Risk charter for medieval defensive earthen architecture in southern Spain

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Abstract. Medieval defensive earthen architecture is typically represented by big and well maintained defensive walls, lookout towers or castles despite mostly represented by remains of tower walls or defensive walls. While studies on natural hazards have been carried out concerning these castles or lookout towers, there are no studies on defensive walls. Both are certainly significant from a cultural heritage perspective, despite the fact that the latter are less popular for the general public. In Southeast Spain, most of this kind of architecture has been affected, and occasionally reconstructed, by destructive earthquakes and/or landslides, in accordance with historical chronicles or field evidence, however, there are no records of low-scale natural hazards. Hence, aware of the importance of the prevention of natural hazards regarding the conservation of the cultural heritage, a National Emergency and Risk Management Plan for the Cultural Heritage, a National Plan for Preventive Conservation as well as a National Plan for Defensive Architecture have been enacted by the Spanish Ministry of Education, Culture and Sport. According to these plans, a risk charter, including natural and man-made hazards, should be completed in order to improve investment programming. Cultural heritage risk and cultural assets maps should be connected in order to become an instrument for managing preventive conservation. Natural hazards studies should be conducted in order to protect cultural heritage, though they are not usually performed, most likely due to their cost. However, some natural hazards studies have been published in scientific journals, mainly signed by university researchers or various Spanish research institutions such as the Geological and Mining Institute of Spain. Some of them, including the Spanish Seismic Network or the old Ministry of Environment (currently known as the Ministry for Ecological Transition), have published several hazard and risk maps which can be usually used in GIS format. Yet, most of them are not even known by researchers on cultural heritage due to the different administrative levels in charge of natural hazards. In this paper, some recommendations to prevent natural hazards in medieval defensive earthen architecture will be discussed.
1. Introduction

A catalogue of defensive earthen architecture (figure 1 and 2) located in the Spanish Southeast (Granada, Almería and Murcia provinces) has been addressed as part of the R+D+I of the National Programme for Research Aimed at the Challenges of Society, entitled "Sustainable Methodology for the Conservation and Maintenance of Medieval Rammed-earth Fortifications in the South-East of the Iberian Peninsula Diagnosis and Prevention Against Natural and Anthropic risks (PREFORTI)".

In this part of Spain, most of this kind of architecture has been affected, and occasionally reconstructed, by destructive earthquakes and/or landslides, in accordance with historical chronicles or field evidence, such as the 1674 Lorca earthquake or the 1680 earthquake in Málaga. However, there are no historical records of earthquakes or landslides with less harmful effects, and field evidence is difficult to observe due to the scant remains of this defensive architecture. Flooding does not normally cause damage to medieval defensive earthen architecture since these structures are typically located on hills, although some river undercutting can trigger landslides.

![Figure 1. Location of the medieval defensive earthen architecture in the study area](image-url)
Medieval defensive earthen architecture is typically represented by big and well maintained defensive walls, lookout towers or castles despite mostly represented by remains of tower walls or defensive walls. (figures 3 and 4). While studies on natural hazards have been carried out concerning these castles or lookout towers, there are no studies on defensive walls. Both are certainly significant from a cultural heritage perspective, despite the fact that the latter are less popular for the general public.
The Spanish Cultural Heritage Institute (IPCE) is aware of the importance of the prevention of natural hazards regarding the conservation of the cultural heritage, and therefore has promoted some national plans, which are effective tools for the management of the cultural heritage related to natural hazards prevention. Thus the National Plan for Cathedrals [1], was the first one to be approved in 1990. It was followed by the National Plan for Abbeys, Monasteries and Convents [2], drafted in 2004; the National Plan on Cultural Landscape [3] or the National Plan for Defensive Architecture [4] were both approved in 2006. All of them were reviewed and updated in 2010 and consequently approved in 2012. In 2010 the National Plan for Preventive Conservation [5] was proposed to be drafted and finally approved in 2011, while the National Emergency and Risk Management Plan for the Cultural Heritage [6] was approved in 2015.

The Geological and Mining Institute of Spain (IGME) and the Spanish Cultural Heritage Institute are working together in the Geographic Information System (GIS) highlighting the Geoscience Information System applied to Monumental Architectural Heritage (GIS/PAM) for the Spanish Autonomous Community of Extremadura [7]. The GIS/PAM (figure 5) integrates Monumental Architectural Heritage catalogue together with the Spanish geological map (at scales between 1:1.000.000 to 1:50.000), but different maps (active faults, expansive clays, hydrogeology or mass movements), delineated by IGME, can be added (at scales between 1:1.000.000 to 1:200.000).

