БЕЛОРУССКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ /
BELARUSIAN STATE UNIVERSITY

УТВЕРЖДАЮ / APPROVED

Ректор Белорусского
Государственного университета/
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_____ А.Д.Король /Andrei D.Karol

15.07.2024

Регистрационный/Registration № 2374/m.

СОВРЕМЕННАЯ ГЕОМЕХАНИКА/ MODERN GEOMECHANICS

Учебная программа учреждения образования по учебной дисциплине для специальности:

The program of the educational institution of the discipline for the speciality:

Специальность / Speciality:

7-06-0533-06 Механика и математическое моделирование

7-06-0533-06 Mechanics and Mathematical modeling

Профилизация / Profilization:

Теоретическая и прикладная механика

Theoretical and Applied Mechanics

2024 г.

Учебная программа составлена на основе образовательного стандарта ОСВО 7-06-0533-06-2023 и учебного плана № М54а-5.4-114/уч. от 11.04.2023.

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РЕКОМЕНДОВАНА К УТВЕРЖДЕНИЮ:

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(протокол № 12 от 28.05.2024)

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ПОЯСНИТЕЛЬНАЯ ЗАПИСКА

Цели и задачи учебной дисциплины

Цель учебной дисциплины – создание базы для освоения основных идей и методов современной механики и математики, подготовка высококвалифицированных специалистов, способных ставить и решать задачи из различных областей науки и техники. Формирование установки на творческую профессиональную деятельность; развитие профессионального мышления, которое обеспечило бы будущему специалисту возможность свободно оперировать профессиональными знаниями, видеть проблемы и оптимальные пути их решения в самостоятельной практической деятельности.

Задачи учебной дисциплины:

– ознакомление магистрантов с основными методами, техниками, концепциями, подходами и математическими моделями современной геомеханики;

– формирование навыков решения прикладных геотехнических задач с использование аналитических и численных методов;

– использование комплексного подхода к изучению геомеханических явлений и процессов.

Место учебной дисциплины в системе подготовки специалиста с углубленным высшим образованием (магистра).

Учебная дисциплина входит **в модуль** «Special problems in continuum mechanics-2» компонента учреждения образования.

Учебная программа составлена с учетом межпредметных связей и программ по дисциплинам: «Continuum mechanics» и «Computational Mechanics».

Требования к компетенциям

Освоение учебной дисциплины «Modern geomechanics» должно обеспечить формирование следующей **специализированной компетенции:**

SC. Apply the methods of the geomechanics theory in the design and strength calculations of soil structures.

В результате изучения дисциплины «Modern geomechanics» магистрант должен:

знать:

– проблематику составления математических моделей и постановки граничных задач для описания напряженно-деформированного состояния геотехнических систем;

– проблематику составления алгоритмов решения граничных задач геомеханике;

уметь:

– составлять алгоритмы для решения систем алгебраических, дифференциальных, интегральных уравнений, описывающих механические процессы;

– получать аналитические решения для модельных задач и проводить анализ полученных результатов;

– проводить анализ надежности и безопасности конструкций в различных условиях эксплуатации;

иметь навык:

– решения математических моделей основных задач геомеханики.

Структура учебной дисциплины

Дисциплина изучается в 3 семестре. В соответствии с учебным планом всего на изучение учебной дисциплины «Modern geomechanics» отведено для очной формы получения углубленного высшего образования: 126 часов, в том числе 72 аудиторных часа, из них: лекции (в том числе дистанционно) – 36 часов, лабораторные (в том числе дистанционно) – 36 часов.

Трудоемкость учебной дисциплины составляет 3 зачетные единицы.

Форма промежуточной аттестации – экзамен.

EXPLANATORY NOTE

Aim and tasks of the discipline

Aim of the discipline is to create a solid base for future mastering of main ideas and methods of modern mechanics and mathematics; to teach the high skilled specialists which can set and solve problems of various fields of science and technology. Formulation of the creative professional activity, development of professional thinking, which helps the future specialist to easily operate with relevant knowledge, see the most efficient ways of problem solution is their own professional work.

