

ANALYSIS OF VULNERABILITY OF CULTURAL HERITAGE AGAINST FLOODS

K. Nedvěďová^{*}, V. Kostkanová, J. Frankl, R. Pergl^{}**

Abstract: *Introducing first part of the project Methodology of Protection and Rescue of Cultural Heritage against Flood dealing with creating catalogue of damage on cultural heritage due to floods. The aim of this catalogue is to collect, synthesize and analyze possible known information about the damage linked with a particular object of protection and material.*

Keywords: *Cultural Heritage, flood, material vulnerability, damage risk.*

1. Introduction

Flood is a natural phenomenon that cannot be avoided but in past years its impact is rapidly growing. During last 15 years we have been experiencing many severe flooding that influenced almost every part of the Czech Republic. Except damages of life and property there have been loss of historical monuments, devastation of sites and changes in historical landscape. Irreversible loss and great expenses spent to restoration and renewal led to the conclusion that integrated flood risk management is needed if we want protect effectively historic environment against flooding.

From the analysis of flood impact in selected towns and villages and from other European projects emerged series of serious facts:

- insufficient foreknowledge of owners and stakeholders about value of cultural heritage objects and necessity of special approach during remedial works, especially in heritage reservations and zones,
- inaccessibility of practical experience from floods in past years,
- lack of effective instructions for owners and administrators,
- lack of experience and methodic guidelines for local government in unusual situation happening on cultural heritage site,
- inappropriate use of materials during renovations,
- importance of proper maintenance and good technical condition of buildings,
- importance of preventive measures,
- absence of guidelines for flood protection planning on outstanding cultural heritage sites,
- need of transparency in legislative and processes of flood protection planning to achieve maximal efficiency and sensitivity,
- underestimated role of historical water works

2. Catalogue of damage

According to this experience our project Methodology of Protection and Rescue of Cultural Heritage against Flood was formed. First part of the project is dealing with creating catalogue of damage on cultural heritage due to floods. The aim of this catalogue is to collect, synthesize and analyze possible known information about the damage linked with a particular object of protection and material. Furthermore this catalogue analyzes possible damage vulnerability at these objects of cultural heritage. A special attention is paid to prevention and tends to recommend suitable measures for different

^{*} Ing. arch Klára Nedvěďová, Mgr. Vladislava Kostkanová, Ph.D., Ing. Jiří Frankl, Ph.D., Institute of Theoretical and Applied Mechanics, AS CR v.v.i., Prosecká 809/76, 190 00 Praha 9; CZ, e-mail: nedvedova@itam.cas.cz

^{**} Ing. Robert Pergl, Faculty of Economics and Management, Czech University of Life Sciences Prague, Kamýcká 129, 165 21 Praha 6; CZ, email: pergl@pef.czu.cz

situations in this part. Both moveable and immovable objects of cultural heritage are included in the catalogue.

Catalog will have an electronic form and should be available within wider informational server of Ministry of Environment ČR POVIS for free. Owners, administrators of the cultural heritage and professional public are considered as possible users. Catalogue should serve as a tool for assessing damage vulnerability for moveable and immovable cultural heritage.

The experiences from last recent floods in the Czech Republic (especially disastrous floods in 1997 and 2002) are used as inputs. Also the practical knowledge about possible damage and its prevention from specialists of different branches serves as an important resource.

A conceptual ontological map was created and it serves as a functional tool for creating the base of the damage vulnerability catalogue for various objects of cultural heritage. The catalogue is organized in two main parts. Input factors will be given to user to define his object of interest and characteristics of flooding. As input data are specified:

- characteristics of flooding – water height, dynamics, cleanness of water, period of occurrence, length of activity,
- temperature, moisture, season,
- construction system, technical state and material creating the object of interest

Based on these user defined inputs, output analysis is created:

- vulnerability of the object to probable damage,
- damage description, description of damage mechanism,
- recommended preventive measures

The vulnerability of flood damage is categorized according to the flood action and object type to three main degrees: a) no consequence or very small damage (resistant objects) b) medium damage or significant consequence c) critical consequence, total damage, destruction of the object. However finer categorization within these main degrees is also possible. Examples of recorded damage on cultural heritage in the past are demonstrated in the form of damage cards. There are described object characterization, flood action and damage description in detail. Performed reconstruction and protective measures are described as well.

3. Conclusions

Right prevention is considered as most effective measure and more sensitive towards objects itself. It reduces loss of cultural historic value and authenticity. The catalogue of the damage vulnerability due to floods will help to plan and optimize the correct prevention measures applied in time to protect the objects of cultural heritage in the future.

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References

- Drdácký, M., Binda L., Hennen I.Ch., Koepp, Ch., Lanza, L.G., Helmerich, R. (eds.) (2011) *CHEF – Cultural Heritage Protection against Flooding*. Institute of Theoretical and Applied Mechanics AS CR, v.v. i. Prague
- Drdácký, M. (ed.) (2010) Special Issue: Flood impacts to Heritage Structures, *Journal of Performance of Constructed Facilities*. Vol. 24 No. 5
- English Heritage (2004) *Flooding and Historic Buildings*, Technical Advice Note.

