CONSERVATION OF ANDALUSIAN MONUMENTAL HERITAGE: THE CASE STUDY OF THE NIEBLA WALLS IN SPAIN

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Theme 7: Ancient/Historic and Innovative Solutions for Damage Prevention and Performance Improvement
Keywords: Assessment, risk, conservation, vulnerability

Abstract

The conservation process through interventions in a building requires adequate prior expert opinion. The diagnosis and subsequent safety assessment - raised in ICOMOS guidelines - are suitable mechanisms for the study of a heritage structure. Diagnosis involves a historical analysis of the past, as a tool to predict future responses; qualitative analysis determines the deterioration and the origin of the pathological process; and quantitative analysis characterizes components by observations and experimental measurements. However, in the short or medium term ineffective decisions might be taken if assessing the state of a building using only the aforementioned tools.

The Declaration of Assisi (ISCARSAH, 2000) stresses the need for prevention and the successful management of a risk-prevention program. By completing all assessment reports, in addition to a suitable risk assessment focused on the intervention and design of appropriate preventive measures, ensures a reduction in the vulnerability of a structure by managing a significant improvement in durability and, therefore, the sustainability of conservation and maintenance processes.

In order to verify such vulnerability of different degrees of interventions (comprehensive, partial, or none), the Almohad rammed earth walls of Niebla, Huelva, Spain was considered as a representative case study. It is almost 2-km long and includes 47 towers. The fortification complex currently has heterogeneous characteristics, although an almost entirely uniform appearance has been maintained. Since 1980, there have been several restorations that, from the beginning, reflect mixed results over time. Based on the results of an assessment, current circumstances and risks, a diagnosis was made in order to design and prioritize preventive and corrective measures that will permit greater durability of the walls of Niebla.

1. INTRODUCTION

Andalusian defensive heritage incorporates more than 2,000 buildings, all listed as cultural assets but only a small percentage of which are in good condition. The city of Niebla is one of the few Spanish cities that preserves the entire perimeter of its almost intact city walls, which were declared BIC (*Bien de Interés Cultural*) in 1945. The current layout is considered to be from the Almoravid period, which occurred approximately between 1090-1145, although some scholars believe it is from the Almohad period (1147-1212) (IAPH, 2011). Other sources argue that these are a heightening of pre-existing walls, identifying Roman remains and even Tartessian (paleo-Hispanic). Archaeological studies show traces of an older, much smaller walled enclosure that can be traced back to the first millennium BC (Campos Carrasco, Rodrigo Cámara & Gómez Toscano, 1996). The relevance of the location of Niebla is justified having been a commercial center between Minas de Rio Tinto and Bajo Guadalquivir, especially around the 9th and 10th centuries, acquiring noteworthy historical heritage significance as the Almohad fortification, as well as an urban and landscape element of integration.

Currently, the wall of the town is about 2-km long flanked with 47 towers (most of them rectangular and only two octagonal) enclosing an area of approximately 16 urban hectares, and composed almost entirely in military rammed earth. It does not incorporate any albarrana or barbican towers; however, it maintains a natural moat with the Tinto River in its southeast sector, which is the roughest. The enclosure is completed with the Guzmáns' Castle, rebuilt in the 15th century on top of the old fortress of Muslim origin (Junta de Andalucia, 1991).

Despite its proven value as monumental Andalusian heritage, its present condition is questionable, which substantiates a thorough analysis of vulnerability and the presence of risks.

Fig.1 Aerial view of Niebla showing the identification of its walls and the different phases of intervention (credits: Goolzoom, J. Canivell, & A. González, 2011)

2. HISTORY AND EVALUATION

Before identifying a diagnosis, it is necessary to make a compilation of the clinical history of the wall (anamnesis) that includes a historic, conditions, materials, and metrics assessment, as well as an understanding of its pathologies and, finally, vulnerabilities.

