Structural damage index identification
for historical masonry bridges

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Abstract: - In the paper, based on a cataloguing developed on more than a hundred historical masonry bridges in the Campania Region geographical area, focus is given to the introduction of a synthetic index able to give back a measure of the structural decay of the single construction. The developed archive collection of historical, dimensional, technique and technology data, and crack descriptions through surveys in situ and inspections allow to determine for each case a synthetic index of the overall decay under the structural profile (both referred to the material and the structure) and give a concise measurement of the conservation state about the analysed bridges.

Key-Words: - Masonry constructions, Monumental Heritage, Preservation, Damage, in-situ Surveys, Study cases.

1 Introduction
The analysis of a masonry bridge construction usually requires the jointed consideration of a number of features including functional, environmental, urban, technical and architectural ones [1]. This study refers to an archive accounting for the most important historical masonry bridge
constructions over the geographical area of the Campania Region starting from the Roman period, where 107 bridges are classified according to construction historical period, materials, the geometrical and technical properties, structural conservative state.

In details, particular focus is posed on the identification of a synthetic measure of the structural decay of the single bridge. Generally speaking particular significance acquires the understanding of the behavior of such infrastructure in relation to its condition of damage and the ability to relate it to the causes of the damage.

Analogously it appears to be of fundamental interest the ability to distinguish what can be accounted to a purely physiological behavior mode of the material and of the structure, which tend to absorb the internal stresses through the redistribution of balances within the building masses with the development and spread of fractures and cracks, from what is, on the contrary, to be considered pathological, and which must, therefore, be the starting point for any planning and design for consolidation purposes.

To this aim one should emphasize that modeling issues are of primary importance in current analyses (for referenced by the authors one may refer to [2]-[7]) although simplified modeling may be adopted for first stage expeditious analyses for qualitative understanding about the structural behavior.

On the basis of the mentioned archive the final objective is to give a rapid feedback and capture a picture then elaborated through a synthetic damage measure about the current structural conservation of the observed bridges over the territory, also allowing to identify the most critical situations.

2. Damage index identification in the masonry bridges’ cataloguing

2.1 Overview of data sheets for cataloguing on regional scale

The archive data sheets have been set according to tabular criteria in order to highlight the principal quantitative, qualitative and structural features.

The sheet is subdivided in three sections, each one being focused on specific features. In the following a synthetic description is given of the sections.

2.2. Framework data: Section 1

The first section concerns the geometry, the use type, and the artifact geographical identification over the territory, by reporting:
- The header with the sheet identificative number and bridge name.
- The territorial framework including the planimetry with the location of the artifact and the chart with specification of, the Province and district codes, and district name.
- The identification of the construction age by historical period, i.e.: Roman age, Medieval age, XVI- XVII centuries, XIX-XX centuries.
- The interventions suffered during centuries by type, including the construction phase, restoration, consolidation and other interventions.
- The charts allowing to identify the bridge use destination, degree of integrity, use and use intensity by traffic typology.
- The geometry in terms of overall dimensional data, such as the total span, height, width, number of spans and orders of arches.
- The geometry in terms of dimensions of the structural parts of arches and piles, and shape.
- The plano-altimetric map

2.3. Structural decay: Section 2

The second section (one may refer to Fig.1, as regards the S. Barbara’s bridge, as an example) concerns construction and technology features, and the identification of a synthetic structural decay index.

This section is divided in two parts, the first one concerning a recognition on the materials and building technologies, reporting:
- The type of masonry elements divided in clay bricks, stone and tuff.
- The prevalent typology of masonry, distinguished in three classes, stone masonry, clay brick masonry and mixed masonry, and classified according to the model of realization, i.e. drystone or with mortar.
- The typologies of used materials, identified trough some codes referring to:
M1: stone masonry cutting
M2: ordinary masonry squared with mortar
M3: brick masonry with mortar
M4: ordinary masonry squared without mortar
M5: ordinary masonry not squared
M6: drystone masonry in rough stone
M7: masonry with regular and homogeneous elements.

The map of wall covering, with the pattern of the masonry tissue for the single element.

The second part of this section is organized in order to identify the structural damage coefficient relevant to the conservation state of bridge as regards to its structural decay due to recorded cracks and damage type, by reporting:

- The crack geometrical development (horizontal, vertical, diagonal, longitudinal)
- The crack location on the bridge (vault, piles,..)
- The degrade, according to the following classification:
  T1: No damage, cromatic alteration, concretion, scub, surface sediment, patina and/or film.
  T2: Efflorescence, gap, stain and/or biological patina.
  T3: Deformation, differential degradation, wear and/or pitting.
  T4: Crumbling, exfoliation, pulverization.
  T5: Dissociation, crack, infesting vegetation and/or swelling.

The damage quantification based on the damage extension in percentage terms with reference to the bridge volume, by subdividing into percentage classes varying for the minimum recorded damage from 5% (if the damage is extended to individual elements without continuity) up to 80% (if the damage interests the major part of masonry). All intermediate percentage classes are considered, including ranges between 20% and 40% that identify limited degrade areas, to those with more substantial degrade between 40% and 50% (prevalent degrade), and finally the more critical situations between 50% and 80%.

By crossing data referred to the type of damage/decay and its extension, it is identified a summary measurement of the decay state of the bridge classified through the indexes D1, D2, D3, D4, D5, developed in agreement with [8].

<table>
<thead>
<tr>
<th>T1</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
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<tbody>
<tr>
<td>T2</td>
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</table>

The damage quantification allows to finally identify the synthetic index of structural decay of the bridge follows the scheme in Tab. 2.

The highest value of coefficient denotes a significant structural decay.

<table>
<thead>
<tr>
<th>D1</th>
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<tbody>
<tr>
<td>D2</td>
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<td>D3</td>
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<td>D4</td>
<td>1.10</td>
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<td>D5</td>
<td>1.20</td>
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2.4. Additional notes and graphics: Section 3

The third and last section of the data sheet concerns the insertion of possible notes and graphics that may include pictures, detailed imagines, or data from survey when available.

3 Conclusions

In the paper, issues aimed at providing a structural conservative state framework for this masonry bridges historical infrastructures are reported.

The proposed approach is aimed at identifying the most critical situations on the regional scale territory, as regards to decay of material and structural properties, by crossing data from the set up archive.

A synthetic index is introduced according to [8], intersecting data and information obtained as concerns damage typology, extension and location with those concerning the main characteristics of the bridge.

The index is given numerical values ordered in ascending order as concerns the degree of structural decay, for possible subsequent use within further analyses, indicating the amount and intensity of damage affecting the bridge as a whole, to give a
summary indication of bridge decay structural state. The proposed model is extensible and feasible on different scales and geographic areas.

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References: