DELIVERABLE D.T2.2.2

Resilience controllable criticalities of cultural heritage suitable for innovative mitigation

Final

12 2018

CONTENTS

1. INTRODUCTION

1.1. Objective and scope

WP T2 C*ultural heritage vulnerability in emergency situations*, under the activity A.T2.2, concentrates on the critical analysis of local vulnerability and measures in emergency situations for cultural heritage. In this context, the deliverable D.T2.2.2 has the scope of presenting the technical details and findings for the use of the manual (D.T2.2.1) among municipalities and regional authorities. More specifically this report has the following objectives:

- To provide a general overview and definitions of resilience controllable criticalities of cultural heritage suitable for innovative mitigation.
- To define a straightforward and appropriate methodology for the categorisation of the resilience controllable criticalities found in cultural heritage assets.
- To outline the essential criticalities which apply to climate change related events with technical details and insights on possible remedies and examples.

This deliverable should be read in conjunction with the following documents:

- D.T2.1.3 which aims at the definition of a decision support tool for the harmonization of data related to cultural heritage vulnerability and for a conscious definition of procedures, agreements and cooperation in an overall transnational approach.
- D.T2.2.1, which provides a manual with a critical overview of the foremost examples of good and bad practices, learned from experience, in managing risk for cultural heritage located in Central Europe (considering mainly flood, heavy rain and fire due to drought).

The next section describes the structure of the report.

1.2. Structure of the report

The deliverable D.T2.2.2 *Resilience controllable criticalities of cultural heritage suitable for innovative mitigation* is composed of the following sections: section 2 introduces a general review and the basic definitions related to resilience controllable criticalities and how these differ from vulnerability indicators; section 3 summarises the proposed classification methodology for the categorisation of resilience criticalities based on the principle of scale or size; descriptions and examples of such criticalities are also provided for each of the category determined in the same section. Subsection 3.6 highlights the importance of maintenance in the management of criticalities for the sake of maximising the resilience of cultural heritage systems.

2. DEFINITIONS AND GENERAL OVERVIEW

Recalling the information presented in the deliverable D.T2.1.3 *Decision support tool*, criticalities refer to managerial and physical features of a CH object which can be controlled and adjusted in order to improve its resilience. In other words, “a criticality can be defined as a factor or aspect of a CH system, intended as the ensemble of its physical and managerial characteristics, which proves to be crucial for the determination of its resilience against natural disasters and climate change actions”. Furthermore, such criticality must represent fundamental controllable features of a CH system which can be modified and adjusted by adopting appropriate management actions and measures [ProteCH2save 2018]. Cultural heritage criticalities should not be confused with vulnerability indicators [Birkmann 2007], which are used to assess the level of a predefined quantity or quality peculiar to a particular asset; criticalities rather define conditions of cultural heritage properties which are critical by default. Criticalities, therefore, are of extreme importance when setting the priorities which resilience and risk management policies should address. The decision support tool developed within the framework of the ProteCHt2SAVE project proposes a simplified categorisation of criticalities which are divided into two main groups, namely 1) managerial and 2) physical criticalities. Managerial critical elements relate to those aspects of a CH system which are not connected to the physicality of the asset but rather to its operation, administration and care. Managerial critical elements therefore include how CH environments are used and protected involving social and economic as well as policy and regulation issues. From the main findings of deliverable D.T2.1.1, examples of managerial critical elements include the lack of knowledge or information, negligence (lack of maintenance), inadequate decision making, poorly designed emergency or post-disaster plans, missing funds etc. All these represent fundamental controllable features of a CH system which can be modified and adjusted by adopting appropriate management actions and measures. Each managerial critical element is strongly context-specific and requires an accurate assessment and thoughtful prioritisation in order to reduce the risks related to natural hazards and climate change and improve the resilience of the overall CH system. Physical critical elements relate to the aspects of a CH system involving its actual material composition and structural conditions. The sensitivity of historic structures and structural elements to weather and disasters is influenced by material and structural capability to resist exceptional loads and environments during disastrous situation. As mentioned for the previous category, also physical critical elements are significantly context-specific and require a thorough investigation of material characteristics and the general environmental situation (e.g. hydrogeological conditions) before being adequately evaluated. In some cases, in fact, it is not the historic structure itself that is sensitive to climatic conditions, but the surroundings and the supporting structure can also be affected. It should be emphasised that it exists a wide range of historic structures and materials, and also a wide range of types of damage. This makes it difficult to design widely applicable measures and unified methods. The next section presents the resilience controllable criticalities of cultural heritage suitable for innovative mitigation.