2.1 Sequence and recording of the interventions

These walls have been several times historically and partially rebuilt with inefficient results in the medium term. From the second half of the 20th century, several phases of intervention can be distinguished. An initial phase of several intermittent interventions took place up until the 1970s, including those made in 1957 promoted by the Department of Fine Arts, and others made in 1974. In the 1980s, the Andalusian Ministry of Culture chose to invest in a comprehensive project that continued through the 1990s. Finally, from 2003 until the end of 2010, emergency actions were implemented. Fig. 1 locates different interventions on an aerial view of the city walls of Niebla. Details of those interventions are specified in Table 1.

This research uses the same identification and numbering of towers used by Guarner in his initial project (Martínez Martín-Lucas & Espinosa de los Monteros Choza, 2000), while the parts of the wall are named in alphabetical order, marking sections between every two towers. The designation starts from Tower 1, located in the southern part of Niebla, coinciding with the Puerta del Buey. The scope of this study follows the wall sections between the Towers 1 to 10, since these corresponds to one of the sectors that, due to the degree of deterioration, permits the identification of several types of damage. These are also exposed to adverse weather conditions due to their harsh orientation. Moreover, it is in these sections where four different phases of interventions overlap in time.

2.2 Technical and building characterization

The walls of Niebla are built almost entirely with ordinary rammed-earth. For its building characterization, it is considered under the typological classification developed for the study of historical rammed-earth masonry in the province of Seville (Graciani and Tabales, 2008, p.135-158). In general, all precinct fabric corresponds to monolithic rammed-earth, although the peculiarities of some sections are noted, where there are parts built of natural-stone masonry (exterior castle fabric) wall. Also noteworthy are certain typical Almohad resources, such as lime mortar wrapping rammed-earth joints to imitate the appearance of large solid stone blocks and, perhaps, to also protect these joints. Moreover, most of the towers of the enclosure are quite similar in their building concept. All of them are resolved with rammed-earth reinforced with stonework masonry at the corners and rammed-earth on their façades. Different construction solutions differ at their copping, although all of them are solid, and all lack a compartment in their upper section with the exception of Tower 1, which in fact is a gate and have a inner zigzag corridor.

Specifically within the area under study, stone masonry (probably as a veneer) is identified only in Section A where there is a trace of the old buildings attached to the wall; the other sections, were built and restored using the same type of monolithic rammed-earth (type 1), while the towers present the stone reinforced rammed-earth wall (type 5), according to Graciani and Tabales (2008, p.139). All the elements present in this area were from interventions in 1980.

Specifically, in the area of study of this work, only in the section A it can be identified stone factory (probably as a coating), a trace of the old buildings attached to the wall; the other sections, were lifted and restored following the same type of monolithic wall (type 1), applying the technique in the towers mixed with chained stone wall (type 5) (Graciani and Tabales, 2008, p.139). All elements of this area, intervened in the 80`s, have traces of mass restitution running to one side.

2.2.1 Materials characterization

Considering the data extracted from Guarner González (1987), earth was used in the most comprehensive intervention. This material was collected from quarries in the immediate surroundings, along with gravel from Tinto riverbed, attempting to source the same chalky-red earth with a similar content of clay to that of the original rammed-earth walls. It is clear, however, that in order to improve the quality during successive restorations, the earthen materials were stabilized with lime from quarries and kilns in Huelva that was modified with 10% cement (1). Fragments of ceramics, stones and gravel of different sizes can also be identified in the mixture.