Tasks of the discipline:

– Familiarization with main methods, techniques, concepts, approaches and mathematical models of modern geomechanics;

– Development of skills which allow to solve applied geotechnical problems using numerical and analytical methods;

–Using complex approach to study geomechanical processes and phenomena.

Place of the academic discipline in the system of training a specialist with higher education (master).

The academic discipline is part of the module «Special problems in continuum mechanics-2» of the educational institution component.

This program is developed taking into consideration the curriculum of other subjects «Continuum mechanics» and «Computational Mechanics».

Requirements for competences

Mastering of the academic discipline «Modern geomechanics» should provide the formation of the following competences:

SC. Apply the methods of the geomechanics theory in the design and strength calculations of soil structures.

As a result of mastering the academic discipline, the student is expected to:

know:

– problems of development of mathematical models and boundary value problem statement for the stress-strain state description of geotechnical systems;

– problems of algorithm development for solving problems of geomechanics.

be able to:

–develop algorithms for solving systems of algebraic, differential and integral equations which describe mechanical processes

– obtain analytical solutions and analyze the results of model problem solving;

– Analyze the safety and durability of mechanical systems;

have skills in:

-solving mathematical models of basic problems of geomechanics.

Structure of the academic discipline

The discipline is studied in the 3rd semester. In total for the study of the discipline «Modern geomechanics» is allocated:

– for full-time higher education – 126 hours, including 72 in-class hours, of them: lectures – 36 hours, laboratory classes – 36 hours.

The labour intensity of the discipline is 3 credit units.

Form of certification - exam.

CONTENT OF THE STUDY MATERIAL

Topic 1. Introduction. Relevant fundamental and applied problems of modern geomechanics

General comments and main definitions. Geomechanics and rock mechanics. Overview of fundamental and applied problem of modern geomechanics. Examples.

Topic 2. Geomechanics as a branch of modern mechanics

Place of geomechanics in the field of mechanics. Connection of geomechanics to other mechanical subjects. Related disciplines and assumptions.

Topic 3. Main mechanical characteristics and properties of rocks and rock masses. Classification of geomaterials according to the nature of deformation

Mechanical properties of rocks. Rock samples. Laboratory testing of rock samples. Types of laboratory tests. Density. Young's modulus. Poisson's ratio. Inner friction angle and cohesion. Dilatancy angle. Ultimate compressive and tensile strength. Yield surface and yield strength. Scale effect. Classification of geomaterials according to the nature of deformation. Mechanical properties of rock masses.

Topic 4. Finite deformations and fracture diagrams under uniaxial compression and tension

Small and finite strains of rocks. Superposition principle. Stress-strain diagram. Main points of stress-strain diagram. Uniaxial tension and compression of rock samples. Failure and fracture. Mechanical behaviour of rocks beyond the ultimate strength.

Topic 5. Some basic concepts of stress-strain state theory

Stress-strain state of a continuous media. Stress tensor. Strain tensor. Deformation vector. Principal values of stress and strain tensors. Principal axes. Hydrostatic and deviatoric tensors. Physical dimensions of quantities.

Topic 6. Basic systems of equations describing the stress-strain state of deformable solids and applications in geomechanics

Elasticity problems. Boundary value problem statement. Equilibrium equations. Introduction to constitutive relations (Hooke's law). Cauchy relations (Green-Lagrange strain tensor) for small and finite strains. Types of boundary conditions. Problem statement in terms of stress and deformation. Strain compatibility equations. Examples.

Topic 7. Constitutive relations for solids and geomaterials

Definition of a constitutive relation. Elastic, plastic and viscoelastic constitutive relations. Mathematical models of mechanical behaviour of geomaterials. Generalized Hooke's law. Nonlinear elastic constitutive relations. Mohr-Coulomb and Drucker-Prager models. Creep and relaxation constitutive relations.

Topic 8. On the stress state of rock masses. Natural stress state of rock strata

Stress-strain state of rock masses. Scale effect. Effective mechanical properties of rock masses. Natural stress state of rock strata. Change of stress state of rock masses with underground structures and cavities.

Topic 9. Rock pressure in rock masses

Rock pressure. Nature of rock pressure. Lithostatic pressure and side pressure. Dinnik's formula. Classification of depths in the rock mass.

