Advances in Civil Engineering and Building Materials IV

Editors: Shuenn-Yih Chang, Suad Khalid Al Bahar, Adel Abdulmajeed M. Husain & Jingying Zhao

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Editors

Shuenn-Yih Chang
Department of Civil Engineering, National Taipei University of Technology, Taiwan

Suad Khalid Al Bahar
Kuwait Institute Scientific Research, Safat, Kuwait

Adel Abdulmajeed M. Husain
Kuwait Institute Scientific Research, Energy and Building Research Center (EBRC), Safat, Kuwait

Jingying Zhao
International Science and Engineering Research Center, Wanchai, Hong Kong

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Preface

Following the great progress made in civil engineering and building materials, the 2014 4th International Conference on Civil Engineering and Building Materials (CEBM 2014) aimed at providing a forum for presentation and discussion of state-of-the-art development in Structural Engineering, Road & Bridge Engineering, Geotechnical Engineering, Architecture & Urban Planning, Transportation Engineering, Hydraulic Engineering, Engineering Management, Computational Mechanics, Construction Technology, Building Materials, Environmental Engineering, Computer Simulation & CAD/CAE. Emphasis was given to basic methodologies, scientific development and engineering applications.

This conference is co-sponsored by Asia Civil Engineering Association, the International Association for Scientific and High Technology and International Science and Engineering Research Center. The purpose of CEBM 2014 is to bring together researchers and practitioners from academia, industry, and government to exchange their research ideas and results in the areas of the conference. In addition, the participants of the conference will have a chance to hear from renowned keynote speakers Prof. XIAO-YAN LI from University of Hong Kong.

We would like to thank all the participants and the authors for their contributions. We would also like to gratefully acknowledge the production supervisor Janjaap Blom, Léon Bijnsdorp, Lukas Goosen, who enthusiastically support the conference. In particular, we appreciate the full heart support of all the reviewers and staff members of the conference. We hope that CEBM 2014 will be successful and enjoyable to all participants and look forward to seeing all of you next year at the CEBM 2015.

November, 2014

Prof. Shuenn-Yih Chang
Dr. Suad Khalid Al Bahar
Dr. Adel Abdulmajeed M. Husain
Dr. Jingying Zhao

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Intervention construction techniques in monumental rammed earth architecture in Spain through ministry archives (1980–2013)

L. García-Soriano, C. Mileto & F. Vegas López-Manzanares
Instituto Universitario de Restauración del Patrimonio. Universitat Politècnica de València, Spain

ABSTRACT: This research aims to analyse the intervention techniques proposed in monumental rammed earth architecture restorations in Spain through state-funded projects over the last thirty years. This work was based on files from the Spanish Ministry of Culture and the Ministry of Development, which have been in charge of managing budgets for heritage interventions. Therefore this research aims to carry out a comprehensive analysis of the techniques proposed in the restoration of monumental rammed earth buildings over the last thirty years (1980–present), as well as to extract initial conclusions on how they have fared over time.

Keywords: rammed earth architecture, intervention, ministry archives in Spain

1 INTRODUCTION

This article should be viewed as part of a broader investigation which aims to analyse and study the restoration work carried out on rammed earth architecture in Spain from 1980 until the present, taking into account both the intervention criteria proposed and the construction techniques used in the interventions.

The ministerial structure in charge of the interventions on Spanish heritage was a basic source of information from which numerous case studies could be selected for this research on the restoration of rammed earth architecture in Spain.

It should be noted that since this study focuses on the analysis of interventions with public funding, particularly from the state, the buildings intervened on are monuments, and rammed earth constructions of vernacular architecture are excluded from the analysis.

The analysis of the work presented here focuses basically on the interventions in the construction techniques proposed for the actions.

1.1 *Aim of the study*

The main aim of this article is a global study which systematically and homogeneously covers the study and analysis of intervention techniques used on monumental rammed earth architecture under centralised supervision from the state through the various ministerial structures.

The main goal of this study is to analyze the similarities and contrasts in interventions which have a same building technique.