INTERVENTIONS IN NIEBLA CITY WALLS			TYPE OF REPAIRS															
			MATERIALS												EXTERNAL			
			BASE		WALL							TOP						
START DATE OF WORKS	TECHNICAL TEAM	Phase of Intervention Element being treated	Reinforcement of base with lean concrete fundation	Reinforcement of base with reinforced concrete fundation	Restitution of variable thickness of disaggregated rammed earth	U-shape metallic anchoring	Reinforcement in corners of towers. Sustitution of stone blocks	Earth renders	Thermography of interphase to assess disaggregation of layers	Lime grout through putlog holes to seal and consolidate interphase	Consolidants and waterproofing	Protection of wall top. 10cm thick layer, metallic mesh reinforcement	Protection of wall top. 25cm thick layer, metallic mesh reinforcement	Water channelling / Rainwater draining	Demolition of dwellings attached to city walls	Removal of irrigation systems close to walls	Removal of trees in garden areas closed to walls
1957	Before second half of 20th century, specific interventions are known at the perimeter of current city walls. Only referenced in archaeological and historical studies. Always refered to material disaggregation in sectors of the city walls																	
1974 1975	Arq. R. Manzano M. Lopez Vicente	Castle - T. Homenaje T7 y T10																
1982 1983	Arq. I. Guarner	Phase 1: T1 a T7 Phase 2: T7 a T14																
1985	Arq. R. Manzano Arq. I. Guarner	Phase 3: T14 a T18 Phase 4: T18 a T20																
1990	Arq. I. Guarner M. Lopez Vicente	Phase 5: T35 a T47 Phase 6: T26 a T31 Phase 8: Castle																
2003	Arq. M. Lopez Vicente	Phase 7: T21 a T26 Emergency T22 a T25																
2010	Arq. M. Lopez Vicente	Phase 9: T10 a T11																

Table 1. Phases of intervention throughout the second half of the 20th and beginning of the 21st centuries (credits: J. Canivell & A. González, 2011)

Although there have been no more than visual inspections, without the ability to count on quantitative test data, it is known that for the execution of the various phases of the work, only organoleptic tests were performed (2) to control the plasticity of the earth and the corresponding percentages of blond-colored sand from the river, as well as fine gravel. It is known that ceramic sherds were not removed from the mix if the amount stayed below 10% in each load (Guarner González, 1987). While analyzing the study areas, almost complete pieces of bricks or stone pieces, exceeding 10 cm/side, were found intermixed in the composition of some lifts of rammed-earth in the lower parts. Furthermore, although the specific composition of the original rammed earth is unknown, a clear color differentiation of the restored wall can be observed. Therefore there is an inconsistency in rammed-earth dosages, which may contribute to the development of certain pathological processes that will be described below.

2.2.2 Metrics characterization

The configuration of the enclosure and, in particular, the distance between towers (from 10 to 12 m), highlights the Caliphate heritage as a construction resource (Qantara Patrimonio Mediterráneo, 2008), although there are sections that increase to more than double this size. In general, the rammed-earth wall's metrics corresponds to the classical Almohad. Thus, the high of the lifts of the original rammed-earth varies between 0.85 and 0.90 m high (from two mamuníes cubits of 47 cm) around the enclosure. Where joints and traces on the rammed-earth walls are visible, the length of a rammed earth box ranges between 1.50 and 2.50 m, being greater in the area of the last emergency intervention. The restored rammed earth does not account for the height (0.90 m) or the sequence of the rammed earth. According to module of lifts (their height) it can be distinguished 10 to 12 layers of 10-15 cm thick per lift. In reference to the restored rammed earth, particularly in the T1-T10 study sector, it was performed a restitution on one side with proper thicknesses

Code	Elements
NMU-01-02	Tower 1
NMU-01-03	Tower 2
NMU-01-04	Tower 3
NMU-01-05	Tower 4
NMU-01-06	Tower 5
NMU-01-07	Tower 6
NMU-01-08	Tower 7
NMU-01-09	Tower 8
NMU-01-10	Tower 9
NMU-01-11	Tower 10
NMU-01-12	Sector A
NMU-01-13	Sector B
NMU-01-14	Sector C
NMU-01-15	Sector D
NMU-01-16	Sector E
NMU-01-17	Sector F
NMU-01-18	Sector G
NMU-01-19	Sector H-I

Damage degree: Minor damage; Moderate damage; Severe damage; No damage

Table 2. Damage characterization of Niebla wall between Towers 1-10 (credits: J. Canivell, 2011)

of more than 0.50 m, although thickness of less than 0.20 m has been recorded, which negativity affects to execution and durability.

