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In-situ NDT testing procedure as an integral part of failure analysis of historical masonry arch bridges

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ABSTRACT

A nineteenth-century masonry arch bridge was analyzed as an illustrative example to explain the role of in-situ test campaigns in failure analysis and retrofit design. Test results were studied to find out the advantages of each technique, with the aim of proposing an optimized in-situ testing procedure. Standard static penetrometer, flat jack, thermographic and georadar in-situ tests were conducted. Traffic effects were analyzed by means of vibrational tests. The experimental analysis performed to investigate damage on the bridge structures shows the degree of reliability offered by each technique in evaluating specific information and reproducing the global behavior of the structure.

1. Introduction

Several roads in Italy and Europe are connected by masonry arch bridges. Throughout the centuries, traffic loads have increased significantly, resulting in steady erosion of safety margins. Evaluating structural safety of historic masonry bridges is a key issue for the maintenance of national and international infrastructural heritage. In Italy and Europe, several 18th century bridges are still operating, e.g. "The Castagnara Bridge" in Padua, dating from 1848 [4], "The Stone Bridge" in Verona, "The Cernadela Bridge" Mondariz in Northwest Spain etc. Venice counts about 480 masonry arch bridges today, but historical records tell us that their number was twice as much in the past. Venice lagoon environment and soil characteristics are not adequate for the conservation of historical heritage. In fact, Venice soil is generally made of clay layers with a low bearing capacity and variable position and thickness. Only some areas of the lagoon feature overconsolidated clay, named "caranto", which formed during a sea regression between about 6000 and 10,000 years ago, and where the Serenissima Republic erected its buildings.

Historical experience demonstrates that masonry bridges and buildings, unlike the ones made of reinforced concrete and steel or equipped with seismic isolation [13,16,19], were not built to withstand seismic actions. Therefore, sometimes, they collapsed, partially or totally. Moreover, masonry aging leads to continuous erosion of the security level of a structure, with respect to both service and ultimate limit states, as compared to its original conditions. However, structural damage is often caused by geotechnical or hydraulic problems [15]. High pressure transmitted from abutment foundations to soil can produce large deformations and differential displacement in abutment foundations. These effects represent a danger for masonry arch structures because they translate into a loss of horizontal and rotational restraint at the arch base likely to evolve in hinge formations along the structure and eventually in collapse. This

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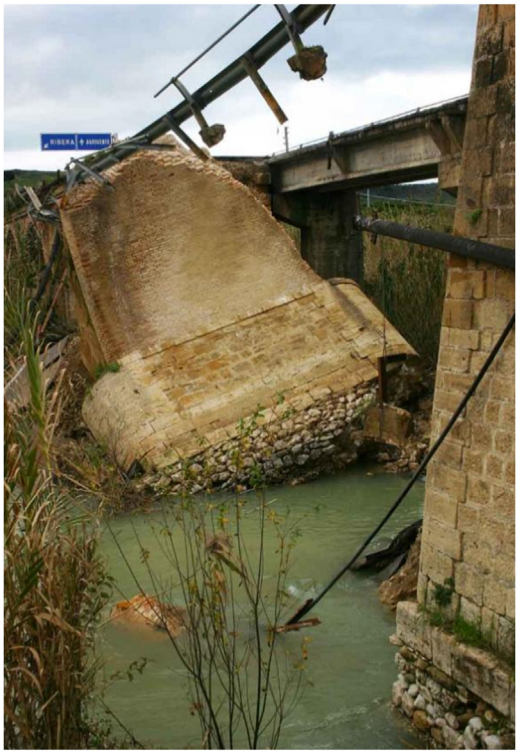

Fig. 1. The collapse of "Ponte Verdura" in Sciacca (Sicily).

demonstrates that understanding the real causes of structural damage, and consequently performing in-situ tests, are essential steps of retrofit design development [10].

The recent collapse in Sciacca (Sicily — Italy) on 4th February 2013 of the masonry arch bridge "Ponte Verdura", dating from 1870, is shown in Fig. 1. The collapse as "rigid body" of the pier is principally due to geotechnical and hydraulics causes.

Fig. 2. The "Paleocapa Bridge".