

# DISCONTINUOUS PETROV-GALERKIN METHOD FOR ARCH STRUCTURES

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ABSTRACT. Development of effective numerical methods for the analysis of curved arch structures is of interest in many application areas of architecture, civil engineering and mechanical engineering. In this work we study the circular arch problem taking into account transverse shear deformations. The starting point is a structural model where the kinematic assumptions of the classical Timoshenko beam model are imposed in the curved reference geometry. We analyze ultra-weak variational formulations with small parameter, proportional to the slenderness of the structure. We prove wellposedness of the formulation and consider discontinuous Petrov-Galerkin finite element approximation of the problem involving direct approximations of all stress and displacement variables. The method is shown to be stable in the assumed finite element spaces for different boundary conditions and the performance is demonstrated by numerical experiments.

**Keywords:** Arches; Structural analysis; Numerical analysis; Finite element theory

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## REFERENCES

- [1] A.F.D. Loula, L.P. Franca, T.J.R. Hughes and I. Miranda. Stability, convergence and accuracy of a new finite element method for the circular arch problem. *Computer Methods in Applied Mechanics and Engineering*, 63:281-303, 1987.
- [2] A.H. Niemi, J.A. Bramwell, and L.F. Demkowicz. Discontinuous Petrov–Galerkin method with optimal test functions for thin-body problems in solid mechanics. *Computer Methods in Applied Mechanics and Engineering*, 200:1291-1300, 2011.
- [3] T. Führer, C. García Vera and N. Heuer. A Locking-Free DPG Scheme for Timoshenko Beams. *Computational Methods in Applied Mathematics*, 21(2): 373-383, 2021

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