![Figure 5. Snapshot of GIS/PAM developed by IGME](Image)

2. Cultural Heritage National Plans and natural hazards

The first national plans to be approved were on Cathedrals and Abbeys, Monasteries and Convents both considering a risk charter, in which natural and man-made hazards were included. Both of them should be completed in order to improve investment programming and become an instrument for managing preventive conservation. Prevention of stability and leak tightness problems related to earthquakes, rock falls or hydrology would allow conservation and restoration interventions. The National Plan for Cultural Landscape considered seismic hazard and rock falls [8], while the National Plan for Preventive Conservation established earthquakes and floods prevention through risk identification, analysis and assessment.

The National Emergency and Risk Management Plan for the Cultural Heritage established that natural hazards studies should be conducted in order to protect the cultural heritage though they are
not usually performed. Natural hazards that have been taken into account are as follows: earthquakes, subsidence, landslides, volcanoes, tsunamis, hurricanes, floods, tornadoes, snow/ice/rain and fires.

In this context, natural hazards assessments on cultural heritage are important, but Risk Charters have not been developed.

On the other hand, the National Emergency and Risk Management Plan for cultural heritage established the creation of risk charters as a line of action for the protection of cultural heritage against disasters, but it is necessary to use hazard and vulnerability maps for generating risk charters.

In fact, the terms risk and hazard are usually misunderstood, and usually used as synonyms, therefore it is necessary to clarify their meaning. From a legal point of view, taking into account that there is no legislation in place setting out rules on natural hazards, some definitions of what risk factors are can be found in different Spanish national and regional sectoral legislation. Consequently, in the nineties, Civil Protection Basic Guidelines for flood risk and Civil Protection Basic Guidelines for seismic hazard set out the basis for the first definitions of hazard, vulnerability, elements at exposure or risk. Elements at risk are "the population, buildings, infrastructures, economic activities, public services, environmental elements or other uses of the territory expose to a natural hazard in a particular place", meanwhile vulnerability is "the degree of losses in an element at risk after the occurrence of a natural hazard with a determined magnitude".

Nevertheless, we will stick with the definitions provided by the Spanish specific legislation on hazard and risk to set out the meaning of hazard and risk maps.

Flood risk means "the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, the cultural heritage and the economic activity associated with a flood event” according to the European Directive 2007/60/EC of 23 October, on the Assessment and Management of Flood Risks. The definition of a hazard as "the probability of a flood event, in a determined period of time and a particular place" complies with the transposition of that directive into the Spanish legal system through Royal Decree 903/2010, of 9 July. Hazard is characterized by its intensity or magnitude and its frequency or return period. The European Directive 2007/60/EC also sets out that hazard and risk maps should be delineated. On one hand, hazard maps shall show: "flood extent; water depths or water level, as appropriate and where appropriate, flow velocity or relevant water flow". On the other hand, risk maps should show the "indicative number of inhabitants potentially affected; type of economic activity of the area potentially affected; installations as referred to in Annex I to Council Directive 96/61/EC of 24 September 1996...". Hazard and risk maps must consider different scenarios in both legislations: high, medium and low probability of floods, established in 100 and 500 years of return period for the last two in the Spanish legislation.

3. Sources of natural hazards information
Natural hazards reports are not usually conducted for the conservation of cultural heritage most likely due to their cost. However, there are some natural hazards studies and maps that have been already published that could be used, such as those included in Spatial Data Infrastructures (SDI) and institutional websites or research papers in scientific journal or conferences.

The Spanish Spatial Data Infrastructure (IDEE), established by Law 14/2010 on Infrastructures and Services of Geographical Information in Spain (LISIGE), transposes the European Directive INSPIRE (Infrastructure for Spatial Information in Europe) into the Spanish legal system. It allows the access and management of datasets and geographic services (described through their metadata) available on the internet. Most information is presented as Web Map Services (WMS), but the use of Web File Services (WFS) is recommended because it would allow working with it in a GIS.
The National Geographic Institute, the Geological and Mining Institute of Spain (IGME) and the Ministry of Ecological Transition, at the national level, have the most useful sources of data regarding natural hazards assessments in their websites. The Andalusian/Murcia SDI websites, for instance, the Environmental Information Network (REDIAM), at the regional level, are the most useful. Yet, the scale of their maps is not sufficiently detailed to prevention recommendations.