Topic 10. Mathematical statement of geomechanical problems within the framework of continuum mechanics and discrete media mechanics

Assumptions of continuum mechanics and discrete media mechanics. Continuous and discrete problem statement. Continuous and discrete equations. Interaction conditions for discrete elements. Advantages and disadvantages of each approach. Coupling of continuous and discrete statements.

Topic 11. On the statement of model problems of underground geomechanics (rock mechanics)

Models problems for underground structures with enclosing rock masses. Types of problems. Stress-strain state definition problem. Short-term and long-term stability problems. Durability problems.

Topic 12. Solution of the stress-strain determination problems for rock masses in the vicinity of deep underground structures

Solving boundary value problems of rock mechanics. Analytical and numerical methods. FEM and DEM solutions. Analysis of the results. Examples.

Topic 13. Examples of analytical solutions of typical geomechanical problems for underground mining excavations

Examples of analytical solutions. Analytical solutions for mining excavations of various cross-sections. Analytical solutions for underground structures with complex topology. Fundamental solutions. Bussineks, Flaman, Cerutti and Herz solutions.

Topic 14. Limit state of rock masses and geotechnical structures

Limit state definition. Determination of limit states for various problem statements. Reasons of limit state occurrence. Limit state criteria. Complex limit state criterion for rock masses and underground structures.

Topic 15. Numerical simulations in geomechanics

Numerical simulations in geomechanics and rock mechanics. Numerical methods. CAD and CAE software. Solution convergence and analysis of solution results.

Topic 16. Coupled problems of geomechanics

Coupled problems of geomechanics. Thermal-structural problems. Fluid-structural problems. Prestressed modal problems. Coupled numerical methods.

TEACHING AND METHODOLOGICAL MAP OF THE DISCIPLINE

Full-time form of higher education with the use of distance learning technologies (DLT)

Title of section, topic	Title of section, topic	In-class hours						Form of control
		Lectures	Practical classes	Seminar classes	Laboratory classes	Other	Independent work	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
1	Introduction. Relevant fundamental and applied problems of modern geomechanics	2			2			Control questions, interview, problem solution, report on individual assignment
2	Geomechanics as a branch of modern mechanics	2			2			Control questions, interview, problem solution, report on individual assignment
3	Main mechanical characteristics and properties of rocks and rock masses. Classification of geomaterials according to the nature of deformation	2			2			Control questions, interview, problem solution, report on individual assignment
4	Finite deformations and fracture diagrams under uniaxial compression and tension	2			2			Control questions, interview, problem solution, report on individual assignment
5	Some basic concepts of stress-strain state theory	2			2			Control questions, interview, problem

								solution, report on individual assignment
6	Basic systems of equations describing the stress-strain state of deformable solids and applications in geomechanics	2			2			Control questions, interview, problem solution, report on individual assignment
7	Constitutive relations for solids and geomaterials	2			2			Control questions, interview, problem solution, report on individual assignment
8	On the stress state of rock masses. Natural stress state of rock strata	2			2			Control questions, interview, problem solution, report on individual assignment
9	Rock pressure in rock masses	2			2			Control questions, interview, problem solution, report on individual assignment
10	Mathematical statement of geomechanical problems within the framework of continuum mechanics and discrete media mechanics	4			4			Control questions, interview, problem solution, report on individual assignment
11	On the statement of model problems of underground geomechanics (rock mechanics)	2			2			Control questions, interview, problem solution, report on individual assignment
12	Solution of the stress-strain determination problems for rock masses in the vicinity of deep underground structures	2			2			Control questions, interview, problem solution, report on individual assignment

13	Examples of analytical solutions of typical geomechanical problems for underground mining excavations	4			4			Control questions, interview, problem solution, report on individual assignment
14	Limit state of rock masses and geotechnical structures	2			2			Control questions, interview, problem solution, report on individual assignment
15	Numerical simulations in geomechanics	2			2			Control questions, interview, problem solution, report on individual assignment
16	Coupled problems of geomechanics	2			2			Control questions, interview, problem solution, report on individual assignment
	Total	**36**			**36**			

INFORMATION AND METHODOLOGICAL PART

List of basic literature

1. Zhurakov M.A. Modern numerical methods / M.A. Zhurakov; БГУ, Mechanics and mathematics faculty, Theoretical and applied mechanics department. - Minsk: BSU, 2022. - 132 p. - URL: https://elib.bsu.by/handle/123456789/286556.

