quality in terms of strength and stability (Fig. 1).

With the addition of retaining elements, the roots act as chains able to link two wall panels in order to counter their estrangement. The wooden chains, placed to the portion of the horizontal structures, also according to inter-floor height, are precisely secured within the thickness of the wall with iron and wood retaining elements, or nailed to the wooden cables; they can also be placed inside out, on the outer face of the wall by means of 'stacking' systems, with wooden or metallic anchor bolts and bolted end-plates.

Wooden beams are also placed outside the wall, near the masonry hammers (martelli murari), embedded in the thickness of the floor and in particular in the space of the abutment of the vaults often incorporated into the system of the steering cables (Fig. 2).

With the aim of ensuring an improvement of the box-like behaviour of the walls compared to a significant longitudinal development of the fronts, they are mainly found in the type of the building.

With the same purpose, the systematic placement of roots in the masonry structure generates spiral reinforcements, placed at different heights in relation to the size of the building and its vertical structure; the wooden beams, properly steamed by simple riveting or 'Jupiter dart-pin' connections, intersect near the angled and end outside the cantonal with metallic anchor bolts studded on the head of the beams and retaining bolted-end-plates, according to different shapes that, in the High Renaissance, are characterized by floral and animal motifs.

Figure 1: Wooden chains placed inside the wall. Building in Piazza San Domenico.

Figure 2: Wooden chains placed outside the wall of Palazzo Zuzi.

2.2 Thrust-retained vaults

The wooden roots are also employed in the vaulted systems with different modalities according to their structure and size. They are mainly used in heavy brick vaults: 'reinforcement or counter-thrust keystones of arches vaults (…) placed especially in the arches and also in the vaults, especially when these are characterized by a considerable width and length, serve to counterbalance the effect of the thrust, mostly when the rise is significantly depressed' (Astrua [7]).

In L'Aquila, this approach was mainly used during the construction or reconstruction of the vaults, after the earthquake of 1703, in the palatial architecture intended for large rooms, built with brick course laid on edge according to different types of equipment; in fact 'it is important to encase the vault in larch and pine board, so that the vaults can be robust and long-lasting' (Pellegrino [8]).

In the case of barrel vaults with longitudinal structure, the wooden beams are placed transversely to the generatrix, partially embedded into the upper part of the element, free or leaning against the steering cables and connected to the exterior wall, thanks to concealed or exposed retention systems. The chain can be integrated with other wooden elements, just like the 'sling chains' described by Valadier [9], or according to more complex structures in which the transverse chains are longitudinally contrasted by rafters where retaining elements, embedded in the abutment, are connected (Fig. 3). Conversely, in the case of 'intersected' vaults (e.g. rib vaults), the roots are placed parallel to the generators and integrated inside the bricks to about a third of the rise. The beams are placed on the four sides of the vault; they intersect and connect near the corner, and then bound to the exterior walls. Mainly on the longest sides of the vault, the beams can be supplemented with other retention wooden elements that reconnect them to the perimeter walls.

Figure 3: Palazzo Gualtieri. The transverse chains are longitudinally contrasted by rafters where retaining elements, embedded in the abutment, are connected.

In the case of roofing, the system of the wooden chains can become even more complex with beams leaning against the cymatia of the interior walls, horizontally connected with those placed at the top of the vaults. This system can also involve the chains of the trusses when the attic is moderately high.

2.3 Staked trusses and box-shaped roofs

Even in the context of smaller building works, the roofing system favours the use of the truss, searching for optimal criteria just inside the good rule of art. The assessment of the effects of the earthquake on roofing systems and the development of local anti-seismic culture, lead to the adoption of elements and systems that can eliminate or counter the most common risk associated with extraction of the trusses from the exterior field. Therefore, to increase the retention capacity of the chain in the phase of oscillation of the walls, which is normally only entrusted to the single friction force, the truss construction structure is modified through a different solution of the support knot (Fig. 4).

The chain becomes ligament and, extended beyond the wall thickness, it is equipped with a bollard retaining system, in order to ensure an improved connection between the roofing and wall, synchronizing the oscillation and leading to a better 'behaviour' of the building.

The 'staked' truss is completely embedded in the wall and equipped with a wooden cushion, carved and sometimes moulded, in the support area. It is characterized by a much greater length than that of a normal shelf, 'a piece of rustic beam, and sometimes shelf-shaped at the extremities, which is nailed under another wood, under the beams, to the struts of roofs, inside the frames and in almost all the rebars (…)' (Ragucci [10]).

This damper, also known as 'slide' that is surely intended to protect the head of the truss, comes out and allows the creation of the fixing hole of the wooden stake, and extends inside under the chain so as to increase the surface friction of the retaining mechanism and avoid compromising its support in the event of chain sliding (Fig. 5).

The same construction knot can also be complemented with further wooden element, a tilted beam called 'polsa', which is nailed and paired with the rafter and the cushion while extending itself outside so as to create the warping of the eaves.

Figure 4: The typical example of the staked trusses applied in Palazzo Farinosi.

Figure 5: Details of the support knot solution in Palazzo Farinosi.

Another type of solution for the roofing does not change the type of the truss but otherwise resolves its correlation with the masonry. In this case, longitudinal beams are embedded and connected to the summit walls by stakes where the elements of the roof structure are placed and secured in order to create a box-like system. ‘A kind of rebar of continuous beams, first staked and then snapped; which tightened with clamps and iron bands, and fit along the thickness of the walls, on which the roof lies. The extremities of the chains, rafters and racks joint and embedded in the box, generate a system that instead of pushing the walls, it evenly press over their whole length’ (Ragucci [10]).

3 SEISMIC CULTURE AND HUT SYSTEM

The structural type of ‘hut’ house is one of the oldest and most used systems for the purpose of seismic safety. Usually, it is made of wooden skeleton and a part of light-materials infillings, but also bricks or stones (Barucci [11]), and its alleged origin refers to the ‘opus craticium' discovered in Pompeii and Herculaneum, where a framework of wooden beams made of uprights and transoms marks modular areas within which a masonry of stone chips and mortar (Ceniccola [12]).

In fact, the use of wood inside the masonry in order to chain and make the structure supportive structure has very ancient origins, already described in the construction of the walls of the city by Vitruvius and by Gaius Julius Caesar for those of the Gallic city built with beams, freestones and soil.

In historical treatises, it is extremely rare to see a section specifically dedicated to the anti-seismic construction, as the 'rule of art' at the base of technical and constructive culture was considered sufficient to make buildings able to withstand earthquakes. During the 18th century, more attention was attached to anti-seismic construction studies and specific writings (Paolini [13]). In 1781, Francesco Militia in his work 'Principi di Architettura Civile' describes a reinforced masonry system with wood and also proposes one of the first wooden anti-seismic home models provided by the manuals (Barucci [11]).

Only after catastrophic earthquakes, the 'hut' system is coded in its many variations even within specific, and not only Italian, regulations.

The Benevento-style hut system is considered as the best and most suitable technique for the reconstruction of Benevento after the 1627 Gargano earthquake, which also involves the Sannio area, although other sources connect the birth of the technique to the reconstruction following the 1688 Sannio earthquake (Ceniccola [12]). 'A timber reinforcing cage, created with the so-called Benevento-style frames, made of many nailed and bolted wooden studs with as many beams, whose resulting meshes were closed and secured with light material; or better with a wicker or cane woven, secured to the frame by thin chestnut slats and covered with mortar or a well smoothed rough coat' described by Masciari-Genovese [14] in 1915 as the first stage of anti-seismic architecture.

Fabrizio [15], in 1933 refers to it as 'a chestnut timber skeleton with rectangular meshes, with squared studs, directly planted in the ground, or in a base masonry. Both sides of the frames were complemented with wicker walls: common reed (Phragmites australis), suitably plastered slats. Everything was plastered after application of mortar rough coat or well coated clay'. However, in the Sannio area both variants with studs and transoms with masonry infill, and variants with studs, transoms and diagonals arranged according to St. Andrew's cross model with infill masonry made of an uneven texture of rows of bricks and blocks of hewn limestone (Ceniccola [12]).

Another system provided for by an anti-seismic regulation is the 'gaiola pombaliana', introduced after the 1755 Lisbon earthquake. The 'gaiola' or pomabaliana cage (named after the Marquis of Pombal, a minister who presided over the reconstruction of the city) was a wooden structure independent from the masonry, able to support the floors and the roof in case of earthquake.

The system consists of a set of poles and oak/holm beams. The beams were connected to the wall with a kind of nuts. The tops of the poles were linked together by beams and in the compartments of doors and windows by lintels and rafters (A. França [16]).

After the 1783 Calabria earthquake, the structure of the 'hut' house acquires a more precise and accepted definition with the name of the Bourbon building system or Calabrian hut building according to the actual instructions issued by the Bourbon government in 1784, which represent a real seismic Regulation and provide for an internal timber network for the houses (Barucci [11]). Giovanni Vivenzio [17], was a member of the Commission responsible for the definition of a reconstruction plan. In his 'Historia de' tremuoti' of 1783, he shows the prototype of anti-seismic construction employed using three boards drawn by Vincenzo Ferraresi: a wooden-framed building structure uprights, transoms and diagonal stiffening (Ceniccola [12]), that according to the thickness of the wall provided for a single or double frame.

In the case of the double frame, in which the two wooden structures were connected by transverse connections, the masonry infilling was placed in such a manner to remain visible. Conversely, the 'instructions for the engineers employed for the Calabria Ulteriore' issued the following year and whose technical solutions belong to the engineers Antonio Winspeare and Francesco La Vega, suggest the use of a completely embedded wooden framing in the wall, to prevent the risk of deterioration of the wood elements. In particular, the houses had to be built with a skeleton of big chestnut or oak uprights, placed in the corners and at a reasonable distance from each other, connected by transverse beams, which were to support the beams of the floors and roofs. This whole timber frame had to be surrounded by a brick wall or small stones bonded with slaked lime.

3.1 Hut technique and local building practice

The 'hut' technique, documented in southern Italy since the beginning of the 17th century, was also used in L'Aquila after the catastrophic earthquake in 1703. In his book 'Stabilità sismica dei fabbricati' of 1912, Ruffolo [18] refers to two wooden huts covered in masonry dating back to 1750, located near Belvedere and behind the Convento di Sant'Amico. Masciari-Genovese [14] also refers to 'hut' models built after 1703.

The anti-seismic house built in Piazza San Bernardino, demolished only after the middle of the 20th century, represent a testimony of the 'hut' system used in L'Aquila after this earthquake. The pictures of its demolition show a framework of uprights, transoms and St. Andrew' crosses, placed inside a stone masonry (D'Antonio [19]).

The earthquake of 2009 has brought to light another example of 'hut' building, still visible in Via Forcella, dated a few years ago after the earthquake of 1703 as a result of the radiocarbon analysis performed on a wooden fragment of the frame ((D'Antonio [19]). It is a three-floor house, with a typical 18th-century construction layout: brick rib vaults on the ground floor, wooden floor on the first floor and embedded (incannucciate) vaults below the wooden trusses roofing.

It is made up of two adjoining rooms and a small subsequent expansion on the street side, now collapsed, and has a structure of wooden uprights, partly squared, simply debarked, connected by squared beams that seem to support the wooden floor. The exterior walls and interior partitions are characterized by the presence of secondary wooden frames.

The case is made of masonry stone blocks and bricks in the same position of the vertical posts so as to form slightly projecting pilasters with respect to the external face of the wall. Inside the wall, there are a series of uprights and wooden elements of 7 × 5 cm section. The internal partition between two rooms is in stone masonry on the ground floor, while the upper floors is composed of a wooden trellis infilled with brick masonry to one extremity (Fig. 6).

Other findings resulting from the reconstruction work show how the 'hut' technique was used not only as a system involving the entire wall unit, but also as building approach for individual wall panels after partial interventions of transformation and for the realization of light internal partitions. Such use, also documented in the Sannio area (Ceniccola [12]) can be found in L'Aquila both in standard building and in palace buildings.

In a group of buildings in Via delle Aquile, this construction method was probably used during transformations due to the 18th-century reconstruction (Fig. 7).

Figure 6: Example of 'hut' building, still visible in Via Forcella, dated a few years ago after the earthquake of 1703.

Figure 7: The 'hut' technique in individual wall panels of buildings in Via delle Aquile.

It is a series of wall panels placed on the last of two levels that create the transverse spine walls, which are orthogonal to the main front. The structure of the panels, with a thickness of about 30 cm, is made of three horizontal beams, an upper one, a lower one and an intermediate one, whose section is 15 × 15 cm, connected by a double sequence of small 8 × 5 cm section uprights, studded on the two exterior sides of the beams and placed at a distance of about 40 cm. In some cases, there is a bracing of diagonal elements arranged in the shape

Figure 8: Light partitions attributable to the 'hut' technique in Palazzo Ardinghelli.

of St. Andrew's cross. The resulting meshes are infilled with a stone masonry, made of small blocks with irregular texture, arranged in such a manner that the uprights remain on the external faces of the panels covered with plaster only.

Very similar is the 'hut' masonry found in the 18th-century Palazzo Ardinghelli in Piazza Santa Maria Paganica.

In the phase of 18th-century reconstruction, very common was the use of wooden elements for the realization of framed partition walls useful to the spatial reconfiguration of the indoor settings also in many Aquila palaces. In this case, the wooden trellis represented not only a reinforcement able to increase the stability of thin walls, but also to ensure their better anchoring to the contiguous walls and, last but not least, to ensure the possibility of building non-bearing walls without affecting the underlying vaulted spaces.

In the same Palace, light partitions attributable to the 'hut' technique were found. The first is a partition wall consisting of a frame of uprights and squared-section transoms whose meshes are infilled by a brick masonry as big as a head.

The second, even lighter and weighing on an underlying vault, is formed by a dense lattice of reduced section uprights and transoms, infilled by bricks (Fig. 8).

4 CONCLUSIONS

The knowledge of these anti-seismic systems, included in a broader building culture linked to the pre-modern building, and the critical assessment of their role, let us learn from the past about how to preserve the material and construction values of historic buildings according to an approach able to reassess the rules of art even in the choice of intervention procedures not only in terms of repairing the damage but also in terms of improvement of preventive systems of historical buildings.

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ANALYSIS OF BUILDING SYSTEMS AND TECHNOLOGICAL CHARACTERIZATION OF MEDIEVAL SHIPYARD

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ABSTRACT

Shipyards, an architectural typology developed since the classical civilizations to build military or merchant vessels, found their greatest technological progress in the Middle Ages. Especially in the Mediterranean area, they were built with different techniques and materials, generating different characteristics related to the context in which they were grown. These architectures, which are examples of prosperous times for the medieval harbour towns, seemed obsolete a few decades ago regarding the original functions for which they were built. Today, they are partly in an evident degradation state and partly recovered. In a contemporary logic that provides for the reuse of places, by the characteristic industrial feature now disused, in new cultural centres and attractive poles for these cities, the constructive conformation as well as technologies and materials applied should be understood. Some of the most influential medieval dockyards in the Mediterranean basin were analyzed, considering the places in which they are based and the main constructive elements, with particular attention paid to the analysis of representative technological systems of the whole structure (i.e. piers, pillars and arcs; old wooden roofing systems; stone vaulted structures). The study aims to develop a comparative analysis in terms of morphology, materials and construction techniques of the elements that configure the aisles or lanes in which different boats were built, repaired or preserved or stored. The aim is to demonstrate that, despite the peculiarities of each site, in which the traditional building techniques linked to local materials were used, the medieval shipyard architectural type have evolved and consolidated in a homologous way in the whole Mediterranean area.
Keywords: Mediterranean basin, middle ages, shipyard, typo-technological analysis.

1 INTRODUCTION

The research on historical dockyards, both in Italy and abroad, is currently based purely on the historical and archaeological points of view, based on classical examples (Hellenistic *neoria* and Roman *navalia*), and studied through archaeological excavations. The shipyards found their significant typological progress in the Middle Ages, the period in which the architecture began to experiment with new construction techniques that allowed creation of more articulate shapes and consistent spaces, too. These new architecture techniques, originally used for building worship places, were promptly transferred to civilian facilities, and then to military structures (i.e. the arsenals that allowed keeping and/or making greater and greater vessels).

This drove the great naval powers, such as the Maritime Republics in the Mediterranean, to build new port facilities of strategic importance from the military-political, but also social and economic, aspects.

Today, these huge monuments are embedded within the fabric of ancient cities [1].

Although medieval arsenals are infrastructures of major influence in the Mediterranean basin, their recovery has not been addressed until now. The study and knowledge of these places have been performed mostly by historians and archaeologists, who so far have rather analyzed the relationship with the port, the trade routes and their impact on military development, focussing mainly on the activities that actually were held inside the yards: construction of boats and their crew, composition of cordage, sails and anchoring elements, as well as the

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production of artillery. Today, we know enough about naval engineering, about the art of producing boats and the technologies used, but attention has not been given to the building sites in which they came to life. Those structures not only had to contain several mini-workshops, but also to preserve and repair all types of vessels.

In fact, these yards need to have large spaces capable of holding in their turn of more or less large construction sites for building boats, arsenals, stores or warehouses, workshops, which were held as a parallel activity, and production units of sheets for sails, ropes and armaments.

Especially in the Middle Ages, within the discovery of America, Europe (particularly in the Mediterranean basin) saw a substantial growth and development of these port infrastructures, which allowed several powers, both in military and commercial fields, to be able to extend their borders. Therefore, they spent enormous energies to fully know, design and build vessels more and more advanced and able to reach unexplored lands, and innovative and impressive spaces such as the arsenals to construct them.

2 FROM '*NEORIA*' AND '*NAVALIA*' UP TO MEDIEVAL ARSENALS

The architectural typology of the arsenal comes from the need to have a sheltered, dry and cool place suitable for the construction, repair, maintenance and custody of all those items and equipment relating to the naval art. In all civilizations with urban settlements near coastal areas, to facilitate maritime trade and especially for military needs, it develops this kind of architecture.

It is supposed that the first arsenals were constituted by a wooden structure, composed essentially of high piers, whole logs of wood, arranged in parallel rows with the function of holding a slightly sloped roof or in a double pitch, such as those of Samo [2] in Greece.

The real original type of naval arsenal can be considered, according to archaeological historical sources, that of *neoria* of Greek civilization. The *neoria*, literally 'the place where there is taken care of ships' [3], was a structure that was used merely to preserve and protect the boats, particularly during the winter or in wartime truces periods. It was in the next external zones of these, however, in which they took shape and worked hulls. In the Periclean era, it developed the so-called Neoria, which were long rows of stone columns, placed in parallel, on which was placed wooden covers that remember to the trusses used to cover the temples. In fact, these buildings could be treated as a series of many temples, when placed side by side, in which, the structural elements were not finished without decoration. These architectures were essentially functional, reflecting the pragmatic character of Greek civilization which wished for colonize new territories and expand trade routes.

The colonnades of *neoria* often followed the slope of the coast to facilitate the launching operations, the entrance or exit of the boats; it foresaw a continuous rear wall perpendicular to these colonnades, which served as the closing, while the front facing to the sea it was kept open. As regards the cover system, some researches highlight that this is constituted by a double-pitch roof truss that rests on three rows of columns (Fig. 1a), covering two cells, while others consider that the rows of columns were alternated by highest rows and lower rows on which were placed a single pitch (Fig. 1b).

A typology variation, documented and never realized, which comes to the arsenals of Carthage (Fig. 2), was constituted from two adjacent basins, both excavated: the first one, rectangular, which communicated with the sea was reserved to trade; the second one, behind the first, was circular and had an island in the middle, where the headquarters of the admiralty was located. This circular ring was the military port around which were the *neoria* for accommodating ships, including a higher level used as warehouses.

Figure 1: 1a Models of the two reconstruction hypotheses of Zea's 'neoria', 1a (C.T. Panagos, 1968; Greek Nautical Museum, 1984), 1b (La ciudad antigua. La vida en la Atenas y Roma clásicas. P. Conolly, H. Dodge. Acento Editorial, 1998).

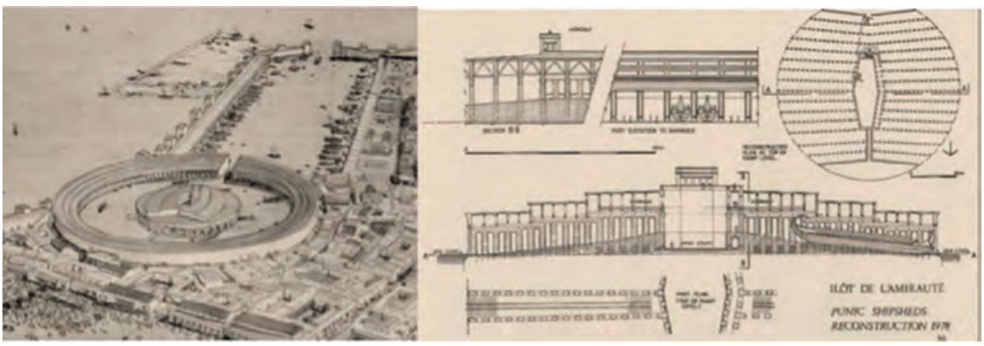

Figure 2: Hypothetical representation of the Hellenistic Carthage port and Reconstruction of the inner harbor.

The Romans refer to the arsenals with the Latin word *navalia*; in the typological structure, there are no substantial deviations from the Greek; the only change is the use of stone elements (vaulted structures) for the covers, instead the wood. A refinement of the construction system linked to safety reasons in case of possible fires, often caused by the processing of the wood of the boats.

Those different building experimentations led to the medieval arsenal. The etymology of the word comes from the arabic *dār aṣ-ṣinā 'ah*, consisting of *dār* (house) e *aṣ-ṣinā' ah* (art or manufacturing), to precisely indicate a building complex where operations of processing and manufacturing related to art shipbuilding were taking place. The word has been declining according to region, *arsenà* in Venece, *terzana* in Pisa, *atarazanas* in Castilian, *dàrsarsenale* in Genovese, these are some of the different ways to call these places in medieval times and which still remain [4].

The structure of the medieval shipyards essentially repeats that of the Greek *neoria* and Roman *navalia*, providing a series of flanked aisles, near the sea or, more often, a artificial basin (wet dock). The aspect that sets them apart from the classic is the choice of materials and the most advanced technological systems that allowed to give special conformations structures, closely related to technical and technological advancement of naval engineering.

3 TYPOLOGICAL CHARACTERIZATION OF MEDIEVAL ARSENALS IN THE MEDITERRANEAN BASIN

Usually, in architecture, the man creates and shapes the space determining measures and proportions by referring to himself (from the '*Modulor*' to anthropometry). In some cases, however, still remaining the proportions with humans, there are other factors which determine the proportion of a space, often linked to human activities, such as spaces for the remittance and the construction of boats.

Humans edify buildings according to their proportions, but dockyards have to be built according to ships' size. So, this observation requires a superior level of proportion. Dockyards, buildings with impressive spatial definition, are created using more complex construction techniques.

Located along the perimeter of the Mediterranean basin for its strong commercial characteristic are numerous arsenals that were developed in medieval times; among them, the most emblematic, given the development of the city in connection with the port, is, good to mention those Italian, Amalfi (Fig. 3) and Pisa (Fig. 4), and the Spanish, Barcelona (Fig. 5) and Seville (Fig. 6). Through the study and the type-technological analysis of these four symbols of the ancient port powers, it is possible to delineate the architectural and technological features that characterize them; characters that for some aspects unite them, for other differentiate them.

Figure 3: *Arsenal* of Amalfi.

Figure 4: *Reales Atarazanas* of Barcelona.

Figure 5: *Arsenal*of Pisa.

Figure 6: *Atarazanas* of Seville.

Depending on whether the city is located along a waterway or directly on the Mediterranean coast, the arsenals can be divided into (see Table 1):

- *Fluvial*, and of course it is navigable rivers, is the case of Pisa over the Arno River and Seville along the Guadalquivir;
- *Maritime*, such as Barcelona on the Balearic Sea and Amalfi on the Tyrrhenian Sea.

The choice of location is also the determining factor in the choice of materials and construction techniques to be used for the construction of the structure of the arsenals. It employs, in fact, available raw materials in the surrounding areas, prosperous parts of clay for the production of bricks or natural stone materials with high structural features that permit the construction of high-quality masonry.

However, despite the structures were increasingly responsive to functional needs of the construction site, they could only accommodate ships' hulls, providing for mounting of the masts, and their sails, only when they were already in the water. In fact, the limited dimensions in height of the shipbuilding spaces, due precisely to the technological systems not yet advanced, did not allow the realization of these spaces to contain a vessel mounted.

Table 1: Typological classification.

	Amalfi	Barcelona	Pisa	Seville
Typology	Maritime arsenals, perpendicular to the coast line, constructed in contact with the water	Maritime arsenals, perpendicular to the coastline, built on the *arenile*	Fluvial arsenals, built on wet dock	Fluvial arsenals, perpendicular to the coastline, built on the *arenile*
Location	Placed near the Tyrrhenian coast, their location was on the western side of the lower town	On the sea side of the Balearic Sea, the western sector of the beach	Western area of the city, north of the River Arno	*Arenal* area on the east coast of the river Guadalquivir
Original name	*Arsenale* of Amalfi	In the early documents it is called by the name of *Arazana*. Then in Catalan, *Drassanes Reials de Barcelona* (in Spanish *Atrarazanas Reales de Barcelona)*	Arsenale della Repubblica di Pisa or La *Tersana* di Pisa, place called by the Pisans with the name of *Cittadella*, with reference to the fortress function	*Reales Atarazanas de Sevilla*

4 TYPOLOGICAL CHARACTERIZATION OF ARSENALS

The usable space to accommodate and protect a vessel is defined by a rectangular area, called aisle or lane, similarity to the longitudinally extending spaces that make up the places of worship such as churches and cathedrals. The combination of multiple aisles determines an arsenal, more or less extensive, depending on the military needs and/or economic port area.

The configuration of the aisle is defined by the scanning of a series of piers or pilasters that develop in longitude, so as to contain one or more boats at the same time in the same aisle. The rows of piers that were created were in arranged in parallel, so that each row was common to the two adjacent aisles, except for the first and the last one that could predict the blind perimeter outer walls for defensive reasons, creating precisely a unitary and compact complex. The interior space, instead, it appeared diaphanous thanks to the succession of pillars, allowing both physical and visual communication between the various aisles and also an optimum room ventilation. The aisles of the arsenals have a width, which varies from 8 to 10 m or so and can reach up to 100 m in length [5].

Built up outside of the wall fence with respect to the core of the city, the arsenals occupy large surfaces, and depending on their development, can be distinguished as follows (see Table 1):

- *Arsenals perpendicular to the coastline*, divided in their turn into:
  - Built on the *arenile*;
  - Built in contact with water;
- *Arsenals on wet dock* (natural or artificial).

The first group is defined by those arsenals whose aisles see their longitudinal direction perpendicular to the coastline, or inland waterway or sea (as in the case of Seville and Barcelona, respectively). It is a setting that allows entry and exit of boats, taking advantage of the natural slope of the coast. Usually, the ships that did not require major maintenance works were halted near the shore and still maintained direct contact with yards, without entering into them. In other cases, the water lick directly the arsenal structure, allowing easy and comfortable manoeuvring to boats, eliminating the huge effort to tow the hulls in the transition zone between water and yard. The arsenal of Amalfi according to some hypotheses intended to have three aisles, which stretched towards the coast with the façade in direct contact with the water [6], unfortunately has not survived the entire structure, but only the back part. This configuration, however, is still noticeable in the arsenals of Alanya in Turkey [7], where it is evident penetration in the water of the foundations on which rest the façade arches and the direct contact between the aisles with the sea.

The arsenals belonging to the second group, on the contrary, elude direct contact with the coast for defensive reasons. In Pisa [8] or Venice, in fact, the shipyards are real productive neighbourhoods that possess their own wall fence. Wide arches are the doors through the ships pass without masts, accessing a large pool of water, called dock, around the naves are developed. The docks can arise out of natural bays, where there were primitive ports, or presenting engineering works in order to own shipbuilding facilities more and more advanced and sophisticated.

5 ELEMENTS AND TECHNOLOGICAL SYSTEMS OF ARSENALS

The typical technological system of arsenals is mainly constituted by a structures that ensures a vertical development, formed by walls marked by arched openings, on which rests a cover system (unique ceiling), generally a double pitch, which can be formed by beams wooden or stone vaulted structures. The essential elements of those structures are piers, flowing directly from foundations, arcs of connection, different depending on the development in the longitudinal and transverse direction; on the arches, there is the roof pitches, more or less sloping (Fig. 7).

5.1 Foundations

The transmission of loads to the ground of shipbuilding facilities take place, generally, through foundations that are realized by wooden piles into the sandy ground.

There is limited information about the foundation systems of the arsenals; however, some pieces of information are available from the case of the arsenals of Seville, on which a detailed study of the foundations has been conducted. There has been a continuous foundation, having a size of 1.30 m in height and 1.94 in width, which runs the full longitude [9]. Blocks or bricks, that form the piers of the real structure of the arsenals, were arranged in direct contact with the foundation.

5.2 Piers

The piers are made usually from natural stone blocks, square or irregular, and sometimes even by artificial stone elements such as solid brick. Have a section mostly square or rectangular,

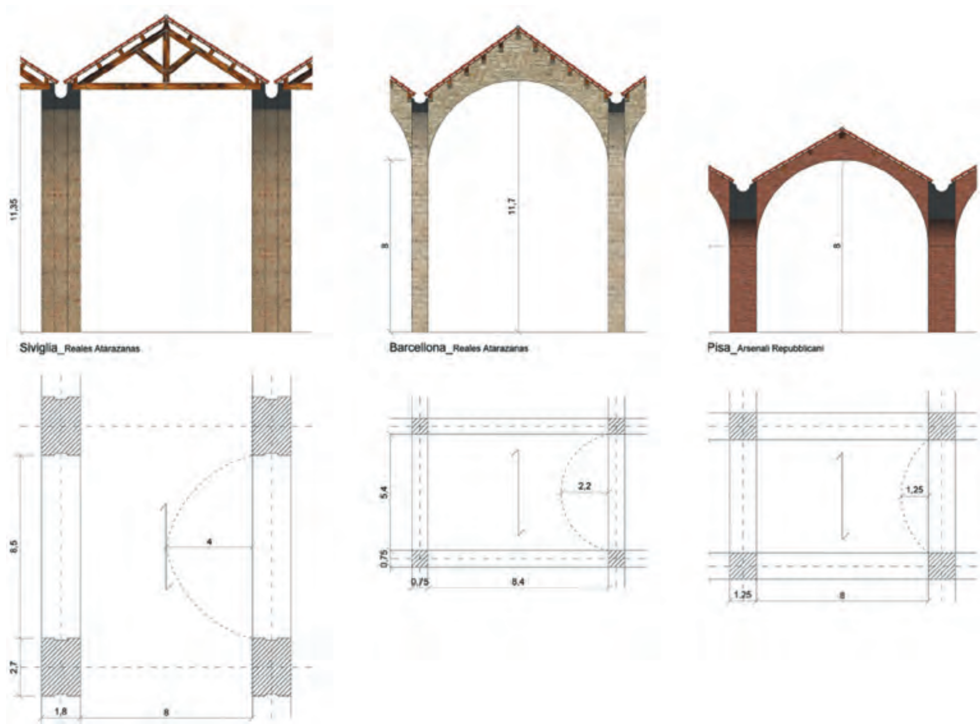

Figure 7: Typological comparison between the arsenals of Seville, Barcelona and Pisa.

circular few times and in rare cases in more articulated forms, for example to ‘H’ shape [10] (this is the case of *las Atarazanas* of Seville). The most frequent ones are of rectangular shape; they have the larger side developed along the direction in which the light to be reached is wider. Depending on the mechanical characteristics of the materials used and the magnitude of the aisles, pillars may appear slim or stocky; however, they are seen connected together by arched systems in the longitudinal direction. Transverse union between the rows can be ensured through further arches or discharging always at the piers, creating solidarity between the parties, or leaving them independent so that the cover system is to put them in connection.

5.3 Arches

The type of arches is different depending on the height of the pillars and the span to be covered, with respect to the longitudinal or transverse direction of the aisle. If the pillars are sufficiently high and allow the passage of a vessel, they are often used round arches [11], on the other hand, when the height is not appropriate are adopted pointed arches that having a larger arrow, allow to reach satisfactory heights anyway. The arches between the aisles, which constitute essentially doors, are mostly segmental arches or pointed arch. Also the arches are constructed with the same materials of the piers to guarantee structural homogeneity.

Table 2: Technological, construction and materials classification.

		Amalfi	Barcelona	Pisa	Seville
GEOMETRICAL DATA	Pier	Rectangular section 1.95 m × 1.40 m	Square section side of 0.75m	Square section side of 1.25 m	'H' section 2.70 m × 1.80 m
	Longitudiarch	Span 2.65 m	Span 5.40 m and rise 2.20 m	Span 5.25 m and rise 1.25 m	Span 8.50 m and rise 4.00 m
	Aisle	Width about 6.65 m	Width about 8.40 m	Width about 8.00 m	Width about 8.00 m
MATERIAL	Bearing structure	Irregular stone blocks bound together by mortar made up of lime and sand	Square blocks of good *Montjuich* stone processing (sedimentary rock)	Solid brick	Solid brick
	Roof	Double sloping roof resting on cross vault of irregular stone blocks bound together by mortar made up of lime and sand	Wooden roof, anchored on the extrados of the transverse arches, consists of longitudinal beams resting on stone corbels	The original roof was presented a double sloping, resting on the extrados of the arches, with schist plates fixed with nails to the wooden structures	Roof in original wooden trusses, later replaced by cross brick vaults in some aisles and in others with steel trusses [15]
General structure		Two aisles (*domus*), each 6.65 m wide and long 44.60 m, they are divided by 10 piers	Eight primitive aisles, currently seven because the two in the middle were merged into one, have a width of about 8.40 m [16]	The entire complex still four aisles whose structure is a rhomboid plant of about 40 m wide	The original complex consisted of 17 aisles, nowadays remain only 7, the southern ones

5.4 Roofs

The roof, which determines the volumetric configuration of the arsenals, is characterized by sloping, with more or less accentuated inclinations with respect to the geographical context, depending on whether it is maritime or river arsenals. Typically, for each aisle, there are two slopes that may be based essentially on three distinct technological systems: (a) on a wooden truss, (b) on the extrados of the vaulted structures or (c) on stone vault (even if present, are solutions have used in post-medieval times).

The first typology is used when the longitudinal walls rows, constituting the aisles, are independent of each other. This solution reproduces the traditional techniques used in the classical arsenals; a transverse ceiling joist on which fit together two oblique rafters, may provide a second order of wooden joists to which anchor the roof covering defined by tiles or stone slabs. Because the lights are to be covered more or less considerable, the trusses are formed by more articulated systems, with junction elements and fitting. The wooden horizontal element of the truss, the ceiling joist, can be placed directly on the walls rows, or with the terminal element incorporated in the masonry.

In the second typology, in the presence of transverse arches, with respect to the direction of the aisles, the roof rests directly on the arches. On the extrados of the arches, in fact, there are more stone elements, by such shaping of the wall at two slopes on which to place the main beams of the roof structure [12] (is the case of *las Atarazanas* of Barcelona).

The last typology is an evolution of the roofing system, mainly used to solve problems relating to the deterioration of the wood. As the arsenals are next to the considerable areas in relation with the water factor, and therefore in environments at high salt concentrations, the use of wood involves frequent maintenances. The problem is solved with the replacement of wooden trusses with vault also formed from the same material (stone elements) of the vertical structure. Is the case of Seville Hispanic-Muslims arsenals [13] or those Amalfi Angevin [14].

In any case, the system for disposal of rainwater is solved by means of a canal formed in correspondence of each row wall, in which is generated the area of valley roof between the pitches of the two adjacent aisles. The canal can end with a projecting element in the façade (the Gargoyle) that ensures the drainage of waters, or with an element for the channelling of water (Table 2).

6 CONCLUSIONS

Regardless of the geographical context, from building materials and the traditional building techniques, in the Mediterranean basin, the naval arsenals (built in the Middle Ages) repeat a similar typological scheme. Buildings from purely industrial character, the arsenals are presented free of decorative elements; indeed they are characterized by their clear and simple structure that defines impressive spatiality such those of monumental majestic places of contemporary worship.

Each arsenal, even in its particularity, shows spaces that predominates the development in length and are marked by pillars joined by arches. The powerful intrinsic formal structure of these architectures has created places from specimen prospects, places that paradoxically seem to possess a contemporary conception of space, pure spaces, anonymous and timeless. This is the characteristic that has allowed the continued existence of these buildings until today.

Because of the various transformations over the centuries, however, these facilities today are diversified and altered from their original condition, both changes that have affected the real structure and on those related to the surrounding context.

Many arsenals have seen the loss of some aisles, the termination of their principal function, addition or subtraction of parts, and therefore does not show more in their integrity.

They constitute undoubtedly architectures capable of evoking the character of the places in which they arise and therefore deserve special attention, which must aim for their preservation and enhancement, to continue to perpetuate the ancient traditions of all those productive activities related to the art of navigation and not only.

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PREVENTION, MONITORING AND CONSERVATION FOR A SMART MANAGEMENT OF THE CULTURAL HERITAGE

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ABSTRACT

Nowadays, the conservation of the cultural heritage requires the development of preventive protection strategies that should be increasingly innovative, effective, long-lasting, as well as economically sustainable. Although existing legislation provides for scheduled maintenance aimed at preventing deterioration and reducing operating costs, to date there are no decision support tools to assist in the periodic planning of the interventions to be executed. The aim of the research is to define the techniques and the innovative strategies of the maintenance process, focusing on the Smart capacity of such process. The research objectives are related to specific phases.

Fact-finding phase: Carry out actions and interventions for managing available resources and for implementing policies through the development of a technological platform for planning preventative maintenance operations.

