The effect of horizontal loads caused by rapidly rising river water on the bearing capacity of masonry arch bridges

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Abstract

Many masonry arch bridges have a culturally significant history, as well as aesthetic appeal, as the arch shape adds to a balanced appearance. Some of these arch bridges are crossing rivers, which have fast rising torrent water, especially after winter. The bridge piers are then exposed to horizontal loads from wave impact and debris. These loads can occur several times a year and are therefore not accidental. Numerical simulations of the case of Devil's Bridge (Bulgaria) demonstrate that nonlinear FE-analysis, on the basis of Mohr-Coulomb's law, is not entirely fit for this type of structure. Determining the shear strength, after cracking is inaccurate, because of the material's brittle character. The torrent wave causes such kind of failure, whereas first the debris impact causes local damage, the latter fostering the failure. Therefore, maintenance of stones and joints of such bridges is of capital importance.

Keywords: historic masonry arch bridge, river torrent load, debris, nonlinear FE-analysis, lateral load on bridge pier, shear in masonry.

1 Introduction

Arched masonry bridges are found in many countries of Western and Continental Europe. Some are dating from the Roman period. Most of these are considered as heritage structures and maintained through monumental care. However, the majority of masonry arched bridges date back from the 19th and early 20th century and are still serving well. Obviously, the construction methods implemented to build these bridges are outdated. Nevertheless, their history may be both culturally significant and have aesthetic value, since the arch shape appeals to the human soul and adds to a balanced appearance.

Apart from those which are seriously degraded, the load-carrying capacity of masonry arch bridges is satisfactory. This would imply regular checking of the condition of these bridges, carrying out maintenance and verifying their strength and stability.

A typical degradation of brickwork vaults consists of the spalling and subsequent failure of the intrados stone layer. This is mostly due to excessive vertical loads, combined with poor maintenance. However, resistance to vertical loads of masonry arch bridges seems to be controlled, verified and assessed adequately. Yet, apart from seismic effects and foundation's equilibrium, less attention has been given to the resistance to horizontal loads. An important type of horizontal loads on the infrastructure of masonry arch bridges is the effect of impact of river water.

One of the effects of climate change is river flooding, either by excessive rain or by melting of upstream ice from mountains. Such sudden torrents of small rivers happened in July 2021 in the Eastern part of Belgium and in the Eiffel region in

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