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Behaviour of a masonry arch bridge repaired using fibre-reinforced polymer composites

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ABSTRACT

This paper describes a series of laboratory tests investigating the behaviour of a large model masonry arch bridge repaired with externally bonded fibre-reinforced polymer (FRP) on its intrados. Many similar masonry arch bridges form critical links in the world's transport infrastructure, but they are often not suited to the increased demands of modern traffic loading, especially in ageing arch structures that have suffered structural deterioration. FRP plates, adhesively bonded to the intrados of the masonry arch are a convenient method for strengthening arch bridges. The tests described in this paper demonstrated that FRP strengthening is an effective technique for improving the structural performance of a masonry arch bridge.

A two-span, single-ring semi-circular brick arch bridge was tested in this study, complete with fill material. Each of the spans was initially loaded to investigate their response and to establish a four-hinge collapse mechanism, simulating damage prior to strengthening. FRP strengthening was then applied to the two arches, and each of the spans was again tested separately until the failure of the strengthening system. The global (load and deflection) and local (crack width and FRP strain) response of the structure was recorded. The FRP strengthening resisted flexural crack opening in the masonry, and hence prevented a four-hinge mechanism collapse. Failure instead occurred when the FRP strengthening debonded from the masonry adjacent to an existing intrados hinge crack. As well as shear debonding adjacent to flexural cracks in the masonry, peel debonding occurred where shear deformation occurred across a masonry crack. Catastrophic collapse did not occur, as the FRP continued to contribute to the load capacity by acting as a tie after the ultimate load had been reached.

1. Introduction

Masonry arch bridges are an important part of many countries' rail and road transport infrastructure. Most of them are historic structures that survive in active service largely due to the inherent stability of the arch form. The combined effects of modern traffic loads (for which they were not designed) and degradation of the masonry mean that some of these bridges suffer from significant damage. It is important to safeguard and extend the life of these structures, especially where arch bridges form critical links in the transport network and where major disruption would result from their closure.

Fibre-reinforced polymer (FRP) systems are increasingly used for bridge repair and strengthening, with particularly widespread application to concrete bridges [1,2]. The FRP is adhesively bonded to the surface of the existing structure, where it provides tensile capacity and restrains the opening of cracks. FRP has the advantages of a low weight to strength ratio, short installation periods and minimal intervention upon the structure [3]. The small thickness of FRP required for strengthening is especially important for historic bridges, as it minimises changes to the appearance of the bridge. The application of FRP composites to masonry structures is less well established, although it has been the subject of research and development in recent years [4], demonstrating that FRP can be used to upgrade the structural performance of a variety of masonry elements, and has resulted in design guidance being issued by the National Research Council in Italy [5] and by the American Concrete Institute [6]. Further work is required, however, to apply FRP strengthening to increase the load capacity of masonry arch bridges.

1.1. Masonry arch mechanics

Masonry is an assemblage of bricks or blocks that are joined with mortar. Failure of the masonry is usually governed by the low interfacial strength between the brick and mortar in tension and shear. In a single-ring masonry arch bridge, the critical failure

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