3. RESILIENCE CONTROLLABLE CRITICALITIES (RCCs)

3.1. Classification methodology

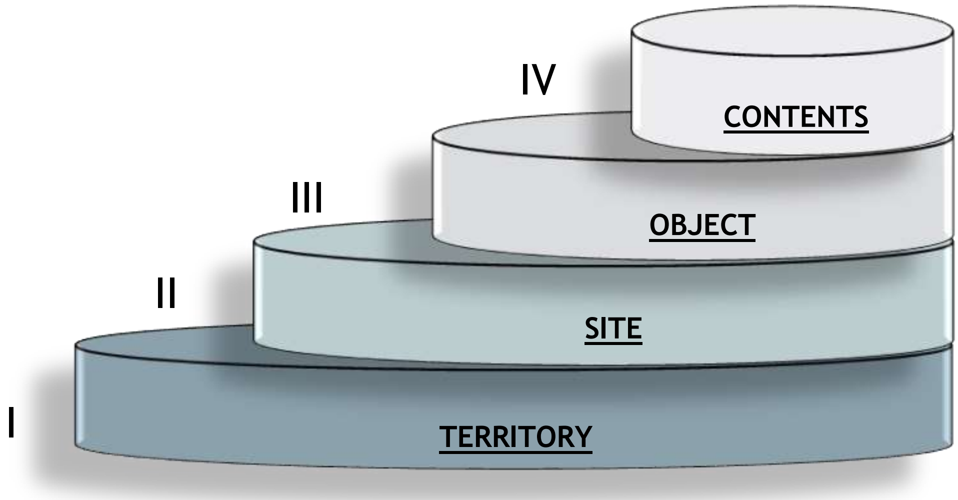
In order to provide a comprehensive and exhaustive description of RCCs related to cultural heritage in the context of climate change-induced hazards, an appropriate classification needs to be introduced. The simplest and most intuitive criterion that can be employed for such categorisation is that of “scale” or “size”. In such a way, four major categories of resilience controllable criticalities can be identified:

I) **Territory RCCs:** controllable criticalities which apply to a larger area or region composed of a number of cultural heritage sites and/or encompassing various built heritage objects. To provide an example of scale, such criticalities may refer to cultural landscapes type of entities i.e. those cultural properties representative of the "combined works of nature and of man" embracing a diversity of manifestations of the interaction between humankind and its natural environment (e.g. garden and parkland; organically evolved landscapes, associative cultural landscapes) [UNESCO 2008]. Territory RCCs may involve physical issues, such as for example in the case of lack of territorial protection of flood prone areas along major rivers or lower coastal areas; or managerial problems such as integrated regional evacuation plans of areas affected by natural disasters.

II) **Site or complex RCCs**: criticalities affecting the resilience of historic towns, districts or cultural heritage assets with even smaller scales still comprising a number of built heritage objects. The scale considered for this category is that of small historic settlements (e.g. villages), specific urban areas (e.g. historic city centres) or sites identifiable by ownership, structural continuity and social uses (e.g. castles; farms, factories etc.). Site or complex RCCs identify mainly those criticalities that impact the cultural heritage object and its immediate surroundings (e.g. other built objects in the case of settlements or natural elements such as trees, rivers etc.).

III) **Object or building RCCs**: controllable criticalities characterising single heritage constructions such as buildings, bridges, roads etc. Object RCCs individuate critical conditions in building components or enforced management strategies which can be optimised for fostering resilience against climate change related hazards. They include various unsustainable structural states such as overloading, settlements, excessive distortions and components´ failures as well as material degradation conditions which undermine the correct performance of the assets in case of disastrous events.

IV) **Contents (moveable object plus users) RCCs**: critical conditions for moveable heritage and occupants of a cultural heritage object. This is a special category referring to the contents of buildings such as furniture, collections, family heritage and people using it for living, work or leisure. Criticalities under this category are mostly related to management strategies (e.g. rescue plan in museums; evacuation routes etc.) as well as to maintenance measures.



The proposed categorisation based on scale is deemed appropriate, not only because it is straightforward and of an easy visualisation but it also quite realistically models the interdependency occurring among resilience building measures. In fact, being the specified categories interrelated by the fact that each is the sub-scale of the previous one while at the same time containing the following ones (e.g. a site is part of a territory and contains objects which in turn have contents), in a similar way, by addressing the criticality at a specific level or scale it might affect also the resilience downscale (at times also upscale).

