# ABSTRACT

of the dissertation for the degree of Doctor of Philosophy (PhD) in the educational program 8D05403 – "Mechanics"

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## REFINED THEORY CALCULATION PLATES WITH THE TRANSVERSE SHEAR

**Relevance of the Research Topic.**

The calculation of plates considering transverse shear deformation plays a crucial role in improving the strength and stability of structural elements in construction, mechanical engineering, aviation, and other industries. In many calculation methods, the effect of transverse shear is either ignored or taken approximately, which reduces the accuracy of results and may lead to inefficient material use or insufficient structural reliability.

Accounting for transverse shear deformation is especially relevant for thin plates or plates under high load intensities, as it allows for a more accurate determination of their stress-strain state. This work aims to develop improved analytical and numerical methods that take transverse shear deformation into account, thereby enabling reliable assessment of the strength and stability characteristics of structural elements in engineering practice.

Although the classical plate theory based on Kirchhoff's assumptions is suitable for thin plates, modern engineering problems require further refinement and development of this theory. While higher-order displacement theories — starting with the first-order refined theory proposed by Reissner and Mindlin — provide more accurate results, their application is associated with more complex and labour-intensive calculations due to the introduction of additional dependent variables.

Therefore, the development of an improved version of the refined theory considering transverse shear and the creation of an engineering calculation method based on it is a relevant task of modern engineering science.

**The aim of this work** is to develop an improved version of the refined theory for calculating isotropic thin plates considering transverse shear deformation and to construct a method for determining the stress-strain state of plates using beam functions.

To achieve the stated goal, the following **research objectives** were formulated:

1. Formulate the main assumptions of the improved version of the refined theory considering transverse shear; derive the main equation and represent transverse shear deformation as a parameter.
2. Transform the plate bending problem into a beam bending problem. Determine the cylindrical stiffness parameter.

3. Develop a variable separation method for analyzing the stress-strain state of a rectangular thin plate and apply beam functions for calculations. Develop a calculation algorithm.

4. Solve complex plate problems using the finite element method based on the proposed refined theory.

5. Calculate the stress-strain state of plates with various boundary conditions and compare the results obtained using the improved method with those from classical and other refined theories.

**The object of the study is** isotropic thin rectangular plate under uniform external load.

**The subject of the study is** refined theory of plate calculation considering transverse shear deformation.

**Research Methods:**

The refined theory with transverse shear consideration is developed using displacement functions. The variable separation method and finite element method are applied. All calculations are performed using MathCAD and Fortran.

**The scientific novelty consists in the following:**

A mathematical model of a refined plate theory considering transverse shear deformation is developed, where shear is represented as a parameter. The plate bending problem is reduced to a beam bending problem using a cylindrical stiffness parameter. A method for calculating rectangular plates with various boundary conditions is proposed using beam functions expressed through simple polynomials.

**Validity of Scientific Provisions, Conclusions, and Results:**

Confirmed by the application of fundamental laws and equations of elasticity theory in building mathematical models, as well as comparison of calculation results with published data in scientific literature.

**Theoretical and Practical Significance:**

The refined theory of plate calculation allows for a more accurate description of the stress-strain state of thin plates. Such models allow for a reduction in safety margins, which leads to a reduction in the weight of structures, costs and material consumption. The theory can be adapted for composite, anisotropic and multilayer materials, making it universal in modern engineering practice. Together with numerical methods, such as the finite element method, the reliability of computer modeling increases.

**The following are submitted for defence:**

- An improved version of the refined plate theory considering transverse shear, including its fundamental equations and relationships. Transverse shear is represented as a parameter. The number of equilibrium equations is reduced to one.
- A method and algorithm for calculating rectangular plates using variable separation and ready-made beam functions.
- The universality of the calculation method for plates with different boundary conditions.
- Integration of the refined theory into the finite element method.

**Relationship of this work with other research works.**

This work was carried out within the framework of the project AP22684709 “Improved method for analysing bending and natural vibrations of beams on functionally graded foundations,” funded under the “Zhas Galym” program for 2024–2026 and supervised by Associate Professor S.B. Akhazhanov.

**Approbation of the work**.

The main results of the dissertation work:

- were presented and discussed at scientific seminars of the Department of "Mechanics" of the Faculty of Mechanics and Mathematics of Al-Farabi Kazakh National University;

- at the XVII International Scientific Conference of Students and Young Scientists "ǴYLYM JÁNE BILIM - 2022", Kazakhstan, Nur-Sultan;

- at the International Scientific Conference of Students and Young Scientists "Farabi World", 2023, Kazakhstan, Almaty, presented and the results were published.

