Investigation of the Response of a Skewed Masonry Arch Railway Bridge using Fibre-Optic Sensing Data and Membrane Equilibrium Analysis

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ABSTRACT

Masonry arch bridges feature in the railway and road transportation networks of many European countries. However, despite their prevalence, their structural behaviour under working loads is often not understood in detail. As a result, assessments typically focus on collapse loads, which can be predicted using limit analysis. Serviceability conditions may not be considered directly at all, despite being a driver of structural deterioration.

To address this, asset engineers increasingly prescribe structural health monitoring for their masonry arch bridges. One such bridge is considered here: a single-span skewed railway bridge in Yorkshire, UK, with a working life of 150 years and which carries passenger, cross-country, and freight trains. It has experienced historic damage, which was addressed in an intervention in 2016. Since 2018, it has been monitored using a range of sensors, including fibre-optic Fibre Bragg Gratings (FBGs) measuring the distribution of principal strains across the arch intrados [1].

The detailed strain data from these FBGs can be combined with analytical methods to further investigate the serviceability condition of the bridge. Membrane Equilibrium Analysis (MEA) has been developed in recent years as a tool for finding statically admissible stress fields in masonry structures which can be assumed to exhibit membrane behaviour [2]. Heyman's no-tension assumption for masonry is enforced by ensuring that the stress potential is concave in form. Starting from such a potential, a minimum energy solution for the form is then obtained through optimisation of the defining parameters, for different loading conditions that include dead load and moving train loads, and for different boundary conditions. The forms which are obtained are confined within the thickness of the arch and filling, even for extreme states. These equilibrium solutions, though sufficient to prove that a structure is safe, may also be used to assess the possible impact of material deterioration.

In general, many masonry arches and vaults prefer minimum energy solutions (e.g. the minimum thrust [3]); however, unknowable conditions may mean that the real structure does not necessarily adopt this configuration. In this study, measured strains on the arch intrados of the bridge are examined alongside predicted minimum-energy strains from MEA. A continuous distribution of strains (i.e. no ring separation) and a linear-elastic stress-strain relationship (i.e. compression-only behaviour at acceptably low stresses) are both assumed, based on observations from the bridge. In this way, the validity of the minimum energy solution for this bridge is investigated.

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