The following sections outline the most important RCCs which belong to each level of the four-scale categorisation proposed above.

3.2. Territory RCCs

<u>**ACCESS OF HIGH WATER**</u>

It causes flooding of a larger territory with cultural heritage assets and affects the objects, buildings and landscape located there. The density and complexity of heritage assets or values of the territory supports decision for installation of territorial protection of cultural heritage preventing inundation. This measure is justified with a cost/benefit or society resilience reasons.

Typical damage
Domino effect with inundation of individual objects, destroying action on water sensitive materials, detachment and transport of floatable objects, soiling of large areas with mud and/or polluted water, destruction of pavements, parks and gardens, blocking of transport and media supply.

Preventive resilience measures
Typically water protection barriers are installed – temporary, permanent and combinations. Temporary barriers include a variety of types from walls built of sand bags till sophisticated demountable prefabricated walls assembled of light transferable elements. In urban areas short duration low water flooding can be prevented with sand bags combined with barriers of existing building or fences walls. Permanent protection walls or earth dams are acceptable in situations where they coincide with existing structures or can be integrated into landscape shaping. In the larger territories with heritage assets the combined systems are preferred because they can be better adjust and harmonized with the historic environment. In all types an effective sealing requires also prevention of flooding through subsoil layers or flooding through channels and sewage disposal systems. It is very difficult to ensure such a perfect sealing and, therefore, the system must be completed with pumping facilities.

Invoked management demands
The measures must be marked and described in the risk maps together with the location of storage rooms and access roads. The installation of barriers calls for permanent preparing measures consisting in the permanent subsoil sealing barriers and for storage rooms for the temporary barrier elements or material. Then it requires a perfect management for transport and assembly of temporary elements as well as their disassembly, cleaning and re-storage for a repeated use at future events.

Examples
Large protected cores of UNESCO listed historic cities (e.g. Regensburg, Prague, Prague Troja) or territories (Wachau) have been successfully saved from the inundation.

Inundated area in Troja during the 2002 flood

Inundated area in Troja during the 2013 flood – the effect of the territorial protection is clearly visible.

Example of permanent protecting wall integrated into existing town wall in Grimma (Germany).

Example of combined protecting wall integrated into existing riverbank in Regensburg (Germany).

Example of permanent protecting wall integrated into existing town wall in Grimma (Germany).

3.3. Site or complex RCCs

CHANGE OF SUBSOIL MECHANICAL CHARACTERISTICS

Rise of water table level or saturation of surface subsoil layers due to heavy rain causes a change in subsoil characteristics, which affects stability of cultural and natural heritage.

Typical damage

In the landscape, parks and gardens it may decrease trees anchoring and their root out. Buoyancy effects spuds subsoil and may cause additional differential settlement or uplift of buildings or their parts, even the underground structures, e.g. massive brick or concrete channels or collectors. This, together with the decrease of load carrying capacity of the raised soil, generates cracks in masonries or tilting of buildings.

Preventive resilience measures

Only local and partly effective measures are possible and economically justified. They involve additional temporary anchoring of protected or other important trees with superficial root systems growing in water sensitive soils.

Invoked management demands

The measures must be marked and described in the risk maps. The owners and/or operators must be trained for the installation in the case of temporary measures.

Examples

A necessity of additional anchoring of trees is also typical for protection against windstorms or combined wet soil/strong wind action. An example shows permanent additional anchoring of a pine tree in the castle of Ravello (Italy).

SURFACE EROSION DUE TO FLUSHING RAIN WATER

Heavy rain may initiate situations with occurrence of fast run off of larger bulks of water in narrow streets or landscape valleys around rivers and brooks or streams.

Typical damage
Destroying effects typically induce erosion of soil, damage pavements of roads, may initiate mud flow and avalanches.

Preventive resilience measures
Only limited measures are available against such damage such as the preventive permanent consolidation (enrockment) or pavement of slopes and banks of rivers and brooks, the creation of capacity water run off drainage channels and dikes. Slopes can be also protected with grassed geotextiles and/or bushes and trees with stabilizing roots.

Invoked management demands
The measures must be marked and described in the risk maps. Massive financial means are necessary for construction of large extent geotechnical measures.

Examples
During the 2002 Central Europe flood one Vltava arm banks were totally washed off and the material transported into the Veltrusy Château park. After the flood the bank was strongly consolidated, enrocked and integrated with the high water protection wall with underground barriers.

