# 3D FE Modeling of Multi-Span Stone Masonry Arch Bridges for the Assessment of Load Carrying Capacity: The Case of Justinian's Bridge

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## ABSTRACT

Substantial part of the heritage structures in Turkey is historic masonry arch bridges. An important issue has always been to understand the true structural behaviour of such structures. To address this issue and to explore modeling issues, a numerical work has been initiated to better preserve and transfer this heritage to the next eras. However, complexity of such bridges and difficulties in determining their true load carrying capacities are the main handicaps during structural evaluation. A case study is preferred to explain modeling issues.

With its historical background, current situation, geometric and material properties, this work presents a numerical investigation into the historic multi-span stone masonry arch Justinian's (or Sangarius) Bridge located in the city of Sakarya in Turkey over the Sakarya River. The bridge was built in between the years of 553-562 A.D within the 6th Century by order of Emperor Justinian (M.S. 523-567) of the East-Roman Empire. This bridge in which restoration work is underway, is a rare sample of such bridges that has reached to the present day. A three–dimensional finite element model of the bridge was generated in DIANA FEA software using isotropic solid elements. In the developed FE model, the main structural elements, such as stone piers, stone inner and outer arches, spandrel walls, infill, bridge slab, and the parapets were modeled individually. Inelastic structural behavior and collapse mechanism of the bridge, are investigated under vertical incremental static loading for three different load cases (the quarter (1/4), one-third (1/3), and middle (1/2) of the maximum span of the bridge). Nonlinear static analysis results obtained for lower and upper values of the tensile fracture energy of the stone material, are compared. The loading procedure was carried out as vertical static loading with increments of 200 kN throughout the full width of bridge between the parapets.

Numerical results showed that the value of fracture energy in tension significantly affect the load carrying capacity and failure mechanism of multi-span masonry arch bridges. A more realistic non-linear response has been obtained for an upper value of the tensile fracture energy of the stone material. The bridge model collapses by a-three-hinge mechanism occuring at the loaded arch in the upper value of the tensile fracture energy. The most critical loading point of the bridge is determined as the quarter-span. Loading position of masonry arch bridges considerably affects collapse mechanisms and corresponding load carrying capacities of such systems.

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