2.3 Characterization of pathologies

The characterization of damage is based on an in-situ methodology of visual and organoleptic analysis (Canivell, 2011), and supported by graphic documentation. Due to the constraints of the selected sections, it has only been possible to analyze one side of the rammed-earth masonry, as the other belongs to private plots with restricted access. As described in Table 2, the characterization of damage has been categorized into three groups according to the severity.

In addition, damage is assessed at three levels that are color coded, taking into account the spread of damage and its severity. It should be added that the purpose of this evaluation is to specify corrective measures for the existing damage.

Structural damage: This is linked to processes that affect or could affect the structural stability of the work. There are many forms of this damage; however, only those showing obvious signs of deterioration were considered. Therefore, fissures and cracks were evaluated, whether active or inactive, being in almost all cases of vertical orientation, possibly due to the curing shrinkage of the mass or thermal variations. Collapses refer to the loss of verticality in the wall. In this case there are no collapses of entire sections of the original wall; however, some layers of rammed-earth restored to one side show signs of collapse. As depicted in Table 2, structural damage has had little impact in this sector and, therefore, there was no need to undertake this type of corrective measure.

Materials damage: These include the damage affecting the integrity of the rammed-earth mass. Lack of consistency is a very clear sign in the restored layers of rammed-earth, which disintegrates with a simple touch of the hand. This rammed earth appears to be of irregular compaction, resulting from insufficient control of the work, in light of the inclusions of large stone blocks, fired bricks and even organic materials. In general, erosion is typically caused by external agents (moisture, wind-driven rain, temperature, and fauna). Severe erosion is found in the highest lifts of rammed earth, which is more susceptible to moisture infiltration and the effects of wind. Erosion at the lower parts of the wall is often linked to capillary rise, or the backsplash of water against the wall at the lower lifts. Surface erosion is generally spread and is normally caused by the continuous washing of rainwater. In the sections studied, erosion is aggravated by the accumulation of water in certain obstacles (joints, weep holes), producing cavities. Mass losses, although sometimes confused with erosion, have a different origin. The poor quality of the rammed-earth is the cause of these types of detachments, also aided by other external agents, showing more severity in Sections B, C and F. Finally, a special mention is made of flaking as a singular condition, through which the mass of the wall disintegrates in slab-like shapes, parallel to the façade.

Generally, damage to the integrity of the mass has deteriorated the rammed earth with greater severity in the sections studied, due to the exposure to the southwest (the predominant direction of winds and rains), and the low quality of the restoration rammed earth (particularly between T1 and T7). In certain sections (T7 to T10), the quality of the rammed earth dramatically improves (3), even though its exposure similar.

Superficial damage usually affects only shallow layers of rammed earth and can lead to erosion. The efflorescence that shows up as surface deposit of salts is difficult to identify on rammed-earth masonry and even more so, if it is eroded. However, small deposits have been observed in some stone areas and towers. The uniform soiling is linked to the existence of an aggressive environment with a high proportion of suspended particles, causing a widespread contamination of the wall. Local soiling is caused by the differential water-washing of the wall, causing staining typically at the top of the wall, or at intersections between walls and towers. These dirt crusts are a result of the accumulation of muddy moisture and the development of fungi and lichens, forming thin harder surface layers, which when detached, leave a weakened rammed earth exposed to the outside environment.

Based on this characterization it is possible to determine the current state of conservation of the asset, which, as described below, should be complemented with the study of other risks for damage, aimed at maintaining a good condition of conservation in the future.