DESTABILIZATION OF SLOPES

Water saturation of soils due to long term heavy rain initiates landslides on slopes of suitable inclination and geotechnical conditions.

Typical damage
Repositioning of large volumes of earth causes the replacement of heritage objects, their collapse or burying. In some cases it produces only heavy structural defects, usually cracks in masonry and vaults.

Preventive resilience measures

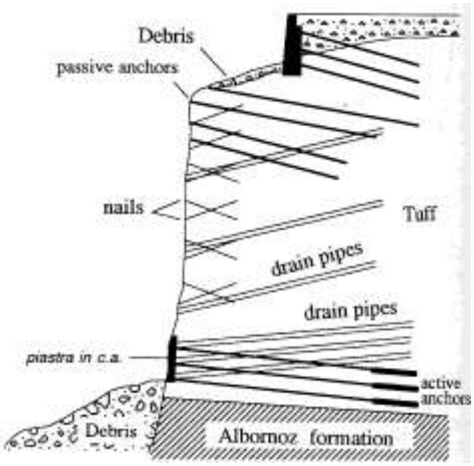
Typical measure is the stabilization of the toe of slope, e.g. with construction of a load imposing wall, decrease of load on the slope, planting stabilizing trees with deep roots and drainage of water from the landslide prone area, deep anchoring with tie anchors.

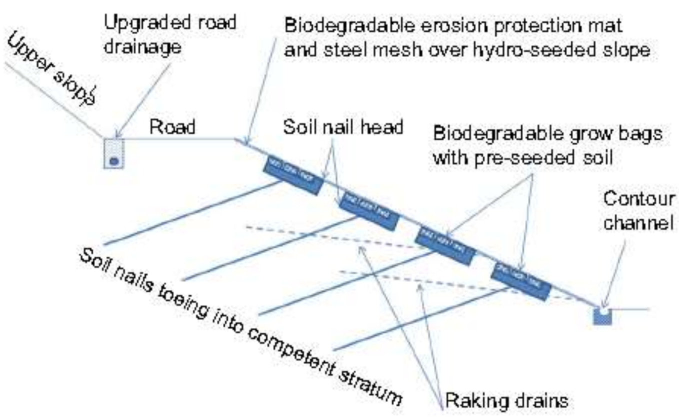
Invoked management demands

The identification of landslide prone areas endangering cultural heritage objects and their marking in risk maps. Hydrological monitoring is highly recommended.

Examples

Not only landslides but also rock-fall or combined must be treated. As an example the stabilization of the the Orvieto cliffs is presented as well as a typical slope stabilization.





WATER PENETRATION INTO BARRIER PROTECTED SPACES

Ancient and unknown channels, forgotten pipe ducts for waste disposal or ventilation and similar defects in the tightening system of barriers are openings for water penetration into protected spaces behind barriers. They can reach a rather high rise in buildings.

Typical damage

Usually only watering materials and structures, however with the subsequent impact of local damage and failures.

Preventive resilience measures

Closing and sealing of all possible inlet ways – automatic closures/doors on ventilation channels, in waste disposal pipes (spherical valves). Temporary closing of ventilation openings with prepared shutters.

Invoked management demands

Study of ancient plans and data for discovery of hidden and forgotten channels. Marking all channels in risk management plans of the historic building. Be prepared for pumping infiltrated water. The measures must be marked and described in the risk maps.

Examples

Penetration of water through water disposition channels into an area protected by means of barriers.

3.4. Object RCCs

OVERLOADING OF UNDERGROUND SPACES

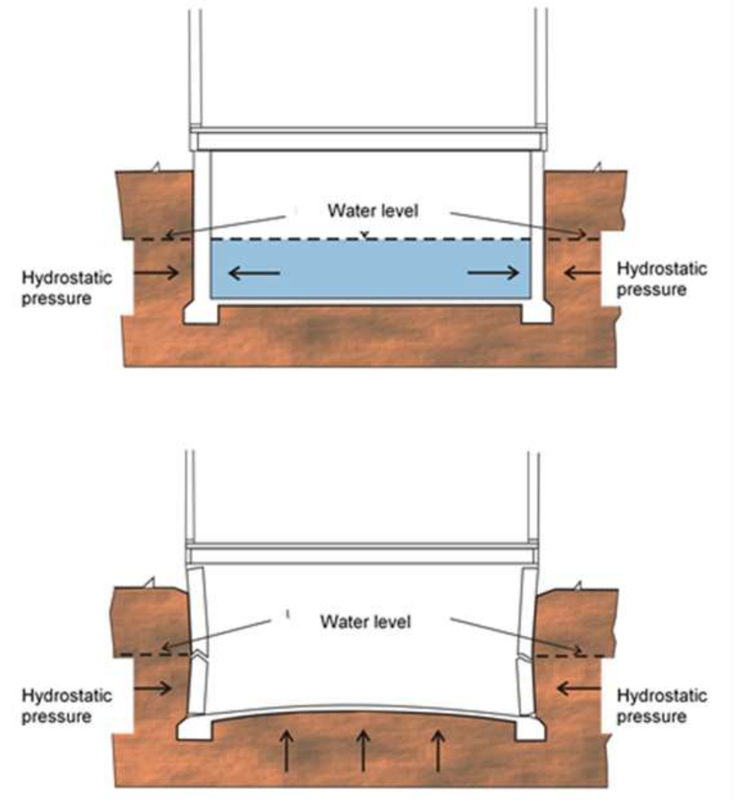
Raised water table level causes overloading of cellar walls and floors.

