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NONLINEAR ANALYSIS OF ARCHES UNDER CONTACT CONSTRAINTS

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ABSTRACT

In recent years there has been a growing interest in underground constructions, especially in big cities, where there is a shortage of ground space. Structural elements in these constructions are supported by soil or are used to support the soil loads (as in the case of walls and roofs). However, in many situations, soils are unable to react under tension, and the structure during the deformation process may loose contact with the surrounding medium. Unilateral contact problems have been actively researched since the late 1960s [1-3]. In most of these works the contact problem is reformulated in approximation spaces using numerical techniques, such as the finite element method (FEM). They generally adopt one of following methodologies to treat the contact constraints: (i) transform the contact problem into a minimization problem without constraint; (ii) use mathematical optimization techniques, where the contact problem solution can be achieved with or without explicit elimination of unilateral constraints.

In the last few years several papers have been published dealing mainly with the behavior of beams and plates resting on a tensionless foundation [4-5]. Little is known, however, on the behavior of curved structural elements such as arches and rings under unilateral contact constraints (see Fig. 1). Approximate solutions to a particular problem involving a thin circular ring which is rigidly radially constrained and under uniformly distributed loading were given by Pian and Bucciarelli [1]. To the knowledge of the authors, no paper has yet been published on support systems like arch-soil foundation where the arch's deflection is prevented from the start by unilateral contact constraints. Sun and Natori [3], for example, studied an arch contact problem in which the unilateral constraints are reached for the first time only during the arch's post-buckling process. This is a deficiency in the technical literature, since in many underground constructions, such as tunnels, pipelines and curtain walls, arches and rings have been widely used due to their optimal behavior under pressure loads.

Therefore, the main objective of the work is to shed some light on this important structural problem and to propose a numerical methodology for nonlinear analysis of support systems constituted by arches in contact with the soil or with a tensionless elastic foundation. A geometrical nonlinear beam-column element is used to model the

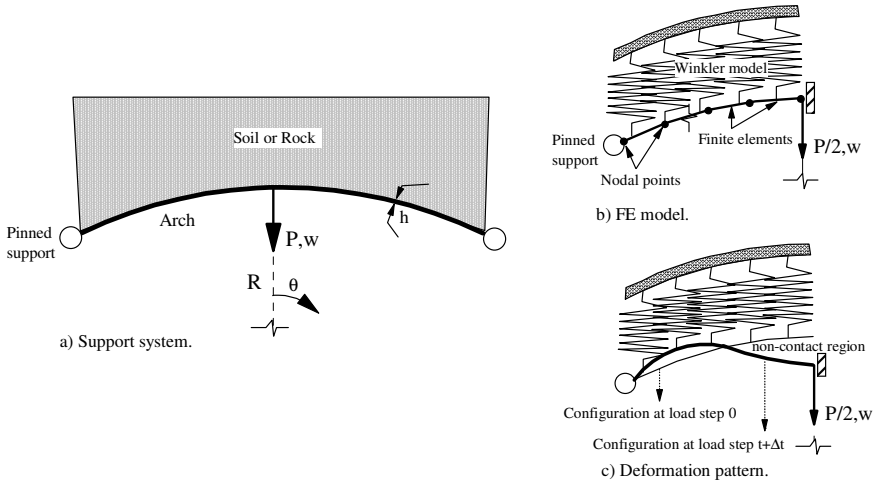

Figure 1. Arch under unilateral contact constraint.

slender structure, while a bed of springs that exhibits a sign-dependent force-displacement relationship is used to model the soil [6]. An updated Lagrangian formulation is adopted to follow the system's movement and the influence of friction in the contact area is ignored. Thus, at each load step, a two-level iteration solution strategy is proposed in order to solve the resulting algebraic nonlinear equations with contact constraints and obtain the structural equilibrium configuration. This numerical formulation is used to study the local one-way buckling of a confined arch under static concentrated loading as showed in Fig. 1.

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