The diagnostic phase: Carried out with the support of the heritage building information modelling methodology. Its aim is to define a specific degradation phenomenon in time and space, and to measure it in order to identify the appropriate steps to take for maintenance or restoration operations.

Participatory phase: The aim is the development of a multimedia platform, accessible to every type of user. This platform should allow the exchange of heterogeneous information, through the implementation of known systems for managing digital assets.

The final result of research will be the formulation of an information and communication technologies model that indicates the optimal maintenance frequency of a work of art based on its state of degradation (measured through indicators correlated with the nature of the material and the internal and external environmental conditions, continuously monitored), cost of maintenance and durability of the interventions performed.

An additional expected result will be the development of a participatory app, designed as a tool for promoting the accessibility and usability of the digital cultural content of an asset or of a cultural itinerary, and present it as a ‘virtual tour’, and for ultimately developing a broader ‘digital culture’ of the cultural heritage.

Keywords: cultural heritage, integrated recovery, scheduled maintenance, Smart technologies, durability.

1 INTRODUCTION

Today, the focus on the historic and modern architectural heritage is now centred on scientific interests specifically related to architectural technology, such as the recovery and promotion of assets, building design, and energy efficiency and saving.

The scientific interests of the research are oriented towards the use of traditional methodologies and technologies integrated with contemporary technical innovations in order to formulate the most appropriate recovery strategy and ensure an adequate state of conservation through a thorough knowledge of the architectural asset.

The importance of taking such an approach stems from the need to consider a recovery project not simply as the sum of individual skills from different sectors, but as a truly interdisciplinary exchange. Various specialists working in synergy can help promote a better understanding of the multiple problems encountered during the recovery and, at the same time, help identify and evaluate the suitability of the solutions proposed [1].

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The historic architectural heritage and the current discussions surrounding the built environment have brought about a change in attitude towards the greater deterioration suffered by historic and the artistic heritage than was the case in the past. Such deterioration is caused essentially by the combined action of different factors: atmospheric pollution, climate change, biological contamination, anthropogenic degradation, and not least, the wrong approach taken during refurbishment work [2].

For these reasons, we intend to research and examine in depth those aspects and methods that are most appropriate to the improvement of the design methodology known as 'integrated conservation'. This relates to areas such as recovery, restoration, promotion and, above all, the preservation of our historic, architectural and urban heritage [3].

An important issue of growing interest is the conservation and preservation of the cultural heritage, which necessarily requires a 'preventive and scheduled strategy' for the execution of conservation and maintenance operations. This strategy is essential in order to guarantee the survival of the architectural asset in a consistent and coherent way.

2 STATE OF THE ART

For some time now, there has been a growing public awareness towards the preservation of the urban environment, and especially of what constitutes the historical heritage of a community. As in the case of human health, so for historic buildings, prevention is better than cure. In the case of the architectural heritage, prevention means a continuous and innovative monitoring [2].

The importance of using Smart monitoring methodologies is reinforced by the fact that all systems, including buildings, have a response time during which it is still possible to return them to the state they were in before being subjected to the stresses that disturbed them, without the system suffering permanent impairment. However, this response time must be shorter than the time the system was subjected to stress or threat; otherwise, the changes that occur tend to produce effects leading to degradation which will be difficult to reverse [4].

One of the initiatives which is investigating a possible solution to the response time issue is a project called 'MONSTER' ('Monitoraggio Strutturale di Edifici Storici con Tecnologie Wireless e Strumenti di Calcolo Innovativi', Structural Monitoring of Historic Buildings using Wireless Technologies and Innovative Computing Instruments), carried out by CNR-ISTI between 2014 and 2016. Two research laboratories were involved: Wireless Networks (led by Erina Ferro) and Mechanics of Materials and Structures (led by Cristina Padovani). During the project, the researchers studied and developed methodologies based on networks of low-cost wireless sensors for the monitoring of ancient masonry buildings. The end users of this project will be the institutions responsible for the preservation of the architectural heritage.

Furthermore, today, before starting any recovery intervention on historic buildings or buildings with a recognized cultural value, the tendency is for the various stakeholders to establish common ground before work starts, as complex design processes tend to cover every historical and technical aspect more often than before.

It is therefore important that the specifics of any recovery project be fine-tuned. This means defining in advance the scope, the mutual relationships, the autonomy and the complexity of the relationships between the various specialists involved in it.

The 'knowledge' of the architectural heritage is the driving factor behind any kind of evaluation or intervention. The observation of the building over its entire 'lifetime', from its conception and initial design to its present condition of abandonment or disuse, is what will determine the necessity for its recovery [4].

It is easy to recognize today the fundamental role played by the new multimedia tools in the shift towards enhanced models for the communication of knowledge, which make cultural offerings open and accessible to everyone. The digitalization of content is therefore the principle underpinning these new models. However, especially today, digital content needs to be structured and be easy to explore in order to reach a larger number of stakeholders.

If we consider the set of tasks and roles assumed by applied research within the knowledge transmission processes, a position of growing responsibility is being assigned to this research field within professional and institutional contexts. It is in fact thanks to the ideas and efforts of applied research that it is being assigned development tasks on various fronts including new processes and communication models, data generation platforms, digital knowledge sharing practices, development of improved technological devices for accessing information and usability of navigation tools on the web.

A significant organization that focuses on such innovative digitalization of content for the transferring and sharing of knowledge is the Network School of Digital Cultural Heritage, Arts and Humanities. It brings together over 50 organizations, including universities, research institutions, schools, technical colleges, cultural institutes, associations, public and private companies. The common aim is to create a 'multi-site campus' capable of developing an educational offering which is harmonized with the national system of education. The ultimate goal is to build a set of digital skills that are essential to engage with the challenges posed by an increasingly multifaceted and heterogeneous interaction with the Smart society, within the framework of a scalable model at European level.

Another interesting initiative promoted by the Ministry for Cultural Heritage and Activities and Tourism is the Memorandum of Understanding signed between the General Secretariat of Cultural Heritage and ASS.I.R.C.CO. (Associazione Italiana Recupero e Consolidamento Costruzioni, Italian Association for the Recovery and Consolidation of Buildings). The aim of this memorandum is the digitalization and dissemination of surveys and project data for the recovery of the architectural heritage, in order to implement or contribute towards the creation of a catalogued archive of the state of our cultural heritage and involve young graduate professionals in the required actions.

The sources for this archive are graduation degree and doctoral theses, final dissertations for post-graduate specialization and master courses in the disciplines of surveying, diagnostics, architectural history, restoration, consolidation and recovery of architectural heritage, structural engineering and seismic engineering. This archived material is a truly valuable resource, which triggers a virtuous circle for all involved parties. Students, the ministry, universities, associations and ultimately the general public (the end users) will benefit greatly from such a digital asset [3].

Considering the technical-digital context alone, despite the widespread adoption of building information modelling (BIM) for the design and management of the life cycle of new buildings, very little research has been undertaken to explore the benefits of using the BIM methodology in the management of historic buildings and cultural landscapes. To this end, studies are in progress for the development of BIM platforms that incorporate both quantitative items (smart objects, performance data) and qualitative items (historic photographs, oral histories, music) [4] .

In addition, the three-dimensional (3D) models generated by this system use BIM software functionalities to provide a navigable timeline, which displays both material and immaterial changes to buildings that occurred in the past, as well as generating projections into the future. In this context, a wider and more innovative use of BIM for the documentation and conservation of the architectural heritage is being discussed.

3 CRITICALITY AND SOLUTIONS IN THE REFURBISHMENT PROJECT

Today, the conservation of cultural heritage context is necessary to intervene with a preventive protection strategy that is increasingly innovative, effective, long-lasting as well as economically sustainable.

There are no decision support tools to assist in the periodic planning interventions to be carried out, even if the currently existing legislation provides for a scheduled maintenance aimed at preventing deterioration and reducing operating costs.

The aim of a recovery project should be the improvement of the overall behaviour of an architectural asset. This improvement is attainable through an indispensable 'knowledge' phase, which characterizes any restoration work and which encompasses all components and disciplines that define the architectural asset itself, allowing for an understanding of its essence and an appreciation of its qualities.

The purpose of the research is to define the techniques and innovative strategies in the maintenance process, focusing on the Smart capacity of this process.

The research objectives are linked to specific phases:

The fact-finding phase, which is preparatory to any recovery process, will help define the characteristics, issues and potential of each of the successive phases that result from a recovery project based on SMART materials, innovative technologies and methodologies.

The immediate next step should be the drafting and planning of a maintenance programme which will cover the management, analysis and verification of all data gathered. This is in order to ensure a complete collection of information on both the artefact being examined (from its construction and including all its subsequent transformative and maintenance phases), and the environmental context in which it is found.

In this context, and considering the current state of the art, one of our main scientific challenges is the development of new methodologies for the analysis and integration of data acquired from cross-platform sensors with different spatial and temporal resolutions. Such methodologies will allow experts from multiple disciplines to study highly complex environmental processes in innovative ways [5].

This original and innovative approach will be used to meet the requirements and needs of the community, of engineers, of employees and of end users in order to manage and promote natural resources, with the ultimate goal of creating a participatory awareness towards recovery and restoration within the community. This participatory philosophy, typical of the architectural domain, aims at the intelligent sharing of knowledge among engineers, businesses, and central and local government. As a result, data and details of the different phases of a project are made accessible to everyday users or to specialist researchers. The intelligent sharing of a project can be achieved through innovations in the existing and future monitoring instruments and in land management, through the integration of data obtained by different technologies (information and communication technologies [ICT], sensors, remote sensing) using the web and the new possibilities offered by navigation technologies and satellite telecommunications, from cloud computing to web sensors [6].

Today, research focuses its attention on building information modelling (BIM) application procedures applied to knowledge management, documentation and the planning of interventions on buildings. BIM is a methodology, which is still being optimized, for the organization of information archived in parametric objects and updated in real time through monitoring activities. Research work is planned with the aim of integrating the full incremental knowledge process within the BIM platform using the HBIM (historic BIM) approach for the management and recovery of the cultural heritage. Such an innovative knowledge management tool is implemented and continuously updated through the collection, cataloguing and digitalization of the precious and unique documentation found in peripheral bodies of the Ministry for Cultural Heritage and Activities such as the State Archives. Given its breadth of vision and the number of areas involved, we can foresee an expansion and a consolidation of its relationships with all the fundamental disciplines, such as archaeology, hydrology, geology and others, all of which have a common interest in the recovery, promotion, security of the heritage and preventing risk to it.

4 OBJECTIVES AND METHODOLOGIES

Considering the various topics and areas of interest to be covered, we can identify different phases and related objectives.

1. Fact-finding phase. Implement actions and interventions for the management of the resources available and for the implementation of policies through the development of a technology platform for scheduling preventive maintenance. Acquire as complete a view as possible of the state of conservation of the asset. This step is crucial for executing maintenance work correctly and preventively, for saving on costs (due to less risk of damage to the asset), for modelling the information and for identifying objective metrics that describe the degradation rate of the assets subject to observation and intervention. The specific methodology for this objectives is building a user-friendly database through the collection, classification and digitalization of documentation held in the State Archives and in the local authority archives (such as Superintendencies), as well as project data coming from freelance professionals. Such information, combined with the data constantly being monitored, will allow the fine-tuning of the BIM simulation models on which the design choices of restoration or maintenance operations will be configured.
2. Diagnostic phase. The diagnostic phase is realized with the support of HBIM methodology. Its purpose is to define specific degradation phenomena in time and space, and measure it in order to identify the necessary steps to keeping or restoring. The final goal is to define areas suitable for investigation in order to fully exploit the capabilities offered by BIM for existing buildings and enhance the traditional process of the acquisition of knowledge through ICT.

   The methodology is the combination of monitoring systems and BIM methodology realizes the concept of an instrumented building, digitized by a 3D model capable of automating the activity recording devices triggered by the sensors. Some examples of monitoring applications integrated in the BIM platform are real-time acquisition of performance data related to plants in order to detect malfunctions or failures; on-site measurement under variable boundary conditions (weather, users' needs, technical system to be controlled) and amplitude measurements of spreading cracks or of ongoing subsidence through strain gauges (structural monitoring).
3. Participatory phase. The objective is to develop a multimedia platform, accessible to every type of user (allowing for an area reserved for professionals and engineers). This platform should enable the exchange of heterogeneous information, through the implementation of known systems (such as Google Earth) for managing digital assets from a socioeconomic perspective and in order to promote and disseminate culture and art, also in conjunction with the tourism industry.

Finally, the methodology for this phase. The participatory approach to such an innovative design process is guaranteed by the deployment of a unified data model, based on an ontological structure specifically dedicated to engineers and professionals. Such approach is crucial in order to execute conservation work correctly and preventively. We will develop a prototype application for smartphones and tablets, using Google Earth as geo-reference base. Such an application will include advanced information generated to dynamically design a system that would allow users to get to know and tour sites through interactive, photorealistic, 3D representations, navigable in real time, therefore giving them access to places where the 'Design for All' principles could not be adhered to.

5 CASE STUDIES

The activities presented in this article is part of a more general research under way, It aims to identify, detect, classify and interpret the historical and architectural heritage with the aim of coordinated and controlled management of degradation and conservation processes. Such activities, extended to the entire national heritage, will initially be validated in the city of Matera, a World Heritage Site since 1993 and European Capital of Culture 2019, through three ecclesiastical architectures used as pilot cases to achieve and implement a protocol and a unified methodology to preserve and maintain the value of the cultural heritage

The three churches are the church of 'San Francesco d'Assisi', the cave church of 'San Pietro Barisano' and the cave church of 'Santa Lucia alle Malve'; the choice has been conducted by the will to intervene and interpret the two different but contextual nature of traditional architecture in a similar context: built and excavated.

In fact, the church of San Francesco d'Assisi (Fig. 1), located just off the main piazza Vittorio Veneto, in a part of the urban perimeter defined as 'the city of the Plan' who consider the built city. The architecture presents a broad and regular baroque façade, dating back to the 18th century, although the original 200, as it was modified several times until reaching its current appearance.

The cave church of Santa Lucia alle Malve (Fig. 2), however, is the first female monastic settlement of the Benedictine Order, dating back to the 8th century, and the most important

Figure 1: Church of San Francesco d'Assisi, Matera, Italia.
(*visitmatera.it*)

Figure 2: Church of Santa Lucia alle Malve, Sasso Caveoso, Matera, Italia. (*tripadvisor.it*)

in the history of the city of Matera being one of the most important evidences of excavated architecture, in the Sasso Caveoso.

The external façade of the former monastery complex stretches along the rocky wall with a number of accesses that enter in as many internal cavities. The interior of the church has three naves separated by columns. The right aisle is still open for worship, and again here today we celebrate the anniversary of the saint on December 13.

The other two aisles had been used as a dwelling. The aisles are richly adorned with frescoes dating back to the 12th century, including the Madonna del latte and San Michele Arcangelo.

Above the church is located a necropolis with tombs in the rock.

Finally, the church of San Pietro Barisano (Fig. 3), is a perfect example of the typical architectural structure of the Sassi: have a façade built in the *tufo*, but the interior is almost completely excavated. The church dates back to the year 1000 and was known as San Pietro in Veteribus, but the façade that presents us today dates from 1755, as it shows an inscription on it, when the church was renovated and partly modified.

The interior consists of three naves divided by columns carved supporting round arches, and has six altars that also dug into the *tufo*. The main altar is of 18th century and is made of gilded wood.

We have started the survey campaign with 3D scanning technique using laser scanner so we can get the autonomous acquisition millions of 3D points in a very short time and with much higher quality than the classical relief tools; also, we performed punctual thermo-visions through thermal imaging camera which non-destructive means of diagnostic techniques to check and detect moisture phenomena, hidden architectural elements, identify gaps in the plaster and identify the structural part of the building.

Below, there are certain findings made on two of the sites concerned: the church of Santa Lucia alle Malve and the church of San Pietro Barisano (Figs. 4 and 5).

Figure 3: Church of San Pietro Barisano, Sasso Barisano, Matera, Italia. (*guida-matera.it*)

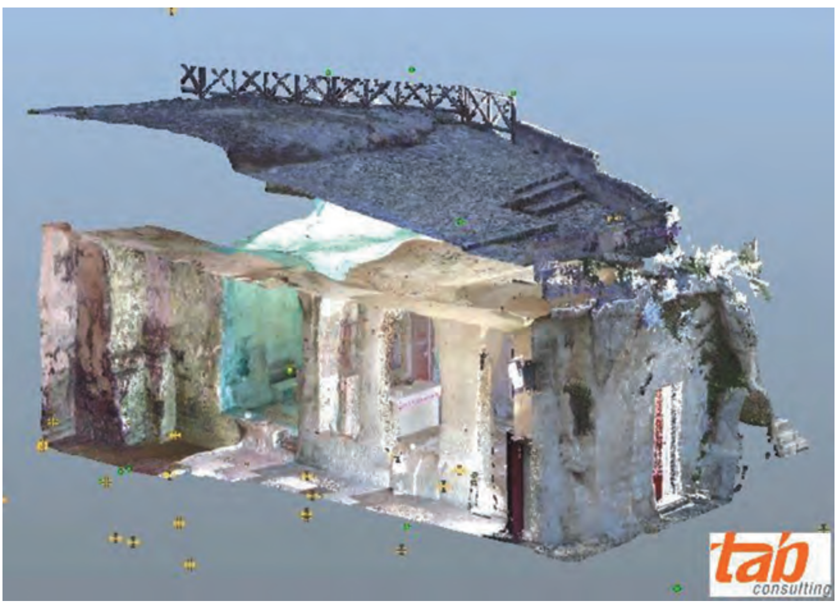

Figure 4: Section of the complex point cloud of the church of Santa Lucia alle Malve.

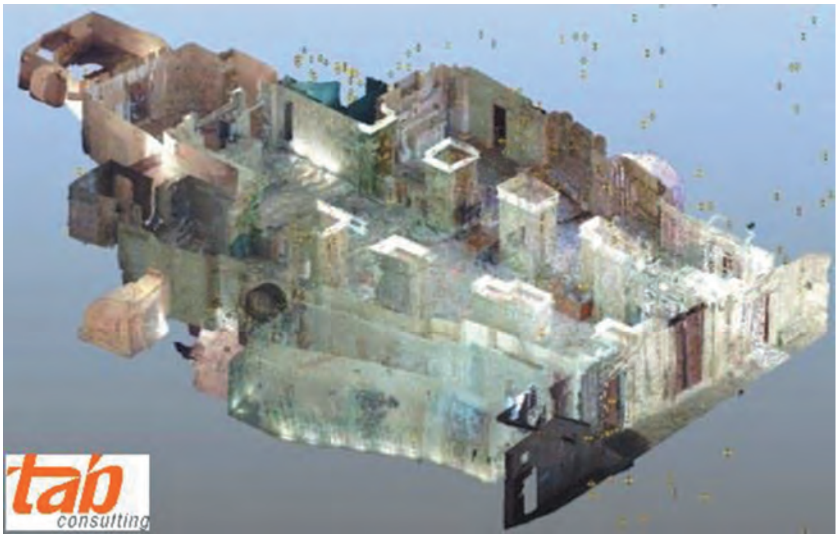

Figure 5: Axonometric section of the complex point cloud of the church of San Pietro Barisano.

6 RESULTS AND CONCLUSIONS

The final result of the research will be the formulation of an ICT model that indicates the optimum maintenance frequency of an architecture according to its state of degradation (measured by means of indicators related to the nature of the material and the internal and external environmental conditions, continuously monitored), maintenance costs and durability of the interventions.

A further result of my research efforts will be therefore the creation of a technological platform composed of a network of sensors, on-site and off-site measuring instruments, and a data storage and processing system for planning maintenance operations and for managing interventions. In addition, we intend to develop a unified procedure based on ‘Adaptable Design’ guidelines that integrates, both in form and technique, the above measuring and monitoring instruments (sensors and so on) within the architectural asset being monitored.

Another expected result will be the development of a participatory application, designed as a tool to promote accessibility and usability of digital cultural content of an asset or a cultural route and present it as a ‘virtual tour’ and for the development of a ‘digital culture’ of the cultural heritage, in order to keep contemporary users up-to-date, as well as to prepare and support future generations.

Such an application is therefore aimed at a diverse target audience. Local ministerial authorities could use it as a tool for collecting significant data that are useful for managing emergencies and for planning maintenance operations. Researchers could use this app as an innovative knowledge tool that provides input for the above-mentioned data collection carried out by the ministerial authorities (output).

The application could also be used in cases of destruction and total loss of architectural and monumental assets caused by natural hazards that sadly occur all too frequently, to allow a fast and complete survey for their rebuilding or as a ‘memory’ of the destroyed assets. At the same time, design engineers could also use this application as a base tool for planning their work, as well as the general public, who could use it simply as an aid for everyday cultural tourism, for visiting and exploring sites in real time through interactive, photorealistic, 3D representations.

Finally, it can be said as the most appropriate strategy must tend to an ever more effective risk prevention also generated by natural events such as the earthquake, in a preventive perspective than the usual intervention of failure, then go from the emergency restoration to ordinary conservation (maintenance); therefore, the activity undertaken aims to define and seek a practical solution to this complex and sensitive issue, through an effective, non-existent today, through which to identify and plan the interventions of high priority using digitization and current instrumentation to make each building Smart.

So, by intervening using this method on every single building structure, the Smart acceptation can be representative of entire towns, and Matera is a candidate to be.

ACKNOWLEDGMENTS

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PRELIMINARY STUDY FOR RETROFITTING OF A HISTORICAL WOODEN STRUCTURE USING BASE ISOLATION SYSTEM

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ABSTRACT
The old assembly hall of Noshiro city, Japan, that was built in 1950, was selected to analyse the possibility of its seismic retrofitting by means of installation of seismic isolation devices that reduce the lateral forces caused by earthquakes. The structure is a two-storey wooden frame with 20 m × 29 m plan dimensions. The building consists of an office part at east side, gallery at west side and a main hall at the middle. It is planned to leave only the main hall and gallery as historic building and to demolish the office part. However, office part contributes also to lateral stiffness of the building and therefore evaluation of dynamic behaviour with and without office part is required. From ambient vibration measurements, periods of normal modes of vibration in main directions were estimated as 0.21 and 0.32 s for EW (large direction) and NS (short direction), respectively. Torsional mode of vibration was also detected at 0.16 s. Then, finite element model was constructed and it was observed that analysis results are in good agreement with measurement results. Then dynamic properties of model without office portion were estimated as 0.23, 0.25 and 0.12 s for EW direction, NS direction and torsion, respectively. As retrofitting option, base isolation system is investigated considering 3 s as target period of the isolated structure. Due to the light weight of the upper structure, low-stiffness natural rubber isolators and sliding bearings were chosen as isolation devices. For that isolated building model, reasonable reduction of maximum acceleration on upper structure during earthquake was observed from analysis. Similarly, relative lateral displacement was reduced significantly. Therefore, retrofitting of historical wooden structures using base isolation devices represents a suitable alternative for improvement of their structural behaviour.
Keywords: base isolation, FEM, vibration analysis, wooden structure

1 INTRODUCTION

Most of the cultural heritage buildings in Japan are wooden structures that have been constructed using traditional methods [1]. These wooden structures are lighter than other historical structures like masonry buildings and reinforced concrete buildings. Then base isolation retrofitting for this kind of structures requires a detailed design of isolation devices since lateral stiffness of these devices affects significantly the dynamic characteristics of light structures.

Conventional methods for wooden construction are influenced by traditional ways of construction. However, at present, elements to increase lateral stiffness of constructions like braces, bolts and plates are used. Based on experience of damages due to earthquakes like Kobe of 1995 and Niigata Chuetsu of 2004, Japanese wooden standards have become stricter, and installation of such elements to increase stiffness is mandatory. For conventional new buildings, evaluation of earthquake-resistant characteristics can be done from well-known properties of reinforcing elements. On the other hand, intricate and complex joints in traditional wooden constructions make difficult their structural mechanic analysis, and moreover particular characteristics in each region contribute to make more difficult an unconditional evaluation of their earthquake-resistant characteristics [2], [3], [4]. Then it is necessary to evaluate case by case the dynamic properties for specific traditional wooden construction.

In this study, the Noshiro city assembly hall was selected as target structure to estimate its dynamic properties as a first step for its repair and conservation. Then a preliminary design

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for seismic retrofitting using base isolation system is performed. The building constructed in 1950 has been declared local cultural heritage building, and its structure corresponding to traditional wooden construction, however, differs from other traditional constructions like shrines or temple gates. The structure is a two-storey wooden frame with 20 m × 29 m of plan dimensions. The building consists of an office part at east side, gallery at west side and a main hall at the middle. It is planned to left only the main hall as historic building and to demolish the office part. However, office part contributes also to lateral stiffness of the building and therefore evaluation of dynamic behaviour with and without office part is required. The base isolation system is planned for the building without office portion. The vibration characteristics of this reduced building are estimated from a model that was calibrated by comparing measurement results and analysis results using the complete building, and then office part is neglected analytically to obtain the target model. Dynamic properties of model without office portion were estimated as 0.23, 0.25 and 0.12 s for EW direction, NS direction and torsion, respectively. As retrofitting option, base isolation system is investigated considering 3 s as target period of the isolated structure. Due to light weight of the upper structure, low-stiffness natural rubber isolators and sliding bearings were chosen as isolation devices. Reasonable reduction of maximum acceleration response and significantly reduction of lateral relative displacement of upper structure during earthquake was observed from analysis.

2 TARGET STRUCTURE: NOSHIRO CITY ASSEMBLY HALL

The selected structure for this research corresponds to the Noshiro city assembly hall, located in Akita prefecture, in the north part of Japan. It was constructed in 1950 as a part of the city hall complex which was designed by the famous Japanese architect and structural engineer Kiyoshi Muto. At present, this city council building of Noshiro city has been declared as a building heritage at risk.

The structure corresponds to a two-storey frame wooden structure, however, to harmonize with the administrative building, which is a reinforced concrete construction, and the finishing was made of cement mortar. Figure 1 shows elevation views and the general plan view of the building. Dimensions of the building are approximately 20 m in front by 29 m in side direction. Figure 2a shows the main entrance of the target building situated at west side.

located at first floor.

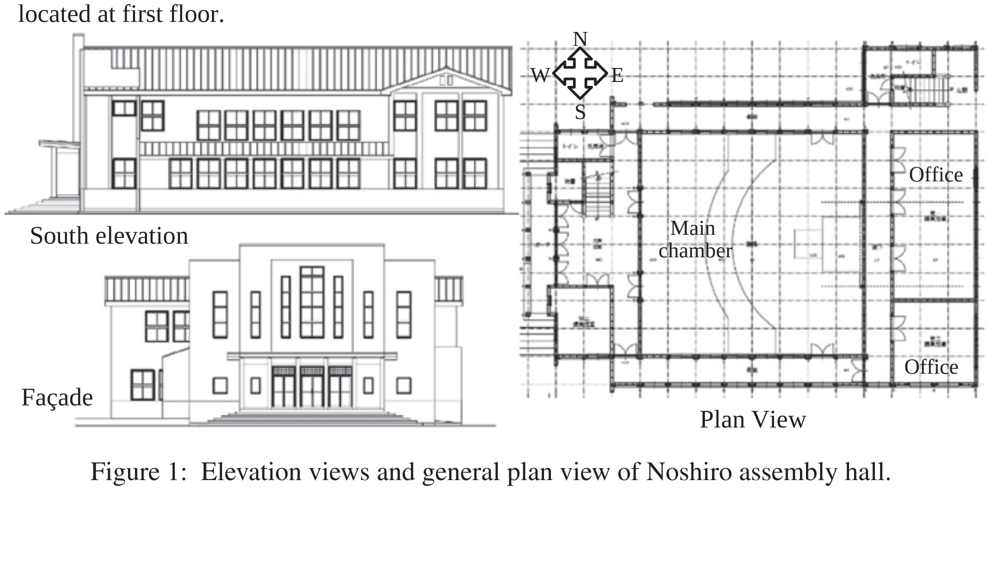

Figure 1: Elevation views and general plan view of Noshiro assembly hall.

(a) (b)

Figure 2: Façade and main chamber of Noshiro city assembly hall.

Large windows arranged in the entrance porch and side parts with a western-style design can be observed. Figure 2b also shows a view of the interior of the assembly hall located at first floor.

At west side in the second floor, near the building entrance, are located galleries or stands for the public. Photograph of Fig. 2b was taken from the stands for the public. In this part are also located offices for chairman and secretary. Offices of assembly members and administrative offices are located at east part in the first and second floors (right part in Fig. 2a). Details of a wall behind chairman desk can be observed in Fig. 3a, where cement mortar was used for finishing. This finishing mortar also contributes to lateral stiffness of building. Curtains and wooden finishing are only decorative elements. Figure 3b shows a photograph of galleries taken from the main chamber. This figure also shows the ceiling of the main chamber which was originally made of cement mortar. However, due to ageing deterioration a sudden falling of some portion of ceiling occurred in December 1998, and ceiling was reconstructed using plaster board that is fixed to a wooden structure with screws. Roof is supported by a truss structure forming a gable roof.

(a) (b)

Figure 3: Detail of interior wall and detail of gallery and ceiling.

3 AMBIENT VIBRATION MEASUREMENTS

Micro-vibrations of target building were measured conforming to the diagrams that are shown in Fig. 4. Since it is assumed that wooden structures are flexible, dynamic characteristics of this type of building can be estimated from Fourier spectrum analysis of signals recorded at upper floors [5], [6], [7]. A set of measurements were done conforming to the scheme of Fig. 4, where simultaneous measurements were carried out to identify also the torsional mode of vibration.

Results of measurement on target building are presented for the short direction that is parallel to the façade and for the longitudinal direction. To estimate the dynamic characteristics of target building a stable portion of the record, with 40.96 s of duration, is taken to perform a Fourier analysis. Only Fourier spectrum is used to estimate the predominant period of the building. Moreover, to estimate the torsional mode of vibration, Fourier spectrum of the relative velocity between two points of measurements is used. As example, the result of the Fourier analysis is shown in Figs. 5 and 6. Figure 5 shows the results for each horizontal direction, and predominant frequencies are estimated as 3.00 Hz for short direction and 4.86 for longitudinal direction.

Table 1 shows the summarized results from a set of measurements. Average values of 4.86 and 3.09 Hz are obtained for longitudinal and short directions, respectively.

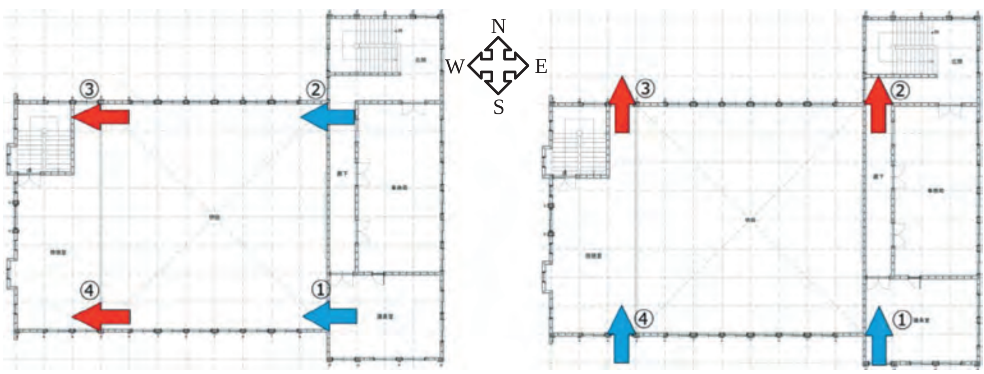

Figure 4: Scheme for simultaneous measurements.

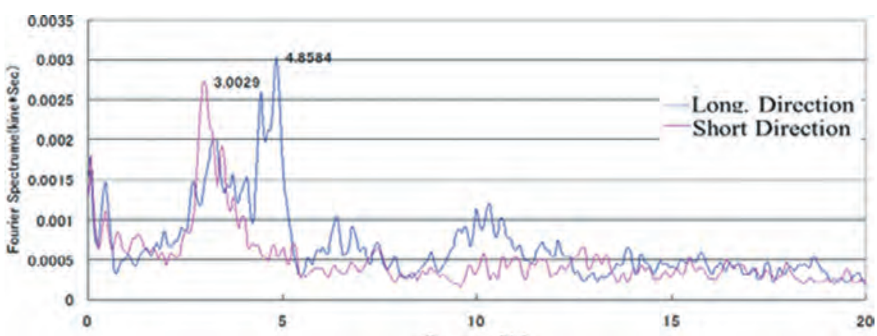

Figure 5: Fourier spectrum results.

Table 1: Results for the second set of measurements.

Point of measurement	Predominant frequency (Hz)	
	Large direction	Short direction
①	4.88	3.32
②	4.83	3.02
③	4.86	3.00
④	4.86	3.01

Table 2: Predominant frequencies for torsional mode of vibration.

Points for relative velocity	Predominant frequency (Hz)
①-②	6.30
③-④	6.25
①-④	6.49
②-③	6.59

Since measurements were performed simultaneously at all points, it was possible to obtain the torsional mode of vibration. For this purpose, Fourier spectrum of the relative velocity of two points (e.g. the difference between points 1 and 4 in longitudinal direction) was calculated to identify the torsional mode of vibration. The result is presented in Fig. 6, and a clear peak is observed at 6.49 Hz.

Results for torsional mode of vibration are summarized in Table 2. These predominant frequencies were estimated from Fourier spectrum of relative velocity between indicated points. Average value for the frequency of torsional mode is 6.41 Hz.

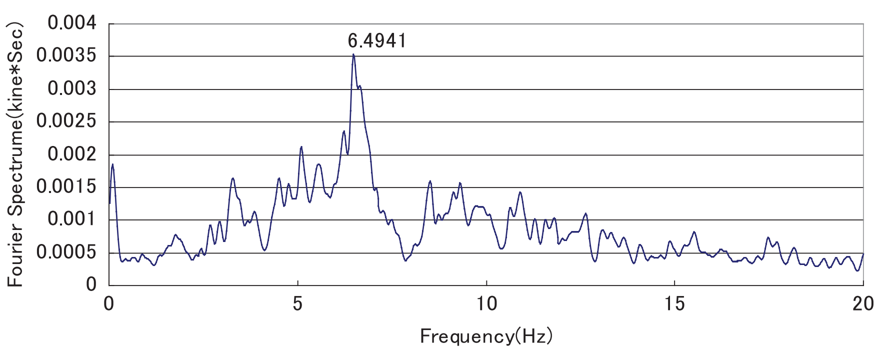

Figure 6: Fourier spectrum of relative velocity.

4 FINITE ELEMENT MODEL AND RETROFIT ANALYSIS

To calibrate the model for analysis the original structure was modelled using finite element method (FEM). Then dynamic characteristics obtained from ambient vibration measurements are compared with those obtained from analysis. Then the office portion of the building is neglected, and dynamic properties of this modified structure are obtained analytically. Figure 7 shows structural models of both structures. The FEM model was constructed based on available data and based on direct measurements of the dimension of the building. As observed in Fig. 7, the general shape of Noshiro city assembly hall is reproduced in the model using frame elements for walls and truss elements for roof structure. Wood elements are made of Akita cedar with elastic modulus of 7,500, 600 and 300 N/mm^2, for longitudinal, radial and tangential axes, respectively.

Finite element model of the original structure consists of 2,327 frame elements for main structure including roof truss and 400 area elements for slabs and roof. Roof is made of metal plate and is modelled as shell structure supported by a truss system. Ceiling and floor slabs are wooden structures and additional mass is considered for plaster finishing. To construct the FEM model, characteristics of the joints were estimated considering that joints present partial stiffness. The office part of the model was deleted to obtain the modified structure. Then, from modal analysis, vibration characteristics of both models are obtained. Table 3 shows these results, and it can be observed that normal modes of vibration for modified structure have lower frequencies for both directions. This is due to the fact that although the structure has smaller mass, the lateral stiffness has also suffered a reduction resulting in lower predominant frequencies. In the case of torsional mode of vibration, the frequency presents a

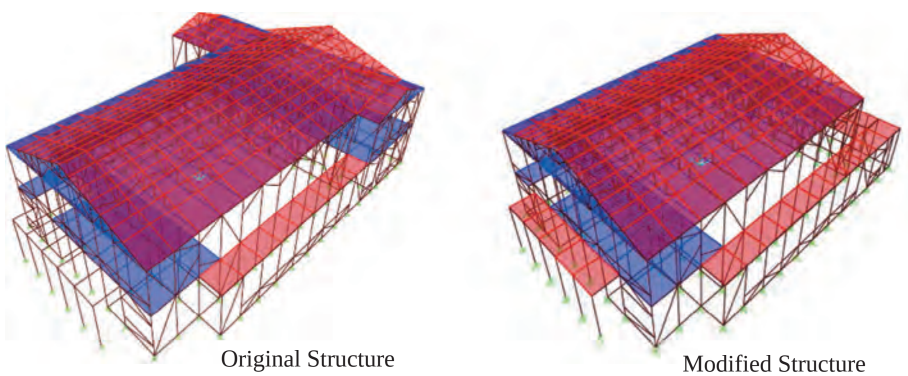

Figure 7: Original structure and modified structure.

Table 3: Vibration characteristics of original and modified structures.

Structure	Mode of vibration	Period (s)	Frequency (Hz)
Original structure	Longitudinal direction	0.25	4.00
	Short direction	0.21	4.68
	Torsion	0.18	5.62
Modified structure	Longitudinal direction	0.25	3.93
	Short direction	0.23	4.41
	Torsion	0.12	8.39

higher value for the modified structure. It means that this mode of vibration will not occur at low frequencies since the structure is more symmetric than the original one.

For the modified structure, seismic retrofitting using base isolation system is investigated. Since the upper structure is a light wooden structure, natural rubber isolator of low lateral stiffness is selected to provide the required stiffness of isolated layer. These rubber isolators are combined with sliding isolators to increase the energy dissipation capacity of the system. A concrete slab and corresponding foundation beams are considered to install the isolation layer. This slab result in a weight of 3,800 kN, while the weight of upper structure has a weight of 500 kN.