Typical damage
It may damage cellar structures by horizontal and vertical water pressure – heavy cracks and deformation in the walls, cracking and lifting up or breaking floor plates.

Preventive resilience measures
Extrados water proof insulation of cellars prevents flooding; however, it needs to create a continuous barrier around the floor and walls. Moreover, walls and floors must resist water horizontal and up-lifting pressure. If the structure has not been designed for such forces an appropriate approach must be adopted. The easiest approach consists in filling the cellar with water and thus to create counterbalance against the outer forces. In buildings with extrados waterproof insulation a water tight foliating of the cellar space and filling with water can be adopted. In other cases, mostly typical in historic buildings, the cellar space is simply filled with water – clean or even flood water.

Invoked management demands
The measures must be marked and described in the risk maps together with the location of storage rooms and access roads. The owners and/or operators must be trained for the measure installation. Water for filling cast cellar rooms must be ensured – even the flood water can be used for which pumping must be available or devices for wall breaking through.

Examples



OVERLOADING OF FREE STANDING HERITAGE OBJECTS WITH HYDROSTATIC PRESSURE

During the flood situation garden walls or façade walls of historic objects may be non-symmetrically loaded with high water hydrostatic pressure.

Typical damage
Failure of walls is a frequent result of such a loading.

Preventive resilience measures
Short walls may be temporarily protected by means of additional supports. The long walls can be saved by the similar approach as the above described cellar wall protection, i.e. balancing the one side force with a counter force ensured by the flood water. So it is enough to break in the standing wall openings which allow to water flow behind the endangered wall.

Invoked management demands
It is recommended to have in such walls prepared easily releasable inlet openings in the height above which the water pressure endangers the wall.

Examples
Frequently endangered are historic gardens and parks fencing walls, as e.g. Troja Chateau failed wall after the 2002 flood.


BREAKING OF WINDOWS OR DOORS BY HYDROSTATIC PRESSURE

Windows or doors with thin glass sheets are vulnerable to breaking due to high water hydrostatic pressure.

Typical damage
Glass sheets are broken or totally destroyed.

Preventive resilience measures
The typical measure consists in installation of temporary shutters protecting the opening.

Invoked management demands
The measures must be marked and described in the risk maps together with the location of storage rooms and access roads. The owners and/or operators must be trained for the measure installation.

Examples
An example of a prepared temporary measure for Prague shop windows in the inundation endangered area.

DETACHING AND TRANSPORTATION OF LIGHTWEIGHT OR OTHER FLOATED OBJECTS

Buoyancy causes detachment of lightweight objects from foundation as well as it enables the transport of floating objects.

Typical damage
Possible displacement of light or floating objects for long distances, their overturning and severe damage.

Preventive resilience measures
Appropriate anchoring of lightweight houses, log houses, cottages, boats and ships. Even freezers or tight steel containers may be subjects of floating.

Invoked management demands
Checking all buildings for their fixing to foundations or wooden parts to masonry.

Examples
Temporary loading of floors of lightweight building against detaching and movement.

IMPACT AND WATER FLOW LOADING ON HISTORICAL BRIDGES AND BUILDINGS

Danger of impact of floating objects on historical buildings and bridges is present during floods.

Typical damage
Mechanical damage up to failures. Destruction or damage of bridge rails.

Preventive resilience measures
It is necessary to reduce the number of floating objects by means of appropriate anchoring as well as a continuous capturing of the floating objects. Bridge rails should be provided with temporary additional supports or be dismantled.

