SELECTED PEER-REVIEWED FULL TEXT PAPERS FROM THE INTERNATIONAL SCIENTIFIC APPLIED CONFERENCE „PROBLEMS OF EMERGENCY SITUATIONS“ (PES 2023)

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National University of Civil Defence of Ukraine

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Selected peer-reviewed full text papers from the International Scientific Applied Conference "Problems of Emergency Situations" (PES 2023), May 19, 2023, Kharkiv, Ukraine

Edited by

Alexey Vasilchenko, Andrii Kondratiev, Andrii Kovalov, Evgeniy Rybka, Konstantinos Sotiriadis, Nataliia Mahas, Mykola Surianinov, Volodimir Trigub, Nina Rashkevich, Volodymyr Semko, Volodymyr Andronov and Yurii Otrosh

Scientific.Net

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Construction Technologies and Architecture
ISSN: 2674-1237, Vol. 9, pp 3-10
doi:10.4028/p-L9yr2n

Submitted: 2023-03-03
Accepted: 2023-05-07
Online: 2023-08-31

Axisymmetric Bending of Circular Plates on a Variable Elastic Base

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Keywords: annular plate; elastic base; variable bedding factor; Fuss-Winkler model; finite element method; LIRA-CAD

Abstract. An algorithm of direct integration method for calculation of annular plates lying on elastic Winkler base with variable bedding coefficient under the action of transverse load is proposed. To verify the results obtained by the proposed method, the finite element method implemented in PC LIRA-SAPR is used. Two examples of calculations are considered. Analysis of the results shows that the values of deflections practically coincide in calculations of a circular plate by the author's method and by the finite-element method, and discrepancy between the values of bending moments reaches 9.3 %. Moreover, the discrepancy in deflections appears only in the fourth (and sometimes even in the fifth) decimal place.

It is noted that the method of direct integration has demonstrated very high accuracy in solving numerous problems of deformable solid mechanics that have exact solutions. The discrepancy in the values of bending moments obtained here is related to the semi-automatic breakdown of the finite-element mesh in PC LIRA-SAPR. This statement is based on the fact that when the mesh is thickened in the circumferential direction, the results obtained by the two methods in determining the radial and circumferential bending moments converge considerably.

1 Introduction

Studies of slabs on elastic foundations have received much attention due to their wide application in many engineering structures, such as building foundations, highway pavements, water, oil, etc. tanks, airport runways and underground pipelines, etc. Soil-foundation systems are very often complex environments. As a first approach to representing the behavior of foundations, the well-known simplified Winkler model is used, which assumes that the represented foundation behaves elastically. A two-parameter elastic foundation model (Pasternak model), which provides mechanical interaction between individual spring elements, shows a more realistic ground reaction behavior. Interest in these problems is increasing as the number of stories of buildings and structures being erected increases. In some cases, the foundation structure may not be completely supported by the elastic foundation. Then the elastic foundation is mapped in the form of a model with a variable bedding coefficient.

The Fuss-Winkler model is still most commonly used, the simplicity of which is based on the hypothesis of a direct proportionality between the pressure transferred to the foundation and the deflection.

2 Recent Research Analysis

The theory of calculation of structures lying on an elastic base with one or two bed coefficients was developed in the works of A. N. Krylov, M. N. Gersevanov, P. L. Pasternak, V. Z. Vlasov, B. N. Zhemochkin, I. A. Simvulidi [1], O. C. Zienkiewicz [2], C. S. Desai, J. T. Christian, A. M. Ioannides and others.

If we talk about the studies of circular plates published in recent years, it should be noted the work [3], which presents a new approach for the analysis of circular plates resting on elastic foundations,

based on the methods of structural analysis for flexibility and stiffness. The classical theory of thin plates for small deformations is applied to obtain flexibility and stiffness coefficients. A circular plate is represented as a series of loosely supported circular plates resting on support springs at their common edges. A new method of deriving an analytical solution for an annular elastic plate on an elastic base under axisymmetric loading is proposed in [4]. The idea of the method is based on the application of Hankel integral transformations and properties of Bessel functions in the corresponding boundary value problem. Some studies are devoted to the dynamics issues. Thus, in [5] a three-dimensional analysis of the free vibrations of circular plates supported on foundations according to the Pasternak model with different boundary conditions is presented. A semi-analytical approach using the method of the space of states in the thickness direction and the method of one-dimensional differential quadratures in the radial direction is used to obtain the influence of the Winkler elasticity coefficients and the shear layer of foundations on the dimensionless natural frequencies of annular plates. The scientists of the Belarusian school are actively engaged in ring plate research [6-9].

The purpose of this work is to illustrate and verify the analytical method developed by the authors [10-12] for calculation of circular plates. For this purpose, a bending calculation of annular solid plates with specific laws of bedding coefficient change is performed, and the calculation results of the author's method are compared with the corresponding calculations using the LIRA-SAP PC [13].

3 Materials and Methods of Research

The method of direct integration is used to calculate annular plates lying on an elastic Winkler base with variable bedding coefficient under the action of transverse load. To verify the results obtained by the proposed method, the finite element method implemented in PC LIRA-SAPR is used. Two examples of calculation of concrete and steel slabs are considered.

4 Research Results

We consider a circular plate of constant cylindrical stiffness D lying on a variable elastic base and subjected to a continuously distributed transverse load (Fig. 1).

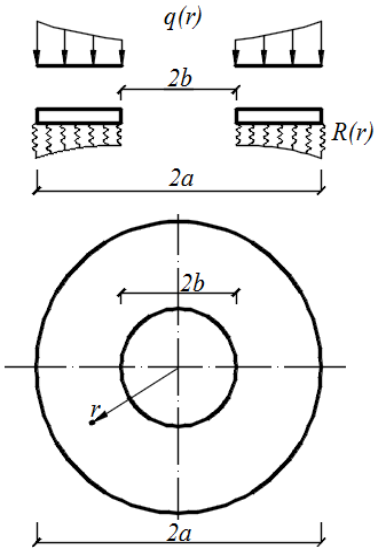

Fig. 1. Circular plate on a variable elastic base under the action of a transverse load

Here, a and b are the radii of the outer and inner contour circles of the plate, r is the radial coordinate ($0 \le r \le a$), $q(r)$ is the acting load, and $R(r)$ is the elastic base reaction. Figure 2 shows the internal forces acting in the plate - radial M_r and circumferential M_θ bending moments, as well as radial transverse force Q_r.