Considering 3 s as the target period of isolated building to be designed, the required lateral stiffness of isolated layer is 18.4 kN/cm. A quantity of 42 rigid sliding bearings GSD90 with a friction coefficient of 0.0046 are considered. Also, ten restoring force rubber isolators are considered to contribute to lateral stiffness of the system. The clearance is estimated as 50 cm. The slab modelling and distribution of isolation devices are shown in Fig. 8.

As input motions, near-source earthquake records (three waves) and far-source earthquake records (two waves) are employed. The objective is to consider short period-type earthquakes and long period-type earthquakes. To facilitate the comparison of analysis results, all signals are normalized to have 50 cm/s as maximum velocity. Characteristics of the earthquake records are shown in Table 4. Time history analysis is performed considering 2% as viscous

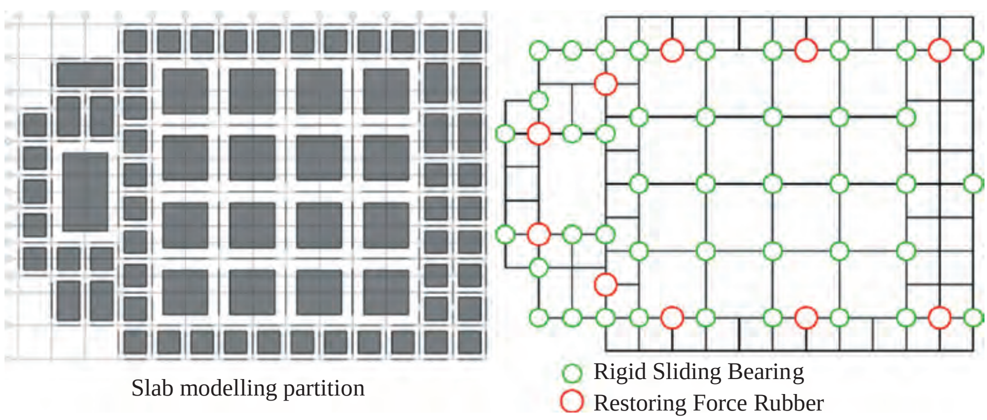

Figure 8: Slab modelling and distribution of isolation devices.

Table 4: Characteristics of input motions.

Record name	Earthquake details	Maximum acceleration (cm/s^2)	Maximum velocity (cm/s)	Duration (s)
ELC-NS	Imperial Valley, 1940 (ElCentro)	510.8	50	53.76
Taft-EW	Kern County, 1952 (Taft)	496.6	50	54.38
Kobj-NS	Hyogo Prefecture, 1995 (Kobe)	423.9	50	50.0
Hach-NS	Tokachi-oki, 1968 (Hachinoje NS)	333.5	50	234.0
Hach-EW	Tokachi-oki, 1968 (Hachinoje EW)	239.8	50	234.0

damping of the system while equivalent damping is proportioned by the sliding bearings. Each unidirectional input motion was input separately for *X* direction (large side direction of building) and *Y* direction (short side direction of building).

Results of analysis are shown in Figs. 9 and 10. Maximum accelerations for ground (input), floor slab (isolated floor), mezzanine (gallery) and roof (top) are shown in Fig. 9. Reduction of input acceleration is observed for both directions, and reduction factors vary from 0.1

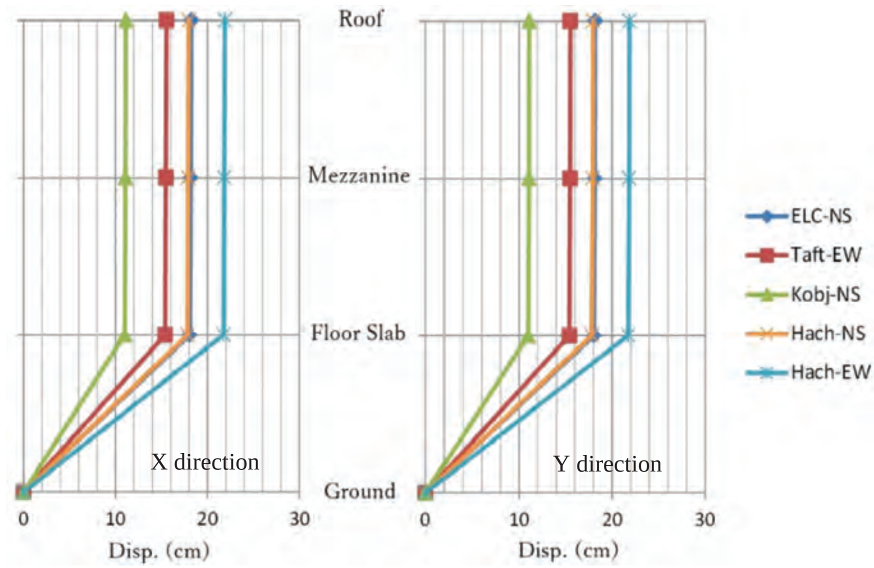

Figure 9: Maximum acceleration responses.

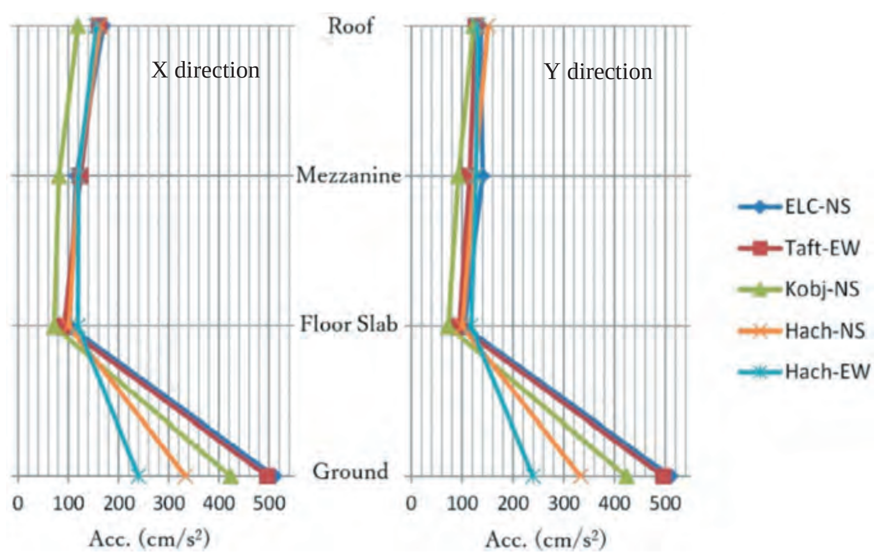

Figure 10: Maximum displacement responses.

to 0.5. Results for displacement are shown in Fig. 10 and it can be observed that displacements are concentrated at floor slab. However, all maximum displacements are smaller than the clearance of 50 cm (maximum displacement of 22.9 cm). On the other hand, relative displacements of upper part are very small.

5 CONCLUSIONS

An analysis for a seismic retrofit of a historical wooden structure using base isolation devices has been performed. The applicability of this kind of retrofitting has been analytically proved.

Effectiveness in reduction of maximum acceleration was demonstrated for all input motions used in the analysis. Reduction factors varying from 0.1 to 0.5 were obtained.

A maximum displacement of 22.9 for the isolated structure is small enough to avoid the impact against retaining walls since a clearance of 50 cm is considered in the design.

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KNOWING TO PRESERVE: THE BUILDING COGNITION PROCESS FOR THE CONSERVATION OF ST'ANNE CHARTERHOUSE, COVENTRY – UK

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ABSTRACT
Every architectural project involving building heritage, for either its conservation or its adaptive reuse, requires an intensive phase of research and analysis in order to learn about the building on which one will intervene. A project done without this knowledge will surely lead to a series of bad decisions that could cause irreparable damage to the building. This article presents as case study the St Anne Charterhouse, a Carthusian Monastery in the city of Coventry, England, and aims to show the cognition process conducted between the months of January and February 2013. It will demonstrate how the historical research, architectural survey and stratigraphic analysis were conducted on the building, showing step by step the knowledge acquired and how each piece of information has contributed to the reconstruction of the Priory during the Middle Ages and to arriving to a proposal for its adaptive reuse, opening The Charterhouse to the residents of Coventry. Knowing where every building was located within the monastery complex was important because only one building still stands after the rest was demolished with the dissolution of the monasteries in 1540 and to ensure that no possible use would conflict with the history of the monument. The building has gone through a long process of cognition that revealed some data that changed some of the initial design ideas. The results showed, for example, that instead of a building with four rooms as we previously thought, there were actually two buildings with no physical connection between them and that an important medieval painting had not been painted over but vanished with the replacement of the original wall. This research has been critical to the assessment of the possibilities for the reuse of The Charterhouse and will be exposed inside the building so the community can learn about its history.
Keywords: Charterhouse, cognition process, monastery.

1 INTRODUCTION

It is known that it is not possible to do any proposal for a heritage building without first getting to know the building [1]. To be able to work on a proposal for the conservation and reuse of The Charterhouse, it was essential to first understand the building and the site history. The medieval building standing today on site was part of a Carthusian priory and it is the only remaining building on site. This article is part of the knowledge process that included, in a first phase, a research on other monasteries of the same religious order in the UK to find out how the monks lived inside the priory and what were its architectural features. After that, the research went more specific, with a historical research and mapping of the remaining building of The Charterhouse, until we got to the analysis phase through the architectural survey and stratigraphic analysis of the standing building.

The goal of this cognition process was to understand how the monastic complex was configured in the medieval period and in particular the changes that the existing building has suffered over the years. The remaining three-floored building, built in stone masonry, used to contain the Prior's house and the refectory, but today there is nothing that indicates that it was a Carthusian Priory, except for its name, Charterhouse, which comes from *Chartreuse*, the name of the mountain where the first Carthusian monastery has been installed, in France. The church was also demolished along with other buildings within the complex.

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The following sections show step by step the knowledge acquired during the process and how each one has contributed to the reconstruction of the monastery during the Middle Ages and to arriving to a proposal for its adaptive reuse.

2 THE CHARTERHOUSE

2.1 Location and history

The Priory of St Anne, or The Charterhouse, is located in Coventry, England. Coventry is a metropolitan city in the province of West Midlands in England and is located 153 km north west of central London and 31 km east–south of Birmingham. Coventry was one of the most important cities in England during the Middle Ages thanks to its textile production booming. The Charterhouse is located next to the river Sherbourne, a few minutes' walk, along London Road, of the ancient walls of the medieval city (Fig. 1).

The Charterhouse was originally part of the Priory of St Anne, founded in 1381. After the dissolution of the monasteries in 1539, most of the buildings were demolished, leaving only a stone building still standing (two wings have been further demolished in 1848) [2]. The building is Grade I listed and the surrounding grounds have the status of Scheduled Ancient Monument. The buildings classified as Grade I in England are of exceptional interest, sometimes considered of international importance.

The monks who lived there were of the Carthusian order. Every monk lived alone in a cell, which consisted of only two or three small rooms, and there they would remain silent and alone, dressed in the most minimal clothing, eating the most meagre diet (peas and fish typically), and they would only meet with other brothers in the choir or for prayer in the chapterhouse [3].

The dissolution of the monasteries in the 16th century by King Henry VIII, after the breakaway with Rome, caused a devastating effect in Coventry. As a method of reducing the enormous power that the Church had all around the world, Henry began to slowly dissolve the secular institutions. The first monasteries in Coventry to fall were The Whitefriars and The Greyfriars and then The Charterhouse [4].

After that, the building was converted into private residence and is now owned by The Charterhouse Preservation Trust.

Figure 1: Location of The Charterhouse.

2.2 The building

The remaining building is believed to be the Prior's accommodation, built in sandstone from the 15th century. A short extension on the left, which was added in the 16th century when the property became a private home, after the dissolution of the monasteries, is built with stone walls on the ground floor and timber framed above (Figs. 2 and 3).

Some original features can be found in the building, including a stone fireplace, some original stone shelves and carved wooden beams. There is also ancient oak panelling, possibly from the 17th century, and doors and sash windows from the 18th century. Perhaps the most notable features are medieval wall paintings from the 16th and 17th centuries, depicting the crucifixion and important elements of the English Renaissance (Figs. 4 and 5).

Besides the Prior's House, part of the north wall of the church and most of the perimeter walls still remain. With the exception of some repair works in grey stone, all the surviving walls are in red sandstone from Coventry.

Like all British convent buildings converted into private residences, the survivor building, located on the northwest side of the monastic cloister, has gone through some important

Figure 2: The Charterhouse, east façade.

Figure 3: The Charterhouse, west façade.

Figure 4: The medieval painting.

Figure 5: The English Renaissance painting.

changes over the years. The building, originally of two floors, has received a third floor, new roof and a northern extension after the dissolution. The first changes are believed to be from the mid-16th century and the last ones from the 1960s. In the initial phase, the interiors have been modified by the insertion of partition walls, forming hallways that now run from north through south of the building, both in the first and second floors.

3 THE COGNITION PROCESS

This knowledge process was possible by analysing the building and grounds through indirect and direct sources. The first part, the research on indirect sources, will not be covered in this article. As indirect sources we are considering the historical research on other Carthusian Monasteries and the cartographic research. The data collected made it possible to assume the location of the main buildings within the complex, along with the records of the excavations conducted in The Charterhouse in 1968–87, by Ian Soden [5].

Once all the information was collected, it was possible to continue with the research on the direct sources, which consisted of the reading of the building itself, via architectural survey and stratigraphic analysis of the building.

3.1 The architectural survey and photo elevations

The survey represents the preliminary activity of each project of conservation, and in the case of The Charterhouse it was done just after the first site inspection. This phase seeks to understand all aspects of the building, leaving behind the old belief that this stage is a simple measurement operation, assimilating it rather to a real reading of the building.

The information that we had prior to the survey was that the medieval painting of the crucifixion had been divided into two by the insertion of the second floor in the 16th century and the top part of the painting had been removed or covered, although no traces of the painting in the second floor have ever been found. The survey showed that it would never have been possible to find the top of the painting because the ancient masonry was destroyed and a new wall was built almost in the same place, which has caused the confusion (Figs. 6 and 7).

For the survey of the elevations, the use of photographs was crucial and gave the supporting documentation for the stratigraphic analysis, which will be shown next. Due to the difficulty of direct measurement, the elevations were produced with the photographic images, using the

Figure 6: Section showing painting in the first floor.

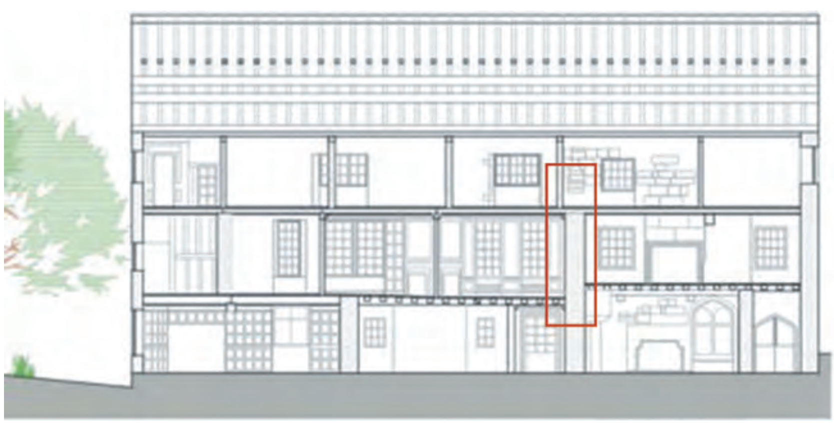

Figure 7: Section showing that top part was demolished.

Figure 8: Photo elevation and analysis of East elevation.

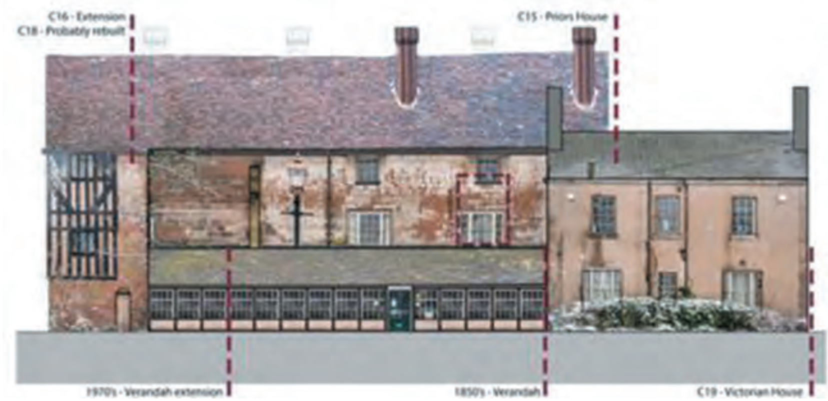

Figure 9: Photo elevation and analysis of West elevation.

image rectification method, a technique that allows you to reduce the geometric distortions to get correct dimensional information (Figs. 8 and 9).

With the architectural survey, it has been possible to recognize some of the changes that the building has gone through. Besides the demolition of an important wall paining, as mentioned previously, it became clear, while drawing the elevations, that two big medieval windows on the east façade have been closed off, probably after the dissolution, when the building became a private house.

3.2 The stratigraphic survey

Along with information gathered with historical research and geometric survey, the stratigraphic analysis made it possible to read the signs presented in the building. This method was first used in the 1980s, when architecture archaeology begun to be studied. Architectural archaeology applies the methods of archaeological research in a non-destructive way. With this method the history of the building can be reconstructed by analysing its construction techniques [6].

In the architectural context, the stratigraphic reading is based on the observation of the external surface by observing all layers simultaneously. The building then becomes a direct source of information. In the case of The Charterhouse, the reading was easy due to the absence of plaster that would hide the brickwork. At the same time, the fact that the stone used is local and has been used in different stages of the building history made the reading a little more complicated. Being a non-destructive technique, the stratigraphic analysis is based only on what is visible.

The identification of the stratigraphic units (SUs) was the first thing done and has been based on the photo elevations. The SUs are homogenous areas with the exact same constructive technique and they can be positive SUs, those that have a continuity clearly distinguishable or negative SUs, those due to removal of material.

To recognize the different SUs, it has been taken in consideration the type of materials used in the facades.Three different types of stone have been identified, one grey and two red, one more regular than the other, and these three types of masonry were encountered all over the observed façade (east). Doors and windows have also been identified, along with the roof and architectural elements, such as the chimneys. The SUs recognized on site were then marked and numbers in the photo elevation. The masonry SUs are numbered from 1001 to 1018, the architectural elements from 2001 to 2004 and the openings from 3001 to 3013 (Fig. 10).

The numbering of the SU does not necessarily match with the stratigraphic sequence. The SUs were then related based on the following: an SU *binds* to another: in the case of clamped walls, indicating *contemporaneity*; an SU *fills* another: it means an existing opening has been closed off and indicates *posteriority*; an SU *cuts* another: it means a transaction of demolition and indicates a *posteriority*; an SU *leans* to the other: in the case in which a masonry leans to a pre-existing, which indicates *posteriority* [7].

Five phases have been identified: the first and second were two different phases of construction; however, more or less from the same historical period and could be identified by two different types of stone. The third refers to infills made after the dissolution of the monastery, when the building became a private home. The fourth phase is the openings, with the typical windows from the Georgian period in England, from the 18th century. Finally, the fifth phase corresponds to the replacement of the roofs and chimneys (Fig. 11).

Figure 10: Stratigraphic analysis.

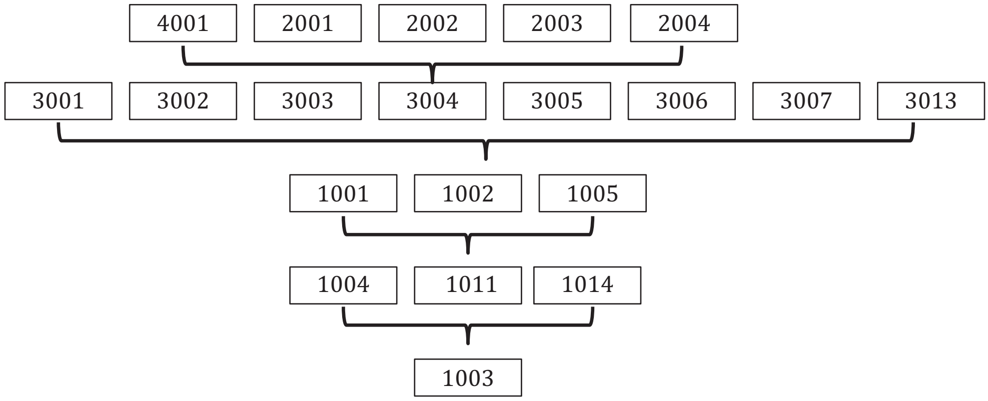

Figure 11: Stratigraphic units.

The data obtained with the stratigraphic analysis of the elevations gave the answers needed to understand what happened to the building, which became the basis for any proposal solutions for its future use. The interiors were also analysed and the modifications could also be identified and will be shown next.

3.3 Chronological dating

After the stage of collection and registration of data from the direct observation of the building, it was possible to move to the interpretive phase. The details were worked out together with the data acquired with the analysis on indirect sources (historical research, mapping, etc.). The dating based on the building stratigraphy is not absolute and needs to be combined with other dating techniques [8]. For this purpose, the stratigraphy was enough and produced a stable framework to work on.

Figure 12: Chronology, east elevation.

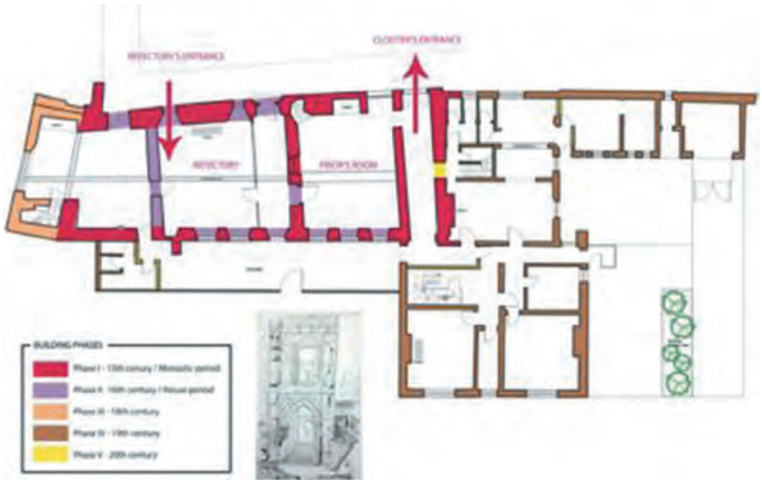

Figure 13: Chronology, ground floor.

With all units arranged, a chronological sequence has been assigned and the units have become the evolutionary stages of the building modifications. Each of these stages, and supported by an adequate investigation of indirect sources, refers to a specific historical period (Figs. 12 and 13).

- Phase I – 15th century, monastic period
- Phase II – 16th century, house period
- Phase III – 18th century, house period
- Phase IV – 19th century, house period
- Phase V – 20th century, house period.

The result of this will help tell the history of the building and will be the base for the adaptive reuse, which intends to respect the phases of the building.

4 RESULTS

4.1 The reconstruction of the medieval monastery

To the community of Coventry, The Charterhouse of St'Anne has always been a mystery. Even if they have always used the surrounding grounds as their park, only in 2012, in an 'open day', they were invited to enter the building and learn a bit about the history of the monastery.

To help tell this story, the medieval monastery was reconstructed in a three-dimensional model, based on the research (Fig. 14). From the archaeological excavations, we knew with certainty the location of the church and the monks' cells and these, together with the standing building, were the starting point for the three-dimensional model. Although only five cells have been excavated, it is known from historical research (the research on indirect sources, which have not been covered in this article) that there were in total eleven, six to the east of the cloister, four to the south and two to the west of the cloister.

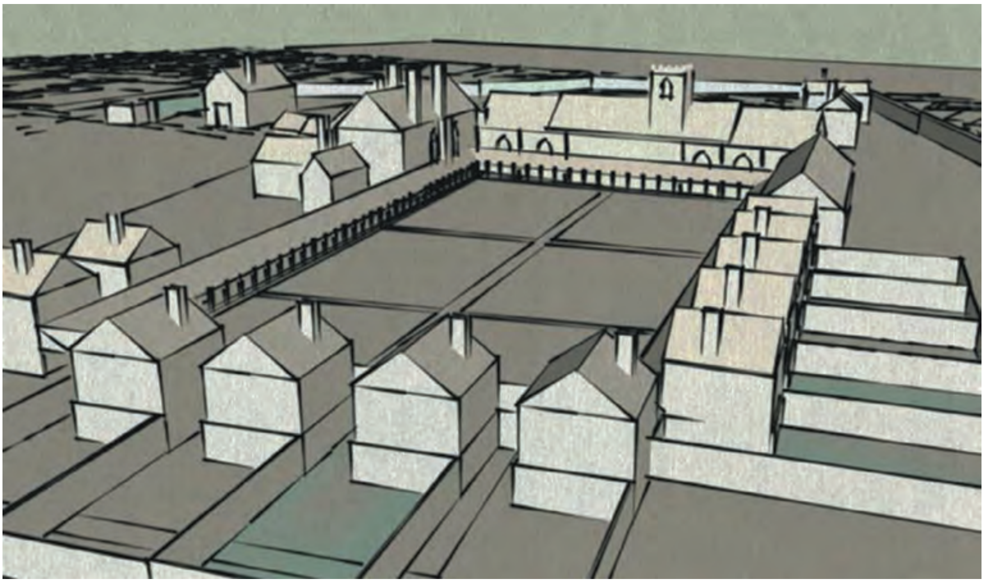

Figure 14: Three-dimensional reconstruction of The Charterhouse.

No excavation has been done in the supposed location of the chapterhouse, but it is known, from the research on other monasteries throughout Europe, this would usually be by the east side of the cloister. To the north of the church, the excavations found part of what is believed to be the cloister of the lay brothers, who certainly were outside the cloister of monks.

To the west of the survival building, based on the usual configuration of the Carthusian Monasteries and also on drawings made in the 19th century, were located the service homes, the kitchen, the bakery, etc. Near the bridge of access to the monastery, there was probably the home of the prosecutor.

The Prior's house (the surviving building) was analysed separately with bases in historical research but mainly by reading the building through the stratigraphic analysis. It has always been said that originally it was a two-floored house which contained the accommodation of the prior, the refectory and the guest house. The southern part of the house was certainly composed of two floors in the monastic period, and we know this by the presence of a beautiful stone staircase connecting the ground floor and the first, which can be seen now only in the ground floor. The whole southern part of the building contained the housing of the prior on the ground floor, which was probably very similar to that of other monks and the first floor was divided into two private rooms for the use of the prior, such as study and pray. A second floor was added later.

The north side of the building has always been thought of as the refectory on the ground floor due to the presence of lavatory in the east facade, where monks used to wash their hands before eating and entering the church, and the guest house on the first floor. However, the medieval painting of the crucifixion, today on the first floor, would most certainly be in the refectory, rather than in the guest house, as most Carthusian Monasteries had a crucifixion painting in the refectory. Besides, there are no traces of a staircase connecting the ground floor to the first, the only staircase is the one in the Prior's house, which had no internal connection with the refectory (there is currently a connection through an opening that cuts the

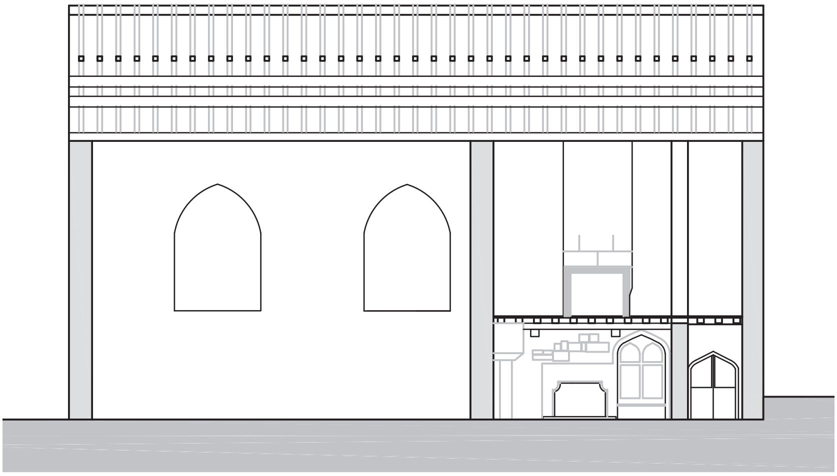

Figure 15: Assumed original longitudinal section.

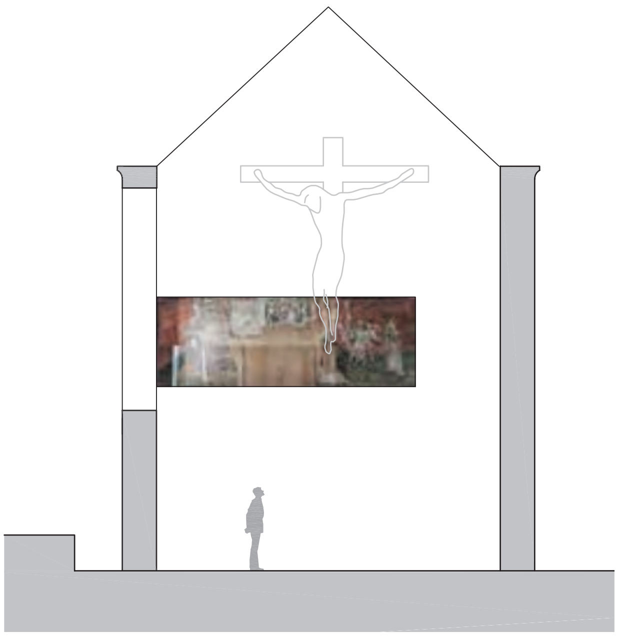

Figure 16: Assumed original transversal section.

medieval painting and certainly this was not the case in the monastic period). This leads to a conclusion that there was actually no first floor and the refectory used to be a double-height room. Other evidence for this conclusion is that the paintings in the refectory were usually located at a height of 2–3 meters from the floor, for reasons of scale (to make it possible to be seen from the ideal angle) and also to re-table the god's importance (in the case of the crucifixion). Today, this is at only 1 meter from the floor where it is located (the first floor) (Figs. 15 and 16).

The refectory contained two openings on the east side and no windows on the west side, perhaps for the rule of not visual contact with the outside courtyard. The building is accessed from the east side through an opening to the north of the lavatory and the opening in the west would probably link the refectory to the kitchen.

4.2 Evaluation of possibilities for the reuse of The Charterhouse

The process of knowledge has been critical to the assessment of the possibilities for the reuse of the Carthusian Priory of Santa Ana and will also be important to tell the story of The Charterhouse to the community of Coventry. The union of all the data collected between historical research and the direct analysis of the building gave us the conditions for planning the reuse of the building, respecting its history and original configuration.

Once the building and the monastic complex was understood, the first step was to determine that the garden – that used to be the cloister – should remain a space of silence since it has been that way in the monastic period. It will be there that the story will be told to visitors of the monastery and the children of the local schools. The gardens outside the walls will be developed for sports and other activities in general because it was the secular space in the monastery. The result of this research and all processed materials will be exhibited in the museum of The Charterhouse with the intuition that the entire Coventry community can learn the history and participate in it from now on.

The future use of the house is still to be confirmed by the trust that owns the house, but the most important decision is that, although it is now known that the building has suffered some important modifications through the years, no work will be done in the attempt to convert the building into its original configuration. All phases are important and it tells the history of The chapterhouse. The only exception will be the reconstruction of one of the cells, where visitors will have the chance to see how the Carthusian monks used to live.

ACKNOWLEDGEMENT

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IMPACT OF TRAFFIC VIBRATION ON THE TEMPLE OF MINERVA MEDICA, ROME: PRELIMINARY STUDY WITHIN THE CO.B.RA. PROJECT

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ABSTRACT

The impact of long-term traffic vibration on ancient structures located in the city centre of big cities is an important issue, as it represents the main factor of fatigue, possibly causing structural damage in historic constructions. This article illustrates the preliminary results of a study on the so-called Temple of Minerva Medica in Rome, Italy, conducted within the CO.B.RA. project, which focuses on the development of advanced technologies and methods for the conservation of cultural heritage assets. The studied monument, which is part of the architectural heritage of ancient Rome, is located very close to several railway tracks just out of the Termini train station, on the north-east side, and to urban tramways, on the west side.

To obtain indications on the dynamic behaviour of the structure and to map the base excitation induced by passing trains and trams, ambient vibration data were acquired by digital recorders with triaxial velocimeters positioned at several measurement points on the ground, around and inside the structure, and at different heights on the north-west façade. For evaluating the structural vulnerability, three-dimensional (3D) architectural surveys and non-destructive investigations on the material properties of the monument were conducted in order to implement a finite element model of the building to be used for structural analyses and dynamic simulations. In particular, to the purpose of obtaining a detailed 3D model, laser scanner and stereo-photogrammetric acquisitions were carried out. Photographic acquisitions were also used to identify the crack pattern and to document the current state of damage. Vibration and 3D reconstruction data were acquired both in summer and in winter, along with thermographic images, for assessing the seasonal effects on the structural behaviour. All collected data were stored into an ad hoc friendly data repository accessible through the internet by the accredited project end-users.

Keywords: 3D reconstruction, ancient Roman masonry, dynamic identification, non-destructive tests, traffic vibration

1 INTRODUCTION

In the maintenance of architectural heritage in contemporary urban environments, a significant issue is the impact of vibrations that may affect the integrity and conservation of historic buildings. This aspect is particularly important in southern European countries, namely in Italy, where the concentration of historical and monumental buildings in urban areas is the greatest worldwide, as documented by UNESCO [1].

In order to understand the potential impact of vibrations on the buildings, an appropriate characterization of materials and structural behaviour is crucial. This knowledge can be gained through a series of material characterization techniques. In particular, three-dimensional (3D) architectural surveys and non-destructive tests (NDTs) on the material properties of the monument can be carried out in order to implement a numerical model of the building. Such numerical models can be used for structural analyses and dynamic simulations that can provide accurate results demonstrating the stress state of the building and possible failure mechanisms affecting its stability.

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This article will illustrate the preliminary results of a study on the so-called Temple of Minerva Medica in Rome, Italy. This study was conducted within the CO.B.RA project [2], which focuses on the development of advanced technologies and methods for the conservation of cultural heritage assets. The main focus of the study will be on the measurements and analysis of the vibrations data. To map the base excitation induced by passing urban vehicles vibrations data were recorded at several measurement points on the ground, around and inside the structure. As particular importance is related to the dynamic behaviour aiming to provide an assessment of the vulnerability of the building, vibration data were also acquired at different heights on the north-west façade.

2 TRAFFIC VIBRATIONS AND HISTORICAL BUILDINGS

The vibration sources in contemporary urban areas are mostly related to transportation infrastructures, such as road traffic, metro systems, urban railroads and tramways. In some cases, there are also other relevant vibration sources mainly related to construction activities and crowded events.

Vibrations are transmitted through the ground to building foundations and from foundations to the upper structure, representing the main factor of fatigue, possibly causing structural damage in vulnerable constructions, such as most historic buildings and monuments. Therefore, the study of this phenomenon has received significant attention by conservationists, scientists and engineers in the last several decades. Also lawmakers or regulatory agencies of many different countries have released various standards to limit the intensity of vibrations that human activities and transportation systems are allowed to release to environment, especially close to the most vulnerable structures.

In the literature, many recent experimental and theoretical studies aimed at characterizing the vibratory phenomena caused by traffic, construction activities, explosions and their effects on buildings can be found, as reported in Refs. [3–8]. More specifically, several researchers studied the effects that external sources of vibration may produce on historical buildings that represent a significant architectural heritage. An interesting discussion on this subject can be found in Ref. [9] outlining that a distinction shall be made between short-term and long-term effects, as the latter could gradually produce damages also for very low vibration intensities and that degradation phenomena due to long-term vibrations are not well known. This is particularly important for historic buildings that may not be structurally sound and material degradation may already have been taking place for other reasons. On the other hand, even small damages, such as just cosmetic damages, may be very significant for both monetary and non-monetary values, when dealing with architectural heritage.

Long-term vibrations are usually associated with traffic in urban roads. Some relevant studies reported the impact of traffic vibrations on monumental buildings in Rome, in which long-term vibrations have been clearly associated with damages (Clemente and Rinaldis [10]), and disclosing of damages in the long run and eventually correlating damages to low-intensity steady vibrations have been indicated (Pau and Vestroni [11]).

Moreover, the frequent transit of heavy vehicles, trains and trams very close to a structure may induce vibrations largely exceeding the intensity of those caused by normal traffic and therefore may be responsible for damages beyond cosmetic level and also involving secondary or main structural components. Careful monitoring of such phenomena is very important for the protection of architectural heritage buildings.

While numerous studies have been made on the vibration caused by railways (Kouroussis et al. [12]), very little research has been carried out on similar problems caused by trams. The two transport systems are conceptually similar, but there are significant differences in terms of infrastructure (tramways are mostly located along roadways shared with other traffic), vehicles (different mass and length of the vehicles) and speed (the speed of trams is normally much lower), as highlighted by Pronello [13]. In Refs. [14–18] some authors reported that vehicle dynamics influence the low-frequency range (up to about 15 Hz, but the upper limit of this low-frequency range is not well defined and depends on the main vehicle dynamic modes). In the frequency range from this limit up to about 100 Hz the ground vibration spectrum is characterized by the track and soil flexibility, with possible soil resonance.

The impact of light transit vehicles, like trams or metros, is very important due to the close distance between the track and the buildings. Such vehicles are characterized by a low speed and a relatively high density of singular rail surface defects, like rail joints, rail crossings or even simple necessities like switching gears. Recent studies [19, 20], which focused on the T2000 tram circulating in Brussels, after receiving a large number of complaints about vibrations, analysed the effects of tram vehicle characteristics and the quality of rail surface on ground vibrations.