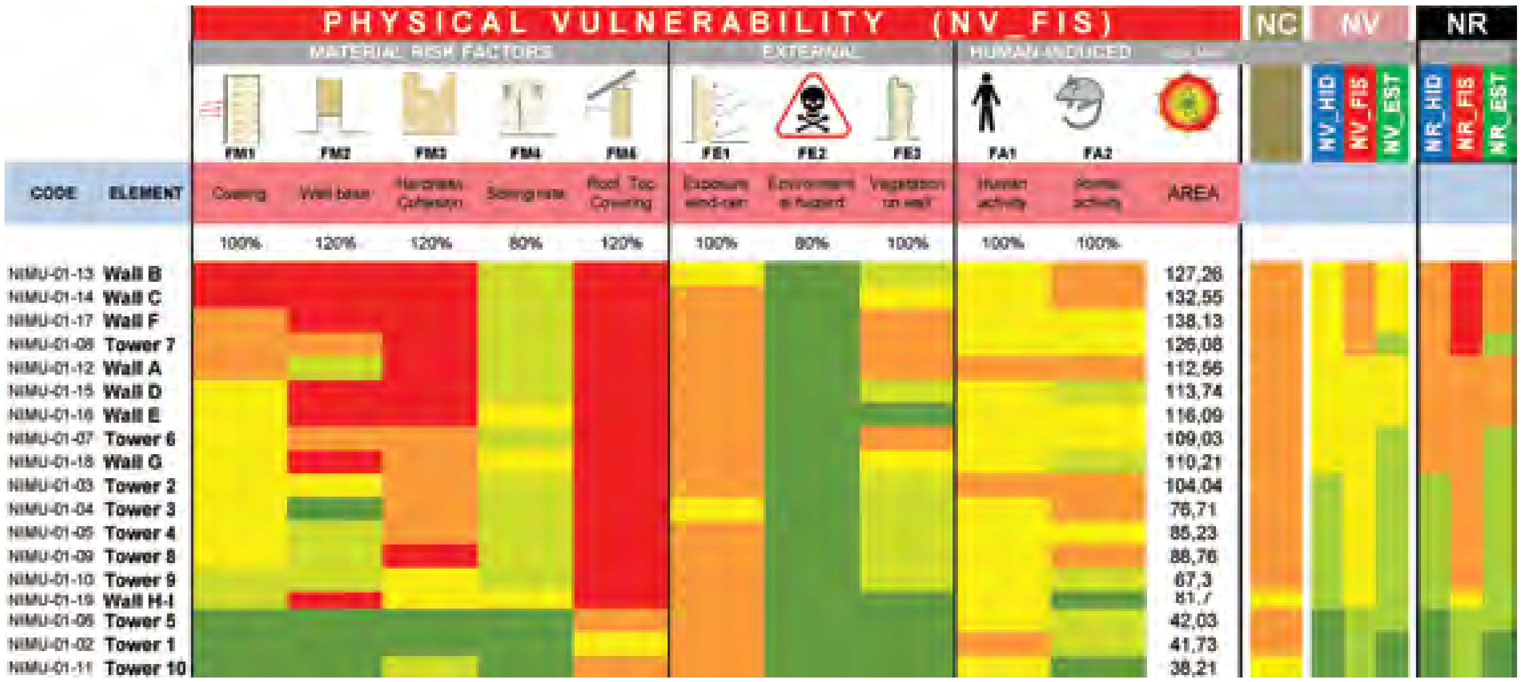

Table 3. Table of risk factors of physical vulnerability to NP (left), NC, NV and NR (credits: J. Canivell, 2011)

2.4 Characterization of Vulnerability and Risk

As damage characterization results in the design of the necessary corrective measures only, given the financial relevance of monumental heritage such as the Niebla walls, it was necessary to expand the evaluation by a characterization of vulnerability, thus facilitating the design and application of protocols and preventive-maintenance measures. To this end, a methodology designed by Canivell (2011) and based on a protocol to the INSHT (4) was applied. Thus, a hierarchy of each of the components of each wall sectors analyzed was achieved, according to an identified state of vulnerability. It is, therefore, essential to divide the construction into components with homogeneous characteristics. This methodology is defined according to the processes described below.

