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Higher-Order Finite Element Vibration Analysis of Circular Raft on Winkler Foundation

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ABSTRACT

On a Winkler foundation, solid circular plate vibration is examined using a higher-order finite element in polar co-ordinate system. The present formulation has developed a Mat-lab code to handle any boundary conditions. Validation of the code is carried out after the convergence studies. The results are compared to other researchers and show excellent conformity. Furthermore, a parametric analysis gave the first 10 natural frequency characteristics in tabular and graphical form. The authors conclude that the present formulation is straightforward, behaves exceptionally well for thin solid circular plates on elastic foundations with reasonable convergence rate and accuracy, and requires less computational effort, resources, and time.

KEYWORDS

Convergence Studies, Elastic Foundation, Frequency Parameters, Higher-Order Finite Element, Less Computational Effort, Natural Frequency, Solid Circular Plates, Winkler Foundation

INTRODUCTION

Due to their wide range of applications in civil, structural, aeronautical, and mechanical engineering, such as highways, buried pipelines, airport runways, water tanks, and railway tracks, vibration analysis of solid circular plates on elastic foundations has attracted a lot of attention. These constructions provide significant soil-structure interaction issues, and it is difficult to determine how dynamic vertical or horizontal forces are transmitted to the foundation. Therefore, structures of different shapes, materials, and models, such as beams, plates, and shells, are frequently employed. Many engineering problems, including highway pavements, bridges, ships, steel bearing plates on concrete, etc., can be simplified into beams, plates, and shells on elastic foundations. Therefore, a thorough study of solid circular plates on Winkler foundations is required. Although this problem may be solved using most finite element programmes, analytical methods have several advantages for comprehending the

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fundamental concepts of physics and mechanics. The interaction between structures and complex media has been extensively studied, leading to the development of numerous theoretical frameworks for structures with elastic foundations. However, a theoretical approach cannot solve most of these problems, which leads to numerical techniques.

Numerous research has been carried out to predict the plate's response to elastic foundations. A reasonably straightforward model by (Winkler, 1867) is predicated on the notion that each foundation point's reaction forces per unit area correspond to the foundation's deflection. (Celep, 1988; Celep and Turhan, 1990) have published their assessments of circular plates using the Winkler foundation model. Using the Galerkin technique to estimate plate deflection, (Guler and Celep, 1995a; Güler and Guler, 2004) stated a study of a thin circular elastic plate supporting both uniformly distributed and symmetrical stresses on a two-parameter Pasternak foundation. The study also considers the Pasternak foundation's tensionless properties, allowing the plate to lift off the surface.

Circular plates have been investigated by simulating the foundation soil (Galletly, 1959) to create a more accurate foundation model to fix Winkler's shortcomings. (Eisenberger and Clastornik, 1987a, 1987b) presented and compared two methods for resolving the issues of static analysis, vibrations, and stability of beams on unstable two-parameter elastic foundations and a method for resolving the issues of beam buckling and vibrations on a variable Winkler elastic foundation. (Olson and Lindberg, 1970) created two finite plate bending elements in a polar coordinates system. The first element has a sector that is nine degrees of freedom in a circle, whereas the second has a sector that is twelve degrees of freedom in an annulus. A continuum-based model was created by (Elhuni et al., 2019) to forecast the flexural behaviour of an elastic soil layer supporting a circular tank foundation. The authors present the coupling problem for the traditional theory of plates on an elastic axis-symmetric circular foundation by considering the soil-structure system's horizontal and vertical displacement in the polar coordinate system. The issue of vibrations of circular plates resting on a Winkler foundation and elastically constrained against rotation and translation is addressed (Rao and Rao, 2013). (Narita, 1985) investigated free elliptical plates comprehensively using the Ritz approach. The trial functions were performed using power series. There were multiple elliptical plates with different ellipticities, and the first five frequency parameters were presented for each. (Kim and Dickinson, 1989) presented approximate natural frequencies and frequency characteristics for fully clamped and simply supported circular plates for completely free circular plates. (Gupta and Bhardwaj, 2004) investigated how the combination of an elastic foundation and a parabolic thickness variation affected the vibration of elliptical plates. Their study looked at the frequency and mode shapes of the first four vibration modes for different aspect ratios, taper, orthotropic, and foundation parameter values for free plates, simply supported edges and clamped edges.

The governing equations of an elastic circular plate on a tensionless foundation are obtained and numerically solved in (Guler and Celep, 1995b) to investigate the impact of the foundation's tensionless nature on the foundation and the plate's static and dynamic behaviours. On the opening page of (Leissa, 1993)., the vibration of a plate supported laterally by an elastic foundation was explored. Leissa reasoned that a full (Winkler) foundation simply results in a continual increase in the plate's squared natural frequency. (Salari et al., 1987) also predicted this. (Laura et al., 1995) studied the vibration of a plate resting on an elastic foundation, in which a natural frequency connection is no longer valid. (Wang, 2005) studies have various goals. First, they'll calculate exact frequency determinants to validate and extend Laura's approximations for clamped and simply supported plates. Second, they analyze plates with free and moving edges. Past authors' assumptions of a fundamental axisymmetric mode may be erroneous in certain instances. It shall be demonstrated. Using a variational formulation, (Ascione and Grimaldi, 1984) investigated unilateral frictionless contact between a circular plate and a Winkler foundation. Leissa (Leissa, 1993) provided one of the early treatments of this issue by tabulating data for the frequency parameter for four vibration modes of a circular plate that was simply supported and had changing rotational stiffness. A circular plate lying on the Winkler foundation underwent a significant deflection, which (Zheng and Zhou, 1988) examined.

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