2 RESEARCH METHODOLOGY AND CASE STUDY SELECTION

As regards state actions relating to interventions on the architectural heritage, a series of case studies were selected from the state archives on heritage interventions. We therefore worked with material from the archives of the Spanish Cultural Heritage Institute, IPCE (Ministry of Culture) and the archives of the Ministry of Development. The selection from these archives of interventions carried out on buildings constructed using the rammed earth technique has provided a series of case studies that are fairly homogeneously distributed throughout Spain if we take into account the parts of the country in which rammed earth architecture is more common (fig. 1).

Figure 1. Geographical distribution of case studies.

2.1 *The IPCE archives*

The task of compiling the information from the archives was carried out based on a database list from the General Archives of the IPCE. The list for intervention work carried out in the period 1980–2011, 2,779 files in total, was obtained from this database. A case-by-case search was then carried out in order to select only the buildings intervened which had originally been built using the rammed earth construction technique. This resulted in a shorter list made up of 102 intervention files relating to 78 buildings, which were included in the database.

It should be noted that a global analysis of the evolution over time of the files in these archives shows that of all the files selected, approximately 89% are from the 1980s, 6 are from the 1990s (6%), while 5 files are recorded in the period 2000–2011 (5% of the total sample) (García et al. 2014).

This variable distribution over time clearly shows that most of the files from these archives date back to the 1980s. A more detailed analysis of the distribution over time for this decade shows that it appears in decreasing order, with most of the files dating back to the first half of the 1980s, since with the creation of the Spanish Historical Heritage Law in 1985 powers and competences were gradually ceded to regional administrations and a decentralisation process began.

2.2 *The cultural 1% programme through the archive of the Ministry of Development*

The cultural 1% programme for conserving and enriching historical heritage began in 1985.

During the first decade of its existence only 200 actions were carried out and at the time it was considered essential to establish criteria for action and priorities in the interventions. Most of the funds for this programme, developed jointly with the Ministry of Culture, are provided by the Ministry of Development (Sánchez Llorente 2010) and an inter-ministry agreement was reached to establish priorities with the creation of a joint committee between the Ministry of Culture and the Ministry of Development. This cooperation between the two ministries began on the 3rd November 1994 and is still in place. In order to carry out an analysis of the interventions on rammed earth architecture funded by this programme we worked with information from the Archive of the Ministry of Development. A total of 77 intervention actions on rammed earth buildings were selected from the data base. This was based on the list of files generated within the cultural 1% programme in the Ministry of Development (where intervention projects from the 2004 joint committee to the present are found), consisting of 627 intervention files in total (García et al. 2015).

Therefore, by researching both archives a database was drawn up with a compilation of 179 actions on rammed earth buildings, carried out throughout Spain over the last three decades (fig. 2).

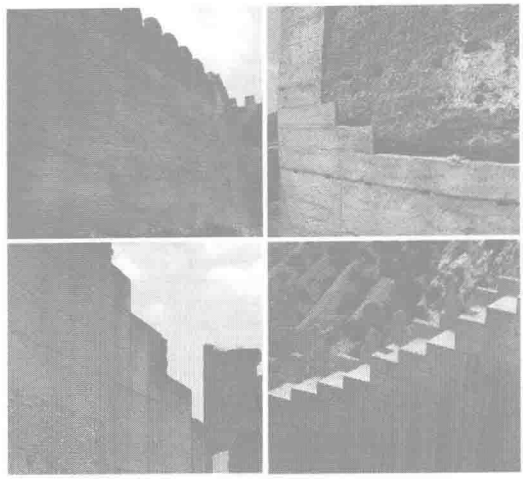

Figure 2. Images of some of the interventions analysed (Author: L. García-Soriano).

A detailed fiche was created for the analysis and assessment of these case studies for each intervention and generated a database that allows us to carry out the most objective analysis possible of the techniques used in each case.