Vulnerabilities of rammed-earth masonry are set first: the hydric, the physical and the structural vulnerabilities, which define pathological processes of uncontrolled water access; erosion, loss of mass and cohesion; and structural stability; respectively. In order to characterize the three vulnerability types, three groups of risk factors were designed, which in turn were classified as external (circumstances outside the masonry), materials-related (in reference to properties or states of the same masonry), or anthropic (external, but with human-activity origins). Like the INSHT system, each factor was evaluated according to its amount of exposure (Level of Exposure: NE), based on a predesigned scale of five levels, from very low to very high northeast exposure.

Nevertheless, it is necessary to note that not all risk factors may have the same weight in defining the state of vulnerability. To this end, evaluations were introduced into the assessment, the so-called Deficiency levels (ND), establishing approximately the probability that a given risk factor is a source of damage. ND accommodates each case study, so the methodology is open and adaptable. By cross-referencing the values of NE and ND, the Levels Probability (NP) are obtained for each risk factor within each of the three vulnerability types. However, although a general reading of the state of the element can be had, as shown in Table 3, there is no value that characterizes a vulnerable state.

With the dual purpose of graphic representation of the NP values and identification of the characterizing value, the use of risk maps was proposed. This is the representation by a radial graph, where each axis represents a value of NP, and depicts a closed traverse. The area of this polygon is used to characterize each state of vulnerability according to a level of vulnerability (NV). Therefore, the greater the area of the polygon, the greater the accumulation of risks to the rammed earth, and hence the greater its vulnerability degree.

However, not all the analyzed elements must have the same treatment or present the same NV. There are a number of external factors (the constructive role of the element, its heritage value, its level of use or maintenance level) that involve different concepts. Evaluating these factors (general anthropic factors) in a similar way to other risk factors leads to their Consequences Level (NC), which define the impact of damage on the analyzed element itself and its users.

Once the three vulnerability types identified by three levels each (NV-HID, NV-FIS and NV-EST) and the consequences (NC) are defined, a true reading of the state of vulnerability can be stated. For this, the pre-defined risk matrices were used, which are instruments typically used in any risk assessment. These define risk levels (NR) for each group of combinations between the values of NV and NC, which is represented in the last three columns of Table 3 (NR-HID, NR-FIS and NR-EST), and in Fig. 2 for the analyzed sector.

Fig. 2 provides evidence of the NR data for each element analyzed. Red represents an accumulation of high levels for risk factors and, therefore, high risk of occurrence and development of pathological processes, producing serious consequences to the asset or its users. The diagrams show how the highest vulnerability corresponds to NR-FIS (erosion, de-cohesion, mass loss), and especially in the fabric and intermittent towers from Towers 1 to 7, which also corresponds to the first phase of intervention (Table 1). In these most vulnerable sections, corrective measures are urgently needed to repair damage, as well as preventive measures to mitigate risks and to ensure greater durability.