Invoked management demands
The capture service must be organized – typically excavators are used. Measures concerning bridge rails must be marked and described in the risk maps together with the location of storage rooms and access roads. The owners and/or operators must be trained for the measure installation.

Examples
The capturing of floating objects is frequently provided from bridges (see excavator on the picture)

UNDERMINING OF HISTORICAL BRIDGES

Fast flow of water stream around the foundation of bridges may cause their undermining. It is usually a reason of floating barriers blocked by a bridge, which causes that water stream declines to the river bed.

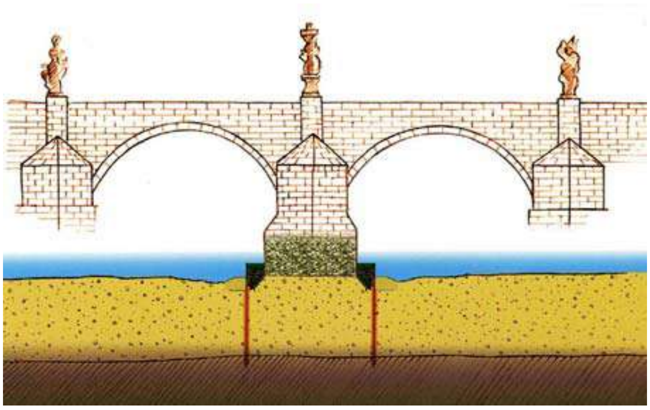
Typical damage
Creation of caverns under the foundations, additional settlement, partial or total failures of piers and total failures of vaults.

Preventive resilience measures
Historically effective were protecting isles around the bridge piers, modern approach takes advantage of geotechnical measures, e.g. sheet pile walls.

Invoked management demands
Regular maintenance of the installed protecting measures is important.

Examples

Example of historic protection of bridge piers against undermining (Regensburg)



Example of contemporary protection of bridge piers against undermining (Prague)

SCOURING OF FOUNDATIONS

Buildings on banks of water ways or founded on soils with fine particles may suffer from scouring of their foundations.

Typical damage
Caverns under foundations or subsoil washed away cause loss of support for the building structure and local or overall failure occurs.

Preventive resilience measures
Prevent water flow and stream to approach the building foundations by permanent means of bank enrockment or foundation strengthening or deepening, or by bank surface consolidation using temporary sand bag lining.

Invoked management demands
The availability of sand bags – storage, sand delivery and transportation.

Examples

WASHING OF SOILS AND FILLINGS

Even underground water flow can wash out fine particles under the shallow foundations of partition walls, under ground floor plates or generally in fillings on the construction site.

Typical damage
Heavy cracks up to total failures occur in partition walls or in ground floor pavement or yard and garden path pavement, exterior staircases etc.

Preventive resilience measures
Soil can be stabilized by means of compacting or grouting, however, this costly measure is usually applied only in a very specific cases, because repair after failure is usually cheaper.

Invoked management demands
No specific demands

Examples
Examples of damage are presented.


Left: Pavement deformation after flooding of infill made of collapsible soil; right: Partition wall deformation after additional compacting of washed away subsoil.

INCREASING DEAD AND LIVE LOADS OF CEILINGS

High water reaching levels above ceiling structures causes water saturation of structural as well as stored materials and increases significantly the loading of structures.

Typical damage
Excessive deflection of ceiling structures, even failures may occur.

Preventive resilience measures
Removal of stored materials with a high water absorptive capacity, temporary support of ceilings especially in cases of wooden floors with joists partly degraded by biological attack.

Invoked management demands
The regular maintenance, inspection for identification of absorptive or degraded materials, transportation service for removal of dangerous materials as well as for supply of material for temporary supporting.

Examples
Examples of damage are presented.

LOADS GENERATED BY MATERIAL EXPANSION

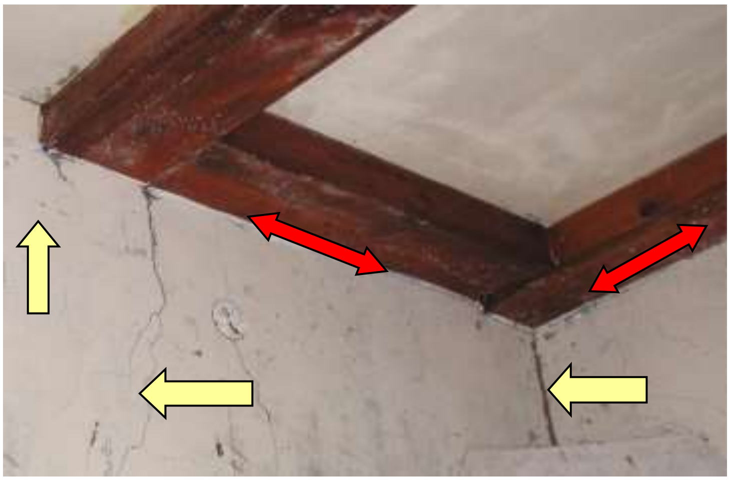
Some materials after water saturation increase their volume significantly (wood) and if this change cannot be accumulated they act as loading jacks.

