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Discrete-continuum approach to assess 3D failure modes of masonry arch bridges

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Abstract

There are two main objectives of this research. First, a full masonry arch bridge with all structural components are considered. The failure mechanism of spandrel wall and backfill-masonry interaction are successfully simulated using a 3D discrete-continuum model as validated by previously published experimental data. Moreover, the influence of the frictional resistance between soil and masonry components is discussed. Second, two different skew arches, with different bond patterns, are analysed to understand the influence of construction method (helicoidal and false) on the damage pattern and capacity. The results of the analysis demonstrated that discrete and mixed discrete-continuum approaches can predict complex 3D collapse mechanisms of masonry arch bridges and provides detailed information about their damage progression.

Keywords: DEM, Mixed discrete-continuum approach, Skew arch, Spandrel wall collapse.

1. Introduction

Masonry arch bridges constitute a significant amount of transportation facilities in European countries. There is also around 1700 masonry arch bridges in United States, where the majority of them exist in the northeastern part of the country [1]. In addition to their transportation purposes, many bridges have historical significance and their assessment requires utmost attention to maintain their structural integrity. In this context, 2D and 3D numerical modelling strategies have been used to analyse these structures since early 1990s. Additionally, several destructive tests of scaled masonry arch structures (laboratory models) and field tests have been performed [2,3,4]. The results of early studies provided a better understanding of the strength and collapse mechanism of masonry arch bridges [5,6]. Most of these studies, both experimental and numerical, focus on the capacity of the arch barrel in the span direction (in-plane), although, spandrel wall collapses, and transverse deformations are also relevant in terms of the load carrying capacity and the serviceability of the masonry arch bridges.

In this study, to represent the full structural response of a masonry arch bridge, a 3D modelling strategy is applied. It is important to note that the performed numerical analysis should address the plasticity of soil material, backfill-masonry interaction and possible damage progression in the structure, i.e. masonry joint cracks, sliding of masonry units and large deformations of spandrel wall. As a result, a mixed modelling strategy is

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