3 VIBRATION STANDARDS

The relevance of population disturbance and potential impact on the structural health caused by vibrations in urban areas led to the development of several standards in different countries to set limits to the vibration intensities recorded at significant reception points in buildings. Current standards give indications on the methods that must be used for the measurement procedure, including the proper choice of type and location of the instrumentation, as well as the measurement data processing and analysis. In most standards, the key parameter considered for assessing the intensity of vibration is the peak particle velocity (PPV), that is the maximum value of vector velocity recorded in triaxial acquisitions. Alternatively, other standards consider the peak component particle velocity (PCPV), which is simply the maximum value of velocity recorded in each triaxial direction.

Vibration limits are stated for various ranges of the dominant excitation frequencies and different building types, having different structural characteristics, among which historic structures are usually the ones with the lowest limits.

An international widely accepted standard for the measuring of vibrations in buildings is the ISO 4866 standard [21]. National standards generally comply with ISO 4866 in terms of procedures. Nonetheless, national limits of acceptability may differ substantially, especially the ones concerning ancient buildings, as the structural characteristics of this kind of buildings are very different from one country to another. Some standards are based on experimental campaigns performed on typical buildings, while some others refer to limits stated in other countries. For example, the recently revised Italian UNI 9916 [22] includes as reference several foreign standards. Among them, the German DIN 4150 and the Swiss SN 640312 (a) state specific limits for historic buildings [23, 24].

The DIN 4150 proposes different limits for short-duration and for long-term vibrations in terms of PCPV and is considered to be conservative also for the typical historical buildings existing in Italy. The short-duration vibrations are defined as the vibrations that do not cause fatigue and resonance phenomena in the structure. On the opposite, if these phenomena cannot be excluded, then long-term limits must be considered. Consequently, such distinction depends on the structural characteristics of the studied building.

Similarly, the SN 640312 (a) proposes PPV limits with different frequency ranges and with a distinction in occasional, frequent and permanent vibrations. In case of historic buildings the Swiss standard suggests that PPV limits are halved.

Many other international standards and recommendations exist, most of which indicate different limits for short-term and long-term vibrations, although they are variously defined (see [25–29]). In general, long-term limits, which are mostly related to urban traffic vibrations, are stricter, as they might generate fatigue and resonance problems in the structures in the long run. Ultimately, as a general indication, most of current international standards and recommendations suggest that long-term vibration intensity at historic buildings should be limited to PPV or PCPV values below 2–3 mm/s.

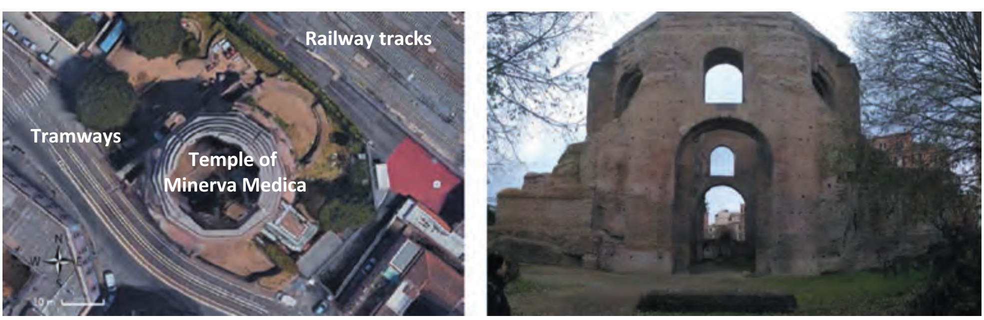
4 THE STUDIED STRUCTURE

The so-called Temple of Minerva Medica is an ancient ruined building in the city centre of Rome. Starting from the 16th century, it was erroneously thought to be a temple dedicated to Minerva Medica ('Minerva the Doctor') mentioned by Cicero and other sources, so that it is still today widely known through such appellation.

In fact, more recently, archaeologists believe it is what remains of an ancient nymphaeum (a building devoted to the nymphs and often connected to the water supply) of Imperial Rome (early 4th century AD), on the Esquiline Hill, between the Labicana and Aurelian Walls, probably part of the Horti Liciniani, but attribution is still discussed (Barbera et al. [30]). More precisely, it is located in modern Via Giolitti, where, in the early 20th century, urban tramways were built very close to the west side of the monument (Fig. 1a) and are still active today. Moreover, a few metres from the building to the north-east are several railway tracks of the nearby Termini train station. Railway tracks exist there since the mid-19th century, when the Rome–Frascati railway line, the oldest in Rome, was built by the Papal State (Panconesi [31]).

The structure is a majestic building with decagonal polylobate plan, a diameter of 25 m and an overall height originally of 32 m, currently reduced to only 24 m after the dome partial collapses during the centuries. The façade with the main entrance is on the north-west side (Fig. 1b).

The initial structure (built around 300 AD) was entirely made up of *opus latericium*, but soon presented structural problems and was restored and reinforced through works in *opus mixtum* of tuff bricks and Roman bricks (Fig. 2a and 2b). Lateral niches were closed and



(a) (b)

Figure 1: Aerial photograph of the temple of Minerva Medica (a). Façade on the north-west side of the monument (b).

(a) (b) (c)

Figure 2: Masonry of a wall (a) and a pillar (b) on the north side. A painting by Josephus Augustus Knip, 1809–1812, showing a view from south of the monument (c).

walls with the function of buttresses were built (Barbera et al. [30]). In fact, the current masonry results are quite heterogeneous in materials and shapes.

This is evidence of several changes of mind during the construction phases and of the various collapses and restoration works executed during the centuries. In particular, structural damages in the past concentrated on the south side (Fig. 2c), where a recent major restoration intervention was conducted in 2012–2013. In that occasion studies and surveys were carried out, highlighting that foundation properties on the south side were mainly responsible for the damages rather than structural weakness of the masonry in that part of the building (Barbera et al. [30]).

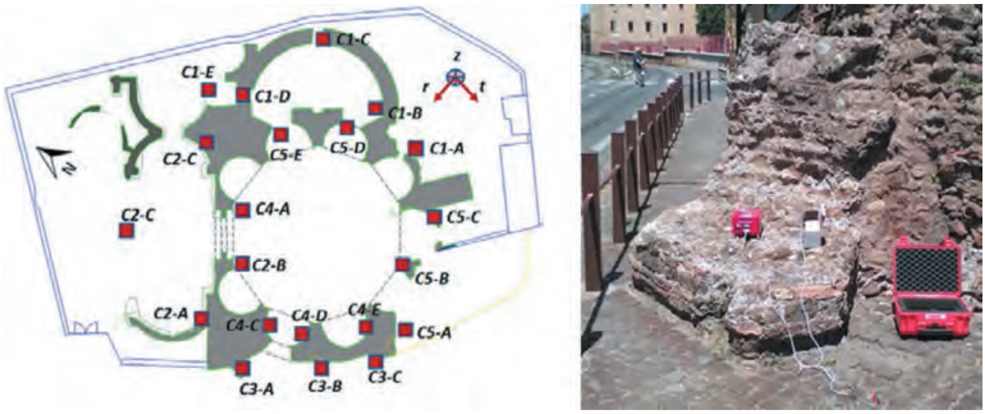
5 EXPERIMENTAL DATA ACQUISITION

The acquisition of several types of experimental data was scheduled starting from July 2016. All measurements were planned to be repeated during a period of one year in order to investigate the seasonal effects and/or the eventual changes in the structural response of the building. For such purpose also weather data were collected for correlation to experimental data. The experimental programme can be summarized as follows:

- Ambient vibration data.
- NDTs (thermal images, sonic tomography).
- Microclimatic monitoring (air temperature, humidity, air pressure, etc.).
- Surveys for detailed 3D reconstruction and crack pattern documentation (3D laser scanning and stereo-photogrammetric survey).

5.1 Ambient Vibration Data Acquisition

Ambient vibration data were acquired on 4 July. The measurements at the foundations (Fig. 3a and 3b) were intended to obtain indications on the points where base excitation due to the nearby traffic (road, trains and trams) is stronger. The data recorded on the façade helped assess the amplification to the structure and the dynamic behaviour of the building (Fig. 4). Vibration data were acquired by digital recorders equipped with triaxial velocimeters provided with a Global Positioning System antenna for time synchronization. The sensors were oriented so as to measure the radial (towards the centre of the decagonal hall), the



(a) (b)

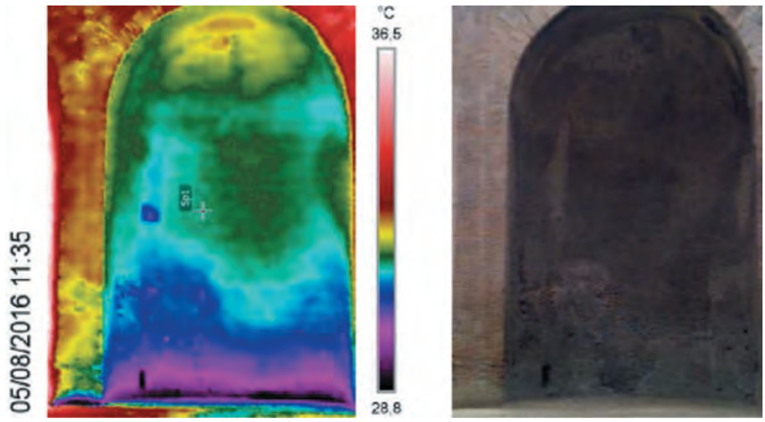
Figure 3: Measurement points at the monument foundations (a). Recorded components are *r* for radial (towards the centre of the hall), *t* for tangential and *z* for vertical. Ambient vibration acquisition at position C3-A on the west side (b).

Figure 4: Measurement points on the façade.

tangential and the vertical components, named *r*, *t* and *z*, respectively, in the following. Each position was acquired for at least 20 min at a sampling frequency of 200 Hz. During vibration acquisition, the time and type of vehicle passages were also noted.

5.2 Non-destructive Tests

Thermal images of the inner side of walls of the monument were captured on 5 August 2016 at 11 a.m. and on 20 December 2016 at 2 p.m. using a Flir T440 thermal infrared camera. Figure 5 shows a thermal image with the corresponding photograph of a portion of the south side acquired on 5th August.



(a) (b)

Figure 5: Thermal image of a portion of south inner side acquired on 5 August 2016 at 11:35 local time (a) and related photograph (b).

A sonic tomography survey was carried out on 2 February 2017. The base of each pillar of the monument was investigated with direct sonic measurements in order to detect the internal morphology of structural elements. This technique is especially useful for investigating heterogeneities in construction materials, such as historic masonry, allowing the identification of layering of the sections, the presence of voids, cavities and anomalies in material density. Equipment comprised an instrumented hammer with a PCB ICP accelerometer, as well as the probe, both cabled to the acquisition unit. Data were acquired with a sampling frequency of 500 kHz.

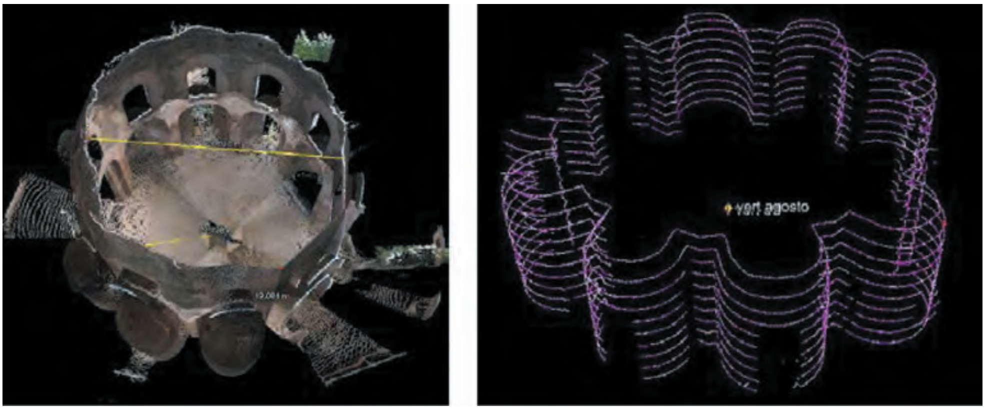
5.2 Microclimatic Parameters

Microclimatic parameters and data of local weather stations were collected for correlation to experimental ambient vibration and NDT data. In particular, air temperature and humidity were monitored by two MSR145 mini-data loggers positioned on the west side (near C4-C) and on the east side (near C5-D).

5.3 Three-Dimensional Reconstruction and Crack Pattern

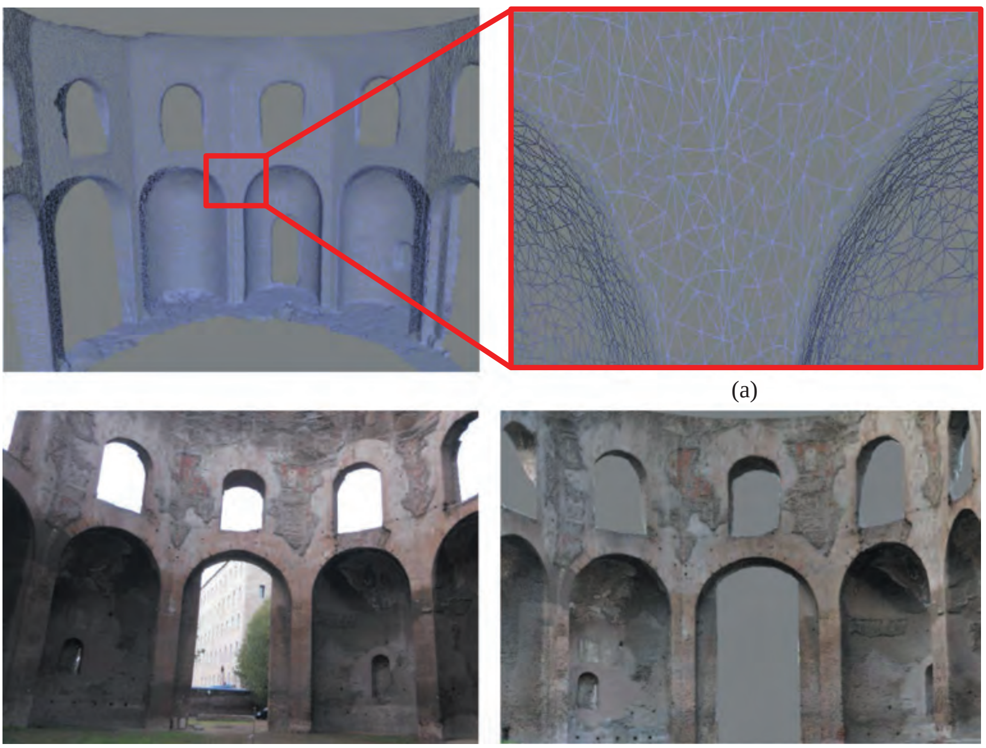
Two 3D laser scanning surveys were performed on 5 August 2016 and on 20 December 2016 using a Riegl Z360 equipped with a Nikon D100 digital camera. The instrument nominal angular resolution is 0.0025° horizontal and 0.002° vertical, while range accuracy can achieve +/− 6 mm. Retroreflecting targets fixed at each pillar at the height 2.5 m from the ground level were used as reference positions in order to compare the two obtained 3D reconstructions. Also a photogrammetric survey was carried out, comprising about 500 digital images (5 MB and 10 Mpx each), acquired by Nikon D60 camera.

The above acquired images were post-processed with Structure from Motion (SfM) methodology (Mongelli et al. [32]) by Agisoft PhotoScan software via ENEAGRID, available on Computational Research Center for Complex Systems High Performance Computing (HPC) infrastructure (Ponti [33]). A dense cloud of 30 million points was obtained and mesh returned more than 200,000 tria elements (Fig. 7). Stereo-photogrammetry by SfM is complementary



(a) (b)

Figure 6: Three-dimensional laser scanner reconstruction in August (a) and matching between August (white mesh) and December (purple mesh) reconstructions (b).



(a)

(b) (c)

Figure 7: Three-dimensional reconstruction by SfM technique: mesh with tria elements of west side and enlargement of the area in the red box (a); comparison between a 2D image (b) and related 3D texture (c) of south side.

to laser scanning, since it is less accurate in 3D geometry reconstruction but is able to provide detailed crack pattern documentation.

6 VIBRATION DATA ANALYSES

First, a visual analysis of velocity time-histories was carried out, trying to match vibrations with vehicle passages, according to their recorded time, in order to interpret what kind of source generated each recognizable vibration greater than instrumental noise. Traffic sources were classified as road, trains and trams. Each source was characterized in the frequency domain by simple fast Fourier transform.

Second, PPV and PCPV values were calculated. The highest values were considered as indication of the most critical points at the foundations.

Data acquired on the façade were also processed for structural dynamic identification of the building. A variety of experimental and operational modal analysis (OMA) techniques were considered, in order to have mutual validation of results and obtain more solid values of modal parameters. In particular, the frequency response function (FRF) was calculated using the transmissibility function H (De Silva [34]) between foundation wall (D) and windows (B and C), as well as between foundation wall and top (A) of the façade. Among the various OMA techniques the frequency domain decomposition (FDD), the enhanced frequency domain decomposition (EFDD) and the Crystal Clear Subspace Stochastic Identification algorithms were applied (De Canio et al. [35]). Finally, also the horizontal vertical spectral ratios (HVSR) were calculated at windows and on top of the façade, providing a further empirical estimate of fundamental frequencies of the building (Gallipoli et al. [36]).

7 PRELIMINARY RESULTS

The acquired velocity time-histories revealed the different properties of the vibrations generated by each type of traffic source (Fig. 8). Common road traffic originated vibrations with PCPV lower than 0.2 mm/s in all acquisitions. Recorded train passages gave higher vibration

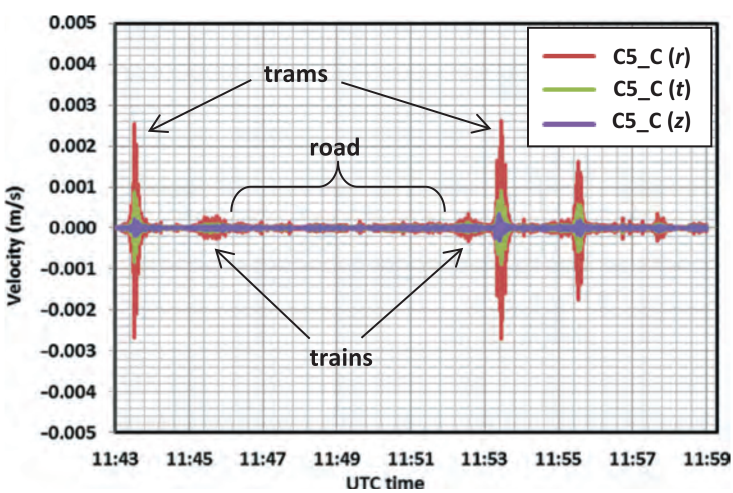


Figure 8: Recorded velocity time-history at position C5-C. The passages of the various traffic sources are indicated (road, trams and trains).

levels, but PCPV was never greater than 0.4 mm/s. Train and tram passages produced similar values of peak velocity on the north-east side, near the railway tracks. In all other positions, tram passages induced the strongest vibrations. In particular, the highest PCPV values were recorded in C5-C and C3-A (2.7 and 2.2 mm/s, respectively) and in several other positions PCPV was higher than 1 mm/s.

Tram and train passages were also characterized in terms of duration and fundamental frequencies. Typical duration of tram passages resulted around 15–20 s, while train passages were generally remarkably longer (40–50 s). As shown in Figure 9, the fundamental frequencies of vibrations induced by trams and trains resulted quite similarly (35 and 37 Hz, respectively, at the most critical position C5-C).

The results in terms of modal frequencies obtained with the several considered modal analysis techniques are illustrated in Table 1. The identified modal frequencies are very similar using all the applied techniques, giving evidence of the consistency and affordability of the results (mutual validation).

The first five modal frequencies resulted within 5 Hz that are much lower than the fundamental frequencies of traffic vibrations. As confirmed by the vibrations recorded at the windows and on top of the façade, which do not show any relevant amplification effect, resonance phenomena are very limited.

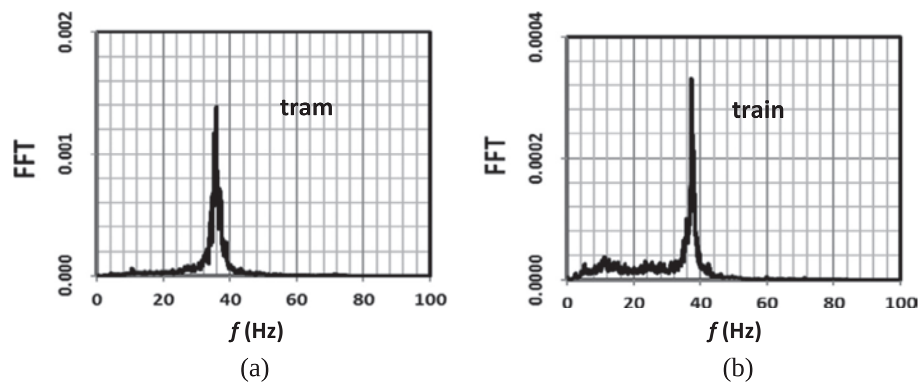


Figure 9: Fast Fourier transform (FFT) of recorded vibration velocity originated by the passage of a tram (a) and a train (b) at position C5-C.

Table 1: Modal frequencies calculated with each used modal analysis technique.

Mode	Modal frequencies (Hz)						
	FRF (r)	FRF (t)	HVSR (r)	HVSR (t)	FDD	EFDD	CC-SSI
1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
2	2.8	—	2.5	—	2.5	2.5	2.5
3	—	2.9	—	2.8	2.8	2.8	2.8
4	—	3.8	—	3.6	3.6	3.6	3.6
5	4.1	—	4.2	—	4.2	4.1	4.1

In August, wall temperatures varied from 28 to 43°C, with maximum values on the upper south-west side. In December, temperatures distribution was much more uniform (from 8 to 11°C). A preliminary estimation of the thermal effect on the monument was calculated considering a coefficient of thermal expansion of 5×10^{-6}°C^{-1}. As an example, the width of the building main entrance at the façade was estimated to increase of about 1 cm in December. This estimation was compared with results from 3D laser scanner data, which gave a measured width increase of 11 mm in December (estimated precision of 0.4 mm), which is very similar to the estimated effect of thermal expansion.

8 CONCLUSIONS

In this article, the preliminary results of a study about the impact of traffic vibrations on the so-called temple of Minerva Medica are described. The relevance of the various traffic vibration sources was assessed. While the road traffic seemed not to represent a dangerous source of vibrations, the vibrations induced by the tram passages in Via Giolitti produced remarkable PCPV values in some points of the foundations, especially on the south and the west sides of the monument. Consequently, as a preliminary indication, the south side, where the monument suffered serious structural problems during his history, and the west side, which is the closest to the tramway tracks, result in the most critical points.

Through the mutual validation of the numerous applied modal analyses, although calculated with very few measurement points, very solid indications of the fundamental frequencies of the building were obtained. Such indications will be used for the calibration of numerical models that will be produced from the acquired 3D reconstruction and NDT data.

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NON-DESTRUCTIVE EVALUATION OF A DIESTE'S HISTORICAL REINFORCED BRICK MASONRY CHURCH

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ABSTRACT

The concept and use of reinforced brick masonry (RBM) has a long history. Engineer Eladio Dieste was one of the most renowned innovators in the RBM field. One of Dieste's outstanding RBM buildings is Church of Christ the Worker (1958–1960) in Atlántida, Uruguay. Even though the structure has been maintained by the local community, it has begun to show signs of aging. In August 2016 the church was selected by *Keeping It Modern*, an international grant program developed by the *Getty Foundation* with focus on the conservation of important buildings. This article presents the inspection of Dieste's church, by means of visual inspection and non-destructive evaluation (NDE), performed under this program. Several NDE techniques – infrared thermography, ground penetrating radar, penetration resistance and ultrasonic testing – were applied to assess the state of conservation of the structure. The visual inspection and NDE yielded results associated with various symptoms of initiated deterioration mechanisms: presence of moisture, corrosion of some steel bars and degradation of mortars. Despite these pathologies that are commonly present in aged RBM structures, the church is in a good state of preservation. This fact reveals the impressive care with which it was designed and built.

Keywords: Eladio Dieste, evaluation, historical structure, NDE, reinforced brick masonry

1 INTRODUCTION

Masonry is bonded to the beginning of architecture and civil engineering, since it represents the first structural system used by humanity. For thousands of years, plain masonry allowed the construction not only of homes but also of works of impressive beauty and grandeur [1]. Nevertheless, the potential of this constructive system is limited by its low tensile strength, which makes it inadequate for structural elements such as beams, slabs and columns subjected to eccentric loads. To overcome this shortcoming, plain masonry is strengthened with reinforcing materials such as steel bars, giving rise to reinforced masonry [2].

Owing to its composite nature, reinforced brick masonry (RBM) has allowed to shape many buildings in which traditional non-reinforced masonry was not an option. The principles behind RBM are the same as those commonly accepted for reinforced concrete: steel reinforcement significantly increases tensile and shear strength as well as the ductility of the brick masonry, broadening the possibilities of its application in civil engineering [1].

One of the most renowned innovators of the RBM field was engineer Eladio Dieste [3, 4]. During his active years, he designed and built more than 200 structures, pushing the composite material to the limit [5]. Some of his innovations were the invention and construction of different types of vaults – many having breathtakingly optimized geometries – e.g. the 'Gaussian' double-curvature vaults [6, 7]; the reinforcement of masonry by fine wire meshes arranged in its joints [4]; and the development of various techniques for prestressing an RBM structure with remarkable simplicity [8]. The value of his work is extraordinary from both a structural engineering and architectural standpoint. For these reasons, his works have become an emblematic artistic and cultural legacy of Uruguay [3, 4].

Dieste's first architectural work, Church of Christ the Worker, is a fundamental piece of that legacy. Built between 1958 and 1960 in Atlántida, Uruguay, the church was conceived

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in response to the modest commission of an entrepreneur, who would donate the work to the local community. Dieste took the challenge and was able to shape an extraordinary RBM structure, which seats 300 people, spending similar budget as the common industrial sheds [9]. This was made possible by optimizing the structural design and construction process.

A schematic plan of the church is shown in Figure 1. At floor level, its plan is a simple rectangle of 16 × 33 m [9], from which double wythe brick undulating walls, of 7 m high and 30 cm width [4], rise to the maximum amplitude of their arcs. These self-stabilizing walls carry continuous double-curvature vaults, of 11 cm total width [9], with tie rods concealed in the valleys that are anchored in the brick edge beams [10]. The floor-level space contains the confessionals, nave, chancel, chapel, sacristy and anti-sacristy. The baptistery is located underground, while the bell tower stands near the west *façade*.

Even though the structure has been maintained by the local community, it has begun to show signs of ageing. In August 2016 the church was selected by *Keeping It Modern*, an international grant initiative programme developed by the *Getty Foundation*. This programme annually supports around ten projects of outstanding significance that promise to advance conservation practices on important buildings of the 20th century [11]. Within this framework, a working group was established with the objective of creating a conservation plan and an administration system of Dieste's church. One of the subgroups of the working group is responsible for the detection of pathologies and damage of the structure.

The objective of this article is to present the methodology and results of the inspection of the church, performed by means of visual inspection and non-destructive evaluation (NDE). NDE results improve knowledge of the structure's condition and allow making better decisions regarding the application of forthcoming maintenance tasks.

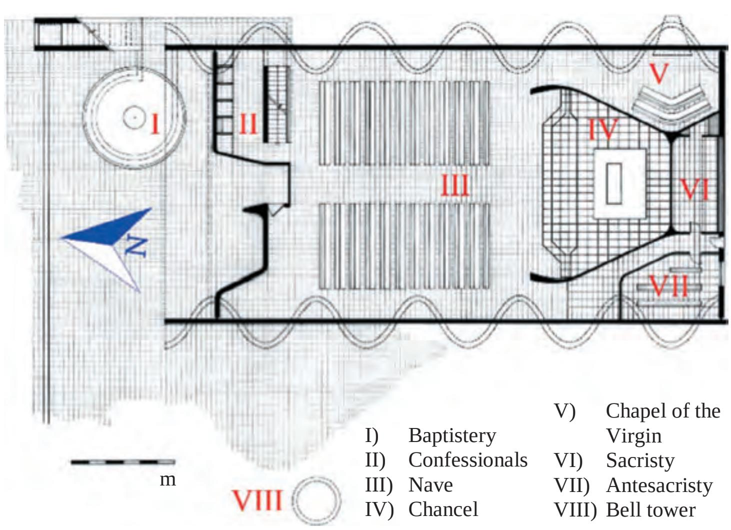

Figure 1: Original plan of Church of Christ the Worker.

2 METHODOLOGY

The methodology followed to assess the state of conservation of the structure can be divided into two stages: visual inspection and NDE. The latter was carried out by means of four different NDE techniques: infrared thermography, ground penetrating radar (GPR), penetration resistance and ultrasonic testing.

2.1 Visual Inspection

Visual inspection is the most important non-destructive technique [12]. It involves performing critical observation of the structure's surfaces. In this investigation visual inspection, complemented with digital photography, was carried out at every sector of the building prior to any other NDE technique in order to identify potential deterioration patterns. Once visual inspection was completed, the rest of the non-destructive testing techniques were planned accordingly to the preliminary findings for further interrogation.

Although most of the structure was studied non-destructively, certain locations in the roof were inspected by removing the top materials. This was necessary to expose the principal steel reinforcement and allow direct visual inspection.

2.2 Non-destructive Testing Techniques

2.2.1 Infrared Thermography

The equipment used in this case was an infrared camera – FLIR E6 – with a thermal image resolution of 120 × 160 pixels. This camera, shown in Figure 2a, uses an uncooled

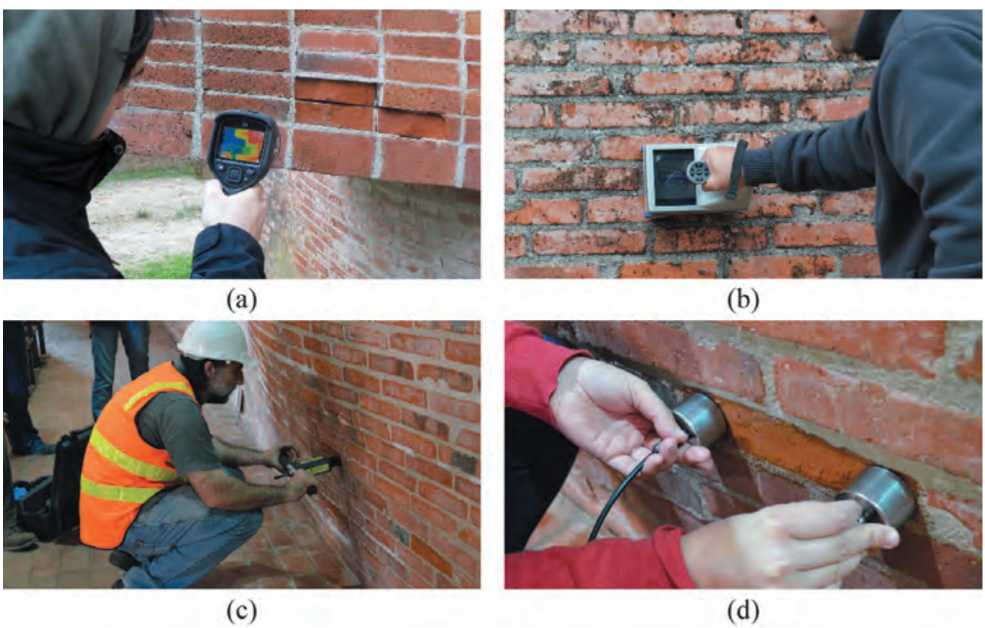

Figure 2: NDE techniques used in field research: (a) infrared thermography; (b) GPR; (c) penetration resistance and (d) ultrasonic testing.

microbolometer and is capable of showing a real-time image – with a frame rate of 9 Hz. Two halogen lamps of 300 W were used in order to make a few tests using an active approach.

Infrared thermography is a relatively low-cost, non-contact, non-intrusive, NDE technique which reveals the surface temperature of an object through the reception of the – non-harmful – infrared radiation that this object emits [13]. The camera sensor detects the total radiation and, using certain parameters that need to be entered by the operator, shows the surface temperature. Thermal radiation can be quantified using the Stefan–Boltzmann equation [14], as presented in eqn (1), where *E* is the radiation, *e* the emissivity, *T* the temperature and σ the Stefan–Boltzmann constant –5.67 $\cdot 10^{-8}$ W/(m^2 K^4):

$$E = e \cdot \sigma \cdot T^4 \cdot \tag{1}$$

There are two approaches for obtaining results using this method. First, it is possible to use a passive approach, which consists in observing the structure with no exterior or artificial excitation whatsoever. By applying this approach several differences between zones may be noticed: dissimilar materials with different emissivity show differences in apparent temperature – even if their real temperatures are equal – zones with dissimilar damage show differences compared with undamaged areas, zones with reparations previously executed or with presence of moisture also show differences compared with unaltered zones [15]. In contrast, the active approach consists in using an external energy source.

A first inspection was carried out using the passive approach. The infrared camera was used to obtain images of both the interior and exterior surfaces of the church's walls and roof, and of the baptistery – which was difficult due to the lack of proper illumination. A second inspection was performed looking for certain defects, based on the primary results of the other methods. With respect to the active test, halogen lamps were used to heat the surface and detect the damage extension in brick delamination – zones with different depths show a difference in the temperature after a time. The general method was to heat up an area and monitor the surface temperature from a fixed point of view.

2.2.2 Ground Penetrating Radar

A GPR, brand GSSI, model StructureScan Mini was used. This equipment, which is shown in Figure 2b, emits and receives electromagnetic (EM) waves with a nominal frequency of 1.6 GHz and a maximum penetration depth of about 50 cm.

GPR has been used for many years and the principles behind the technique are well documented. The GPR method uses a transmitting antenna that emits EM pulses to the object being analysed. In a simplified way, part of the pulse is reflected back when it encounters an interface with a material with different electric properties [16, 17]. A receiving antenna detects the reflected EM pulse and the time history signal is recorded. Equation (2) – in which v is the velocity, c is the velocity of propagation of light in vacuum and ε the dielectric constant of the analysed material - represents a simplification of the phenomenon [18] and can be used for high frequencies. In this case, all frequency components travel at the same velocity and suffer the same attenuation [15]. An impulsive signal will travel with its shape intact, which is propagation without dispersion [19]:

$$v = \frac{c}{\sqrt{\varepsilon}}. \tag{2}$$

Moisture content affects the physical properties of dielectric porous materials and makes their dielectric constant change. The effect on the dielectric constant of ceramic bricks walls by varying their moisture content has been studied previously, where a linear correlation between $\sqrt{\varepsilon}$ and the moisture content (ω) was obtained [15, 17]. In practice, this relationship results in a variation of the arrival time of the EM pulse reflected on the opposite surface of the wall being evaluated when varying the ω, as presented in Figure 3.

Knowing that the thickness of Dieste's church walls is constant, the relationship between $\sqrt{\varepsilon}$ and ω presented was used to determine variations in the moisture content of the walls. The NDE technique was carried out along the east and west *façades* of the church at multiple heights and along the perimeter of the retaining walls of the baptistery. Unfortunately, it could not be performed over the roof, since the EM pulse is totally reflected on a fine wire mesh arranged between the GPR equipment and opposite surface of the wall assessed.

2.2.3 Penetration Resistance

The non-destructive – formally semi-destructive – penetration resistance testing technique was carried out by means of a Windsor Pin Test System equipment, developed by James Instruments. A photograph of the equipment is shown in Figure 2c.

This technique is used to evaluate construction materials by penetration resistance tests. A spring drives a steel pin into the surface of the material and its depth of penetration is used as a parameter to characterize the material, since penetration depth is inversely correlated with compressive strength [20, 21]. Penetration resistance is employed in situ as an indirect method to detect areas with variations of the compressive strength of the material. The method is standardized in Ref. [22] to test hardened concrete and can be applied to masonry evaluation with minor modifications [12].

Windsor Pin was applied on both the bricks and mortars of the east and west *façades* of the church and of the perimeter of the baptistery's retaining walls. In all cases, a statistically significant number of tests were performed in order to obtain reliable results.

2.2.4 Ultrasonic Testing

This investigation used a Pundit Lab – brand Proceq – ultrasonic pulse velocity (UPV) test instrument set with two 54 kHz piezoelectric transducers, as presented in Figure 2d.

UPV test consists in generating and receiving wave (P-wave) pulses that travel through a solid material under inspection. Pulses are sent and detected using a pair of piezoelectric

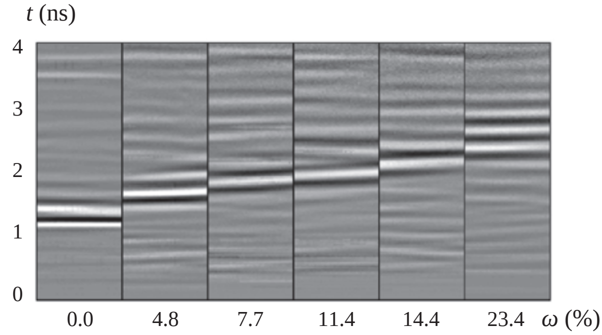

Figure 3: Effect on the travel time (t) of the EM pulse of ceramic brick walls by varying their moisture content (ω), due to the change of $\sqrt{\varepsilon}$ [15, 17].

transducers located at known positions; thus, the distance between them is known. The system allows computing the pulse propagation time. Therefore, the pulses' velocity v_P is estimated using eqn (3), where Δx and Δt correspond to the distance between transducers and propagation time, respectively [23]:

$$v_P = \frac{\Delta x}{\Delta t}. \tag{3}$$

UPV has a positive correlation with the material's elastic modulus and compressive strength and, therefore, is an indicative parameter of the material's quality [16]. Low UPV results could indicate the presence of voids, layer detachment, foreign inclusions, disaggregated material, between others, whereas high UPV results indicate good contact between material layers, and high-quality material with good mechanical properties [12]. Reference [24] presents the potentials of this technique for the characterization of local heritage masonry structures.

