Limit analysis of masonry arch bridges containing internal spandrels

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Abstract

Masonry arch bridges form an essential part of the road, rail and waterway infrastructure of many countries, including the UK. They also have significant historic value, and form an important part of our cultural and engineering heritage.

To ensure they can fulfil their intended purpose, masonry arch bridges need to be regularly assessed. However, due to the range of geometrical configurations encountered (single or multi-span, voussoir or multi-ring arch barrel, skew or square span etc) and the many variables which influence their structural behaviour, assessment is not always straightforward. In recent years our understanding of the fundamental behaviour of masonry arch bridges under static and dynamic loading has increased, and this is gradually feeding into the assessment process. For example, experimental tests and parallel numerical modelling studies have allowed the presence of backfill on overall bridge behaviour to be better understood. However, important gaps in our knowledge remain.

In the present study the behaviour of masonry arch bridges containing internal spandrel walls is explored via numerical limit analysis techniques, comparing performance with that of bridges containing soil backfill. To achieve this, two numerical limit analysis techniques are employed, each capable of modelling both soil and masonry elements directly. The first technique is discontinuity layout optimisation, a numerical procedure that involves discretising a problem using a grid of nodes interconnected by potential discontinuities, with optimization used to identify the critical subset of discontinuities forming the critical failure mechanism. This is an upper bound method, with the true limit load approached when a large number of nodes are employed. The second technique is finite element limit analysis, with lower and upper bound formulations used to bracket the true limit load.

In the study the two limit analysis techniques are first applied to a range of benchmark problems to illustrate their respective strengths and weaknesses. The techniques are then applied to a range of masonry arch bridge problems containing either soil-backfill or internal spandrel walls, permitting differences in behaviour under load and under imposed support movements to be compared and contrasted. Parametric studies are used to illustrate the influence of key parameters. Finally, a case study, Dinting Vale viaduct, on the railway line between Manchester and Sheffield, is modelled using the techniques described, and conclusions drawn.

Keywords: **Masonry arch bridges, limit analysis, discontinuity layout optimization, finite element limit analysis**