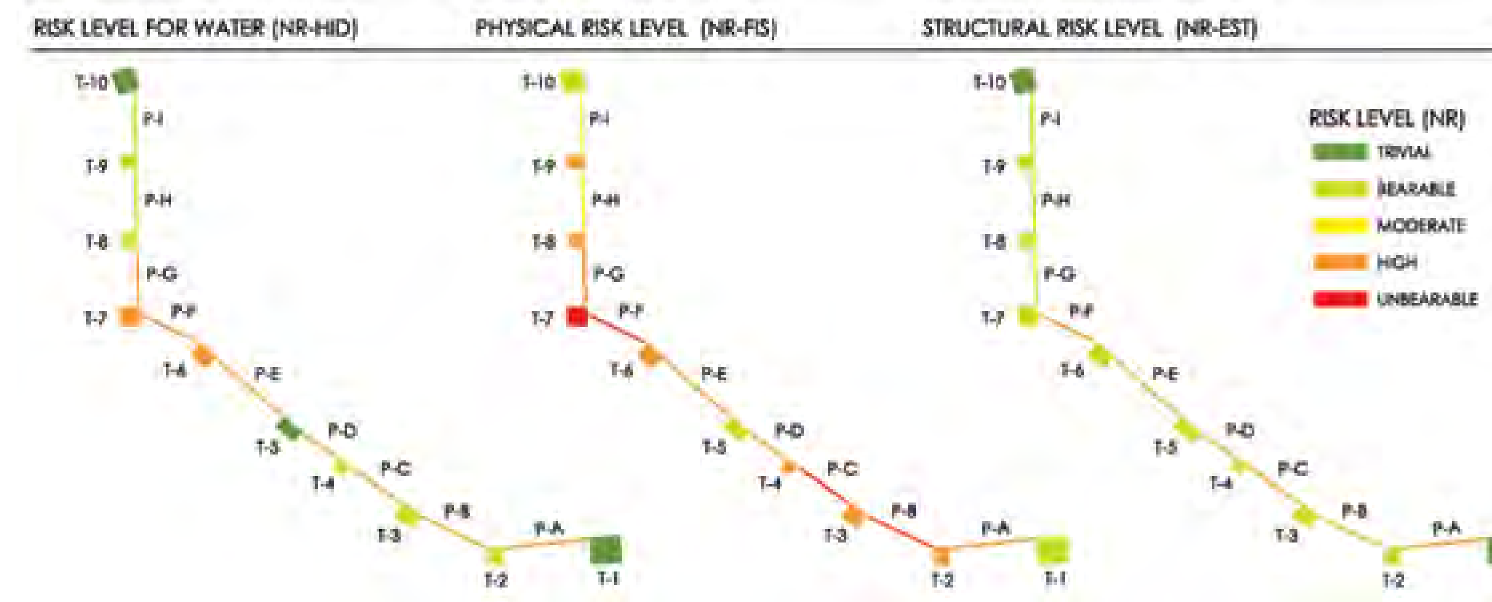

Fig.2 Distribution of the NR for the analyzed wall sections (T1 through T10) (credits: J. Canivell, 2011)

This assessment methodology provides an easy and useful tool to prioritize repair actions on a set of components, assigning different levels of intervention (NI) for each NR. For high NR, more urgent preventive measures and stronger corrective measures will be required, thus reducing vulnerability. Also, in the case of high NC, maintenance plans should be implemented or revised.

3. DIAGNOSIS AND CONCLUSIONS

The current situation of the Niebla wall, in sectors that have had no interventions in the last decade and also considering the sectors under study as a benchmark, presents vulnerability to erosion. Sections B, C and F are the most affected and sensitive, and also have high NR. These sections coincide with the first phase of restoration of Guarner González (1987). In later stages of the work, the technique and the materials used were improved, evidenced by better vulnerability conditions (sections between Towers 7 and 10). The work of Manzano (1974-75) in Tower 7 has demonstrated poor performance and shows a high NR. The poor condition and vulnerability of some elements is based in a series of associated damages: short mass composition and poor compaction of the restored rammed earth, loss of adhesion for the support, failure of certain construction solutions of stitching, anchoring and coating, leaving the original part most affected and exposed to aggressive agents. In addition, water vulnerability increases as a result of the lack of inspection on the inner surface of the wall, in which uncontrolled accumulation of soils leads to severe water leakage through the wall thickness.