3 RESULTS

3.1 Visual Inspection

Overall, as Figure 4 in part shows, Dieste's church is in very good condition. Only particular moderate pathologies were identified at specific locations; these are explained as follows.

Several signs of corrosion with exposed rebar and mortar detachment were observed throughout the building, at the interior and exterior of the church and, particularly, at the baptistery and bell tower. In the case of the church building, these corresponded to secondary horizontal reinforcement along the walls, as Figure 5a shows. Signs of corrosion were also observed at the ceiling, mainly in the valleys. The destructive inspections in the roof exposed the principal steel tie rods in perfect condition without signs of corrosion, as Figure 5b shows. Signs of severe corrosion, with mortar and brick detachment, and mortar patching, indicating previous repairing efforts, were observed in the baptistery's ceiling.

Figure 4: Picture of front *façade* of Church of Christ the Worker.

(a) (b)

Figure 5: (a) Corrosion with exposed rebar and mortar detachment in the church building and (b) actual state of tie rods in the roof's valleys.

The walls and ceiling of the baptistery had presence of moisture. As Figure 6a shows, ponding had occurred at some parts of the baptistery's floor. In other parts of the structure, particularly the valleys of the church's roof, presence of moisture was also visually detected, although to a lesser extent than in the baptistery. Finally, partial degradation of mortars was detected in several zones, especially in those exposed to rain. Figure 6b shows the biological colonization and deterioration of mortars by phototropic organisms.

3.2 Non-destructive Testing Techniques

3.2.1 Infrared Thermography

Both passive and active infrared thermography approaches were useful to detect areas with differences in moisture content and some symptoms of damage in the church's walls.

With respect to the passive approach, a general inspection was performed looking for differences in temperature patterns. The colder areas were further investigated and compared with other parts of the structure. On the one hand, as Figure 7 shows, general presence of moisture was primarily detected in the valleys of the church's ceiling; this was confirmed later in a closer inspection. General presence of moisture was also detected in the baptistery, particularly close to the foundation of the retaining walls. These two results match with those obtained from the visual inspection. The presence of moisture in the exterior walls of the

(a) (b)

Figure 6: (a) Ponding at some parts of the baptistery's floor and (b) biological colonization and deterioration of mortars by phototropic organisms.

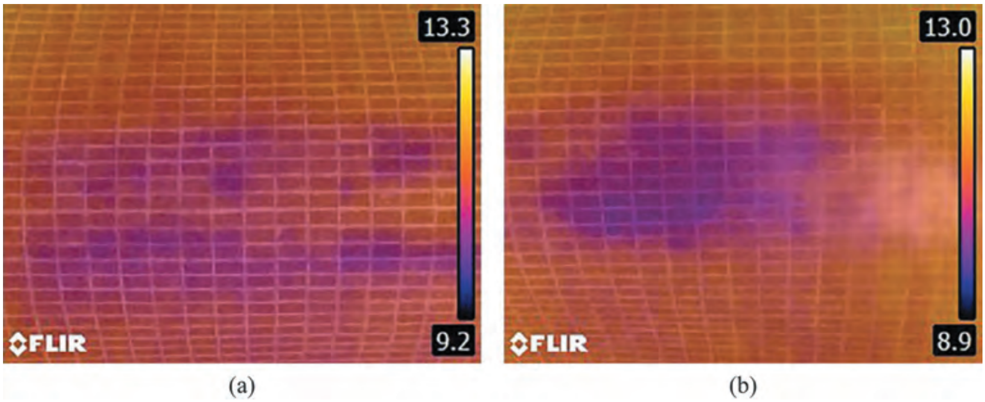

Figure 7: Presence of moisture in the valleys of the church's ceiling.

church could not be assessed because, given that these walls are curved, there were zones with different exposition to rain and wind. On the other hand, some symptoms of damage were detected in the church's ceiling; e.g. figure 8a shows some loose ceramic titles.

Active infrared thermography was carried out on the roof and on the internal surface of the church's walls. This approach was not able to show any new results different from those obtained with the passive approach. Regarding the second location, this technique was used to look for the extension of the damage in the church's walls. With this procedure it was possible to determine the extension of the damaged zone, as Figure 8b shows.

3.2.2 Ground Penetrating Radar

GPR was applied to detect moisture content in the east and west *façades* of the church at multiple heights and in the perimeter of the retaining walls of the baptistery. This technique was useful, in the first case, to detect variations in the moisture content, and in the second case, to confirm the results obtained with the visual inspection and infrared thermography, i.e. severe presence of moisture, particularly close to the foundation of the retaining walls.

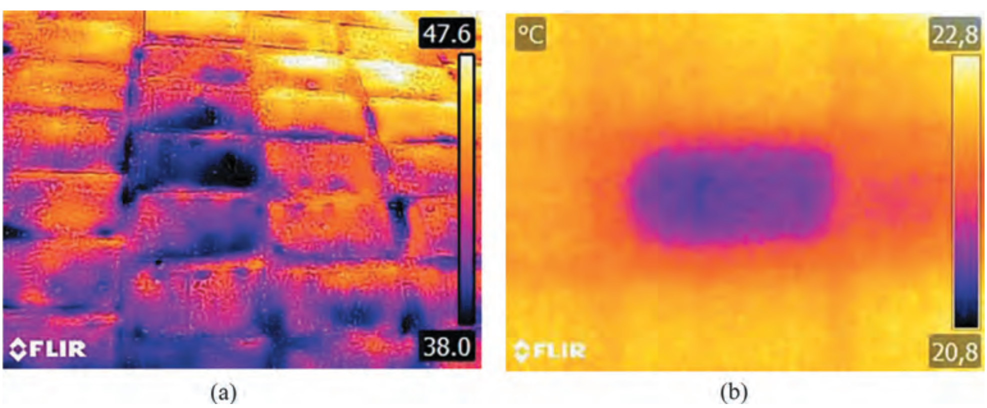

Figure 8: Symptoms of damage in the ceiling and walls of Dieste's church. Thermal images showing (a) an area with some loose ceramic tiles and (b) a loose ceramic brick after two hours of exposure to two halogen lamps.

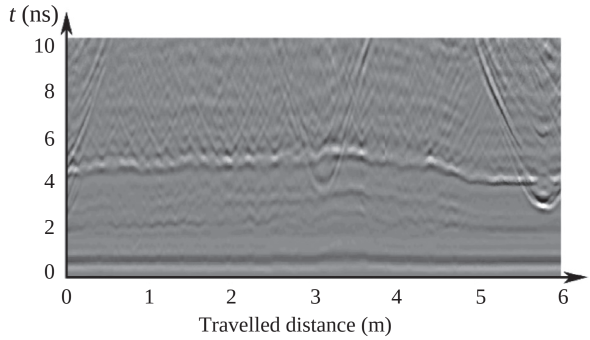

Figure 9: Horizontal GPR profile of a part of church's curved walls.

Figure 9 shows a horizontal GPR profile of the part of Dieste's church curved walls. It can be seen that, in the scanned zone, the EM pulse arrival time changes while the travelled distance varies. More precisely, the arrival time is greater in the centre of the profile – where the inclined geometry of the walls and the edge beam do not provide rain protection to the walls – than in the beginning and end of it – where the walls are indeed protected to rain. Given that these measurements were taken one day after a heavy rain event, it is reasonable to think that differences in arrival times are due to variations in moisture content.

References [15, 17] were used to estimate these variations of moisture content in the walls. For handmade type of bricks, eqn (4) is retained:

$$\sqrt{\varepsilon} = a \cdot \omega + b = 9.6703 \cdot \omega + 1.6727. \tag{4}$$

The relationship between the variation of moisture content ($\Delta\omega$) and the variation of the EM pulse arrival time (Δt) is presented in eqn (5) and was founded from eqns (2) and (4) – where d = 0.48 m is twice the thickness of the wall without having into account the air chamber:

$$\Delta\omega = \frac{c}{a \cdot d} \cdot \Delta t = 6.5 \times 10^{7}\ \text{s} \cdot \Delta t. \tag{5}$$

This relationship was applied to quantify the variation of moisture content along the church's walls. Figure 10 presents $\Delta\omega$ as a function of the travelled distance for the GPR profile shown in Figure 9. In Figure 10, the blue zone corresponds to a ridge while the red

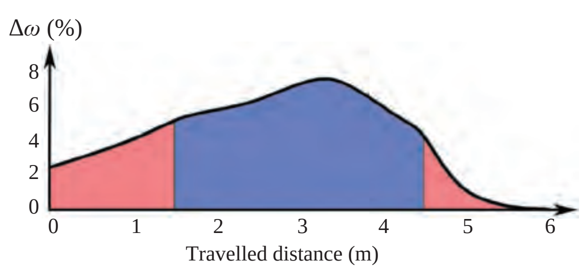

Figure 10: Variation of moisture content (Δt) as a function of the travelled distance.

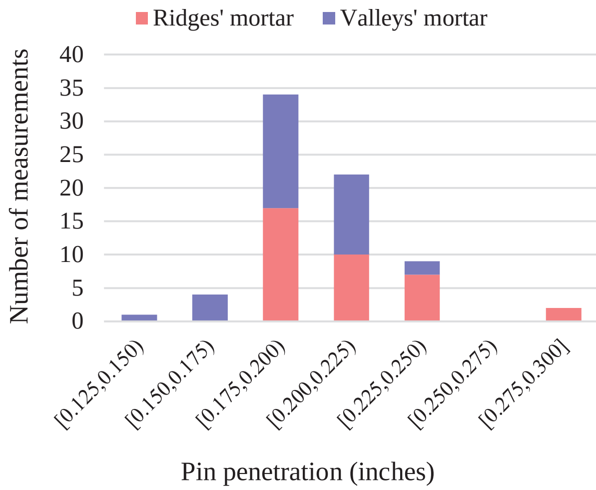

Figure 11: Penetration resistance results on the mortar of church's exterior walls.

one corresponds to two consecutive half-valleys. The average difference in moisture content between the valleys and ridges of the walls was approximately equal to 4%.

3.2.3 Penetration Resistance

This NDE technique was applied on both the bricks and mortars of different parts of the structure. Figure 11 presents the results on the mortar of church's exterior walls. In this case, Windsor pin was used in three inspection points per valley and three inspection points per ridge, giving a total of 36 points per *façade* – west and east.

Figure 11 shows that the ridges' mortar tended to yield higher penetration results – values towards the right in Figure 11 – valleys' mortar. A more detailed analysis indicates that the average pin penetration on ridges' mortar is 0.208 inches while on valleys' mortar is 0.194 inches. A two-sample *t*-test assuming equal variances reveals that the *t*-value is equal to 2.42, which implies that the means of the two groups can be assumed as statistically independent from each other [25]. In addition to the comparative analysis, the penetration resistance values represent a good way of estimating of the mortar compressive strength, since these two quantities are inversely correlated between them [20, 21]. This data will improve the developing of a numerical model of the structure, which will be performed by another subgroup of the project working group.

Table 1 presents the penetration resistance results of healthy and damaged bricks of the church's interior and baptistery. Although penetration resistance is not usually applied on bricks [12], the results show that there is a difference between healthy and damaged bricks. The average pin penetration on healthy bricks is 0.159 inches while on damaged bricks is 0.199 inches. When making a two-sample *t*-test assuming equal variances, the *t*-value results equal to 3.23, which means that the means of the two groups can be assumed as statistically independent from each other [25]. This means that this NDE technique may be useful to detect some symptoms of damage in ceramic bricks.

Table 1: Penetration resistance results on different bricks of the structure.

Inspection point	Pin penetration (inches)			
	Healthy bricks		Damaged bricks	
	Church's interior	Baptistery	Church's interior	Baptistery
1	0.148	0.203	0.167	0.219
2	0.139	0.178	0.200	0.223
3	0.142	0.197	0.160	0.175

3.2.4 Ultrasonic Testing

Ultrasonic testing technique was not useful to detect significant differences between healthy and damaged bricks. Although the mean results of UPV were slightly different between them – 1,637 and 1,436 m/s, respectively – the variances are not high enough to state that the two samples are statistically different from each other [25]. This was concluded by doing a two-sample *t*-test assuming equal variances. This result is in agreement with Ref. [24], where measured the amplitude of the first peak of the P-waves to characterize damaged joints since UPV presented very large variations. Moreover, the UPV values were, in certain cases, highly affected by the moisture content of the bricks.

Even though they are not suitable for the detection of pathologies and damage, the UPV results are an excellent database to estimate the dynamic modulus of elasticity of the materials – bricks and mortars – of the structure [16]. The dynamic modulus of elasticity represents a good way of estimating the static modulus of elasticity [12, 16], and therefore, provides a very important input for the numerical modelling of the structure.

4 CONCLUSIONS

Church of Christ the Worker constitutes an important piece of the Uruguayan heritage, hence the need to preserve it. *Keeping It Modern* program has offered the possibility of evaluating the current state of the structure with the objective of creating a conservation plan and an administration system of the church.

The visual inspection campaign showed that the overall building's integrity is in very good condition. Only particular pathologies were identified at specific locations. These were the presence of moisture in some parts of the church, mainly in the baptistery and to a lesser extent on the roof's valleys; corrosion of steel reinforcement rebars, in many cases being exposed due to mortar detachment; and some deterioration of mortars.

The conjunction of the four NDE techniques used yielded results associated with various symptoms of initiated deterioration mechanisms, such as presence of moisture, degradation of mortars and damage of bricks. The following results are retained:

1. Infrared thermography was useful to detect the presence of moisture in both the baptistery and the valleys of the church's ceiling. These two results match with those obtained from the visual inspection.
2. GPR, in turn, was valuable to detect the presence of moisture in the valleys of the church's walls. Moreover, the applied procedure allows the estimation of the moisture content.
3. The visual inspection and both the infrared thermography and GPR are conveniently complementary. Their application allows a fast and precise assessment of the moisture content with a minimal intervention of the structure.

4. Penetration resistance technique provided good results regarding the evaluation of mortar deterioration. Symptoms of damaged bricks could be assessed with the infrared thermography and penetration resistance techniques.
5. Both penetration resistance and ultrasonic testing will improve the elastic properties knowledge, which will be an input for the numerical model of the structure.

Non-destructive testing techniques applied to the church were able to provide qualitative and quantitative information regarding the building's health condition. This information will be a very useful source for forthcoming maintenance plans in order to succeed in preserving the church's condition in the most efficient way.

Despite the presence of moisture, the corrosion of some steel bars and the degradation of mortars that are commonly present in aged RBM structures, the church is in a good state of preservation. This fact reveals the impressive care with which it was designed and built.

ACKNOWLEDGEMENTS

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MATERIAL PROPERTIES OF HERITAGE WROUGHT STEEL STRUCTURE BASED ON TESTS

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ABSTRACT

Many heritage structures do not fulfil requirements of present standards. Decisions about adequate construction interventions should be based on complex assessment of structural reliability. Such an assessment should take into account new utility plans, actual material properties and environmental influences, including degradation processes, satisfactory past performance and advanced modelling reflecting properties of historic materials that are often distinctly different from those assumed for current construction materials.

The submitted contribution focuses on reliability assessment of balcony girders of the Estates Theatre in Prague, listed as a Czech national heritage monument. Preliminary reliability assessment, based on conservative recommendations of standards for existing structures, reveals that the resistance of the wrought steel girders from the 19th century is insufficient. This is why a series of non-destructive tests supplemented by a single tensile test are performed in order to obtain information about the homogeneity of the historic material, its strength and modulus of elasticity. The results of the tests are then evaluated using statistical methods. The design values of basic variables are estimated, considering uncertainties in material properties, geometry and resistance models. In addition, chemical analysis is performed to identify material composition and verify a type of historic steel.

Keywords: Brinell hardness test, heritage structures, homogeneity; material properties, reliability assessment, statistical approach, wrought steel

1 INTRODUCTION

Load-bearing structures of numerous heritage buildings are made of historic metallic materials. Particularly in the 19th and early 20th centuries, wrought steel and cast iron became popular construction materials [1]. It has been recognized that such structures often fail to fulfil requirements of present codes of practice [2, 3]. Decisions about adequate construction interventions should be based on the complex assessment of a structure considering actual material properties, environmental influences and satisfactory past performance [4]. A key step of this assessment is modelling of resistance of load-bearing members [5].

The submitted contribution is focused on reliability assessment of the balcony girders of the Estates Theatre in Prague under rehabilitation, one of the oldest European theatres, listed as a Czech national heritage monument (Fig. 1). The girders were fabricated in the 19th century; a type of the metallic material is unknown.

Preliminary reliability assessment, based on conservative recommendations of current standards for existing structures, reveals that resistance of the steel girders is insufficient. Reliability analysis of heritage structures have to treat numerous uncertainties related to lack of information about material properties, construction procedures, structural system behaviour, and so on. Focusing on the first aspect, a number of destructive tests (DTs) that are needed to gain credible information on material properties is mostly limited by the requirements on cultural heritage value protection. This is why a few DTs only are commonly supplemented with a series of non-destructive tests (NDTs).

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Figure 1: A view of the balcony of the Estates Theatre in Prague.

The information given in Annex D of EN 1990 [6] provides a first insight into specification of a minimum number of tests. When coefficient of variation of the material property under consideration, V_X, or its conservative estimate is known, a characteristic value of the material property, X_k, can be assessed from one test result only. In case of unknown V_X, no prior knowledge is available and at least three tests are needed.

For the balconies under study, a cultural heritage protection authority has approved to take only one specimen for destructive testing. The submitted contribution illustrates how a characteristic value and partial factor for material properties can be estimated under such conditions. One destructive tensile test is supplemented by

- Non-destructive hardness Brinell tests to verify homogeneity of a material across several balcony girders
- Chemical analysis to confirm a type of the material
- Prior information based on previous experience with historical steel materials.

Characteristic value and partial factor are then estimated in accordance with the principles of EN 1990 [6], ISO 13822 [7] and the Czech standard for assessment of existing structures – CSN 73 0038 [8].

Note that the CIB guide [9] for the structural rehabilitation of heritage buildings indicates that a key issue of historic steel structures is corrosion. This has been addressed in the case study as well; however, information on this is beyond the scope of the submitted contribution.

2 MATERIAL HOMOGENEITY VERIFICATION

Results of Brinell hardness tests are taken into account to verify homogeneity of the material. Measurements are taken at ten locations; eight hardness tests are carried out at each of the locations. Figure 2 displays the histogram of strengths based on NDTs. A conversion factor is applied to make the NDT estimates consistent with the tensile strength obtained by DT.

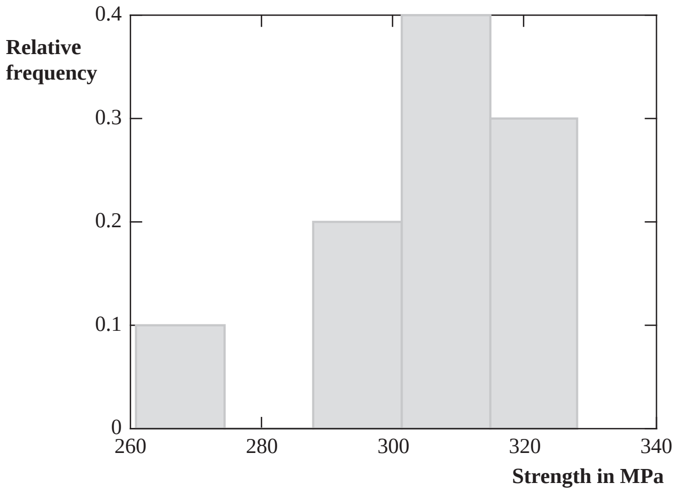


Figure 2: Histogram of strengths based on NDTs.

Grubb's test [10] indicates that the sample likely contains no outlier and extreme observations can result from random variability. This is why the wrought steel is considered as homogenous across all the inspected girders.

3 INPUT DATA AND BASIC ASSUMPTIONS

Tensile test (Fig. 3) leads to the following basic material properties:

- Yield strength: f_y = 275 MPa obtained for strain of 0.2%
- Ultimate strength: f_u = 304 MPa
- Ductility ε_u = 5.1%
- Modulus of elasticity E = 127 GPa

These values well correspond to the general information provided by the report of the European Joint Research Centre [11], where the following ranges are indicated for wrought steel: $f_y \approx$ 220–310 MPa; $f_u \approx$ 280–400 MPa and $\varepsilon_u \approx$ 5–20%. These observations are also in agreement with an experience gained in the Czech Republic – structures constructed before 1894 were mostly made from wrought steel or cast iron, CSN 73 0038 [8]. Table 1 provides an overview of information about properties of historical steels. This evidence thus clearly suggests that the material can be classified as wrought steel.

Material strength based on NDTs exceeds that based on a tensile test by about 50%, which is common for historic steels [12]. This is why the NDT estimates are hereafter considered as indicative only, and wrought steel properties are assessed on the basis of the tensile test and general experience with historical structures.

4 CHARACTERISTIC VALUE

A two-parameter lognormal distribution [10] provides commonly an appropriate model for strengths of metallic materials including historic steels [3]. A characteristic value is then estimated as follows [6]:

$$X_k = \exp m_{\ln X} - k_n s_{\ln X} \approx \exp m_{\ln X} - k_n V_X \qquad (1)$$

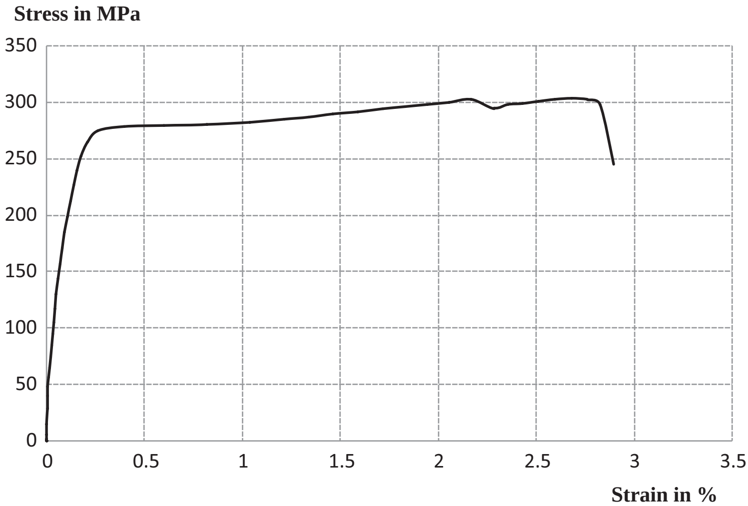


Figure 3: Stress and strain diagram of wrought steel of the beam.

where $m_{\ln X} = \sum_i \ln(X_i) / n$ (for $i = 1,\ldots, n$ and number of tests n) and standard deviation $s_{\ln X}$ corresponds approximately to the coefficient of variation V_X.

CSN 73 0038 [8] recommends for cast iron strength a coefficient of variation in the range $V_{fu} \approx 0.1$–0.15. As variability of wrought steel strength is commonly lower than that of cast iron [3], the middle value of this interval, $V_{fu} = 0.125$, is deemed to provide a reasonably conservative estimate. The same value is taken into account for yield strength of wrought steel, $V_{fy} = 0.125$.

Following the guidance of Annex D of EN 1990 [6] for 'known V_X' – see eqn (1), the characteristic values of wrought steel strengths are estimated on the basis of one tensile test as follows:

Table 1: Material properties of historical steels.

Material	Chemical composition	Use	Material properties (f in MPa, modulus of elasticity E in GPa)	Ref.
Cast iron	C ≈ 2.0–4.0%, Mn ≈ 0.2–1.2%, Si ≈ 0.3–3.0%, S ≤ 1.2%, P ≤ 1.0%		$f_u \approx 90$–135; $\varepsilon_u \approx 0\%$	[11]
Wrought steel	C ≤ 0.8%, Mn ≤ 0.4%, S ≤ 0.04%, P ≤ 0.6%	Load-bearing structures	$f_y \approx 220$–310; $f_u \approx 280$–400; $\varepsilon_u \approx 5$–20%	
Wrought steel (produced before 1900)	NA		Tensile strength $f_{yd} = 180$	

(Continued)

Table 1: Continued

Material	Chemical composition	Use	Material properties (f in MPa, modulus of elasticity E in GPa)	Ref.
Cast iron	NA	All structural members except for columns	Design value of tensile strength 30, design value of compressive strength 65, $E = 100$	[8]
Cast iron	NA	Columns	Design tensile strength 45, design compressive strength 100, $E = 100$	
White iron of very good quality, completely fibrous	S ≈ 0.25–0.5%, P ≈ 1.5–2%	Bridges, truss girders	$f_u \approx 330–360$; $\varepsilon_u \approx 6–9\%$	
White iron of ordinary quality, half-granular, half-fibrous	S ≈ 0.25–0.5%, P ≈ 2–2.5%	Girders, angle, T-profile	$f_u \approx 250–320$; $\varepsilon_u \approx 4–5\%$	[13]
Grey cast iron of high quality	C <0.3%	Bridges, truss roof girders	$f_u \approx 330–500$; $\varepsilon_u \approx 20–31\%$	
Grey cast iron (Germany)	NA	Columns	$f_u \approx 111–125$ (448–462 compressive); $E \approx 96–111$	[14]
Grey cast iron (UK)	NA	Buildings	$f_u \approx 75–160$ with mean 124 (compressive 750); $E \approx 91$	[15,
Cast iron (UK)	NA		$f_u \approx 124$ (compressive 590–780); $E \approx 66–93$	16]

$$f_{yk} \approx \exp\left[\ln 275 - 2.31 \times 0.125\right] = 206 \text{ MPa} \tag{2}$$

$$f_{uk} \approx \exp\left[\ln 304 - 2.31 \times 0.125\right] = 228 \text{ MPa}$$

5 PARTIAL FACTORS AND DESIGN VALUES

Whereas the estimate of a characteristic value may be based on a limited number of tests, the partial factor is commonly based on previous general experience with reliability assessments of steel structures and with uncertainties in modelling, material properties and geometry variables [6]. CSN 73 0038 [8] provides the following relationship:

$$\gamma_M = \exp(-1.645 V_X) \;/\; \exp(-\alpha_R \beta V_R) \tag{3}$$

where α_R = 0.8 denotes the sensitivity factor for resistance and β = 3.8 the target reliability index [6, 7] and V_R is the coefficient of variation of resistance. The target level corresponds to moderate failure consequences, taking into account the effect of cultural heritage protection aspects [3].

It can be considered that resistance of a steel load bearing member R is linearly dependent on its strength X, geometrical properties geo (e.g. sectional areas for failure modes related to compressive or shear forces; in the study under consideration sectional modulus for flexural resistance) and resistance model uncertainty ξ:

$$R = \xi \times \text{geo} \times X \tag{4}$$

Coefficient of variation of resistance – see eqn (3) – can then be estimated as follows:

$$V_R \approx \sqrt{\left(V_X^2 + V_{\text{geo}}^2 + V_\xi^2\right)} \tag{5}$$

Table 2 provides an overview of coefficients of variation for historic metallic materials [8] and justification of the values adopted herein.

Using eqns (3) and (5), partial factors for yield and ultimate strengths become

$$V_R \approx \sqrt{\left(0.125^2 + 0.05^2 + 0.05^2\right)} = 0.144 \tag{6}$$
$$\gamma_M \approx \exp(-1.645 \times 0.125) \ / \ \exp(-0.8 \times 3.8 \times 0.144) = 1.26$$

Table 2: Coefficients of variation for historic metallic materials [8].

Symbol	Coefficient of variation[8]	Adopted value	Justification
V_X	0.10–0.15	**0.125**	The recommended range is deemed to provide conservative estimates for homogenous, high-quality wrought steel [3]. In the absence of structure-specific experimental data, a middle value of the interval is taken into account.
V_{geo}	0.05–0.10	**0.05**	Dimensions are verified in situ; the lower bound is thus considered.
V_ξ	0.05–0.10	**0.05**	The lower bound applies for flexural and shear resistance of steel girders [17, 18]. The adopted model for ξ is deemed to be somewhat conservative as: – Equation (3) is based on the assumption of an unbiased model and yield (not ultimate) strength is to be applied in reliability analysis. – Reliability is not affected by the loss of stability.

and the design values are obtained from the characteristic values in eqn (2) as follows:

$$f_{yd} \approx f_{yk} / \gamma_M = 206 \ / \ 1.26 \ = \ 163 \text{ MPa} \quad (7)$$
$$f_{ud} \approx f_{uk} / \gamma_M = 228 \ / \ 1.26 \ = \ 181 \text{ MPa}$$

It is interesting to observe that CSN 73 0038 [8] indicates a design value of yield strength of wrought steel for structures constructed before 1900 as $f_{yd} \approx 180$ MPa. Design values for cast iron are, however, much lower (30–45 MPa).

Annex D of EN 1990 [6] allows estimating a design value directly from one test ('known V_X'):

$$f_{yd} \approx \exp\left[\ln(275) - 4.63 \times 0.125\right] = 154 \text{ MPa} \quad (8)$$
$$f_{ud} \approx \exp\left[\ln(304) - 4.63 \times 0.125\right] = 170 \text{ MPa}$$

Model and geometrical uncertainties can be easily covered by a partial factor $\gamma_{Rd} \approx 1.05$ [17, 18]:

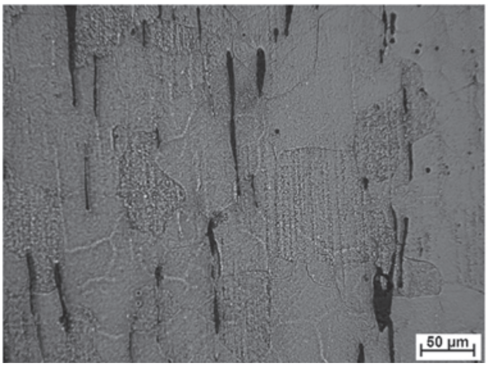
$$f_{yd} \approx 154 \ / \ 1.05 \ = \ 147 \text{ MPa} \quad (9)$$
$$f_{ud} \approx 170 \ / \ 1.05 \ = \ 162 \text{ MPa}$$

These values are about 10% lower than those in eqn (7). However, EN 1990 [6] generally recommends estimating a design value on the basis of the ratio of a characteristic value and partial factor and thus the values given in eqn (7) are recommended for reliability verification.

6 CHEMICAL ANALYSIS

To utilize fully the specimen taken from the balcony girder and confirm the assumption concerning the type of the construction material, metallurgical analysis is conducted to identify individual phases in an unknown ferrous alloy. Figure 4 displays two cross sections of the specimen obtained by a scanning electron microscope. A layered structure with anisotropic localized cracks in the longitudinal direction is observed whilst no intermediate phase Fe_3C (cementite – characteristic for modern steels) and no graphite in any form (typical for graphite cast ferrous alloys) are detected. These observations clearly indicate that the material under investigation should be classified as wrought steel.

To support this conclusion, chemical composition of the alloy is investigated by an X-ray fluorescence analyser (XRF) and an optical emission spectrometry excited by glow discharge (GDOS). XRF provides the information on the content of minor elements typical for ferrous alloys and GDOS identifies carbon content. A considerable amount of impurities measured by the XRF technique (Table 3) and a very low carbon content (less than 0.01 wt.%; see Fig. 5) measured by GDOS conclusively point to wrought steel (compare also with the information in Table 2).



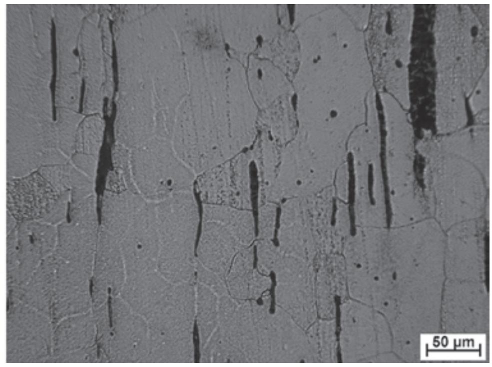


Figure 4: Two cross sections of the specimen obtained by a scanning electron microscope.

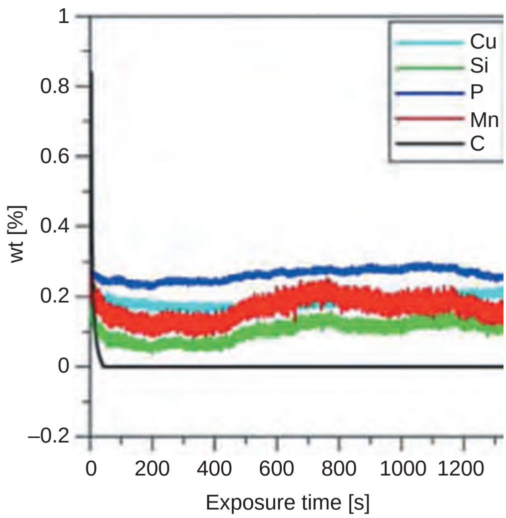


Figure 5: Elemental profile analysis by GDOS.

Table 3: Results of the XRF analysis.

Element	Content (wt.%)	Element	Content (wt.%)
Mg	0.023	Mn	0.266
Al	0.030	Fe	98.875
Si	0.414	Cu	0.157
P	0.125	Zn	0.013
S	0.022	As	0.030
Ca	0.016		

7 CONCLUDING REMARKS

The presented study reveals that the reliability assessment of heritage structures is a complex issue. Numerous uncertainties affecting estimated resistance can be treated by statistical approaches and a semi-probabilistic verification method that is suitable for practical applications.

The case study, focused on wrought steel balconies of a heritage building, indicates the following:

1. Brinell hardness tests can be used to verify the homogeneity of historic steel materials. However, such tests should always be supplemented by tensile tests to provide credible information on which a material model for reliability verification can be established.
2. Unique DT can be used in combination with several NDTs to assess strength of wrought steel balconies. In such a case, classification of the structural material should be supported by a chemical analysis.
3. Values of material properties, recommended in standards, seem to be overly conservative, and therefore, it is advised to specify properties of historic metallic materials by tests. In the presented case study, the design value of material strength based on measurements exceeds the recommended value given in the Czech standard CSN 73 0038 for existing structures (a National Annex to ISO 13822) by about three times, i.e. by ~100 MPa.

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A CASE STUDY: RESTORATION OF HISTORICAL MUSEUM IN SARAJEVO (1963) – A MODERNIST RUIN

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ABSTRACT
The Historical Museum, originally built as the Museum of Revolution in 1963, is an abstract modernist building; a stone-clad lapidary volume placed upon a transparent ground floor creates a strikingly simple and dramatic geometric and material contrast in the best manner of minimalism. The architects influenced by 'less is more' created an audacious building in architectural, material and structural scheme. In structural design and building physics less is, in most cases, simply less, and structural and surface/material deterioration is very visible on the building. This also affects the functionality of the entire building that needs to consume enormous amounts of energy (for cooling and heating), threatening an ever fragile budget of the institution of the museum. Due to its architectural values and cultural significance, the building is protected by law, as a national monument. Interventions must be performed to not only improve the conditions of the building but also maintain its original character and authenticity. A project for restoration of this building is emerging and proving to be even more challenging than initial estimates, especially for the structural aspects of the building that are far from current and needed dimensioning or fire protection codes, which is the case of many buildings from this era. The article will outline the proposals (part of the work is in implementation) and approach for restoration of several elements: structure, insulation, roof light, stone cladding and transparent façades. One of the most prominent features of the structure is the skeletal structure based on slender steel, **+**-shaped columns and hidden concrete grid beam system locked within thin slabs. This presents a challenging task for us – structural engineers and architects – to work in the domain of the hidden, the invisible in order to maintain the building's original ethereal appearance.
Keywords: Historical Museum, modern heritage, skeletal structure, modernist ruin, national monument, roof restauration, static assessment, structural design.

1 INTRODUCTION

The Historical Museum, former Museum of Revolution, is a masterpiece of minimalist architecture. Museum did not undergo through significant alterations, it is architectural intent, material and structure truthfully represent an era. It is almost a perfect poetic ruin, idolized by many architects, a symbol yet again of resistance against the current fast-paced and under-regulated building in Sarajevo that does not pose the identity, structure and meaning of its predecessors. Heritage of the modernist era is very significant, especially today when a society is caught in a permanent 'transitory and developing' political and economical agenda. It was a time when one believed in progress and ideals, a time when architects and structural engineers brought pure, abstract, timeless architecture. What was specific about Sarajevo and Bosnia and Herzegovina is that architects of that time recognized the 'modernity' of existing traditional archetypes and made a powerful statement by using the familiar forms in modernist manner, thus creating buildings of an era, but firmly rooted in place and substance of the city (Getty Conservation Institute [1]).

The History Museum, built in 1963, was designed through a competition that took place in 1957. Architects were Edi Šmidihen and Boris Magaš who later received numerous awards for their design (Kaljanac et al. [2]). The building's minimalist approach is also reflected in its structural system that is composed of slim iron columns and grid-type concrete beams for floor structures, elegant and on the edge of load-bearing capacity – partly a reflection of its time (Fig. 1).

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Figure 1: White stone cladding and glass façade, ‘modernist ruin’.

The ideal is as always in clash with reality. Damaged from war (1992–1995), the building is in dilapidated condition. Main cause of this is also lack of maintenance and knowledge about modern materials. The main question is structural stability, fire protection and adequate methodology for restoration of this masterpiece. Restoration of modernist building is significantly different to the traditional ones due to their specificities: architectural authorship, tendency towards minimalism that is reflected intensively in structural and building material and physics. These specificities along with the current legal building codes (safety, emissions, fire protection) make the restoration process even more contentious than the ‘traditional’ historical buildings.

This research article will discuss the diagnostics, methodology and subsequent consequences of actions or interventions. One must be very clear that the restoration will inevitably cause loss of authenticity and ‘modernist ruin image’ due to replacement or material upgrade of certain elements.