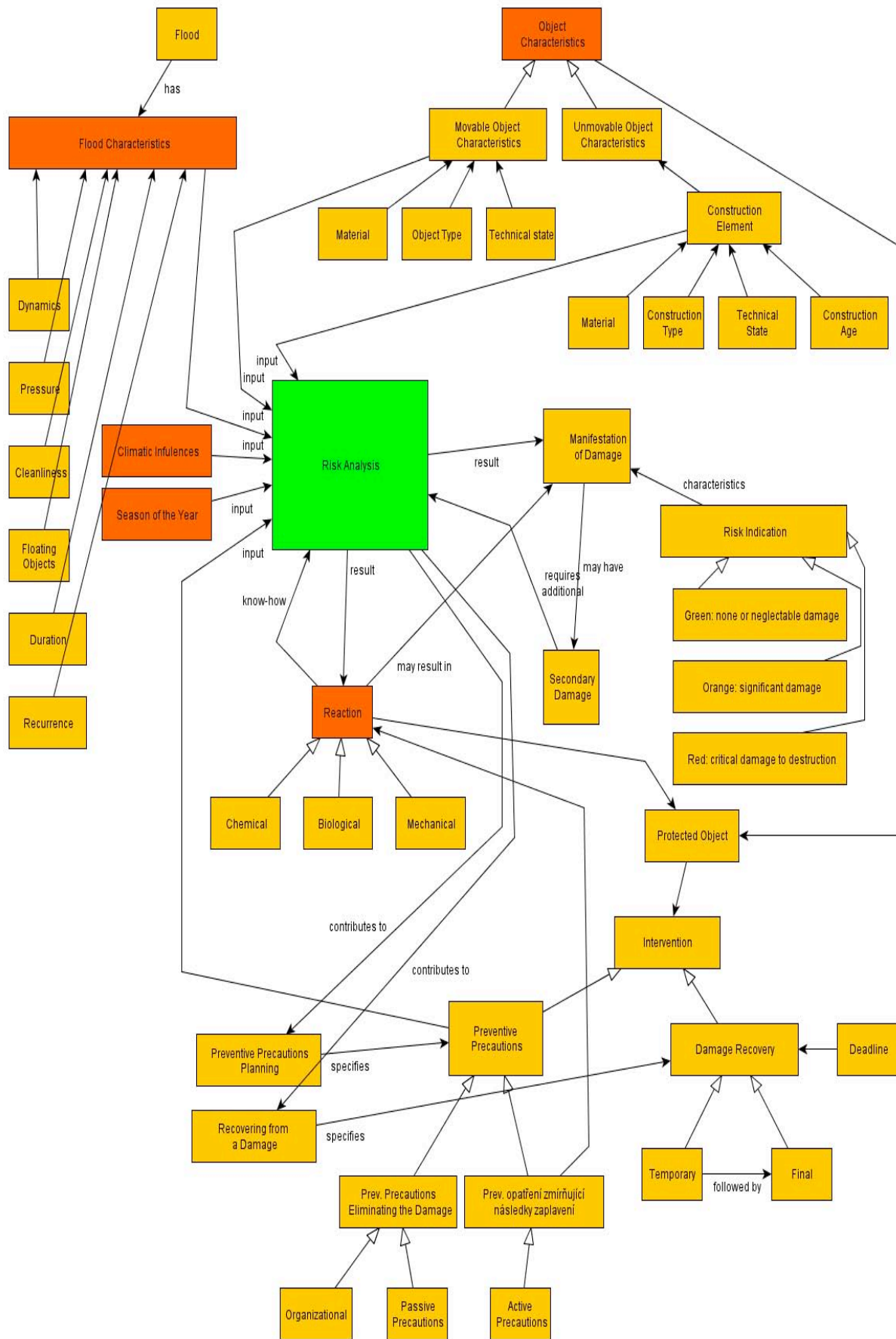


Fig. 1 A conceptual ontological map

CARD OF DAMAGE AT CULTURAL HERITAGE

Object – name, address:	Charles Bridge, Prague 1	Subscribed in: NKP, KP
		Lies in: UNESCO, Prague Protected Area
Object type:	Medieval stone bridge with 17 piers connected with 16 arches	
Construction description:	Stone bridge was built in 14 th century, destroyed in historic floods and reconstructed (rebuilt) in every century thereafter construction materials: marly sandstone, sandstone in 20 th century reconstructed foundations and bearing constructions: concrete, steel, sandstone formerly reconstructed or original foundations and piers: sandstone, wooden piles, wooden grate, bricks	
Object use:	Pathway for walkers, heritage, stands and artists, museum (in bridge towers)	
Description of the damaged construction, material	Subsoil of incohesive coarse river sandy gravels under foundation of pier No. 8 and 9. First pier ring based on wooden grate, which is founded on wooden piles of unknown length. Foundation of pier No. 9: millstones bellow the protective pier ring, perimeter rings founded on wooden sheet walls at the distance of 2 m from the pier trunk reaching the incohesive sandy gravels; stone fill, partly bricked	
Technical state before flood:	Technical state before flood not known in detail – exploration conducted after flood, but from historical sources known damage in the past during floods in 1432 and 1784, partly reconstructed in past Insufficient foundation depth in coarse river sediments of Vltava river (sands and gravels), which are sensitive to scour Original wooden foundations of the 8 th and 9 th piers from the 16 th century partly repaired in 18 th century	
Flood description:	August 2002, Vltava river, $Q = 5\,500\text{ m}^3/\text{s}$ (average normal $Q = 150\text{ m}^3/\text{s}$) Flood type: summer flood	
Acting factors, causes of the primary damage:	Acting force: dynamic action of streaming water - strong horizontal stream, Duration period: days	