Typical damage
Cracks in masonry are typical defects caused by expansion of timber elements

Preventive resilience measures
Appropriate dilation gaps should be done between masonry walls and ceiling joists, floor beams and wood based floor structures.

Invoked management demands
The inspection and identification of critical objects, materialization of dilation gaps.

Examples
Examples of damage presented.



Cracks in masonry generated by expansion of timber joists due to water saturation.

Parapet wall displaced by expanded floor beams.

DECREASING BUILDING SAFETY AND STABILITY

Some building materials after water saturation decrease or loses their load carrying capacity properties as well as stiffness characteristics, e.g. wood, stone, bricks burnt as well as dried or other adobe type materials.

Typical damage
Distress cracks are typical defects caused by wetted water sensitive materials. This load carrying capacity decrease may end with total failures in case of structural elements loaded up to their limits in dry situations, e.g. brick or stone pillars.

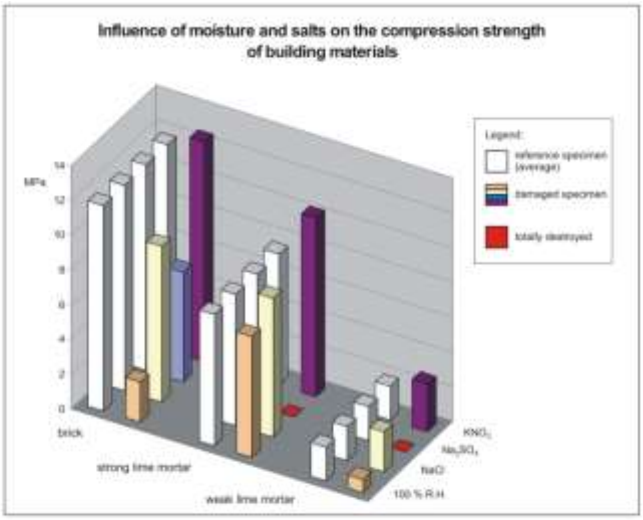
Preventive resilience measures
Resilience measures consist in temporary shoring up of critical structures in order to prevent their failures.

Invoked management demands
Detailed inspection for Identification of critical materials and structural elements. Assessment of safety by a professional expert in statics. Measures concerning shoring up must be marked and

described in the risk maps together with the location of storage rooms and access roads. The owners and/or operators must be trained for the measure installation.

Examples
Damage examples are presented.

Failure of a dwelling house due to a loss of bearing capacity of brisk masonry pillars.



Loss of strength of various building materials due to water saturation or combined with salt action.

WASHING OUT SENSITIVE BINDERS IN MASONRY

Many historic buildings are built of masonries with clay mortars which are vulnerable in flood situations.

Typical damage
Washing out clay mortars from masonry joints after long duration of flooding or due to flow around the surface.

Preventive resilience measures
Permanent covering of clay mortar based masonry with plaster or temporary protection with plastic foil preventing direct contact of flowing water with the masonry surface. Temporary fixing of other sheet materials, e.g. geotextiles or geo-nets on the wall surface.

Invoked management demands
The training of historic buildings owners and managers in installation of preventive measures.

Examples
Damage examples are presented.

Washed out clay mortar from stone masonry wall with fragile plaster not able to protect the wall.

Destroyed retaining stone masonry wall constructed with clay mortar,.

SOILING

Flood water transports not only objects but also a lot of mud, soil or sand particles as well as various pollutants.

Typical damage

Solid particles sediment on building surfaces, pollutants penetrate into porous materials.

Preventive resilience measures

Regular maintenance and on precious architectural surfaces impregnation with water repellent films.

Invoked management demands

Dissemination of knowledge, regular maintenance of historic surfaces.

Examples

WATER PRESSURE UPLIFT IN INTERIORS

Objects immersed in water are uplifted and may move inside interiors by floating.