2 METHODOLOGICAL APPROACH TO RESTORATION

2.1 Analysis and Diagnosis of the Current Condition of the Building

The process of protecting and upgrading the building to contemporary requirements has become relevant and pressing issue. The basic function of the museum is threatened by roof leaks, inability to heat and ventilate space or by pieces of stone cladding falling off. The building needs to be adapted to acceptable standards of comfort for users, and at the same time to recognize the importance of preserving the architectural heritage.

There are two key issues to consider while making a design for restoration:

1. The structural assessment and subsequent needed interventions on the existing construction should make the structure safe to use and functional in the future life span of the building.

2. Architectural restoration that must keep the overall concept of fine modernist details and materials reflected in its skin – the façade layer composed of relatively thin iron profiles and single glazed glass, and white stone cladding of the first floor cube.

Through a detailed architectural survey and drawings, current state of the building has been recorded and analysed. In general, one can state that the outer shell – surfaces of roofs, façades and pavement – is in a state of disrepair and even crumbling. It is possible to state that 50% of stone cladding is damaged or missing and that ground floor's transparent glass and iron façade has severe corrosion throughout all segments and some are nearly collapsing (Fig. 2).

All roof surfaces have major leaking problems that were partially addressed during the last 10 years, but there was never a comprehensive restoration of the entire or large portions of the roof. Flat parts of the roofs are damaged and they consist of layers, thermal insulation, water drainage pipes and surface inclines that are inadequate.

The building's skeletal construction consists of frames tensioned with vertical diaphragms and the elevator shaft. The beams on the first storey are laid in the steel concrete beams. The + cross section of steel columns is 28 and 35 cm on the ground floor and 16 cm on the upper storey; there are nine columns on each storey. The storey concrete slab leans onto the 9-cm-steel concrete grid. The structure of the flat roof is also comprised of steel concrete panels, and the gauge of which is 7 cm in the lower part and 15 cm in the upper part. The oblique parts of the light are constructed using steel hollow rectangular glass-roofed profiles (Fig. 3).

The main bearing system of the horizontal frame bearings on the roof structure level is comprised of four grid bearings with overhanging eaves leaning onto the already mentioned steel columns made as +-shaped profile. In order to reinforce the stability of the existing grid bearings, two hollow steel diagonal poles (Fig. 4).

The building has been assessed not only for constant and movable load but also for the load of seismic zone VII of the MCS scale, Soil Category II. A peculiar characteristic of the building that has been included in the seismic analysis is the fact that the first mode of the

Figure 2: Ground floor openings that show improvised repairs.

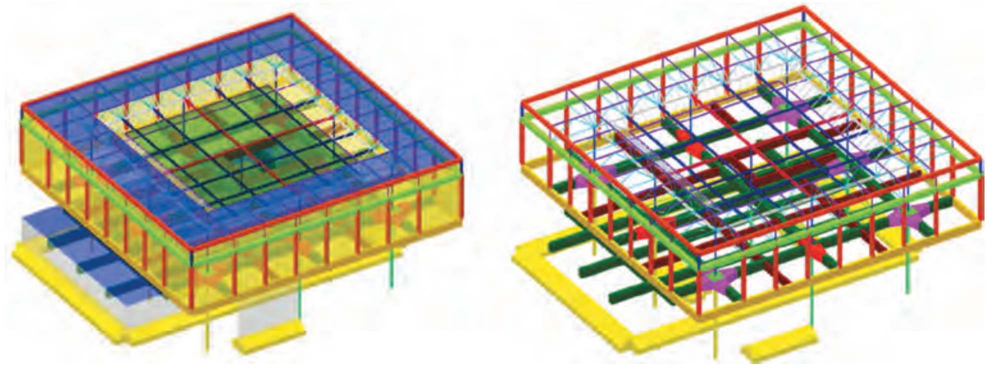

Figure 3: Static model of museum's structure with and without walls.

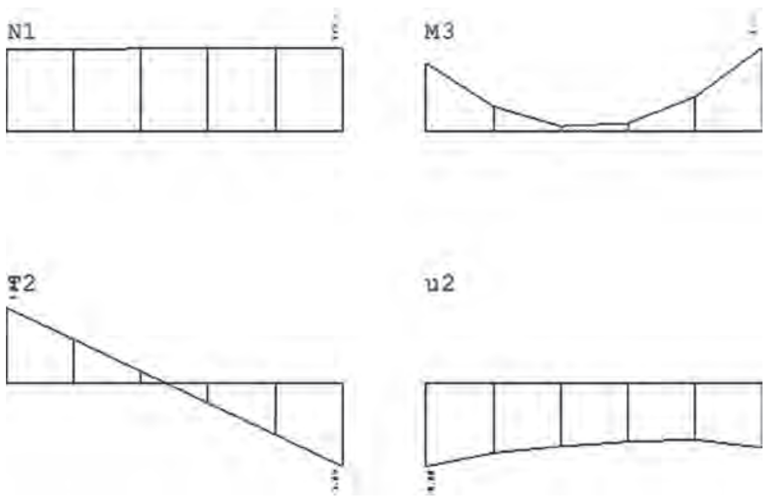

Figure 4: Internal forces and displacement in the most loaded carrier glass cladding.

construction's vibration period T_1 is actually torsion. The roof structure has been assessed for the snow load of 1.50 kN/m^2 (Fig. 5).

2.2 Restoration and Evaluation of Modern Heritage

Restoration of historic buildings has been a challenging and divisive endeavour for architects and structural designers, as well as for relevant international institutions that issue guidelines and charters in order to respond to all complexities and phenomena of cultural heritage. Mostly we are able to deal with the pre-modern heritage restoration in a proper architectural, methodological and material manner. This is partly to accumulated knowledge and practice on traditional, mostly masonry or wood materials and techniques. This has not always been the case – for instance, early restoration attempts of Parthenon produced even more damage due to inadequate connection material that rusted and ill-fitted elements.

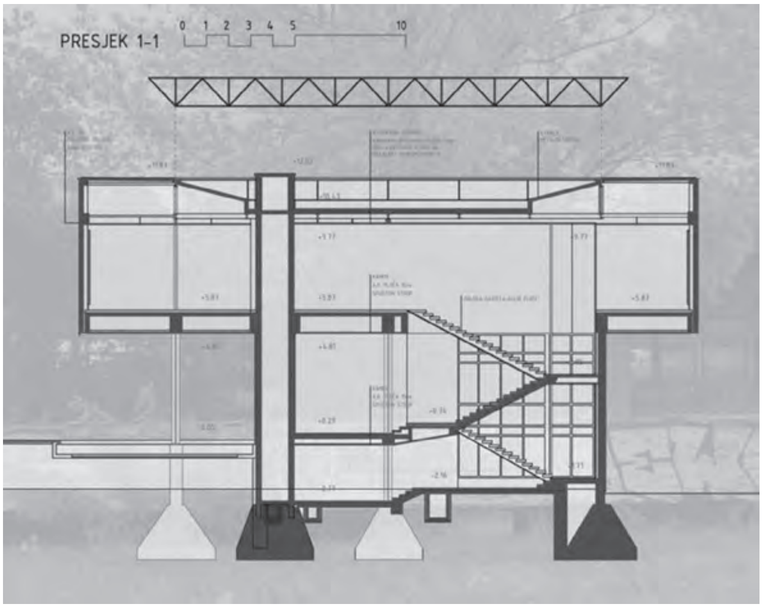

Figure 5: Cross section of the museum.

It is the very material and structural composition of traditional historic buildings that allows dismantling, partial replacement and intervention, and also they are a product of centuries of building experience that is not the case with modernist buildings.

The valourization of building heritage of 20th and 21st centuries is also quite a recent process; the World Heritage List has inscribed modern buildings mostly starting from the beginning of the 21st century out of 1,031 properties (802 cultural) in 2015 and only 10 belong to contemporary architecture.

This information is indicative of the level of difficulty in appraisal of buildings which mostly are in active use and have been subjected to various retrofitting interventions that may have compromised the integrity and authenticity of the buildings.

There have been many cases of restoration of modernist buildings (such as the Weissenhof complex, Corbusier building in Stuttgart, or Viipuri Library) and results are in a way always a form of compromise, even more so that with traditional buildings since using same technical solutions only leads to same problems that will appear over time and will not provide a reasonable amount of user comfort (Kulic [3]).

Essentially there are two approaches: either make double skin leaving all the existing and compensation with another layer that introduces a new element but allows the preservation of the authentic, or replacement of the original with new elements with high technological and precise craftsmanship that can to an extent visually replicate the dismantled segments.

3 STATIC ASSESSMENT

At the very beginning, the preliminary detection and diagnostics were made, a detailed assessment of the original project documentation, in order to get familiar with the building as a whole, especially its structure elements, architectural details, equipment and installations. All potential obstacles and damages had to be registered. Unfortunately, the original project documentation was partly available and some of the drawings were not completed to the necessary degree to be considered professional but were enough to confirm the dimensions and details of the basic elements of the structure. There is always a possibility of hidden damages that are often detected only after 'opening', i.e. beginning of construction works.

Complete insight into the existing condition of the building and its structure was impossible due to the fact that the building was open for visitors and that the budget was limited. That is why it is necessary to make another, secondary round of diagnostics and in that way complete the static assessment before beginning with the construction works. During the process of opening the roof structure and the building structure, i.e. co-operate with the chief designer with the aim of conducting an additional static assessment if necessary and offer a final solution regarding all interventions, especially those pertaining to the roof structure. Considering the circumstances and the fact that a major part of the building and especially its roof structure was not accessible for inspection, detection of possible damages and visual inspection, it is of utmost importance to fulfil this requirement. In this phase, the dimensions, the quality and the type of materials used for construction elements that were hidden or inaccessible will be re-examined. Certainly, to preserve the construction scheme of the original design, it is necessary to make a quality assessment of the character and degree of damage.

4 PROBLEMS AND SPECIFIC FEATURES

At 19 July 2016, works on the roof have started. After booting the cover strips and existing reinforced glass on the south-western parts of the roof we discovered bays. Supervisors noted that the sheet metal and insulation under glass are in a degraded state and therefore unusable.

The discovered bay also showed unacceptable damage to the reinforced concrete beams that support steel sections, which do not meet current standards for this type of structure. These existing concrete structures have significantly reduced cross section with a visible structure, forks that are not closed and concrete largely separated from the beams. It is necessary to replace the collapsed concrete.

The damage in reinforced concrete structures caused by external loads manifest cracks in concrete (vertical and inclined cracks) and separation of the protective layer of concrete reinforcement. These cracks still do not represent a sign of unsatisfactory capacity of the structure. Cracks in this case allow access to reinforcement, and the aggressive actions of environment further cause a change in the structure of the steel reinforcement. The reinforcement that is corroded with reduced cross section does not meet the required capacity and on the surface of the concrete causes peeling (Fig. 6).

Figure 6: Degraded state of sheet metal and insulation under glass.

From the damaged grid diagonals and other damaged elements of the steel structure, it is necessary to cut out samples further to be examined in lab for hardness using the Brinell hardness test method (depth of indentation, D = 10.0 mm). The built-in steel is from the group of soft steel and we will examine its quality by assessing whether it possesses mechanical balance, i.e. if it may be classified as steel of desired quality.

As for corrosion, the nodes of the construction were more exposed to corrosion due to standing water and debris. It is to be concluded that, apart from rehabilitation of the damaged and deformed elements, it is necessary to clean the structure by means of sanding techniques and by applying appropriate tools for removing corrosion in difficult-to-reach spots. Considering the thinness of the construction elements, it is recommended that special attention in the rehabilitation process be given to synchronized purification and primer application. It may be concluded that a quality change of the mechanical features of built-in elements and the whole system occurred. Only after conducting the above-proposed activities, including potential laboratory examinations, it is possible to make a quality decision on all interventions regarding the construction. Starting with the assumption that a correct secondary detection, while recognizing causes of the existing damage, has been carried out, and taking its purpose into account, it is possible to make a decision on measures that would enable certain functions and their future status. It is, therefore, necessary to ensure spatial hardness of the structure by establishing its predictable response to a potential future shock/earthquake.

As a rule, the columns are most gravely affected and damaged in the lower third of the height as well as in places where they are connected with the cross-bars.

During works on the roof the remaining parts of ties were discovered. There were three ties in both directions that facilitated the lower parts of the construction which is cantilevered left outside the main cube. Today there are only anchored parts, the ties are missing and investor should fine the way to finance its construction (Fig. 7).

The circular (CHS – circular hollow section) and rectangular (RHS – rectangular hollow section) hollow steel grid bearings have priority in contemporary civil engineering and construction over the commonly used grid bearings made of hot finished sections due to a range of advantages: less heavy, the anti-corrosive protection is cheaper, the O/A relation is lower, the aero-dynamical shape is better, there are greater possibilities for constructive and

Figure 7: Remaining anchored parts.

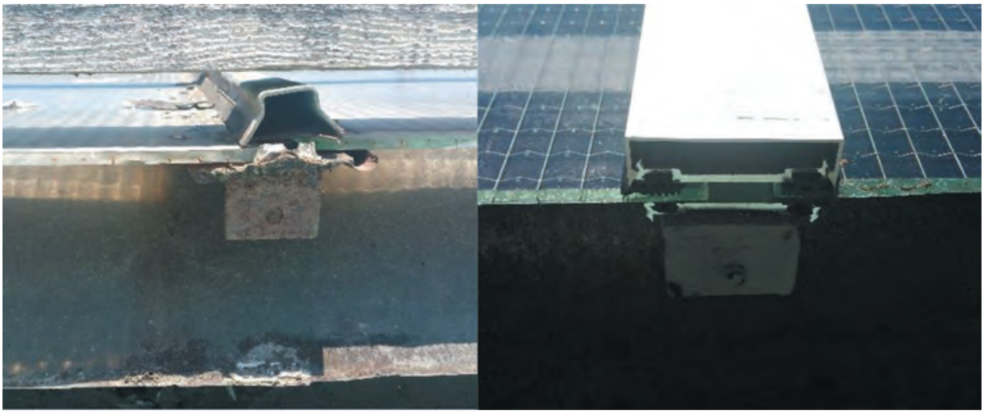

Figure 8: Connection between reinforced glass (old and new ones).

architectural shaping, and so on. They are made of CHS or RHS. All the filling elements are welded. The angled welds are 4.0 mm thick along the whole contour of the joining structures.

The designed horizontal and vertical dimension lines and steel structures should be completed in the final stage. The constructor, prior to construction works, has to develop elaborate workshop documentation on cutting and welding, taking into account the effects of deformations due to welding – such as shrinkage and distortion of elements – in order to make it possible for the final shape and measures to precisely correspond to the plan after assembling. The material-processing details have to be adjusted to the hot galvanization technology in order for the welds not to be damaged.

Only after the secondary level of detection has been carried out, all the necessary sketches of the current condition indicating which spots are damaged will be completed and classified according to the type along with an accompanying textual description (technical report on the conditions found) as the ways and methodology by which the damages will be eliminated. The constructor will be provided with corresponding sketches and textual instructions, and static analysis with construction details, if necessary. Bearing all the listed reasons in mind, it is necessary to make an assessment plan for the replacement of the existing elements of the steel structure the cross section of which is 25–30%.

About 70% of existing undamaged reinforced glass is thoroughly cleaned and reused. Appropriate procedures for the reinforcement of the structure are needed. We suggest using some of these methods: rehabilitation of beams by using additional steel stirrups, reinforcing beams by increasing the cross section and reinforcement, reinforcement beams connecting the existing and additional reinforcement, the use of steel sections glued with epoxy adhesive for concrete section or reinforcing section with carbon strip (Fig. 8).

5 FIRE PROTECTION

Fire protection is another important issue that has to be addressed. In case of fire, especially sensitive are steel structures, and to a lesser degree, concrete steel structures as well. It is necessary to improve the fire protection system. The sprinkler systems are designed to control fire until fire fighters arrive. Their success rate is quite high in EU countries, which make them, from the engineering point of view, among first choices when compared with other methods of fire protection.

It is also necessary to ensure protection of the bearing structure by applying appropriate coating. The protective coatings used in steel structures are paints or metal coatings or the combination of the two. In their essence, paints comprise the pigment, the binding mass and solvents. The surface has to be cleaned of rust, debris and grease. Old layers of paint that have started to peel off need to be completely removed. In the process, the outside temperature has to be at least +10°C (the temperature of steel +5°C at least). The type of paint and the thickness of the layer applied depend on the corrosive aggressiveness of the environment. The coatings are allowed to be used exclusively in the interior parts of the building and in no way on elements that are constantly exposed to high degrees of humidity and aggressive fumes. Once applied, this coating must not have any additional coatings. The surface coating has to be regularly maintained.

In order for the coated steel elements to fulfil fire protection report requirements regarding construction elements, it is possible to apply galvanization of steel elements. Such a fire-protective coating creates a layer of insulation intended for the bearings (full bearings with special requirements regarding bending characteristics), columns and grid structures. The process known as ‘hot-dip galvanizing’ implies that hot zinc coatings are applied by immersing steel structures in a tank of molten zinc at a temperature of about 450°C.

In general, structural aspects of the interventions are complex due to the fact that building regulations of the time that required less safety margin and that contemporary solutions might impose some new weight or elements that must be integrated into the existing.

6 ARCHITECTURAL CONSIDERATIONS

Architectural and technical details that will emerge during the process of design and rehabilitation of the building will be serious compromise on many levels. As previously stated, the fragile and minimalist state of the building contributes to its overall appearance.

Referring to some cases of restoration of modernist buildings such as the Corbusier’s building in Weissenhof in Stuttgart, upon close inspection it is possible to see that the restoration involved a series of compromises, even in its interior (Weissenhof Museum publication, 2008 [4]). The most prominent feature is the continuous strip window that has been replaced with new double glazed glass and frame.

It is the very nature of the compromises that make the restoration of modernist buildings even more delicate. It raises questions of overall integrity and authenticity of building and its concept and materials. The most delicate matter is its envelope elements: upper storey stone cladding and ground floor transparent glass/iron façade. The upper floor is composed of a thin concrete wall of 10 cm that has partial internal insulation blocks made from pressed wood 5 cm thick (Fig. 9).

The outer shell of the façade is made of 2.5 cm thick hard white marbleized limestone cladding directly glued/plastered to the wall. In case of thermal insulation there are technical solutions to place it within the object, but question remains as to how effective this would be, considering many weak thermal spots conduct the energy and in some cases are a moisture-generating zone due to hot and cold surfaces in contact. It is inevitable that a large portion of stone cladding will have to be replaced but will generate a visual distinction between existing and replaced stones due to their patina. This is something that has been already accepted in many cases of post-war restorations on stone masonry buildings and is a truthful and correct procedure in restoration.

An even more complex is the issue of the iron profiles and single glazed glass transparent envelope. To some extent, the current iron frames and mechanisms can be repaired but the main issue remains with the single glazed glass that does not provide sufficient insulation,

Figure 9: Condition of the roof (before and after).

or is the building functionally heated. Proposals range from replacement of frames with aesthetically and visually similar but double glazed thermal glass, or placing a glass curtain a second layer that will provide insulation and allow the building to keep its original framing. The first option is technically preferred due to its clarity and functionality but will lead to loss of the fragile authentic tissue.

Some other features will require interventions such as skylight roof but since these are less visible elements, their restoration can be achieved through sound contemporary solutions that will still keep the original structure.

The essence of this building is partly in its physical features and partly in its symbolism, at the time it was created (communist era), evoking a timeless abstract volume spoke about vision of architects and deeper universal meaning of the structure.

7 CONCLUSION

The delicate 'modernist ruin' image and heritage of the museum is fiercely defended by many architects due to the fact that it has been a part of collective memory, a kind of testament to a culture that has once been, which produced this architectural icon and the current transitional society moral that leaves these important institutions in derelict. This is a valid argument since many inhabitants of former Yugoslavia who romanticize socialist and modernist periods perceived stable and progressive (Štraus [5]).

On the other hand, the basic function of a museum is to preserve collections and items deemed valuable and in present state the museum is trying to function (due to enthusiasts and individuals who support and run the institution) despite the circumstances.

As architects and engineers who have closely inspected and recorded the building, one also has dualistic and mixed emotions and rationale about the actions to be undertaken on the building.

Modern heritage – its evaluation and restoration is becoming more a part of the issue among professionals, and cultural institutions are doing more to claim the buildings as heritage, but currently there is very limited experience in restoring them.

In addition to items of all heritage a minimalist intervention recommendation is to be followed here, although mostly will be irreversible. These minimal interventions would include the extensive repair of the flat roof and basic structural interventions upon inspection of main structural elements as well as their replacement or intensive maintenance.

As for the most visible alterations to the façade the most conservative approach would be preferred with minimal replacement of stone cladding and transparent elements.

In the case study of museum building that started out as a purely technical survey and assessment of conditions, the authors of the article become even more aware of deeper layers and meanings of the building, and of its metaphysical presence that has in the end dictated the main discourse for the process of restoration.

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AUSTRO-HUNGARIAN FORTIFICATION IN BOSNIA-HERZEGOVINA AND MONTENEGRO.CULTURAL HERITAGE BETWEEN VALUE, TOURISTIC POTENTIAL AND EXTINCTION

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ABSTRACT

Just a few years after Bosnia and Herzegovina has been occupied in 1878 the Austro-Hungarian Empire started an ambitious construction programme to build an extensive fortification system. This region including the southern part of Dalmatia was characterized by increasing tensions between the different ethnic groups and traditional resistance against occupying state powers which ultimately lead to the outbreak of the First World War.

The omnipresence of state power was demonstrated by many military buildings – both in the urban context and the outermost periphery. In addition to the strategic positioning of the fortifications, 'visibility' is a deliberately placed calculation and the region became a 'fortified area'. Using archaic, almost outdated forms in the early phase of construction the defensive purpose is clearly recognizable and underlined by the use of the local terminology 'Kula'.

The purpose of the following study is to give both a complete overview about the fortification system and the state of preservation as both of them are essential for all further considerations. The construction effort within more than three decades is divided into three periods. These differ in construction manner as a reaction of the technical development, changes of its geopolitical strategic task and the influence of its planners. Specified typologies of fortifications are categorized and recorded for each construction phase. In the second part the development regarding the state of preservation of the fortifications is listed. A considerable loss of substance has been documented during the research which is even accelerating within the last years although a minor of the objects is protected by law. Overall the state of preservation differs from 'well preserved' to 'former position is recognizable in the ground'. Furthermore a large quantity of fortifications disappeared within artificial lakes.

A determined low local level of information about these objects seems to be one of the factors for a slow extinction although the fortification system including its integral network of roads, paths, caserns, cisterns and magazines etc. could form a potential for economic development where fortifications could be the point of interest.

Keywords: Austria-Hungary, 19th/20th century fortification, loss of substance, military architecture, preservation

1 INTRODUCTION

Through legitimation by the Congress of Berlin in 1878 the Habsburg Monarchy occupied the later provinces Bosnia and Herzegovina and sent military forces to support the Ottoman Empire in the Sanjak Novi Pazar and Plevlje (Pljevlja). Regulated by a treaty signed in summer 1878 they remained officially territory of the Ottoman Empire. Bosnia and Herzegovina, among all 'Crown Lands' of Habsburg Monarchy, is the only one which was administered by both parts of the monarchy and stood under military administration. Although first concepts were elaborated to secure this last expansion of Austria-Hungary by fortifications nothing was done mainly by a lack of economic resources.

At that time only some fortifications already in existence from the Ottoman period were used. These can be divided into two general groups. Among the first fortified towns can be counted where the whole settlement or at least parts of it were protected by walls reinforced by bastions and gate towers. The old town of Sarajevo and the city walls of Trebinje and Zvornik are representative

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examples. These fortifications have been built and strengthened mainly between the 16th and 19th centuries to secure the dominion of the Ottoman Empire. The way of fortifying the cities which was affected by the impact of fire weapons is rather comparable with walled towns in other parts of Europe at that time. To the city fortifications a number of citadels like those at Banja Luka, Bihac, Travnik, Jajce, Vranduk, Maglaj, Srebrenica and Fort Berbir (Gradiška) can be included.

The other group of fortifications which definitely had influence on the later development of Austro-Hungarian fortifications are the small, independent fortifications called Kula (Serbian: *Karaula*). These small tower-like objects with two or more levels (Fig. 1a) were erected between the 17th and 19th centuries. The main building material was local stone; only a few examples were made using wooden constructions. A Kula had different tasks and was built both as protection against the Ottomans and by the Ottomans themselves. Kula's could support the city walls in protecting the settlement against enemy attacks or a rebellion. Livno in the western part of Bosnia for example had a ring of twelve Kula's to protect the town and the Ottoman garrison located there. They had a round or square layout and an elevation of up to six levels. The bottom of the outside walls and the entrance could be defended by machicolations located on the roof level. Kula's on the other hand were erected to protect residential buildings. Important communication buildings like bridges (e.g. the old bridge of Mostar with two semicircular Kula's) or mountain passes were either protected by this type of fortifications. Remarkable is a system of all together 19 Kula's (Fig. 1b) between the Dalmatian-Herzegovinian border at Carina (near Dubrovnik) and Trebinje that protected this important road between the coast and the hinterland against possible assaults. Isolated Kula's like these along communication lines were often surrounded by crenelated walls and the entrance could be protected by an outer bailey (Fig. 1c).

When the Austro-Hungarian army conquered Bosnia and Herzegovina in 1878 most fortifications were found in a poor condition. Both the insurrection of 1875 that affected parts of the southern Herzegovina and finally the fights during the Occupation in summer and autumn 1878 destroyed many of the Kula's and damaged city walls. Besides the city fortifications of Trebinje, Sarajevo and Zvornik and most of the citadels only some of the Kula's between Dubrovnik and Trebinje were improved or reused by the Austro-Hungarian forces [1].

But how was the situation regarding the fortification system of the Habsburg Empire at the beginning of the 1880s? The focus of construction works was defined by the improvement of

(a) (b) (c)

Figure 1: Different designs of Kula's. (a) Kula (Vuka) Brankovića at Trebinje 14th century. (b) Kula along the road Dubrovnik-Trebinje 19th century. (c) Ottoman Kula XIX/Austrian guardhouse Hum at Trebinje 19th/20th century (Sources: (a) archive Pachauer, (b) ÖStA/KAW BS LIII N°121, (c) ÖStA/KAW ZSt KM Abt8 16-8 ex 1914, supplement.)

the defences along the southern frontier (Italy). To secure the approaches to Carinthia and to the city of Trient (Trento) a series of absolutely modern forts were under construction. Besides that the sea side defences of the main naval port – Pola (Pula) in Istria – were to be modernized by adding three armoured coastal forts. All mentioned were the first armoured fortifications that were built by the Austro-Hungarian Empire. On the northern frontier the fortress girdles of Krakau (Krakow, Poland) and Przemysl (Poland/Ukraine) should be extended by new artillery forts against a possible attack by the Russian Empire. That means that all available financial resources for building new fortifications were bound at least till 1884.

Apart from this situation the fortification topic to secure Bosnia, the Herzegovina and Dalmatia quickly got urgent and needed to be reconsidered at the end of 1881 as a rebellion broke out affecting the eastern part of the Herzegovina and southern Dalmatia. As a consequence a military commission under the general inspector of fortification engineers, Field Marshal Lieutenant Daniel baron Salis-Soglio, was sent in March 1882 from Vienna to the affected regions to define which points and in which way these should be secured by fortifications [2, pp. 134–151]. One of the results of the commission was that new types of fortifications and defendable buildings (barracks and casern complexes) had to be developed for a local purpose. The officer in charge of the fortification engineers at the military command in Zara (Zadar), Lieutenant-Colonel Karl Wahlberg, was ordered to design different typologies of fortification, among them a guardhouse (called Kula), a fort ('Kula with battery') and a defendable casern [3].

These principle designs were generally accepted and for the first time realized in the Krivošije area in southern Dalmatia [4, pp. 27–28]. The governor and commanding general in Dalmatia Field Marshal Lieutenant Stephan baron Jovanović defined in a memoir from 1882 the task of military presence (supported by fortification) in the occupied area as follows:

'To allow culture to develop at all, first of all strong garrisons have to be established in southern Herzegovina and in the district of Cattaro for at least several years (…) that the to be cultivated territory is in fact under for all residents full and clearly perceptible [military] force as only on the base of this redoubtable factor of power which has to be recognizable inside and outside the business of cultivating can be done step by step [5]. In his eyes only a higher level of culture stimulated by the Habsburg Empire would provide a lasting peace within this region.

In a post review Salis-Soglio (1908) stated in his memoirs regarding the erection of fortification in Bosnia and Herzegovina: 'Nothing had more impact on those belligerent cruel locals as we dared to build fortifications on top of many of the highest summits in spite of all difficulties in building them. The watch house on top of the "Gliva" near Trebinje is a remarkable monument for almost all of the Herzegovina as it can be seen from everywhere' [2, p. 136].

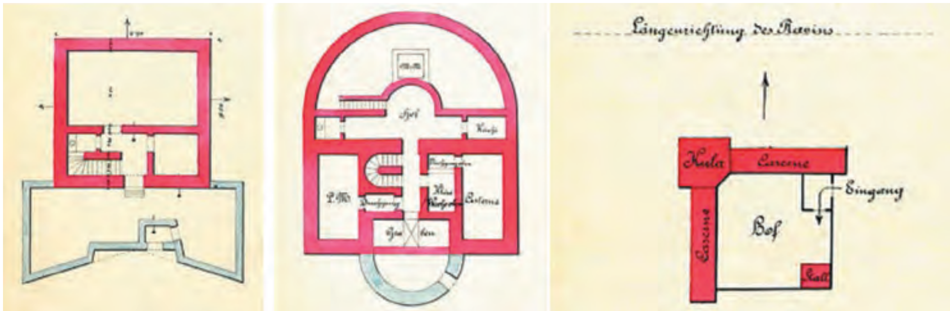
2 CONSTRUCTION OF A FORTIFIED REGION;

Besides the development of different fortification elements for the so-called occupied territory (Okkupationsgebiet) – that is Bosnia, Herzegovina, the Sanjak and parts of southern Dalmatia – the approval of an extraordinary budget for building fortifications by the Ministry of War in Vienna and authorized by highest resolution of Emperor Franz Josef I himself in 1882 marked the official beginning of a radical construction programme. Almost lasting for four decades the construction can be divided into different phases that vary in form, construction and amount of built objects. The whole lapse of time is divided into three separate periods that can be classified by the use of different constructions (designs) which are both a reaction on the technical development in general and caused by the changing strategic task of the fortification system. In the end Bosnia, the Herzegovina and southern Dalmatia were transformed into a fortified region (Fig. 2) comparable with the former Austrian Quadrilatero in northern Italy.

Figure 2: Detail of map from 1884 showing the southern part of the Habsburg monarchy including the existing and projected military network of fortresses, barrages and defendable caserns. (Source: ÖStA/KAW ZSt KM Präs 15-5/11 ex 1885, supplement 2, 1885.)

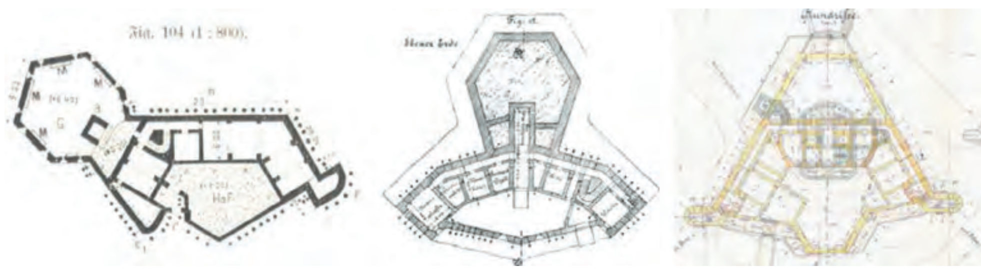
2.1 First period: 1882–1886

Within the first period the most intensive construction programme can be stated. Furthermore it is shaped by the use of Wahlberg's general designs with influence of Salis-Soglio. The main characteristic is the use of the so-called platform fort (Plattformwerk). The armament, mainly two 9 cm or 12 cm breech loader guns, is placed on a small raised platform that is giving the fortification both its name and characteristic form (Fig. 4a, 4b and 4c). In fact, these forts are guardhouses extended by these platforms (Fig. 3b) and in the first realized examples defined



(a) (b) (c)

Figure 3: General design for fortifications in the occupied territory: (a) Kula-type guardhouse. (b) Kula with battery = fort. (c) defendable barracks with a Kula as flanking element. (Source: ÖStA/KAW ZSt KM Abt8 10-19 ex 1882.)



(a) (b) (c)

Figure 4: Different designs of platform forts. (Source: (a) Brunner, 1896, (b) Rieger, 1884, (c) ÖStA/KAW MBeh TMK Sekt II N° 391res. ex 1888.)

as Kula with battery [4, pp. 10–12]. Both the guardhouses and the forts show a wide variety of forms and designs. As a threat was expected only by infantry maximal supported by small calibre mountain guns, the constructions were not built in a very massive way (compared to the contemporary artillery forts). Another characteristic was the common use of tiled roof. In this period a whole system of fortifications and defendable caserns in the Krivošije was built, and the cities of Trebinje and Bileća were surrounded by girdles including forts and guardhouses each. In a similar way the east side of Mostar was protected, forming a bridgehead along the Neretva. The cities of Avtovac, Stolac, Ulog-Obrnja, Nevesinje and Kalinovik were converted into barriers – Kalinovik and Stolac even in the form of small girdle fortresses – consisting of guardhouses on strategic summits supported by semi-permanent open batteries and defendable caserns near the settlements.

2.2 Second period: 1887–1907

Within the second period the fortification rings around Trebinje and Bileća were finalized and the defences to secure the Krivošije and Mostar were strengthened. At Sarajevo works started in 1888 where the first fortifications to secure the eastern frontier of the capital were realized. Although this works can be seen as direct continuation a transition in the way of construction can be found to compare with the years before. At Bileća and Trebinje we can see, influenced by Colonel Moritz von Brunner, the introduction of small artillery forts. Some existing guardhouses got converted into forts as open ramparts for artillery were added. More dramatic is the evolution in Mostar and Sarajevo. After a long discussion and planning phase fort IX in Mostar was finished in 1888 and can be seen as the first all-casemated fortification in Bosnia and Herzegovina. De facto it is a type of a battery and shows astonishing similarities to the first armoured fortification built in Austria-Hungary. With fort number IV Pasin brdo (Fig. 4c) at Sarajevo we can find the first project of an armoured platform fort in Bosnia. Likewise being finished in 1888, the projected two armoured cupolas for a 15 cm mortar each have been installed not before ten years later. The main armament still was placed in open gun platforms. By the turn of 1900 the girdle around Sarajevo consisted of four such armoured forts. In the following years the construction activity continuously decreased. The fortress girdles were reinforced only by a small number of artillery forts and batteries. Around 1906 at Sarajevo and Kalinovik some guardhouses have been built. These differ from the early guardhouses built at Bileća and Trebinje mainly by the use of concrete and flat roofs which should provide protection against small calibre guns whereas the general design was kept.

To secure the narrow gauge railway lines in Bosnia, Herzegovina and Dalmatia small guardhouses were built mainly to protect bridges and tunnels in the difficult terrain. Most of these guardhouses were built along the line Gabela-Zelenika (twelve objects) and along the Bosnian east line (Ostbahn). In their general pattern they are designed similar to the guardhouses of the girdle fortresses. The main difference is the lack of courtyards and sometimes the flanking elements (caponiers) were left.

2.3 Third period: 1908–1914

Beginning in 1904, the third period's first suggestions stated the need for a transformation of the fortification system in this region. This got urgent, as the nearby princedom of Montenegro came in the possession of heavy siege armament in 1903 [6, pp. 50–52]. Both the general inspector of Fortification Engineers baron Leithner and later the army inspector for Bosnia, the Herzegovina and Dalmatia General Potiorek made proposals for a fortification system to secure the southern part of the Habsburg Monarchy. The 'skeletal' should be formed by a network of comprehensive armoured forts. The first concepts considered the reconstruction of platform forts into compact armoured forts equipped with machine guns and revolving turrets, but the idea was dropped soon. The design of the projected new forts was almost identical to those built along the Italian frontier since 1907. Using these types of fortification Sarajevo and Trebinje should be converted into small armoured girdle fortresses [6, pp 61–64]. At the beginning of the First World War only two forts – Dvrsnik in Krivošije and Srač (Fig. 5) at Trebinje – have been in an advanced phase of the construction progress, but have not been finished till 1918. Some other construction sites like Baljke at Bileća and Kravica at Trebinje remained 1914 in an early stage of construction.

Another change was the forced use of Noyau (core) fortifications to secure the caserns and storage facilities within the main fortresses. Whereas the Noyaus of Crkvice and Herceg Novi in southern Dalmatia remained projects, those of Trebinje and Mostar were finished till the outbreak of the First World War. These Noyau girdles consisted of a series of small armoured guardhouses (Fig. 6) heavily equipped with machine guns and searchlights both protected by cast steel shields.

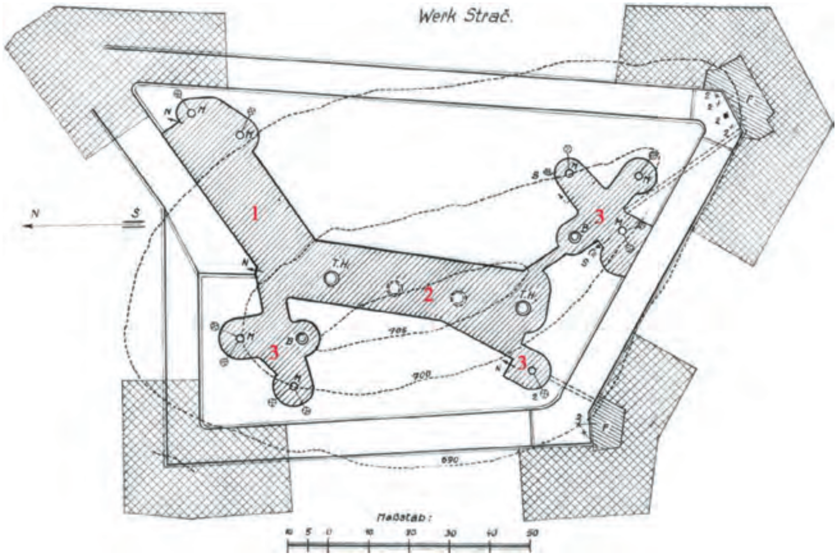


Figure 5: Sketch of the final designs of fort Srač after 1911. 1 – Barracks block. 2 – Howitzer battery. 3 – Machine gun positions for close defence. F – Caponiers. (Source: Pachauer, 2016.)