**Publications:**

Eight publications were made on the dissertation topic: two in international conference proceedings, two in journals indexed in Scopus, and four in journals recommended by the Committee for Quality Assurance in the Field of Education and Science of the Republic of Kazakhstan.


1. S.B. Akhazhanov , N.I. Vatin, S. Akhmediyev, T. Akhazhanov, O. Khabidolda, A. Nurgoziyeva. Beam on a two-parameter elastic foundation: simplified finite element model// Magazine of Civil Engineering, 121(5). Article No. 12107, 2023. DOI:10.34910/MCE.121.7.
2. S. Akhazhanov, A. Nurgoziyeva, A. Kassenova. Refined Theories for Beam Bending: A Simplified Approach to Structural Analysis// Engineering, Technology & Applied Science Research Vol. 15, No. 2, 21709-21718. 2025. https://doi.org/10.48084/etasr.10127
3. Akhazhanov S.B., Nurlanova B.M., Nurgoziyeva A.Zh., Akhazhanov T.B. // Finite element of a beam considering transverse shear deformation. University Works. No. 4(85), pp. 197–202. 2021. DOI 10.52209/1609-1825_2021_4_197
4. Akhazhanov S.B., Nurgoziyeva A.Zh. // Method for calculating an elastic plate considering transverse shear deformation. Bulletin of L.N. Gumilyov Eurasian National University. Series: Technical Sciences and Technologies. No. 3(140), pp. 16–30. 2022. DOI 10.32523/2616-7263-2022-140-3-16-31
5. O. Khabidolda, S. Akhmediyev, N. Vatin, L. Abeuova. Studying dynamics of a cantilever bar with variablebending stiffness // Journal of Mathematics, Mechanics and Computer Science. Vol 119 No 3 (2023), pp. 77-90. Al-Farabi Kazakh National University. DOI 10.26577/ JMMCS2023v119i3a7
6. S. Akhazhanov, A. Kassenova, A. Nurgoziyeva. Examination of a solid stamp on an elastic foundation. Bulletin of D. Serikbayev East

Kazakhstan Technical University. Architecture and Construction Series.№1. Б. 295-303. 2025 DOI 10.51885/1561-4212_2025_1_295

7. Nurgoziyeva A.Zh. Calculation of the bending of a simply supported plate based on the refined classical theory.// Proceedings of the XVII International Scientific Conference of Students and Young Scientists "ǴYLYM JÁNE BILIM – 2022", Nur-Sultan, Pp. 1612–1617, 2022. https://enu.kz/kz/page/science%2Fconference-collections%2Fkhvii-international-scientific-conference-of-students-and-young-researcher-gylym-jane-bilim-2022
8. Nurgoziyeva A.Zh. Calculation of a rectangular plate with rigidly fixed edges using the method of separation of variables.// Proceedings of the International Scientific Conference of Students and Young Scientists "The World of Farabi" (April 6–8). Almaty. P. 69. 2022.

**Author's Contribution:**

The research results presented in the dissertation were developed independently by the author. The formulation of research tasks, method analysis and implementation, and analysis of research results were carried out under the guidance of the author, their scientific supervisor, and international scientific advisor.

**Structure and Volume:**

The work consists of an introduction, four chapters, a conclusion, a list of references, and an appendix.

**Main Content:**

The introduction substantiates the relevance of the topic, formulates the purpose and objectives of the study, the object and subject of the work.

The first chapter analyzes the current state of the problem under study and provides a review of the literature on the refined theory, taking into account transverse shear deformations.

The second chapter presents an improved method for calculating a plate taking into account transverse shear deformations. A mathematical model is constructed based on the first-order shear theory. A method for determining a solution for a plate based on classical theory using the method of separation of variables is proposed, and a solution is obtained according to a refined theory using transverse shear parameters. In addition, the procedure for determining and applying beam functions to find a solution for a plate is outlined.

The third chapter describes the method of calculating an isotropic plate taking into account transverse shear deformations using the finite element method.

In the fourth chapter, as an example of the application of the proposed method, the values of changes in the stress-strain state of a rectangular isotropic plate under a uniform load with different types of fastening are given, and their comparative analysis is carried out. The results of calculations using the finite element method for a plate on an elastic foundation, a plate with an elastic support and a plate with a hole (defect) are also presented.

In conclusion, conclusions are given on the results obtained during the implementation of this dissertation.

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