Typical damage

During uplifting the objects with prevailing height over the base dimensions are unbalanced and loss their vertical stability. Open door and gate wings are typically unhinged and float in horizontal position. The floating objects easily block entrances into buildings and complicate rescue works.

Preventive resilience measures

The best way consists in evacuation of furniture including shelves from the buildings. The doors should be fixed against spontaneous opening or the hinges should be fixed against unhinging.

Invoked management demands
Training of building managers and owners, evacuation plans, availability of transportation means and storage rooms.

Examples
Damage examples are presented.

DECREASING SUSTAINABILITY IN SYNERGIES

Serious damage of cultural heritage assets can originate due to post disaster effects caused by inappropriate rescue actions or due to side effects supporting action of deteriorating phenomena.

Typical damage
Historic materials can be infected by deteriorating biological or chemical agents during flood situations. Their impact is intensified by long term increased moisture in timber elements or materials with a high porosity. Therefore, bacteria, fungi and crystallized salts may significantly contribute to cultural heritage damage or even losses. Also frost damage may occur in buildings and sculptures or architectural details which remain wet during winter periods. On the other hand in dry periods the impact of draught can be increased by vegetation (trees) which consume water from subsoil layers and may increase clay shrinkage with subsequent surface deformations and cracking of masonries.

Preventive resilience measures
Sensitive materials should be impregnated with water repellents as well as biocide agents even though they can be dissolved during long term flooding and the treatment must be repeated shortly after the disaster. Wet masonry can be protected against frost with temporary insulation, e.g. straw bale covering. Sculptures, fountains and other small objects can be sheltered using various types of temporary wrapping.

Invoked management demands
The preventive protection plans, training of staff, availability of necessary materials, storage and transportation means. The measures must be marked and described in the risk maps. The owners and/or operators must be trained for the installation in the case of temporary measures.

Examples
An example of wrapping of sculptures (after Embacher).

3.5. Contents (moveable objects & users) RCCs

Contents of endangered buildings should be preferably evacuated. The measures must be marked and described in the risk maps. The owners and/or operators must be trained for the installation in the case of temporary measures. There must be available suitable storage room for moveable heritage and transportation means, sometimes with specific packing tools and boxes. In the case of flood danger rooms for emergency storing of wet books, paper, photographs etc. equipped with freezing facilities must be prepared. Please note that contents RCCs are here just briefly presented as they will be discussed in detail in WP3 with the elaboration of rescue plans and evacuation strategies.

3.6. Role of maintenance

Regular maintenance is needed for all categories of cultural heritage objects. It is one of the most important strategies against damage and failures. Unfortunately, regular maintenance is widely neglected, and underlies most failures of the built heritage. Lack of regular maintenance leads to material decay and to the loss of mechanical properties, which enable structures to resist the acting forces. It also has a substantial influence on the subsequent measures, which are mentioned above.

Maintenance measures are usually initiated as a result of a regular inspection, or they can be carried out regularly on a basis of a maintenance plan, which is a better approach. Maintenance actions in most cases do not require design work or even engineering supervision. They can usually be left to the skills of properly trained craftsmen. This, in turn, enables action to be taken quickly, and prevents a defect developing into more serious damage or even into a failure. A maintenance guide is a useful tool, and should combine tips for inspection with recommendations on how to fix problems that are identified. In the event of flooding, the work should focus on the state of the fixtures and anchors, and on the remaining load-carrying capacity of the materials and structures [Drdácký et al. 2011]. In this context it should be underlined that especially defects on objects subjected to repeated damaging action must be repaired in time in order to prevent major problems. For example a small missing stone of a structure exposed to sea waves opens continuation of damage, (see figure below).

4. REFERENCES

- Birkmann, J. (2007) Risk and vulnerability indicators at different scales: applicability, usefulness and policy implications, Environ Hazards 7:20–31

- Drdácký, M., Herle, I., Pospíšil, S., Slížková, Z. (2011). Protecting cultural heritage against natural hazards, in Keynote Papers "Seismic protection of cultural heritage", Proc. of the 2nd WCCE-ECCE-TCCE Joint Conference, Antalya, ISBN 978-605-01-0188-1, Turkish Chamber of Civil Engineers, Ankara, pp. 103-122.

- ProteCH2save (2018). D.T2.1.3 Decision support tool.

- UNESCO (2008). Operational Guidelines for the Implementation of the World Heritage Convention-Annex 3. Available at: https://whc.unesco.org/archive/opguide08-en.pdf#annex3. Accessed on 18.10.2018.