3 ANALYSIS OF THE CONSTRUCTION TECHNIQUES USED

It can be stated that the intervention construction techniques used in the different cases are closely linked to at least two factors: the original construction technique (generally associated with the type of building) and the author's own intervention criteria.

The interventions proposed in civil and religious architecture are often indirect, that is to say, the intervention is carried out on other elements of the building, such as floors, ceilings, roofs, stairs, etc. These interventions have an indirect effect on the walls while direct actions on rammed earth walls are generally for cleaning or treating the surfaces or structural actions (stitching cracks and fissures). In contrast, in military and defensive architecture, walls are generally the main protagonists and interventions on them are carried out directly.

In the case of this research, given that most of the buildings which form the study sample are military (castles, defensive walls, citadels, towers....) the analysis of the construction techniques used in the interventions should be viewed as relating mostly to this typology.

3.1 *Intervention projects in the 1980s*

This group is made up of the oldest files from the sample. It should be noted that in these projects documentation us scarce and that in some cases the construction details are not completely defined in the

Figure 3. Current image of the Castle of Tabernas, Almería (Author: L. García-Soriano).

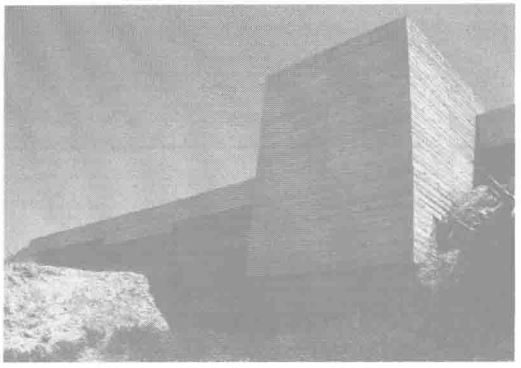

Figure 4. Current image of the Castle of Nogalte (Puerto Lumbreras, Murcia) (Author: L. García-Soriano).

project as the intention was to define them during the work. Nevertheless, if we analyse all the interventions from the 1980s, one fairly common criterion is the search for aesthetic harmony between new and old, trying to respect the principle of distinguishability. In some cases, such as the intervention by Alfredo Vera Botí of the Walls of Aledo (Murcia, 1980) the text specifies that "all the finishes will be as similar as possible to the original, but showing the differentiation line in them so that there is no confusion between the original construction and the new construction and so that the work introduced now may be reversible and identifiable".

In most cases, this attempt to establish a relation with the original building promoted the use of the original construction technique, rammed earth, although there is also a small proportion of projects in which other techniques were used, for example consolidation with masonry or brick, more frequent in interventions in previous decades. Nevertheless, at this point there had already been some major interventions carried out on rammed earth buildings using the original technique, as in the case of the initial restoration phases by Ismael Guarner of the Walls of Niebla, which became a point of reference for numerous other projects. Although the original technique was used, cement was added as a bonding agent in most projects, that is to say, although the technique used was original the materials were not, and at times new elements were even introduced to bind the original walls to the new ones (metal structures and meshes . . .). When the walls were very deteriorated and had lost part of their sections, interventions tended to propose attaching a new rammed earth wall to the original wall using auxiliary elements made mostly out of smooth steel. An example of this is the intervention by Roberto Puig Álvarez on the Castle of Tabernas (Almería, 1983) which stated "as the walls of this castle are built in rammed earth, we will use the same construction system replacing the rammed earth mix with cement-lime mortar with arid soil and tinting the mortar to match the tones of the original wall, adding formwork and putlog holes with planks whose size was deduced from the remains of the wall" (fig. 3).

3.2 *Intervention projects in the last decade*

The main objective of the actions from the more recent projects, carried out in the first decade of the 21st century, continues to be the general search to establish a harmonious relationship between the new intervention and the existing building, both with chromatic and constructive integration. This is why the original construction technique, rammed earth, is used in the interventions for these cases. As regards materials in these projects, the use of original material is also more frequent, as is the case of the 2004 intervention on the Castle of Nogalte (Puerto Lumbreras, Murcia) which states that "once all the existing structures are consolidated, general filling will be carried out on them. To do so the traditional construction system will use rammed earth with lime mortar for the oldest part and rammed earth reinforced with layers of lime mortar in the extension, just as in the original construction" (file 13-30033-00562-04) (fig. 4).

