Dynamic, distributed FBG sensing of the structural response of a skewed masonry rail bridge

CSIC Cambridge Centre for **Smart Infrastructure & Construction**

The Barkston Road skewed bridge

In operation since the late 1860s, this bridge has a complex history of damage and repairs. Key existing longitudinal cracks are shown in dashed red lines, in the plan view to the right. In 2016, the bridge underwent structural interventions to address crack growth in these regions and an increasingly lively response to train loading.

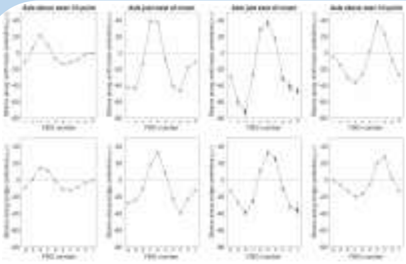
Uncertainty in the structural response – particularly due to the presence of skew in the bridge geometry – meant that the long-term effectiveness of the intervention was unclear. Since 2018, the bridge has been monitored by CSIC and AECOM. This includes distributed, dynamic Fibre Bragg Grating (FBG) sensing of its response to train loading.

↑ New FBG clamping arrangement to measure crack shearing movements

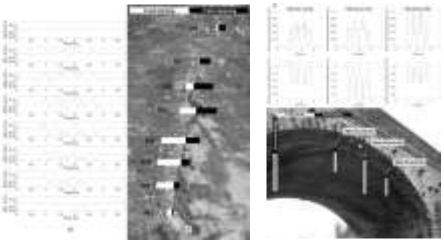
↑ Elevation view of the bridge

↓ Subset of FBGs discussed in this poster

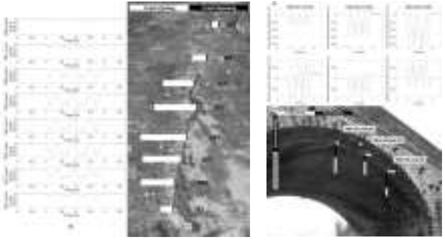
Characterising the structural response



↑ Boxplots of the instantaneous strain distributions in the longitudinal FBGs, measured when axle loads are applied in key locations, show strong agreement across many hundreds of trains, indicating consistent thrust lines adopted by the arch



↑ Typical crack movements for a Class 185 passenger train passing on the south track



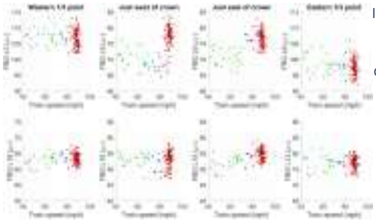
↑ Typical crack movements for a Class 185 passenger train passing on the north track

The high resolution and repeatability of FBG measurements allow for the structural response of the skewed arch to be measured in detail. In-plane strain distributions are consistent with anticipated behaviour. These strains and the movements across cracks – both in crack opening and shearing – demonstrate stable behaviour following the 2016 intervention. The FBG system is sensitive enough to detect deviations in behaviour, which may correspond to either trends in the structural response, or a change in the damage state of the bridge.

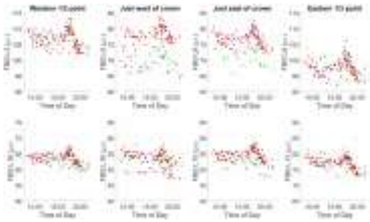
Trends in the response

Trends have been identified that link the magnitudes of structural movements to:

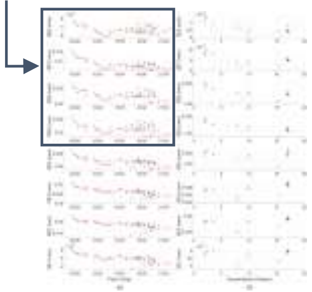
- *Train speed*: Close to the arch crown, where there is minimal fill material between the arch and rail tracks, local strain amplification occurs for trains travelling above ~80mph. These strain magnitudes are increased by ~15%.
- *Time of day*: Strain magnitudes follow expected trends for passenger behaviour, with the largest movements observed for peak-time commuter trains. Observed strain amplification of up to ~27% agrees with anticipated axle load increases, caused by peak passenger levels.
- *Temperature*: an inverse relationship has been identified, whereby thermal contraction causes crack widths to grow, leading to increased movements under train loading. Longitudinal strains and predominantly tensile crack opening movements are sensitive to this effect.



Variation of longitudinal strains with: ↑ train speed, and ↓ time of day



In this region of the crack, movements are primarily tensile (i.e., the crack opens, rather than closes, when loads are applied) and are sensitive to ambient temperature. In colder conditions, crack movements follow the anticipated variation with time of day (i.e., passenger loading)



↑ Variation of crack opening at the south-eastern longitudinal crack with (a) time of day and (b) temperature (data coloured by temperature; subsets of Class 185 trains passing on the south track are plotted, to control for other variables)

For more information, please see: Cocking, S., Alexakis, H., and DeJong, M. Distributed dynamic fibre-optic strain monitoring of the behaviour of a skewed masonry arch railway bridge. *J Civil Struct Health Monit* **11**, 989–1012 (2021). https://doi.org/10.1007/s13349-021-00493-w.

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