Figure 6: Guardhouse Bregovi at Trebinje as an example of a Noyau guardhouse. (Source: Pachauer, 2014.)

Table 1: Overview of all built fortifications. (Source: Pachauer, 2017).

Period	Typology			
	Fort	Battery	Guardhouse	Redoubt
1882–1886	**22**	**4**	**29**	**10**
1887–1907	**17**	**3**	**29**	**–**
1908–1914	**2**	**2**	**26**	**12**
TOTAL	41	9	84	22

Table 1 gives a summary of all built permanent fortifications in the mentioned area between 1882 and 1914 categorized in typologies including redoubts (strongholds). In total 41 forts of different constructions and designs, 9 batteries, 84 guardhouses and 22 redoubts were finished or under construction in 1914, which are 155 fortification objects in total.

3 STATE OF PRESERVATION

Only a small number of the fortifications got involved in combat during the First World War. In particular the forts II, III and IV east of Bileća were shelled by Montenegrin artillery (actually French and Russian pieces) in 1914 and 1915 but most damages have been repaired. The bigger part of the fortification got disarmed (artillery and machine guns) in the spring of 1916 as Montenegro and Serbia were defeated and the front line went far away from these fortifications. Finally in 1918 almost all objects lost their function and only a small number were used as military storage. The abandoned fortifications soon were cleared either by the military or by local people.

Although only a minor of the objects were damaged during the First World War some fortifications were locations of intense combat during the Second World War and therefore suffered damages. For many decades the decay just was a result of atmospheric conditions. Comparable to the situation during the Second World War many fortifications were used as shelters in the Yugoslav Wars. Especially fortifications around Mostar and Sarajevo suffered heavy damages between 1992 and 1995 and are still partly located in mined areas. Another thread which must be seen as the most lasting in the meaning of loss of substance developed within the last 15 years. Preserved fortifications are misused as stone carriers (e.g. fort VIII Petrinja at Trebinje or guardhouse Goli Vrh in the Krivošije) to get the valuable handcrafted natural stone blocks (Fig. 7b and 7c).

(a) (b) (c)

Figure 7: Different examples regarding the state of preservation: 'good' – 'damaged' – 'destroyed'. (a) Fort IV Pasin brdo, Sarajevo (2011). (b) Fort 6, Mostar (2015). (c) Guardhouse Goli Vrh, Krivošije (2008).

Table 2: Classification of the state of preservation. (Source: Pachauer, 2017).

Typology	State of preservation			
	Good	Adopted	Damaged	Destroyed
Fort	**19**		**15**	**7**
Battery	**3**		**4**	**2**
Guardhouse	**13**	**5**	**19**	**47**
Redoubt	**4**		**9**	**9**

The focus of theft is definitely laid to the metal elements of fortifications. Beams and other construction elements made from steel are most eligible. Even rusty tin roof was removed to sell as scrap metal (e.g. fort IV Pasin brdo at Sarajevo). Most dramatic is the robber of cast-iron cupolas around 2014. Both at fort Grabovac (Montenegro) and fort II Vratca at Sarajevo an observation cupola has been removed. The second one was located on a site protected by law and listed as a national monument.

Another reason why many fortifications are destroyed or disappeared in the past was the building of hydroelectric power stations mostly along Trebišnjica, Neretva and Drina rivers. More than 20 objects, mainly guardhouses along railway lines and roads, are at the bottom of artificial lakes today. It seems that policy and the police are unable to prevent this loss of substance even if the objects are officially protected. Most of the locals do not show much interest in the former Habsburg fortifications. The prevention of the destruction of fort VIII Petrinja at Trebinje, which was mainly politically motivated, is an exception.

There are still some fortifications that are in a rather good state of preservation (Fig. 7a). Only a very small amount is adopted and used for different purposes (Table 2). Kula Gradonj at Sarajevo was reconstructed and is used as a museum, guardhouse 18 at Mostar is the atelier of an artist, guardhouse Dubrovnik gate at Trebinje is used as office of a speleologist club and former guardhouse Pogača in the same town is converted into an orthodox church. Important is the fact that from each period and from each type of fortification, (local) special types are rather well preserved. The focus should be given to protect and preserve at least these fortifications for the future as they are historic, architectural and, technically, cultural monuments. An augmented knowledge about these fortifications would be essential to increase the interest in them both from public authority and locals and could from the base to preserve them. In the best way an increased interest will reduce robber directly and on the other hand will make the fortifications more attractive for possible users. In the end giving the fortifications a new utilization will be the most effective way to preserve them.

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'CONSERVATION RURAL SPACE' – THE CASE OF AGRICULTURAL COOPERATIVE SETTLEMENTS AND OPEN SPACE IN ISRAEL

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ABSTRACT
Progressing development trends threaten the continued existence of open space, natural resources and cultural heritage sites in rural areas. These trends are evident in many countries worldwide, yet they are especially conspicuous and threatening in Israel, a small and densely populated country with limited land resources. Moreover, the present urban-biased development trends pose a threat to the continued existence of Israeli rural cooperative settlements (*Kibbutz* and *Moshav*), which comprise universally unique settlement models and are therefore very highly valued cultural heritage assets. The purpose of this paper is to offer the 'missing link' in creating an integrated planning approach to conservation of rural areas, their settlements and agricultural lands together with open landscapes that have been declared for preservation. Such a framework will utilize the prevailing act of the planning authorities which, at present, rarely develop (or at least stabilize) agricultural heritage assets, most of them vernacular, embedded in open space or natural reserve, or part of a rural landscape which holds historical and cultural values.
Keywords: conservation, cultural heritage complexes, Kibbutz, moshav, open space, rural landscapes.

1 INTRODUCTION

In recent years, rural areas, namely, agricultural settlements and cultivated land, are perceived as a part of the overall spatial open space system (Draft National Landscapes Typology [1], Eetvelde & Antrop [2], Fleischman & Feitelson [3], Maruani & Amit-Cohen [4], Melnik [5], Stern [6]). This conception evolved in response to increasing development pressures since the last decades of the 20th century that consumed large tracts of open space and natural landscape resources, while also creating irreversible changes in the rural countryside. The impending loss of open space was further strengthened by low density urban sprawl at the rural fringe. In other words, the progressing development trends threaten heritage values that are embedded in the agricultural zone as well as natural attributes and resources that exist in non-agricultural open landscapes with their ecological, environmental and social amenities (Alanen & Melnick [7], Kaplan et al. [8]).

While the trends described above characterize, in varying rates, developed and developing countries worldwide, in Israel they are particularly conspicuous for two main reasons. First, Israel experienced an intense demographic change in the 1990s, due to mass immigration from the former Soviet Union. This, coupled with an exceptionally high natural growth rate, lead to increased demand for development, primarily for housing and employment purposes, thus aggravating the pressure on open space and agricultural land. Moreover, given the limited land resources in a small country like Israel, the conflict and competition for land between various land uses are further intensified.

Second, Israel has a unique structure of rural settlements, especially cooperative settlement types such as kibbutzim and moshavim (singular – Kibbutz and Moshav), which together make just above 80% of total rural settlements. The Kibbutz is based originally on communal property, in which members have no private property but share the work and the profits of some collective enterprise, agricultural as well as industrial. Although this system

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has undergone some changes towards privatization, the ownership of the properties remains communal and profits are shared equally, or by seniority – years of being a member of the Kibbutz. The moshav is based on family households operating their farms and personal property individually. It is characterized by equal allocation of land and means of production. Size and structure of farms are determined by natural conditions and income potential. Holdings include a built-up plot and agricultural plots that are legally inseparable. The multi-purpose cooperative organization was originally supposed to handle joint purchasing and marketing, to underwrite individual loans, to provide assistance in times of crisis and to run municipal affairs. This is not the case today.

These types of settlement are distinguished by their ideological, social and structural characteristics, and are tangibly expressed in their spatial organization and built assets (Amit-Cohen [9, 10], Feinmesser [11], Kahana [12], Kliot [13]). Their significance for cultural heritage both in discrete tangible assets such as public facilities, agricultural structures, tree avenues, groves and also in their overall spatial organization reflect a unique combination of principles, values and lifestyle characteristics (Applebaum and Sofer [14]). Such unique cultural heritage entities based on historical association of settling the land deserve special attention and ought to be considered for conservation in the face of progressing development.

Planners and preservationists may successfully work together in urban areas, mainly in the conservation of historic neighbourhoods, as long as the two groups encourage solutions that present balance between the old and the new. Thus, a neighbourhood's historical values must be weight against: (a) economic development needs and associated land use changes, and (b) the preference of both current population and intended residents (McCabe and Gould Ellen [15]). Such cooperation does not always exist in the case of cultural heritage properties that are embedded in open areas, which were designated for preservation mainly because of their natural characteristics. In these cases, while conservation of nature and natural landscapes have already become customary over the last decades through various approaches and methods (Maruani and Amit-Cohen [4]) – approaches to the conservation of cultural heritage as part of the open space are still evolving.

The conservation of cultural heritage in the rural zone is intertwined with the issues that relate to conservation of open landscapes and natural resources in general. This linkage may lead to the identification of an integrated fabric distinguished by visual, social, cultural and economic properties that are to be preserved as whole heritage landscape entities. The link between cultural heritage assets and open landscapes has already been recognized in past documents and studies. For example, in 1999, a classification of rural landscapes that was developed in the UK, based on the European Landscape Convention in Florence, 20 October 2000, assigned considerable weight to cultural heritage assets (e.g., settlement patterns, farm types, field patterns, agricultural facilities, rural built heritage). These ideas were in contrast to former approaches that primarily stressed the physical-ecological attributes of the landscape [1]. This classification method was also driven by the UK Countryside Agency's desire to preserve the character of England as a land of rural landscapes. The US National Parks Authority also classified the landscapes where the natural encountered the created cultural landscape, emphasizing both the historical dimension and landscape characteristics (Birnbaum & Asla [16]). This classification was based on the 1992 decision of the UNESCO World Heritage Committee, which added a new definition, 'Cultural Landscape', to its document from 1972 (Charter of the World Cultural and Natural Heritage [17]). According to this, cultural landscape relates to cultural sites that represent the integration of natural landscapes and human cultural creation. It also expresses the concept that natural landscape serves as the background and inspiration for cultural creation. Cultural landscapes reflect the evolvement of human society and settlement over time and the manner in which these are affected by the physical environment (Birnbaum [18]). The term ‘cultural landscape’ is not new to research. In 1925, the geographer Carl Sauer explained that spatial observation is based on recognizing the integration of physical and cultural foundations of the landscape. Thus, nature does not create culture, but instead, culture works with and on nature [19]. However, the 1992 decision to include cultural assets of exceptional universal value in the world heritage list endowed them with a new status and encouraged to protect them.

Conservation of natural and cultural heritage landscapes contributes to the quality of life and is currently perceived as an indispensable part of sustainable development (Stephenson [20]). However, while conservation of nature and natural landscapes have already become customary over the last decades – through various approaches and methods [4] – approaches to the conservation of cultural heritage are still evolving. Moreover, natural and cultural heritage are rarely considered together, even when both are closely linked within certain landscapes and could be conceptualized as inseparable. These are also managed separately, often based upon separate legislations and institutional structures (Speed et al. [21]). In addition, even in cases where planning addresses both natural and cultural heritage in a given area, heritage assets are treated as individual items within the open landscape (Agnoletti [22]), thus disregarding the potential synergistically increased value of the heritage landscape fabric. Moreover, natural and cultural landscapes involve such common values as continuity, stability or aesthetics, and are perceived as important factors contributing to both the quality of life and the creation of an environmental experience. Similar functions, representative rather than economic, have contributed to the rising demand for natural and cultural landscapes. Open space containing cultural heritage assets or adjoining a heritage complex such as rural texture, fields and orchards, an industrial site alongside a mine and an agricultural school, further reinforce this argument. Both of these serve as a ‘romantic’ object for the urban society – a mass society in which the individual has lost his identity, and pines for ‘other landscapes’. The contribution of this continuum is not merely social but also synergetic, an expansion that stresses the public importance of the landscapes and facilitates their planning, management and protection (Antrop [23, 24]).

2 RESEARCH OBJECTIVES AND METHODOLOGY

The purpose of this paper is to present the ‘missing link’ in creating an integrated planning approach to conservation of rural areas, its settlements and agricultural lands together with open landscapes, which were declared for preservation because of their ecological and social values (natural reserves and open space for recreation, tourism and public uses). This approach is a challenge to planning systems, which need a guiding framework for integrated conservation. Such a framework will utilize the work of the planning authorities, which, until now, are divided into two separate systems: the natural planning authorities and the cultural heritage authorities. To present this approach and to prove the missing planning framework for integrated plans in cases of heritage landscape fabrics in the rural zone, this research included three stages: 1. A review of the national and district statutory outline plans in Israel in order to identify and document the manner in which they treat and relate to open space resources and cultural heritage properties. 2. A field survey in order to document tangible cultural heritage (existing built assets, agricultural fields, groves, settlement lay out, etc.) of each Kibbutz and Moshav, describe their physical condition and location, note their former and present function and identify their linkage to events representing national and local memory. This stage included classification of the assets and identification of their spatial distribution in relation to designated open space resources as marked in the national and district statutory outline plans. 3. Compilation and mapping of the information of the first two stages, using a GIS system. The understandings and insights gained by this methodology were served to draw the target product of the research, which was used to present a guiding framework for integrated conservation of heritage landscape fabrics. To describe the need for special planning system for integrated landscape in rural area, a region was selected in the rural space of the Central Coastal Plain of Israel. This area is located within the jurisdiction of two regional councils, The Lev HaSharon and Emek Hefer regional councils (Fig. 1). This area is essentially rural, with many kibbutzim and moshavim that are representative of the

Figure 1: The Central Coastal Plain of Israel and the two regional councils.

cooperative settlement models which are unique to Israel, and are therefore of a special value for conservation. This rural zone is naturally characterized by an abundance of open space landscapes – agricultural cultivated land, rural land (not cultivated) and natural landscape. Moreover, these two regional councils are located at the northern section of the rural-urban fringe of the Tel Aviv metropolitan area.

3 COOPERATIVE RURAL SETTLEMENT IN ISRAEL

As this article is being written, the Kibbutz Movement has already celebrated the 100th anniversary of the founding of the first Kibbutz (Degania 1909), while the moshavim are preparing their festivities to celebrate the founding of the first moshav, Nahalal (1921). Both these settlement types represent a unique form of settlement, combining social values of equality, cooperation and mutual aid with economic accomplishments in agriculture and industry. They are organized as a legal cooperative society, and incorporate several unique structural principles – both ideological and practical. Notable among these is the principle of state-owned land, which stipulates that the land will not be sold but leased for renewable periods of 49 years to the members of the cooperative. These sought to create scale economies for the member farmers (in the case of the moshav) and the community (in the case of the Kibbutz) by handling joint purchasing and marketing, underwriting individual loans (in the case of the moshav), providing mutual aid and running the municipal affairs of the community.

The uniqueness of these two settlement forms, the moshav and the Kibbutz, is tangibly expressed in their physical layout (Kliot [13]). The ideological distinction between them, as expressed primarily in respect to cooperation, is stressed even further in the physical layout of each. For example, the demarcation and separation between the family farming sections in the moshav is the result of the location of farm fields adjoining the family homes. Usually, the layout of the houses within the space, commonly referred to as the 'towel' moshavim, which are stretched along axes, or the centralized 'fist' moshavim, characterized by separation between the residential unit and the farming plot, with central public areas, differing from the Kibbutz layout. The latter is characterized by zoning, division of its area into 'spaces': residential space, economic space, public space, education space, agricultural space and green space (Feinmesser [11]). Due to its deserved distinction and its historical and cultural values, a cooperative settlement is entitled to a cultural heritage status: a space whose built textures, layout and fields constitute a single landscape unit worthy of conservation for the generations to come, and thus the development within it or in its proximity must take this distinction into account.

The last three decades have witnessed extensive changes in the cooperative settlements in Israel, in ideological concepts, physical, organizational and economic structure and in their social composition. For example, they have witnessed occupational changes (Palgi and Reinharz [25]) and a continuous decline in the number of families whose principal income is from agriculture [14]. The variety of occupations among residents within the rural space has expanded while economic cooperation between residents of the rural settlements and entrepreneurs residing elsewhere is on the rise.

There have also been demographic changes. Rural settlements in their various forms have opened up to new residents as part of community expansions, and thus, they began to undergo organizational, economic and physical changes; this development has recently been accelerated in the kibbutzim (Charney and Palgi [26]), Yearly Book of Kibbutz Movement [27]).

In recent years, changes in the rural settlement from occupational-economic, physical and social standpoints have been examined extensively. In addition to these studies, there is an intensified interest in the implications these changes bring to bear on the status of cultural heritage assets among the residents [9]. These studies, however, just as the planning, lack an integrative examination of the frequent confrontation between open space, which was legally designated by the planning authorities, and rural space in the limited sense of built texture and adjacent agricultural areas, whose distinction justifies their definition as cooperative settlement heritage landscapes.

4 PLANNING IN ISRAEL: ATTITUDE TO POSSIBLE LINK BETWEEN CULTURAL HERITAGE AND OPEN SPACE

The planning authorities in Israel function on three levels: national, regional and local. National planning is based on Israel Master Plans (also called Israel National Outline Plans – INOP), which serve as an outline for long-range planning and policy. These plans are guiding proposals, and once they are statutory, the government's budget must follow their outlines. Regional and local planning is based on planning regulation. Israel is divided into six districts and the district outline plans (DOP) represent decisions that are accepted at the district level. Local planning represents planning decisions taken by local governments: city councils, local councils (small municipality) and regional councils (a group of communities often of a rural nature).

Over the years, several national and DOP present in Israel were not restricted to merely proclaiming a cultural heritage item or an open space or nature reserve, but related in some manner to the entire heritage complex and possible encounters between cultural heritage and quality open spaces. Following is a review of these plans, citations and attitude to the encounters between heritage complexes and open space, since these are the objects of this article.

The first attempt to create a unique national plan for the preservation of cultural heritage assets in Israel was the 1969 National Outline Plan for Preservation Cultural Heritage (NOP 9 [28]). This plan showed a preference for settlement sites of historical importance, and did not relate to open space or heritage complexes. The plan mentioned the layout of the first *Moshav* in Israel (Nahalal) and the first *Kibbutz* (Degania), together with their agricultural fields, but there was no mention whatsoever of open space or nature reserves which were adjacent to them.

The National Outline Plan for National Parks, NOP 8, 1981 [29] was intended to consolidate areas designated as national parks or landscape preserves. Since the plan was not intended to deal with cultural heritage, it merely noted the possibility of an encounter between cultural heritage properties and open space in the definition of national parks.

The National Outline Plan for Tourism and Leisure, NOP 12 (1983/1989) [30], defined tourism regions as 'including areas of tourism quality due to their nature, landscape and historical assets, among others'. This plan included, within the rural sites, fields and orchards, as well as nature reserves adjoining built textures. In other words, the attitude of the plan represents an approach suggesting the existence of heritage complexes and the possible linkage between these and open spaces.

NOP 31 – Combined National Outline Plan for Construction, Development and Immigrant Absorption 1998, was created in response to the need to cope with the large immigration waves of the early 1990s and the consequent development momentum [31]. The plan called to protect open spaces and was the first outline plan that also designated these as 'open rural landscapes'. Eventually, this designation contributed to an inclusive approach presented in the National Outline Plan for Construction, Development and Preservation, NOP 35, 2005 [32], which is the main Israel's NOP at present.

NOP 35 stressed the social, cultural and environmental importance of open spaces, while, at the same time, presenting the necessary balance between areas slated for development and areas slated for preservation. In seeking to present the 'image of the land (of Israel)', the plan considered the open spaces to be not only as nature and ecology, but also their contribution in reflecting culture and historical social processes. The plan divided the Israeli space into five textures, one of them being rural texture, which included 'areas of occupation, agricultural areas and tourism areas'. The plan mentioned the importance of continuum of open and agricultural spaces and titled it combined landscape, which unites the values of nature and agriculture landscape. It also stated that the aim is to preserve the ecological and cultural values of these continuous areas but did not include an exact definition or any management plans.

The approach for bringing together open spaces and cultural properties has also been presented in recent years in the district and specific outline plans. Such are the Central District Outline Plans, which, relating to rivers, detailed the historical assets scattered along their banks (CDOP, 21/3 2003 [33] and Outline Plan for Alexander Stream, 27/3 2005 [34]).

Altogether, the plans mentioned above lack a mode of examination and characterization of the continuum between the rural heritage landscape, built textures, agriculture lands and the open spaces in this region.

5 PLANNING, CULTURAL PROPERTIES AND OPEN SPACE IN THE STUDY AREA

5.1 Planning

Analysing NOPs and DOP showed that, notwithstanding the expanding discussion of the landscape-cultural uniqueness of Israeli space as well as attempts to define these landscapes, there is a lack of a plan, which focuses on the cultural heritage of the rural space. To wit, not much attention has been given to the importance of cultural heritage assets located in the cooperative settlements, and to the synergetic contribution observed when a continuum exists between the heritage complexes, built texture, tilled fields and the open space, whose importance has been stressed in the various outline plans.

In the study area, the Lev HaSharon and Emek Hefer regional councils encompass open space of considerable preservation value from the standpoint of national as well as regional planning (NOP 31). These areas are perceived to be a link in the national 'spinal column' of open space in Israel. This link is also important for maintaining open space between the metropolitan areas in the Central Coastal Plain of Israel.

According to several National Outline Plans (NOPs' 8, 31 and 35), eight protected open spaces were declared in the study area, most of these as national parks. Only five areas were designated as nature reserves. This small number is due to the extensive agricultural activity in the area, primarily citrus orchards planted from the 1920s onward. The largest concentration of citrus plantations led the planners of NOP 35 to believe that the Sharon citrus orchards and the rural settlements were among the most important historical elements of Israel in the past 100 years. Their concern about its disappearance led to a decision to 'mark' and place them under the definition of 'a rural landscape complex' worthy of preservation.

District and Local Outline Plans of the two regional councils in general are not aimed at identification and protection of the 'Image of the Land' as stressed in the National Outline Plan (NOP 35). The district plans are partial and their treatment of unique landscapes, textures or assets of prominent design or historical value is very general, lacking direction, details and the means for their protection. The emphasis in these plans is mostly on streams and their rehabilitation (the Central District Outline Plan, CDOP 21/3 2003 [33], the Outline Plan for the Alexander Stream [34] and the Outline Plan for the Poleg Park and Stream, 2009 [35]). The two streams and their drainage basin dominate the landscape of the region and the plans state the importance of a survey of natural landscape and the area of the streams and their tributaries as a contiguous open space system.

Altogether, the plans mentioned above lack a mode of examination and characterization of the continuum between the rural heritage landscape, built textures, agriculture lands and the open spaces in this region.

5.2 Rural heritage complexes of cooperative settlements in the study area

Altogether, among the 51 settlements in the two regional councils, more than 78% of them have more than 11 cultural heritage sites within their territory. About 22% are located within the open areas: the farmland (fields and plantations), along the streams' banks and agricultural roads. The total number of cultural heritage sites in both regional councils are 1,172. Within the kibbutzim borders, in the built-up area and the fields, there are 537 assets, averaging 59 assets per Kibbutz. Among these properties, those related to agricultural structures and public services are the most prominent. Within the moshavim borders, there are 635 properties, averaging 15 properties per moshav. The number of properties related to agricultural structures and residential property, those representing unique style, are the highest in numbers.

The vernacular assets are scattered throughout the settlement texture – built areas and fields – in three forms: cluster, axis and solitary items. In the moshavim, it is possible to identify a heritage cluster encompassing public buildings and agricultural services in the centre of the moshav (water tower, silo, agricultural sheds, cold storage warehouse, synagogue, grocery, community centre). Found also are memorial sites, a memorial park or monuments, located usually at the centre of the moshav or at the edge of the built area.

Identifiable in the kibbutzim are groups of heritage assets in two areas. First, the production area, otherwise known as the yard, is usually located close to the Kibbutz entrance. It contains agricultural structures, many of which have lost their original designation, such as a water tower, silo, barn, poultry houses, bakery, garage, carpentry shop, shoemaking shop and the secretariat, the latter located at the edges of the yard, adjoining the public space. Second, the public space, the heart of the Kibbutz, which includes the dining room, central lawn, kindergartens and children's houses (where in the past, children lived separately from their parents), cultural centre, memorial centre and memorial park and the residential area. School classrooms are usually located at the edge of the public area, adjoining the residential area, or as a separate education area located between the residential area and the production area. At times, sports facilities are also located in this area.

Identifiable alongside the heritage asset clusters are the 'tangible heritage avenues'. These are the tree alleys at the entrances to the moshavim and kibbutzim, the sidewalks in the Kibbutz and historical roads, security roads and trenches for defence purposes. Included are items of some physical prominence (architectural, construction material and construction technology), a tree or a bush related to some event or a person who is part of the local history (local memory) of the Kibbutz or moshav or is connected to national events (national memory) (Amit-Cohen [10]). In the Kibbutz, such properties are located within the various spaces, while in the moshav, within the built area or in the agricultural space. These can be a guard post, hidden armament store, a solitary tree, bridge, etc.

Within the agricultural areas, in the two regional councils are ‘spots’ of citrus orchards that once covered the entire red hills (red sandy clay loam), area typical of the central coastal region of Israel. A few of these spots represent a relic of an old Arab orchard house, as well as the family-house and the packing house from the mid-19th century until the 1920s, while others are typical of the Zionist settlement process in the Sharon area. The latter include remnants of private agricultural activity in the Sharon region in the 1920s and 1930s. A combination of a shortage of water, residential pressure on the land and reduced profitability of citriculture led to the uprooting of a considerable portion of the orchards. Yet, it is still possible to identify components related to this vanished landscape: avenues of trees, primarily cypress that separated the groves and served as windbreakers, packing houses, pools and water well structures. These components remained in the landscape as clusters, avenues or solitary items.

The above vernacular cultural heritage properties were classified into seven groups (An example of a specific group of widespread assets, related to supply of water to agriculture and residential purposes is shown in Fig. 2):

1. Water structures (water tower, water reservoir and well)
2. Agriculture structures (silo, cooling structures, chicken coops, dairy barn, etc.)
3. Residential properties (the ‘first’ building, wooden sheds, the children’s houses)
4. Public services (library, schools, kindergarten, dining hall, cultural hall)
5. Green space, gardens (the central lawn, memorial garden, the historical grove)
6. Defence infrastructures (secret hiding place for weapons, watchtower)
7. Memorial sites (cemeteries, memorial hall)

Within these two regional councils, five heritage complexes were observed (Fig. 3). All the complexes include cooperative settlements, built and vegetative cultural heritage assets within the settlement textures and in the agricultural fields. Four complexes were characterized by a high concentration of assets linked to the history of the kibbutzim and the moshavim. The fifth complex also includes, in addition to the settlements’ assets, various remains within the landscape – antiquities and structures dating from ancient times. All complexes contain many vernacular assets and their distribution within each settlement shows a high degree of similarity. Notwithstanding the landscape ‘uniformity’, the unique characteristics of each complex can be identified.

5.3 Open space and nature reserves in the study area

Most of the area encompassed by the two regional councils examined in this study consists of open space. It contains few natural reserves recognized in NOP 35 as being worthy of preservation due to their quality and ecological sensitivity. These natural reserves are few and of limited extent. On the other hand, the rural fabric, built-up area and agricultural lands dot this open space with moshavim and kibbutzim being the most predominant. While the open space and agricultural lands were recognized as a continuum landscape and were defined as rural open space, the rural built complex was not included. The land cover of the study area can best be described as a patchwork with open spaces in many of the moshavim and kibbutzim, various forms of land use, heritage assets and small protected areas. While on the face of it, moshavim, kibbutzim and heritage assets are scattered within them, they actually interrupt the open space continuum.

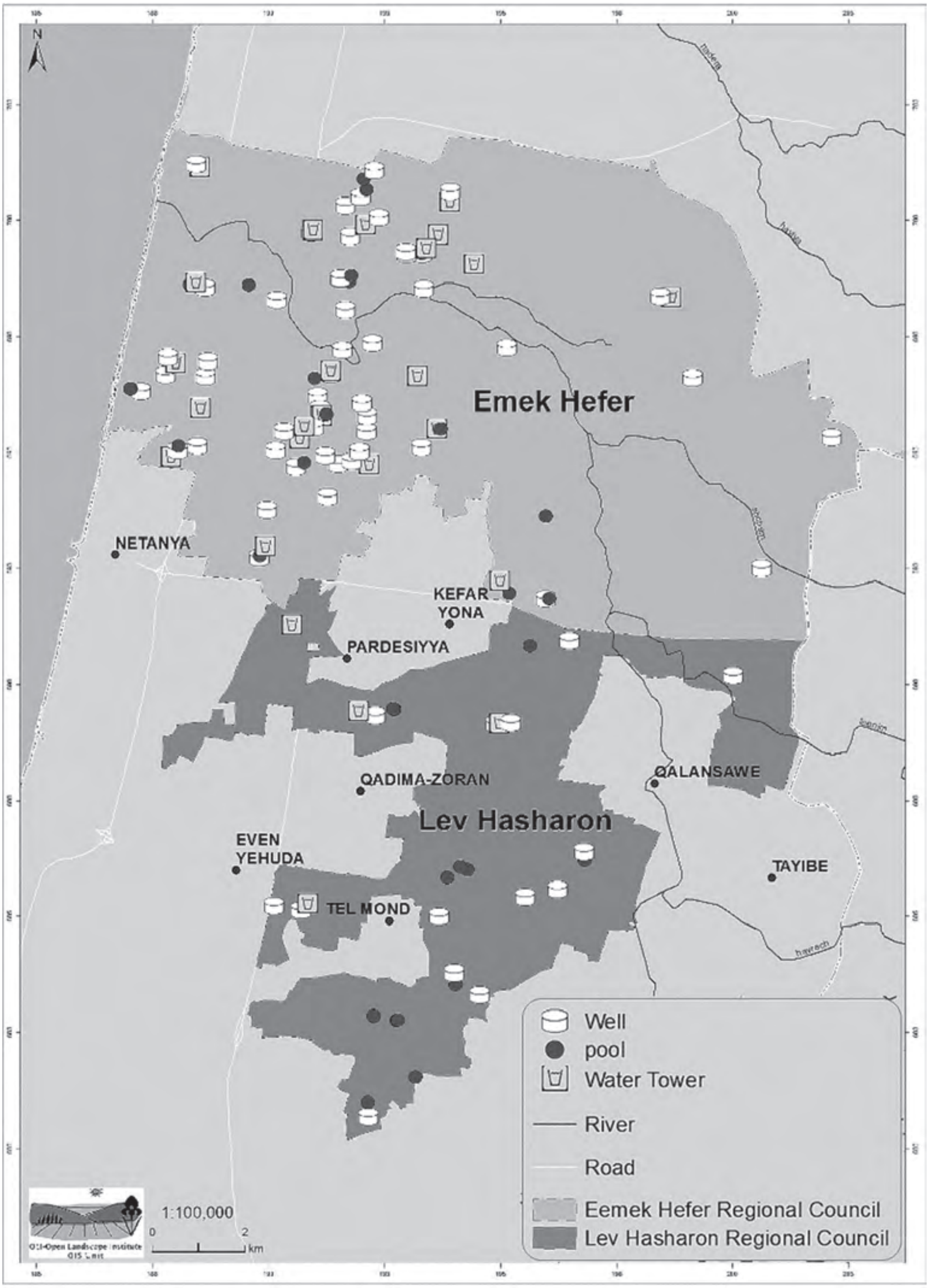

Figure 2: Water structures.

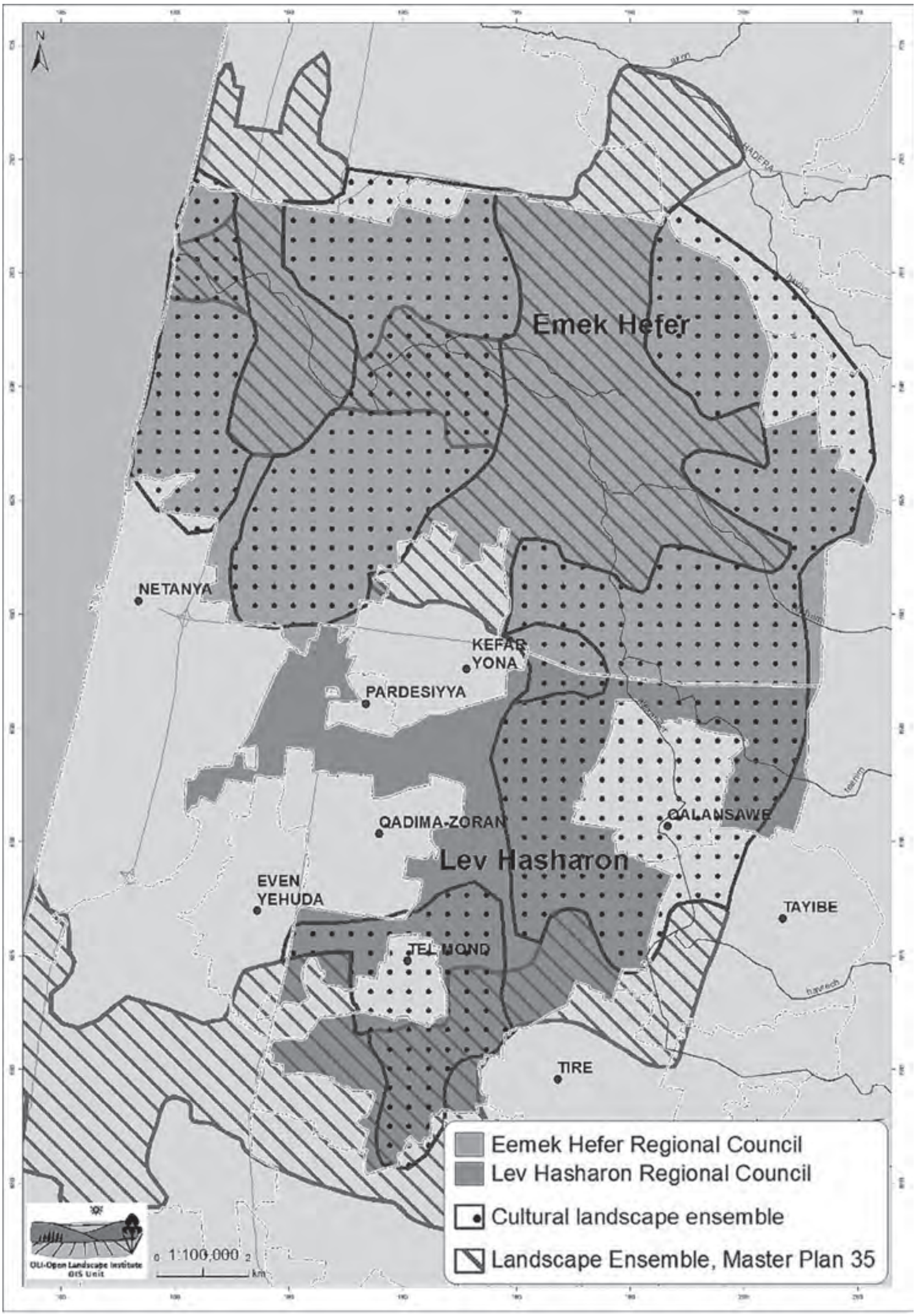

Figure 3: Heritage complexes within these two regional councils.

6 CONCLUSION

Israel, like other countries, promotes local or universal recognition of cultural heritage assets, cultural landscapes and landscape complexes worthy of preservation, including rural complexes (NOP 35). However, unlike other countries, the rural complexes in Israel present a unique manifestation not observed in other countries, the cooperative settlement complex, the kibbutzim and moshavim. This complex not only expresses a functional interdependence between its land designations, but also a settlement ideology displayed in two dimensions: the textural dimension – the settlement outline and its internal division for land use, as well as a point by point dimension – heritage assets ensconced within the settlement texture, in the built areas as well as in the fields.

Heritage assets of the cooperative settlements in Israel are a common manifestation reflecting folk architecture and common crafts. Yet it is precisely this common incidence that expresses its uniqueness. At present, the survival of these cultural complexes is threatened by economic, social and ideological developments, bearing implications on the planning structure of the moshavim and kibbutzim and the cultural heritage assets within them. Recognition of the importance of these complexes would bestow upon them the status of cultural heritage and thus, include them in the list of assets worthy of preservation. Because of development needs, the planning authorities are not favourably predisposed to declare the cooperative settlement heritage complex, covering a substantial land area, as deserving preservation. However, an additional examination of the relationship of these complexes to open space could change this situation. The national and DOP published in Israel in the past two decades refer extensively to open space as well as to agricultural land. And yet, although these plans linked the agricultural areas to open space, they did not express the uniqueness of cooperative settlements nor recognize it as part of a unique continuous complex within the mosaic of Israeli rural landscape. As such, this continuum should be recognized as rural conservation space.

As shown in Fig. 3, the recognition of agricultural areas as part of the open space and part of the Kibbutz or moshav heritage complex actually creates continuous unique landscape units due to the encounter within them between open space and the cooperative settlement complexes, cultural built heritage and agricultural lands. This continuum covers more than 80% of the area of the two regional councils, in the form of a crescent with its two ends in the coastal plain and surrounding the built texture of the city of Netanya and its suburbs. Within this continuum are heritage complexes of the cooperative settlements, including the built texture, the agricultural areas and the heritage assets, representing the local and national memory. Since these complexes overlap the defined municipal borders of each moshav or Kibbutz, they could also be referred to as heritage villages or focal points of rural heritage while also distinguishing between the moshav tangible heritage and the Kibbutz tangible heritage.

This situation, however, is threatened by real estate development pressure from the urban textures, as well as by the opening of the kibbutzim and moshavim to new populations moving into newly created adjoining 'expansion' and 'community' quarters.

Since the planning bodies and the new populations seeking to develop extensive areas within the space of the regional councils are often unaware of the importance of the values that are part of both local and national values, their attitude to the heritage assets expressing these values depends on their landscape and design prominence. Since most of these properties are vernacular, their value is not sufficiently recognized, while their importance even less so. Compared with the low awareness of the historical or design value, there is considerable awareness of the importance of open space, due to its perception as 'alternate landscapes' compared with urban landscapes and the growing demand for quality of life. This situation encourages emphasis on continuums containing open space and settlement space entitled to conservation – and in the case of the present study, the conservation of rural space, cooperative settlements and open spaces. Defining these continuums endows this entire manifestation with synergetic qualities leading to several recommendations:

1. The various planning procedures should properly address the linkage between quality open space declared in the national and district plans as worthy of a high degree of preservation and cooperative settlement heritage complexes – the built environment, the landscape agriculture within the surrounding agricultural layout and assets that, due to their unique value, are worthy of preservation. Such linkage could encourage preparation of local plans that integrate the preservation and development programs promoted by some of the settlements with the local plans promoted by the regional councils themselves.
2. Comprehensive planning relating to a continuous preservation space can minimize development in open spaces, such as economic development in a built heritage asset, packing house or a remnant of an Arab house in the midst of an open space. Preservation of such assets and the experience of developing these to realize their economic development potential can cause harm to open space of high ecological sensitivity. Such assets deserve to be stabilized and preserved, and are under continuous supervision and examination of their physical condition, but without any attempt to imbue them with any economic content whatsoever. The presence of these assets contributes to the landscape and cultural character of open spaces and is worthy of being viewed as a 'memory reserve' within the open space. The development may be directed to heritage assets within the built texture of the heritage complex of a moshav or Kibbutz. Thus, for example, assets such as a silo, water tower, farm buildings and public buildings located within the built texture of the moshav and Kibbutz, which are owned by the cooperative society, can be rehabilitated by using their value potential (ability to express their historical values and settlement's ideology) as well as their inherent economic potential (size and location). The fact that they are owned by the cooperative society simplifies the decision making process and increases the likelihood of broad consent regarding their preservation and development.
3. The likelihood of overall planning devoted to 'preservation space' is high, precisely because of the multitude of public bodies involved therein: national and district planning authorities, regional councils and local committees. In the case of heritage complexes within a Kibbutz or moshav, since these also constitute heritage assets representing the local memory of each and every such settlement, it is also highly possible that the population of these settlements will also become involved in this process. The fact that so many are involved in the process removes economic and/or social concerns and facilitates the decision to join in its realization.

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ANALYSIS OF ANCIENT VENTILATION AND ILLUMINATION PRACTICES IN ANATOLIAN SELJUK AND OTTOMAN HOSPITALS AND SUGGESTIONS FOR THEIR CONSERVATION MEASURES

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ABSTRACT

As one of the necessities of humanity, ventilation is closely linked to the heating and illumination of spaces, and spaces such as in hospitals were among the first to need appropriately clean air for the health conditions of both patients and workers. In the different regions of Anatolia, many historic hospitals were built during the Seljuk and Ottoman periods. The primary function of those buildings was to take care of patients, yet in time they needed to care for themselves: so much so that only eleven of them are intact today, and just one continues to be used for its original function. Hence, this article presents the key ventilation and illumination practices applied over the centuries in those existing hospitals located in different regions of Anatolia and built during the 13th and 18th centuries; it also shows their influence on the architecture of the buildings in order to raise awareness of these issues in respect of their conservation. The study examines foundation archives and literature on the historic hospitals, including in situ observations, with a special focus on their ancient ventilation and illumination practices. The analysis reveals the similarities in and differences between these practices in the Seljuk and Ottoman periods. In addition, it assesses the potential conservation measures of these ancient passive survivability means used in Anatolian historic hospitals. The major conclusion of the study is that ancient ventilation and illumination practices may provide for the sustainability of historic hospitals in the long term and may, with the correct conservation solutions, contribute to their longevity.

Keywords: Anatolia, conservation, functional systems, historic hospitals, illumination, Seljuk and Ottoman period, ventilation.

1 INTRODUCTION

In the Seljuk and Ottoman periods in Anatolia, there were many hospitals providing services to both inpatients and outpatients every day, with a considerable labour force, as clearly indicated in their endowment deeds. In those health institutions, the patients were treated without any fee for either health services or food and medicine [1–3]. Against this general background, this study examines aspects of the functional system of the Anatolian Seljuk and Ottoman period hospitals' history as one important perspective. Among those system aspects, it focuses on ventilation and illumination practices, as inevitable parts of health conditions, in order to explore the relationship between those systems and the architecture of the building itself. The network of functional systems, such as heating, refrigeration, drainage, ventilation and illumination, which are somehow connected to the building entity and to the urban planning in larger contexts, were hardly superficial; rather, they played a significant role in the longevity of the building itself, as well as in the services performed in it. Thus, the patients and workers of the hospitals, who in fact were unaware of those systems, were those mostly affected by the poor or high quality of ventilation and illumination of spaces inside the hospitals.

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2 BACKGROUND OF CASE STUDY AND THE MAIN EMPIRICAL EVIDENCE

In the early 1980s, John F. Fithchen III reported common problems of ventilation through the ages. He wrote that 'problems of illumination, warming and smoke elimination in cold climates, cooling and air circulation in hot climates, of humidification, and maintaining the integrity and longevity of the structure itself were vitally affected by ventilation' [4]. Almost all of those problems were also valid for the historic hospitals of Anatolia. Yet, few scholars either today or in the past have been sufficiently interested to record the ventilation and illumination practices of the historic buildings of Anatolia, let alone of the hospitals [2, 3, 5–8]. Hence, the notes on those practices applied in the case of Anatolian Seljuk and Ottoman period hospitals, and presented in the following pages, are mostly the result of the author's field works from 2010 to 2014 or of historic records including endowment deeds and texts on previous interventions. Although the hospitals have undergone many alterations over the centuries, resulting in the destruction of some details, ventilation and illumination could still be identified to some extent.

2.1 Illumination systems in historic hospitals of Anatolia

In historic hospitals, both natural and artificial illumination elements were observable. Sun was the primary illumination source in the daytime. Natural illumination was provided by ceiling holes/vents/windows with varying dimensions, forms and numbers and by windows at different levels during the day. According to archival sources, such as the *waqf* deeds of the hospitals, it is understood that oil lamps, candles, torches and similar artificial illumination sources were used during the nights and early mornings. For instance, there are small niches in the walls of the rooms in historic hospitals, which might have been designed to hold candlesticks or oil lamps. Such details are also observable in historic Turkish baths. Bathing scenes in miniatures and research studies clearly exhibit hung oil lamps, or niches for candlesticks recessed in the walls above the basins, or a form of cantilevered projections [7]. As an instance, in Divriği Melike Turan Hospital, the cantilevered projection at the end of the stairs towards the first floor was interpreted as being used for artificial lighting elements [3, 9]. Similarly, in the bath section of Atik Valide Hospital, in the walls of the caldarium section above the basins, there are niches that might have been used for artificial lighting (Fig. 1). Although there are

Figure 1: Wall niches above the basins in the caldarium of the bath section in Atik Valide Hospital (photo: author's archives, 2011).

no traces in the historic hospitals, in some other historic buildings, such as Doğu Beyazıt, İshak Pasa Place, located on the tops of wall niches designed for the placement of candles or candlesticks, there are circular ventilation holes to emit the smoke (Fig. 2) [3]. In the baths and toilets of the hospitals, specially shaped ceiling openings, made of terracotta pipes with glass tops arranged above the brick bonds of the domes/vaults, called oculi (light holes), were another illumination detail, reminiscent of the light-collecting glass application of today's technology (Fig. 3) [2, 10].

In the case study of Ottoman period hospitals, narrow, long windows with frequent intervals, expanded to the whole facade, provided illumination of the whole interior space into the

Figure 2: A niche (left) and its ventilation hole (right) on one of the walls in Ishak Pasa Palace, used for candles (photo: author's archives, 2011).

Figure 3: Oculi (light holes) on the vaults/domes of the bath section in Süleymaniye Hospital (left) (photo: archives of Fatma Usluer, 2011) and the light-collecting glass application of today's technology (right) [10].

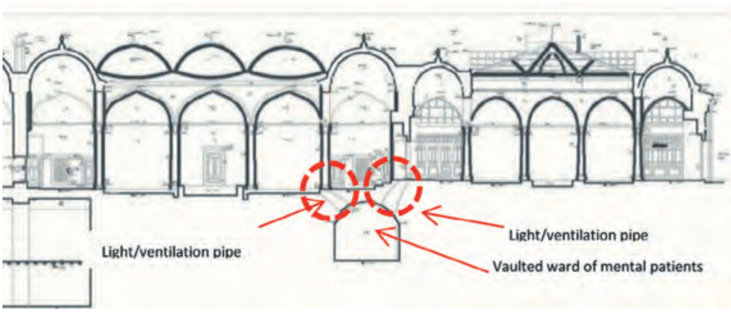


Figure 4: Süleymaniye Hospital light/ventilation pipe detail on the vault of the mental patients' ward (left) (source: drawing archives of Directorate General of Foundations, 2016) and contemporary light pipe detail (right) [10].

deepest areas. In addition, there are windows located at different levels of the facade in order to increase the amount of natural lighting.

2.2 Ventilation systems in historic hospitals of Anatolia

In the Ottoman period, hospitals, fireplaces and their chimneys were used not only to heat the space on winter days but also to ventilate the space on hot summer days. Thus, besides doors and windows, the fireplace chimneys were alternative ventilation elements [2, 3, 5, 11]. In the Seljuk period, however, as there were no chimneys and fireplaces, the ceiling holes of the vaults, as well as doors and windows, were the primary means of ventilation and illumination [5]. For instance, in Kayseri Gevher Nesibe Hospital and Madrasah and in Amasya, Anber Bin Abdullah Hospital, there are ceiling holes located at certain intervals on the vaults of the rooms. Considering their small dimensions, small splayed openings (dimensions: 0.30 m × 0.95 m) on the walls of Amasya Anber Bin Abdullah Hospital were also used for ventilation [12]. In hospitals, which have separate baths, *tüteklik*/vertical ventilation pipes located inside the walls and lying along the hypocaust section up to the roof level provided for the emission of excess smoke. In Edirne Beyazıt II Hospital, the central space and the summer rooms opening onto it were ventilated by means of a ventilation lantern in the middle of the dome covering the central space. In the winter rooms, on the other hand, the fireplace chimneys, as well as windows, were the main ventilation elements. In Süleymaniye Hospital, another ventilation/illumination detail was observable in the mental patients' wards. The problem of ventilation/illumination of this vaulted room, located on the basement floor, was solved by six hidden splayed windows, with dimensions of 0.47 m × 0.55 m, and small vents (dimensions: 0.41 m × 0.17 m) opening onto the courtyard [3]. Those small vents can be interpreted as functioning as the light pipes of today's technology, used to allow the light to penetrate and thus illuminate the spaces that lack sunlight [10] (Fig. 4). Open courtyards, semi-open porticos, courtyard fountains, greenery and vegetation were the other ventilation and cooling means in historic hospitals (Tables 1 and 2).

3 ANALYSIS OF KEY POINTS AND IMPLICATIONS FROM THE EMPIRICAL CASE

Tables 3 and 4, compiled mostly from in situ observations and historic analysis, list the possible ventilation and illumination practices of the hospitals and therefore allow some conclusions to be drawn about those practices; these are briefly explained below.

Table 1: Illumination systems/elements in Anatolian Seljuk and Ottoman period hospitals [3].

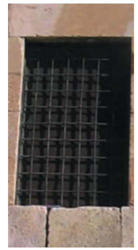
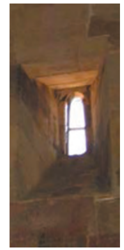
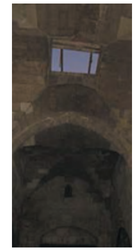
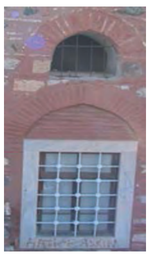
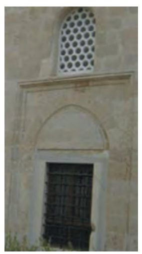
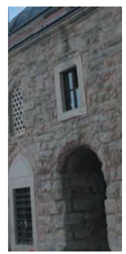
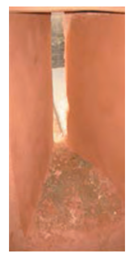
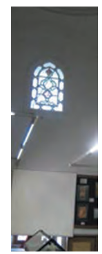
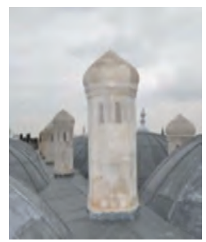
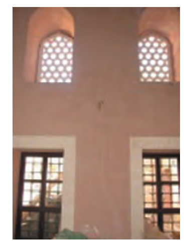
Period	A: First-level windows		B: Top windows				C: Ceiling holes/vents/windows	
	Arched window	Flat window	Arched window	Flat window	Splayed opening	*İçlik/dışlık*	Ceiling hole	Lantern
Anatolian Seljuk period	 Amasya Anber Bin Abdullah Hospital	 Amasya Anber Bin Abdullah Hospital	 Divriği Melike Turan Hospital	 Divriği Melike Turan Hospital	 Divriği Melike Turan Hospital	–	 Sivas, İzzeddin Keykavus I. Hospital	-
Ottoman period	 Manisa Hafsa Sultan Hospital	 Edirne, Bayezid II. Hospital	 Haseki Sultan Hospital	 Süleymaniye Hospital	 Süleymaniye Hospital	 Edirne, Bayezid II. Hospital	 Atik Valide Hospital-bath oculi	 Haseki Hospital

Table 2: Ventilation systems/elements in Anatolian Seljuk and Ottoman period hospitals [3].

Period	Natural ventilation systems/elements						
	Ceiling hole/vent/ window	Lantern	Ventilation holes on the wall surfaces				
			Splayed openings	Chimney		Door	Window
				Tüteklik/vertical pipes inside the walls	Chimney of the wall fireplace		
Anatolian Seljuk period	 Ceiling hole example in Kayseri Gevher Nesibe Hospital and Madrasah	–	 Splayed opening example in Kayseri Gevher Nesibe Hospital and Madrasah	There are no *tüteklik* examples reached up to today in bath sections of historic hospitals.	–	 Amasya Anber Bin Abdullah Hospital archway	 Divriği Melike Turan Hospital window detail
Ottoman period	 Ceiling window in Atik Valide Hospital bath section	 Lantern in Edirne, II. Bayezid Hospital	 Splayed opening in Süleymaniye Hospital	 *Tüteklik* holes in roof level in Atik Valide Hospital	 Chimney of the wall fireplace in Süleymaniye Hospital	 Archway in Manisa Hafsa Sultan Hospital	 First- and second-level windows in Süleymaniye Hospital

– Ventilation in Anatolian Seljuk hospitals was mostly provided by ceiling holes and by windows and doors in varying dimensions and shapes. In the Ottoman period, lanterns and fireplace chimneys were added, as well as doors and windows. For instance, the ceiling holes/vents of the Seljuk period hospitals, such as in Amasya Anber Bin Abdullah Hospital (radius of the vent ≈0.60 m), in Kayseri Gevher Nesibe Hospital (base area of the vents ≈0.40 × 0.30 m, ≈0.30 × 0.20 m, ≈0.40 × 0.40 m) and in Divriği Melike Turan Hospital (radius of the vent ≈0.90 m), have been replaced with the polygonal roof lanterns of the Ottoman period, as in Haseki Hospital (base area of lantern ≈1.50 × 1.50 m and height ≈1.90 m) and in Süleymaniye Hospital above the baker's room (one side ≈0.45 m and height ≈1.52 m). *Tütekliks* (vertical ventilation pipes) were used during both periods in the bath sections of the hospitals. In addition to wall fireplaces and their roof extensions, such as chimneys in the Ottoman period hospitals, an open courtyard plan layout, semi-open spaces, such as *iwans* and waiting lounges, colonnaded porticos, pools and vegetation in the courtyards were the other details affecting the ventilation quality of the spaces in both periods. It is understood that technological developments in ventilation systems of historic hospitals such as an increase in the number and dimensions of window-door openings in spaces, and the addition of ventilation/illumination lanterns and fireplace chimneys, instead of ceiling holes/vents, were directly related to the developments in illumination and heating systems [3].
– The sun was the primary illumination source in the hospitals. After sunset, either the oil lamp or candle was used, in addition to the fire in the fireplaces in winter times. The niches on the wall surfaces of the hospitals and the endowment deeds prove the use of those indirect illumination sources. In the hospitals' baths and toilets, where privacy conditions were provided for, oculi (light holes) and small window dimensions were applied for the illumination of the spaces. In Anatolian Seljuk period hospitals, the small dimensions and limited numbers of windows resulted in dimly lit spaces, whereas in Ottoman period hospitals, with the increase in the number and dimensions of wall openings, more well-lit spaces were observable. A special space used for the preparation of medicines was evident in Kayseri Gevher Nesibe Sultan Hospital. This space, with the minimum illumination – just a door opening – is interpreted as being used for the preparation of medicines sensitive to sunlight [13]. In addition, again in Kayseri Gevher Nesibe Sultan Hospital, in spaces that are thought to have been used for surgery operations, there are only ceiling openings and doors for ventilation and illumination purposes. This arrangement could mean that artificial illumination elements were used during the operations and/or all the operations were conducted during the daytime [3].

As a result of the analysis of the detection of ventilation and illumination systems/elements in the case study hospitals of each period, according to their reliability degrees, it is understood that most of those systems/elements have been determined precisely because of their existence in the building (85% of ventilation systems and 49% of illumination systems) or their existence and traces could be identified from the historic and local service systems observed in the region (40% of illumination systems). The existence and traces of only 1% of ventilation and illumination systems/elements in historic hospitals could be identified from the other examples in the mosque complex, while the existence of 12% could be identified from written, oral or visual sources (Table 3).

Table 3: Results obtained from the analyses of ventilation and illumination systems in Anatolian Seljuk and Ottoman period hospitals.

		Analyses of functional systems according to their reliability			
Type of functional system	Functional system/ element	Those known precisely because of their existence in the building ■	Their existence and traces could be identified from other examples in the mosque complex ▲	Their existence could be identified from written, oral or visual sources ◆	Their existence and traces could be identified from the historic and local service systems observed in the region ●
Ventilation systems	Ceiling holes/vents	■ (5)	0	0	0
	Roof lantern	■ (4)	0	0	0
	Splayed windows/ openings	■ (5)	0	0	0
	Tüteklik (ventilation pipes)	■ (4)	0	◆ (2)	0
	Chimneys	■ (5)	▲ (1)	◆ (2)	0
	Doors	■ (11)	0	◆ (1)	0
	Windows	■ (10)	0	◆ (2)	0
Sub-total		44 (85%)	1 (2%)	7 (13%)	0 (0%)
İllumination systems	Doors	■ (11)	0	◆ (1)	0
	Windows	■ (10)	0	◆ (2)	0
	Ceiling holes/ vents/windows	■ (5)	0	0	0
	Oculi (light holes)	■ (4)	0	0	● (2)
	Roof lantern	■ (4)	0	0	0
	İllumination openings	■ (5)	0	0	0
	Torch	0	0	0	● (12)
	Oil lamp	0	0	◆ (3)	● (9)
	Candle/candlestick	0	0	◆ (3)	● (9)
Sub-total		39 (49%)	0 (0%)	9 (11%)	32 (40%)
Total		83 (63%)	1 (1%)	16 (12%)	(24%)

Table 4: Ventilation and illumination practices applied in Anatolian Seljuk and Ottoman period hospitals [3].

		Ventilation and illumination elements in Anatolian Seljuk and Ottoman period hospitals																																			
	Name of the hospital	Door				Window				Ceiling hole/vent				Oculi (light holes)				Lantern				Chimney of the fireplaces				*Tüteklik* (vertical ventilation pipe)				Oil lamp				Candle			
		□	○	△	◇	□	○	△	◇	□	○	△	◇	□	○	△	◇	□	○	△	◇	□	○	△	◇	□	○	△	◇	□	○	△	◇	□	○	△	◇
1	Gevher Nesibe Hospital and Medicine Madrasah	■				■				■				■												■						■					■
2	I. İzzeddin Keykavus Hospital	■				■				■							■											■					■			■	
3	Melike Turan Hospital	■				■				■																							■				■
4	Anber Bin Abdullah Hospital	■				■				■																							■				■
5	Yıldırım Bayezid Hospital	■				■																■											■				■
6	Fatih Hospital			■				■																■								■					■
7	II. Bayezid Hospital	■				■												■				■										■				■	
8	Hafsa Sultan Hospital	■				■																■											■			■	
9	Haseki Sultan Hospital	■				■											■	■				■						■					■				■
10	Süleymaniye Hospital	■				■								■				■				■				■							■				■
11	Atik Valide Hospital	■				■				■				■									■			■							■				■
12	Sultan I. Ahmed Hospital	■						■						■				■						■		■							■				■
	Sub-total	11	0	1	0	10	0	2	0	5	0	0	0	4	0	0	2	4	0	0	0	5	1	2	0	4	0	2	0	0	0	3	9	0	0	3	9
	Total	12				12				5				6				4				8				6				12				12			

□ Those known precisely because of their existence in the building.
○ Their existence and traces could be identified from other examples in the mosque complex.
△ Their existence could be identified from written, oral or visual sources.
◇ Their existence and traces could be identified from the historic and local service systems observed in the region.

4 ASSESSMENT OF CONSERVATION MEASURES FOR VENTILATION AND İLLUMINATION SYSTEMS/ELEMENTS

A thorough investigation of historic conservation studies and project preparation works conducted by the Directorate General of Foundations and the Ministry of Culture and Tourism – as the chief governmental institutions responsible for conservation studies in Turkey – has clearly shown that rather few conservation measures are defined for the conservation of original functional systems in historic buildings. In addition, both survey and restoration project preparation specifications and also specifications for the implementation of restoration works lack detailed conservation measures and definitions in relation to possible/original functional systems. The Regulations on Energy Performance in Buildings dated 5 December 2008, number 27075, state that [14]:

> The Regulations contain all business and process related to applications and precautions for the increase in energy efficiency in buildings registered as cultural heritage to be preserved without affecting their exterior surface and character defining features, in the view of the Ministry of Culture and Tourism.

Yet, those aforementioned regulations include only general suggestions instead of separate and special applications to be developed for historic buildings. In addition, the 1983 Cultural and Natural Heritage Conservation Act (no: 2863), Article 8, states that 'Conservation Councils shall identify the conservation site of the cultural and natural property to be protected that has been registered according to article seven, and make a decision on whether or not to build and install in this area' [15]. However, detailed mechanical and/or functional system projects have not been submitted to Conservation Councils; instead, restoration projects have been founded without enough critical review. Furthermore, Conservation Councils do not include experts on the analysis and investigation of historic functional systems, let alone on their conservation measures. Upon investigation of the 'Technical Specification on Survey, Restitution, Restoration Projects on Single Building Scale', it is understood that all the duties related to electrical, mechanical and heating systems are entirely designed for contemporary technologies, with no suggestions for either their possible adjustments and applications for historic buildings or the detection and preservation of original systems [16]. Thus, all those regulations, laws and specifications show that new arrangements are necessary for the detection and preservation of original functional systems and for their adjustment to the new technologies. Open courtyards with colonnaded porticos, splayed windows, wooden window shutters, high ceilings, ceiling holes, earthen roofs, ceiling windows and such construction details applied in historic hospitals are important passive survivability means required for the longevity of the buildings. Thus, it is important to increase the awareness of the relevant governmental bodies, university departments and non-governmental organizations in respect of the preservation of the aforementioned details. Hence, primary efforts and measures for the detection and conservation of ventilation and illumination systems/elements in historic hospitals have been determined below:

- In Seljuk period hospitals, on the vaults/rooftops of rooms that have no ventilation opening, except for doors today, possible ceiling openings originally used/designed for ventilation but destroyed in due course should be investigated.
- In bath sections of historic hospitals, research rasps are necessary on the wall surfaces in order to protect the original *tuteklik*/vertical ventilation pipes inside the walls and in order to determine the possible niches and projections closed today that might have been used for holding artificial illumination elements such as candles, candlesticks and oil lamps. It

is also necessary to conduct an archival and historical literature survey to determine the original form and number of ceiling openings in the domes/vaults of bath sections.

– In some Ottoman period hospitals, because of the destruction of wall fireplaces, their roof extensions cannot perform their ventilation function as chimneys. In addition, since the windows are closed most of the time, today ventilation inside the rooms is provided by mechanical means, such as air conditioners and ventilation units installed on the exteriors walls. Therefore reopening those fireplaces and their roof chimneys is important for natural ventilation.
– In hospitals in which original illumination/ventilation system details are still protected, these should be preserved for future generations.

5 CONCLUSIONS

This study reveals a distinct perspective in architecture: the identification and analysis of the ventilation and illumination practices in Anatolian Seljuk and Ottoman period hospitals, previously unidentified and little explored. Hence, the study was an attempt to show that not only the building itself, but also the architectural details and different functional system practices, such as ventilation and illumination in a hospital, could and did play a significant role in both the longevity of the building and the preservation of healthy conditions for the users of those buildings. Those systems did not emerge untouched and unaltered – in some cases they were totally destroyed – yet, in the historic hospitals of Anatolia, those systems had often been the main concerns, which affected the heating, cooking and other daily practices of the time and region. The study showed that sometimes a hole in the ceiling or on the wall, or a hole lying along the wall, and sometimes indirect illumination sources, such as candles and oil lamps, as well as architectural details and specially planned layouts, played an important role in the ventilation and illumination of the spaces in historic hospitals.

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ISLAMIC HERITAGE ARCHITECTURE 2016

The first international Conference on Islamic Heritage Architecture and Art took place in Valencia, organised by Wessex Institute, represented by Professor Carlos A. Brebbia, and the Polytechnic of Valencia, represented by Professor Arturo Martínez Boquera.

The Conference aimed to highlight the importance of Islamic Heritage Architecture and Art to the world and its influence across different regions.

Papers presented at the Meeting deal with the design of many types of buildings in Islamic countries, including not only the better known public constructions, but also houses and gardens, engineering work and many others that have also had a profound impact on society.

Islamic architecture has enriched design with a wide variety of structural shapes, including among others, unique arches and a variety of vaults and domes which allowed new forms to develop. The Conference dealt with the influence of these structural elements in different countries around the world.

There is much to learn from past experience to arrive at solutions that are environmentally sound and sustainable in the long run. Islamic design heritage offers valuable lessons on how to deal in an effective manner with cases of harsh and extreme environments.

Papers presented at the Meeting also analysed the materials employed and the types of structural elements, particularly those unique to Islamic architecture.

Traditional architecture and urban environments in most Islamic countries is now being eroded by overemphasis on global type of architecture and city planning. As a consequence, many regions are losing their identity. The Conference looked at these developments in the light of what the classical Islamic urban designs and architectures have to offer modern society.

OPENING OF THE CONFERENCE

The Meeting was opened by Professor Arturo Martinez Boquera from the Department of Structural Mechanics of the Technical University of Valencia and Co-Chairman of the Meeting. He addressed the Meeting as follows:

“Welcome to Valencia to participate in this Conference on Islamic Heritage, which aims to highlight the importance of Islamic architecture in the world and its influence on the architectural and cultural heritage in many countries, among them Spain, and more specifically, Valencia

“For the Muslim civilisation, the Iberian Peninsula was one of the main gateways to Europe. The legacy of Muslim civilisation is often blurred, but long present in the habits and daily life, both in material and intangible ways.

“In Valencia, most of the Islamic period buildings have not survived to this day, although we can still see important remains of the Arabian wall that surrounded the city between the 11th and 14th Centuries.

Professor Arturo Martínez Boquera and
Professor Carlos A. Brebbia opening address

“However, there are numerous intangible elements of Arabian culture in architecture preserved in many walks of life, including the extensive network of irrigation canals that still serves the Valencian region, administrated by the famous and ancient Water Court. Another important legacy of the Islamic period is represented by the ceramics from Manises and Paterna whose tradition is still preserved. Nor should we forget such influences in cooking, music and singing, folklore and language.

“The Arabian wall of Valencia began to be built during the 11th Century. With the fall of the Caliphate of Córdoba, the city became capital of the Taifa of Valencia.

“The Islamic wall, which surrounded the City, had a total of seven gates. From the 12th Century, the city wall was extended, incorporating new defensive components, such as towers and reinforced doors.

“The remains of that wall are preserved in the Plaza del Tossal and the Temple in the Carmen Quarter. There one can see some towers; one in the Plaza del Ángel and another on the street Mare Vella. The wall brought together the Barrio de la Seu, the eastern half of the Carmen Quarter, the Xerea Quarter and North Market Quarter.

“With the construction of the new Christian wall afterwards, part of the old wall was employed as a boundary wall between houses and in some places to separate the Christian city of the Moors Quarter which was behind the Portal de la Valldigna.

“The Christian walls were built in 1356 during the reign of the King of Aragon, Peter IV, who commanded the General Council of the City to build them in order to endorse the slums and quarters, formerly outside its boundaries. The new wall, with a perimeter of about 4km, trebled the inner surface enclosing the old Arabian wall. The towers of the Arabian wall of Valencia have not survived, but what remain are watch towers around the city.

“These watch towers are present in many villages of this area and were part of the defensive system providing protection to the city of Valencia. The towers could belong to a castle or farmstead. They are preserved in towns like Albal, Paterna, Silla, Torre Espioca in Picassent,

Delegates at the conference

Towers Plaza and Mussa in Benifayó and Bofilla tower in Bétera. The latter has recently been restored and received the Europa Nostra 2013 award. One can appreciate also Serra Castle, which was part of north Valencia's defence system and one of the bastions of the Arabian Taifa"

Professor Boquero closed his remarks by saying that the choice of the city of Valencia to hold the Islamic Conference on Architectural Heritage is most appropriate and he invited the delegates to enjoy a visit to this beautiful city full of heritage and good architecture.

Professor Carlos A. Brebbia then welcomed the delegates in the name of the Wessex Institute and emphasised the motivation behind convening this Conference.

Carlos said that the main function of the Wessex Institute is to act as a mechanism for the transfer of knowledge, particularly in the case of science and technology. The Institute has developed its own line of research and development, based on unique computer simulation tools which originated at WIT and are now accepted by the engineering profession. These tools form the basis for a series of computer codes which can be applied to solve a wide range of problems.

WIT, Carlos explained, has participated in many collaborative research programmes, involving partners with different expertise. This has allowed the Institute to collaborate in finding integral solutions to many practical cases, leading to a wider understanding of the problems involved.

WIT continues also to collaborate with the engineering industry, providing research and development as well as advanced consulting services.

The emphasis in all cases, Carlos said, is on interdisciplinary solutions, trying to broaden the perception of how our work fits in with society's requirements.

This has led to a very active knowledge dissemination programme, achieved in two complimentary ways, i.e. by a series of publications and by arranging a programme of international conferences.

The publication of papers either from Journals or conferences is fully Open Access, which contributes to providing the widest dissemination possible to the work. Papers archived in our WIT eLibrary (witpress.com/elibrary) are downloaded in increasing numbers from colleagues around the world.

The most relevant development in this regard for this Conference has been the launching of the International Journal of Heritage Architecutre, dealing with studies, repairs and maintenance issues.

Amongst the many topics covered by the Journal, it is particularly important to mention its aim to achieve a better understanding of the influences and cross-fertilisation of different cultures.

WIT organises an annual programme of interdisciplinary international conferences which now includes this meeting on Islamic Heritage. In addition, a well established conference on Structural Repairs and Maintenance of Heritage Architecture has been running since 1997 and a further meeting on Defence Heritage was started some years ago. These meetings were the basis for launching the new Journal, the first issue of which was distributed to the delegates.

Carlos ended by explaining the motivation for holding this Conference in Spain, to highlight the influence of Islamic Architecture there and to offer the participants the possibility of touring other sites of interest, particularly in the Andalucian Region. Valencia is not as well known as places such as Córdoba – with its large Mosque – or Granada – with its Alhambra – or Seville with the Cathedral built on the site of a Mosque and its Minaret, now a bell tower and the symbol of the city. Valencia however has a Cathedral of importance, not only because it was built on the old mosques, but also because the benches at one of its doors is where the ancient Water Court still sits. This is a living reminder of the influence of the Islamic engineers in developing a unique water management system, consisting of irrigation canals and aqueducts.

It is through our knowledge and understanding of our common heritage, Carlos stressed, that we will achieve a stable, balanced and peaceful society, and he hoped that the Conference would be able to contribute in its modest way to a better and more just world.

INVITED PRESENTATIONS

The Conference programme included some outstanding contributions from well known colleagues. The keynote address was given by Professor Bashir Kazimee of Washington State University in the USA on the topic of "Urban heritage of Kabul and post war recovery efforts". The paper is published in the first issue of the International Journal of Heritage Architecture, launched during the Conference, Volume 1, Number 1, 2017.

Other invited contributions were:

- "The role of mate-guarding behavior in old Kuwait city" **Abdul Al-Ballam** from Kuwait University
- "Islamic heritage architecture analysis and restoration in Fez, Morocco" **Khalid El-Harrouni**, National School of Architecture and ICOMOS, Morocco
- "Climate adaptability in the Hejazi traditional architecture" **Mohammad Bagader,** University of Manchester, UK
- "Conserving the Palestinian architectural heritage" **Jihad Awad**, Ajman University of Science and Technology, United Arab Emirates

- "The morphology and typology of the Ottoman Mosques of Northern Greece" **Maria Loukma**, Aristotle University of Thessaloniki, Greece, published in the International Journal of Heritage Architecture, Volume 1, Number 1, 2017.

Another interesting talk was by **Khatijah Sanusi** from the University of Technology Mara in Malaysia, on the topic "Encountering globalisation: Works of Sulaiman Ese from 1950s to 2011".

The other substantial number of papers were grouped under the following session headings:

- Historical aspects
- Architecture in Malaysia and Indonesia
- Heritage studies
- Conservation and restoration
- Urban environment
- Mediterranean heritage
- Mosques and minarets

CONFERENCE DINNER

There was a special dinner arranged for the members of the International Scientific Advisory Committee who helped to promote the meeting and review the papers. Carlos expressed the gratitude of Wessex Institute to them; their work was essential to ensuring the quality of the papers presented at the Meeting and to be published in the WIT Transactions, as well as the newly launched International Journal of Heritage Architecture.

The delegates had many occasions to meet outside the conference room and discuss topics of common interest. They included not only the coffee breaks but also the lunches arranged by the organisers and the conference banquet for those attending the event.

Delegates at coffee break

The Conference dinner took place in one of the best restaurants in Valencia offering typical dishes accompanied by regional wines. Valencia is famous for the quality of its rice specialities (the renowned Paella) but there is a variety of excellent dishes, some of which were served during the dinner. Carlos referred to the importance of the Conference and in particular the number of different countries represented. He believes that the most important aspect of WIT meetings is to bring people together and increase the communication and interaction between delegates.

At the end of the meal, the delegates were given a gift to remind them of the occasion, i.e. a book with excellent illustrations showing Valencia and its adjacent region.

CLOSING OF THE CONFERENCE

The Conference was closed by Carlos who thanked the delegates for their contribution. The quality of the proceedings was very high and this will ensure that the Conference is reconvened in 2018.

Carlos hoped that the delegates will continue to collaborate with WIT, not only by participating in the Conference series, but also in other research and publishing activities.

Conference banquet

OBITUARY – LUIGIA BINDA (1936–2016)

It is with great regret that we announce the passing away of our dear colleague, Luigia Binda of the Politecnico di Milano.

Luigia had a distinguished career at the Politecnico where she became Associate Professor of Structural Engineering, before being appointed Full Professor of Restoration. Upon her retirement she was made Honorary Professor at the Politecnico, where she continued carrying out research in architectural heritage.

She will be remembered with deep affection for her passion for teaching and research and her dedication to the Politecnico and her students.

She continued until very recently to lead a course on Historical Buildings Degradation and Diagnostics, carrying out research work on historical masonry structures and their durability as well as the effectiveness of different types of interventions.

Luigia was able to encourage with her passion for cultural heritage her many students in the School of Architecture including those in doctoral programmes.

She was recognised internationally as an authority in her field having written numerous papers and edited and authored several books.

Until recently, Luigia participated in the Structural Repair and Maintenance of Architectural Heritage (STREMAH) Conferences organised by our Wessex Institute in different locations around the world, being part of the International Scientific Committee. In 2011 she was Chair of the Conference when it was held in Tuscany and was awarded the Eminent Scientist Medal of our Institute in recognition of the excellence of her research and in the field of structural heritage restoration at the 2007 STREMAH Conference which took place in Prague.

She was also editor of a unique volume on "Learning from Failure: Long Term Behaviour of Heavy Masonry Structures" published by our WIT Press.

Luigia will be missed by all her colleagues throughout the world who appreciated her knowledge and professionalism, but most by those of us who were also privileged to be considered her friends.

Carlos A. Brebbia
Wessex Institute, New Forest, UK

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This site contains information on past and forthcoming international conferences organised by the Wessex Institute of Technology and other associated institutions in many different locations around the world. The meetings provide friendly and congenial means to achieve a high level of interaction amongst the participants. The emphasis is on high quality presentations which are afterwards published in the Transactions of Wessex Institute.

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