Mechanism of damage:	Erosion of coarse river sediments as a consequence of strong dynamic impact of streaming water, scour of the pier foundations, founded in these sediments	
Manifestation of damage:	Potholes at the pier rings, which did not reached the original pier trunk Scoured cavern below the millstones – foundation of the 9 th pier	
Secondary damage in consequence of the event	Damage mechanism: thread of the possible inclination of the foundations and piers, possible uneven settlements (were not present at the time of exploration) foundations are in metastable state	
	Damage manifestation: none at the upper construction thread of the crack formation due to uneven settlements and construction inclination possible thread of collapse of the whole pier construction during floods in the future	

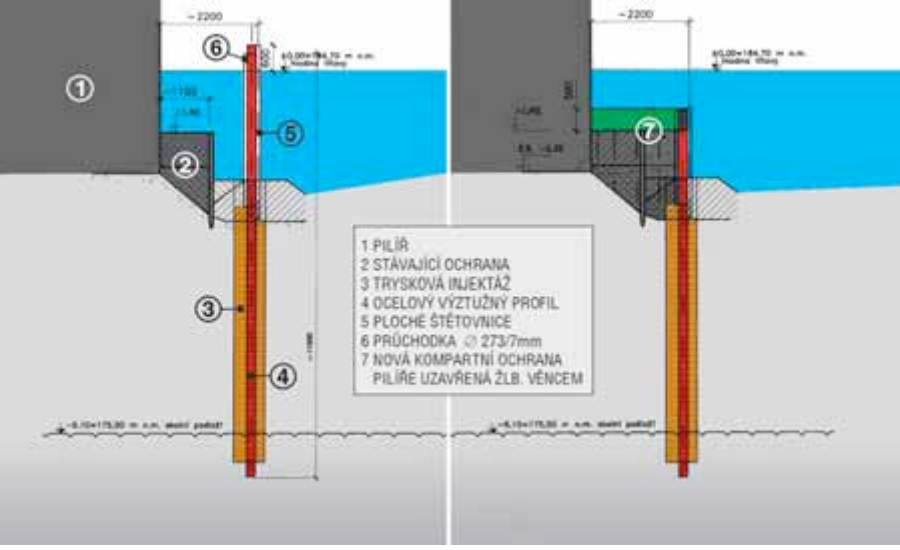
Reconstruction measures	<p>Reconstruction duration: 2004-2005, reconstruction of the damaged foundations founded into insufficient depth in scour sensitive river sediments, permanent protection of the foundations against scour</p> <ol style="list-style-type: none"> 1. Prolongation of the foundation depth through the sheet pile wall combined with jet grouting into the ground layer of low permeable rock horizon 2. filling of the caverns by jet grouting
Prevention measures:	<ol style="list-style-type: none"> 1. permanent scour protection of the pier 8th and 9th foundations, sheet pile wall was embedded into the ground layer of low permeability and connected with the bridge pier through a reinforced concrete beam 2. reconstruction of icebreakers (2003/2004) – protection against floating objects
Picture documentation:	 <p>1 PILÍŘ 2 STÁVAJÍCÍ OCHRANA 3 TRYSKOVÁ INJEKTÁŽ 4 OCELOVÝ VÝZTUŽNÝ PROFIL 5 PLOCHÉ ŠTĚTOVNICE 6 PRŮCHODKA Ø 273/7mm 7 NOVÁ KOMPARTNÍ OCHRANA PILÍŘE UZAVŘENÁ ŽLB. VĚNCEM</p>
Reference/further information:	<p>Remeš M. (2004) Karlův most — definitivní ochrana základů pilířů; 8 a 9 časopis Zakládání staveb). 4/2004, pp. 2-4.</p>

Fig. 2 Card of damage at cultural heritage – Charles Bridge (8th and 9th pillars)