Despite floods do not usually affect medieval defensive earthen architecture, the National Flood Zone Mapping System (SNCZI), specifically focuses in fluvial and coastal floods, is a good example of how hazard and risk maps could be presented for their use for cultural heritage stakeholders. The SNCZI was established by Royal Decree 9/2008, of 11 January, updating hydraulic public domain standards, which was developed in compliance to Royal Decree 903/2010.

Different return periods for fluvial flooding, according to this Royal Decree, are shown in the SNCZI website: high probability-10 year flood, frequent 50 year flood, medium 100 year flood and low 500 year flood as well as the hydraulic public domain and the preferential flow area. The information (flood extent or water depth) can be downloaded in shape format, allowing to work together with the PREFORTI catalogue with GIS software (figure 6).

Figure 6. A snapshot of the National Flood Zone Mapping System (SNCZI) website for the Romilla’s Tower (Granada). Different return periods for flooding are shown: high probability-10 year flood (red), frequent 50 year flood (pink), medium 100 year flood (orange) and low 500 year flood (yellow)

4. Natural hazards maps and cultural heritage management

It is important to select the right type of natural hazards maps in terms of cost/benefit and utility. As we mentioned earlier, hazard and risk maps have been already set out so the government shall issue regulations to implement the laws as needed. However, susceptibility maps shall be enough to establish protective measures, because they allow a spatial prediction through conditioning factors especially in case of landslides. Despite hazard and risk maps allow a spatial prediction as well, they also allow a temporal prediction through triggering factors. Nevertheless, their cost is higher than that of susceptibility maps, which is the main constraint to develop risk maps [9], and even to perform hazard maps (figure 7). In any case, mapping cost will be similar for hazard and risk maps used in cultural heritage assessments, but hazards maps could be sufficient to improve investment programming.
However, the use of maps already delineated, as those mentioned in the section above, shall reduce the mapping cost. Some maps could be even developed using the information downloaded from the aforementioned institutional websites. For instance, the first estimation to landslides susceptibility could be obtained using the aerial photographs and DEM downloaded from IGN website and the geological map at 1:50,000 (figure 8) obtained from IGME. Using the same geological map and the base ground acceleration obtained for every municipality from the Building Seismic Code, a seismic hazard map including the local effect (figure 9) may be calculated when the seismic hazard maps cannot be downloaded from these websites.
Getting "qualitative" information is more useful than getting no information, mainly if investment in prevention is usually scarce. Then information must be carefully managed due to the scale of source maps and the procedures followed to get some maps.

Considering natural hazards information already available, a systematic database will be developed in order to program more detailed and scientific studies or countermeasures according to the hazard/risk level (figure 10, 11 and 12), as it has been recommended by the National Plans of Defensive Architecture and Preventive Conservation in the Cultural Heritage. This selection will later be treated more thoroughly to develop systematic databases that allow the creation of preventive measures charters related to hazard/risk charters.

| FREQUENCY | Low | Medium | High |
|-----------|-----|--------|------|
| INTENSITY |     |        |      |
| High      | Medium | High | High |
| Medium    | Low | Medium | Medium |
| Low       | Low | Low | Low |

**Figure 9.** Seismic hazard map including local effect for the Wall of de la Hoya (Almería)

**Figure 10.** Hazard matrix (modified from [10])
The information that has been already published on natural hazards in scientific journals, mainly signed by university researchers or various Spanish institutions (Geological and Mining Institute of Spain, Spanish Seismic Network or Ministry of Ecological Transition) is actually an inexpensive source of studies and maps, despite the fact that access to information is difficult. The main obstacle is the fact that Cultural Heritage stakeholders do not have easy access to scientific journals neither have the knowledge and the necessary skills to interpret academic papers, which make it difficult for them to easily handle valuable and accurate peer reviewed data. [9]. Researchers should upload their outputs on a portal by law to provide better, efficient use and access to this information. Legislation should also state that natural hazards maps/assessments have to be updated periodically. Use of GIS formats will help to update hazard/risk maps around cultural heritage assets.

5. Conclusions
The Spanish Cultural Heritage Institute has promoted some national plans related to the natural hazards prevention in order to improve investment programming and become an instrument for managing preventive conservation. However, risk charters, which should be included in those, have not been developed yet most likely due to their cost. Susceptibility/Hazard maps would be enough in most cases. Natural hazards maps already delineated could be used in order to program natural hazards assessments and countermeasures.

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