Although this desire to use the same original materials exists in some cases, albeit not as many, new materials like cement are incorporated, perhaps because authors are more familiar with them. However, these materials are completely foreign to the original constructions and could cause future pathologies, as can be observed from older interventions. Among examples we could mention the 2010 intervention carried out on the Castle of San Juan in Calasparra, where it is stated that "the filling of the rammed earth construction will be carried out following the traditional method, similar to those already executed: paste prepared using natural soil, stabilised with slaked lime and a small amount of white cement and colourant if necessary" (file 13-30013-01908-09).

Just as above, the union between the original and the new material is one of the main problems to be resolved. In these more modern projects, the most frequent proposals are those which suggest improved bonding of the new materials with the existing ones increasing the gripping surface with elements acting as rods or connectors. There are two types of proposals: those which aim for all the elements to be executed with the original materials and those which introduce

contemporary materials. The first group is composed of interventions proposing the use of wooden stakes for this union, as wood was the material used originally in the execution of the wall (stays) and there is reasonable certainty that this material is compatible with the earth of the wall itself. Nevertheless, most of the cases analysed fall into the second category and are cases in which the union is planned using current materials, primarily fibreglass.

4 CONCLUSIONS

From this global analysis it is possible to formulate some general conclusions relating to the interventions carried out on monumental rammed earth architecture over the last thirty years.

In the 1980s, despite proposals using different techniques (masonry, brick ...) which had inherited criteria and proposals from previous decades, the original rammed earth construction technique continued to be the most popular option and was therefore the most widely used in intervention projects. As mentioned above, despite restoration architects' interest and desire to use the original construction technique, which may have still been relatively unknown or unexplored at the time, the decision was taken to incorporate modern materials such as cement into the mix, in order to improve the quality of the walls proposed in the intervention. New elements, usually in smooth steel, were also proposed to improve the union between the original and added material.

Time has revealed the successes and failures of these interventions and this has influenced the more modern proposals for intervention, which seek to improve the technical solutions and respect the original elements. This is why in these interventions the current construction technique is still valued as the most appropriate option for these interventions, but the current aim is to also use the original materials, without additions. This change is undoubtedly the result of the increasing study and knowledge of rammed earth technique over these last few decades, which has enabled professionals to use the technique more rigorously, having seen that the use of cement in the mix often caused pathologies in the wall, such as the appearance of salts and efflorescence which in an advanced state may even lead to major material losses. In addition, the materials used in the bonding elements also varied in relation to the initial proposals from the 1980s, as it has been observed that the behaviour of steel in these structures was not optimum, and in many cases material incompatibilities have caused detachments, uncovering the metal rods, exposed to the elements so that they continue to deteriorate, in turn, damaging the wall.

With all this in mind, it can be stated that past experiences contributed to reinforcing some criteria in the proposals, while rejecting or modifying others. It is important to state that this text does not aim to be a criticism, but rather aims to show that each moment has its positive contributions, both in the more successful proposals and the more unfortunate ones, since these all contribute to the improvement of future interventions. As regards the more modern interventions it is not yet possible to assess the extent of their accuracy, since it is still too soon to know how these materials are going withstand the passing of time. This is why this work should be understood as a small step in learning about the interventions in monumental rammed earth architecture.

NOTE

This study is part of a research project funded by the Spanish Ministry of Science and Innovation "La restauración de la arquitectura de tapia en la Península Ibérica. Criterios, técnicas, resultados y perspectivas" (Ref.: BIA 2010–18921; main researcher: Camilla Mileto) and is part of the research work of "La restauración de la arquitectura de tapia de 1980 a la actualidad a través de los fondos del ministerio de Cultura y del Ministerio de Fomento del Gobierno de España" by PhD student L. García-Soriano.

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