Shape optimization of masonry arch against static seismic loads

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Abstract

Shape optimization of shell structure is extensively studied in this century, and various important results have been obtained. Kimura and Ohmori [1] developed the method of simultaneous optimization method of shape, distribution of thickness and topology of shell roof structures. Fujita and Ohsaki [2] proposed an optimization method in which non-structural performance measures such as constructability are considered. In most of the studies on optimization of shells, elastic strain energy is assigned as the objective function in order to find mechanically rational shapes in the early stage of design process.

Graphic statics is a conventional graphical approach to investigation of basic mechanics of statically determinate structures. It has been utilized for shape determination of truss, cable net, and arch. Computational graphic statics is recently extensively used for finding optimal bar structures dominated by axial forces [3]. Michiels and Adriaenssens [4] utilized graphic statics for generating rational shapes of arches against self-weight and seismic loads. Contrary to structural optimization based on successive structural analysis, graphic statics enables us to generate structural forms without carrying out structural analysis. However, optimality of the obtained shape is not ensured, because the shapes are generated through simple geometric operations.

In this study, we proposed a method of shape optimization to generate rational shapes of tapered planar arches that can resist seismic loads through compressive forces only. For application to masonry arch, axial deformation is assumed to be small, and external forces are to be transmitted to the supports through compressive forces. In the process of optimization, the arch is modeled by continuous beam element without considering contact and separation. Constraints are given for axial force and bending moment so that only compressive stress exists in the section. The curved shape of tapered arch is discretized into many beam elements. Computational cost for optimization is reduced and convergence property is improved by considering locations of control points of B-spline curves as design variables. The height of section is also modeled using a spline function. The objective function is the total strain energy that is to be minimized. Numerical examples are presented to demonstrate an effectiveness of the proposed method. The properties of optimal shapes are investigated in comparison to the shapes obtained by graphic statics.

References

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