SCOUR AND UNDERMINING EFFECT ON MASONRY ARCH BRIDGE: THE EXPERIMENTAL MODEL

Local scour and undermining are causes of many of the observed masonry bridges failures and collapses. These hydro-geological phenomena produce accentuated erosion of the bed material at bridge pier foundation due to higher flow velocities and formation of vortices around the base of the obstruction during flood events.

The direct damage states are the abrasion of the foundation material and the failure of the others supporting elements (like wooden or steel piles under the foundation) and the reduction of the footprint. Foundation settlements and rotations, which come from the progressive support loss of the foundation soil, result to serious structural damage which threaten masonry arch bridges integrity.

In order to study the evolution of this particular damage scenario and to identify some structural symptoms which could early warn of its development, an experimental model of a little masonry arch bridge is under construction in the DISTR laboratory at the Politecnico di Torino (fig. 1).

The 1:2 scaled masonry model is 5.90m high and 1.6m wide and is built with handmade clay brick also scaled to 130x65x30mm. The blocks have law compressive strength and are bounded using a mortar with poor mechanical properties trying to reproduce the same materials of historical constructions. The two arches are supported at the edges by two masonry abutments, which rest on two concrete blocks fixed to the lab floor. At the top of the model, longitudinal and transversal spandrels walls retaining the fill material that loads the arches are also realized to respect the typical geometry of masonry arch bridges. The mid-span pier, supposed to be placed on the riverbed and so affected by scour, is positioned on a settlement application system expressly designed to simulate this effect. Vertical displacements and rotations around coordinated horizontal axes can be applied turning the four screws which support the pier. Different settlement profiles of increasing extent will be applied, based on the results of specific hydraulic tests carried out on a small scale model of the pier.

Figure 1- Laboratory experimental model (under construction)

Before the application of the controlled damage states some preliminary tests and analyses will be performed to better understand the model behaviour and to derive a reference (virgin) system for the comparison with the damaged situations. Furthermore, the results of these preliminary analyses will be useful for the plan of the following "damage-applied" tests. These initial studies include the characterisation of the employed materials, the numerical predictions of crack locations and the numerical estimation of modal parameters. A preliminary Finite Element (FE) model of the experimental structure has been realized with 8 node isoparametric linear elastic solid elements (fig. 2). In order to improve the analysis reliability, the input material properties of the numerical model has been collected by some static tests performed on samples of brick, mortar and masonry blocks. The large number of these destructive tests, generally not permitted on real historical structures, has also allowed to derive the masonry compressive and flexural bond strength. The cracks location and

occurrence in the preliminary numerical model has been easier evaluated on the basis of these parameters.
The experimental survey will consist in the application of increasing displacements and rotations to the structural model so that a set of damage scenarios of growing intensity will be produced. After the enforcement of each of these states both global and local dynamic tests will be carried out in order to identify the variation of some modal parameters (natural frequencies, mode shapes, damping ratios and their combinations and derivatives). Our study is mainly focused on the definition of those overall parameters which are more damage sensitive and that could be adopted as warning bells against the development of crack mechanisms in masonry arch bridges affected by scour. Different kind of excitation sources (ambient vibration, instrumented hammer and exciter) will be tried to give higher robustness to the results of the dynamic identification. Moreover, the acquired vibration signatures will also be used to refine a more accurate FE model of the structure in order to estimate location and extent of each damage scenario. Further tests will be performed to investigate the influence of temperature and air humidity inside the laboratory on the acquired vibration signatures and on the derived modal parameters.

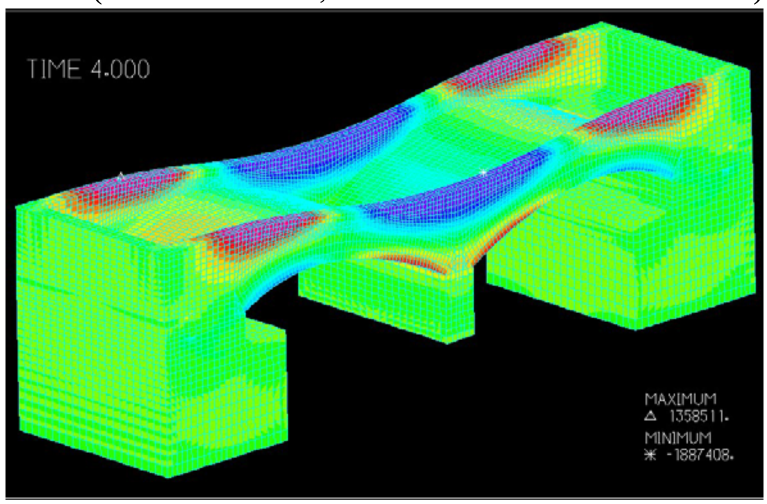

Figure 2 – Preliminary arch bridge FE model

On the other side, some non-destructive techniques based on acoustic emissions and cracks opening monitoring through strain gauges and fibre-optic sensors will allow to assess local failures and defects more precisely and to track the evolution of the damage state in the course of the experimental study.
Finally, the possibility of applying some restoring techniques and to evaluate their effectiveness has been taken into account. Thin sheets of carbon FRP material could be placed at the intrados of the damaged arches in order to restore their initial bearing capabilities. Further dynamic tests could be carried out to assess the strengthening intervention and to investigate the variation of the same overall modal properties, previously adopted as damage sensitive parameters.

The described experimental model under construction in the DISTR laboratory at the Politecnico di Torino has been designed by the Dynamic and Seismic Engineering Research Group led by Prof. A. De Stefano. Growing interest on the scour problem is proved by recent works of S. Foti and D. Sabia who show the influence of the foundation system conditions on the dynamical behaviour of existing masonry arch bridges. These works gave the starting point for the experimental laboratory investigation that has been developed as case study within the PRIN 2006/8 national research program: “Guide-lines for the surveillance and management of historical structures and infrastructures, with the aid of automatic innovative monitoring systems”. The model could also find space within the TISMAD European research program that the group of Prof. De Stefano will take part in and which is specifically addressed to study the scour and undermining effect on the foundations of masonry arch bridges.