Issuing a more well-founded and comprehensive diagnosis would require the analysis of the internal face of these sections, as well as extending this assessment to other sections of the walled enclosure. Supporting this qualitative assessment with a quantitative one is also recommended, which will provide more accurate information, for example, the type of lime used, particle-size distribution or identification of the mineralogical composition and clay. Thus, the comparison between the original rammed earth and the restored one would determine the suitability of interventions, as well as permit the adaptation and optimization of the materials used to serve as a reference for future action to the wall.

Generally speaking, each intervention has attempted to successively address the mistakes made by the previous intervention, with conservation solutions adapted to the current conditions. Nevertheless, lacking a broad overview over time, specific quantitative data, and comprehensive plan of restoration, the results have been insufficient and inefficient on the medium term. The absence of a control and rigorous maintenance plan, already established by Guarner González (1987), has made these sections more vulnerable, and exposed them to different environmental conditions and climatic variations. Therefore, this study tries to systematize a continuous process of review and control, which should be extended to other sections and generalized for any asset management.

Fig.3 Damage in earthen the fabric of the wall between Towers 6 and 7 in 2009 (credits: A. González, 2009)
Fig.4 Damage in earthen the fabric of the wall between Towers 6 and 7 in 2011 (credits: J. Canivell, 2011)

Notes

(1) According to the special conditions of the Restoration of the Niebla Wall by Ismael Guarner, poor cement (P-150) was used considering to that period's requirements.
(2) Any change in the source of lime required further testing for quality control of the dosage added into the mixture during the work, according to the document's special-conditions requirements.
(3) Following specifications by Guarner, adding lime improves the stabilization of the wall.
(4) The Spanish National Institute for Health and Safety at Work designed a simplified procedure for accident-risk assessment, which has been used as a reference methodology.

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DEVELOPING AN EMERGENCY-CONSERVATION PROGRAM FOR THE CULTURAL HERITAGE OF ABU DHABI, UNITED ARAB EMIRATES

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Theme 7: Ancient/Historic and Innovative Solutions for Damage Prevention and Performance Improvement
Keywords: Rapid assessment, emergency, conservation, planning

Abstract

Over-shadowed by its rapid growth and new developments, the historic environment of Abu Dhabi is, in fact, rich in cultural heritage that dates back to the 3rd millennium BCE and is comprised of cultural landscapes, archaeological sites, and vernacular buildings built with traditional materials, such as earth or stone. The fragile condition of these buildings and archaeological sites has made immediate action imperative.

The Abu Dhabi Authority for Culture and Heritage launched the first comprehensive program for Emergency Conservation in 2009. The program, intended as a "first response," addresses the urgent conservation needs of these structures by ensuring their safety and stability until further measures can be planned. The program was first developed on a building-based approach; however, it was difficult to prioritize interventions and only six buildings were stabilized in 2009. To better prioritize across multiple buildings and sites, a task-based approach was adopted. A system for rapid assessment, prioritizing and planning intervention tasks, and implementation and reporting was developed (Ziegert, 2010). For each task, the material resources and time needed were estimated. Tasks were then rated, organized and scheduled based on a set of priorities into six-month cycles. The progress of a task was tracked and documented with standardized forms.

The Emergency Conservation Program has thus far been very successful in rapidly tackling a large number of issues among numerous buildings and sites, and ensuring that they are stable before carrying out longer-term conservation. 85% of emergency issues have been addressed since the program's inception with over 36 sites in stable condition. This paper will present the methodology developed for this program and demonstrate how it can be applied in response to emergency situations, such as natural disasters.

1. INTRODUCTION

Over-shadowed by its rapid growth and new developments, the historic environment of Abu Dhabi is, in fact, rich in cultural heritage that dates back to the 3rd millennium BCE and is comprised of cultural landscapes, archaeological sites, and vernacular buildings built with traditional materials, such as earth or stone. The fragile condition of these buildings and archaeological sites has made immediate action imperative.

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2. PLANNING AND PRIORITIZATION

2.1 The development of EC

One of the main challenges facing ADACH was the large number and poor condition of the Emirate's historic resources.