2. Zhuravkov M.A., Lapatsin S.N. Main approaches, principles and peculiarities of mathematical models in geomechanics: lecture notes / M.A. Zhuravkov, S.N. Lapatsin; BSU, Mechanics and mathematics faculty, Theoretical and applied mechanics department. - Minsk: BSU, 2022. - 125 p. - URL: https://elib.bsu.by/handle/123456789/320041.

List of additional literature

1. Zhuravkov M., Lyu Y., Starovoitov E. Mechanics of Solid Deformable body. Springer, 2023. – 308 c.

List of recommended diagnostic tools and methodology for final mark formation

The object of diagnostics of Master's students' competences is knowledge and skills acquired by them as a result of studying the academic discipline. Identification of Master students' educational achievements is carried out by means of current control and interim attestation.

Diagnostics of the results of learning activities in the discipline “Modern geomechanics” is carried out, as a rule, during classroom training. For diagnostics are used:

- Control questions;
- interview;
- problem solution;
- report on individual assignment.

Assessment for answers in lectures (questioning) and laboratory classes includes the completeness of the answer, the presence of arguments, examples from practice.

Control activities are carried out in accordance with the educational-methodical map of the discipline.

For undergraduates who missed the control events or received an unsatisfactory mark, the decision to repeat the control event is made in accordance with the Regulations on the rating system for assessing the knowledge of students in the academic discipline at the Belarusian State University.

The form of interim certification in the discipline “Modern geomechanics” in accordance with the curriculum is exam.

A rating system of the student knowledge is used for the final mark formation, which makes it possible to trace and evaluate the dynamics within the process of achieving learning objectives. The rating system stipulates the use of weighting coefficients for current and interim certification of students in the academic discipline.

The final mark formation in the course of control measures for current certification (approximate weighting coefficients determining the contribution of current certification to the mark for passing interim certification) includes:

- Control questions -10%;
- interview-10%;
- problem solution-20%;
- report on individual assignment-60%.

The final mark for the discipline is calculated on the basis of the mark of current certification (rating system of knowledge) - 40% and exam mark - 60%.

Approximate list of laboratory classes

Topic 1. Introduction. Relevant fundamental and applied problems of modern geomechanics (2 hours).

Topic 2. Geomechanics as a branch of modern mechanics (2 hours).

Topic 3. Main mechanical characteristics and properties of rocks and rock masses. Classification of geomaterials according to the nature of deformation (2 hours).

Topic 4. Finite deformations and fracture diagrams under uniaxial compression and tension (2 hours).

Topic 5. Some basic concepts of stress-strain state theory (2 hours).

Topic 6. Basic systems of equations describing the stress-strain state of deformable solids and applications in geomechanics (2 hours).

Topic 7. Constitutive relations for solids and geomaterials (2 hours).

Topic 8. On the stress state of rock masses. Natural stress state of rock strata (2 hours).

Topic 9. Rock pressure in rock masses (2 hours).

Topic 10. Mathematical statement of geomechanical problems within the framework of continuum mechanics and discrete media mechanics (4 hours).

Topic 11. On the statement of model problems of underground geomechanics (rock mechanics) (2 hours).

Topic 12. Solution of the stress-strain determination problems for rock masses in the vicinity of deep underground structures (2 hours).

Topic 13. Examples of analytical solutions of typical geomechanical problems for underground mining excavations (4 hours).

Topic 14. Limit state of rock masses and geotechnical structures (2 hours).

Topic 15. Numerical simulations in geomechanics (2 hours).

Topic 16. Coupled problems of geomechanics (2 hours).

Description of innovative approaches and methods for teaching the discipline

When organizing the educational process, a practice-oriented approach is used, which implies:

- mastering the content of education through solving practical problems;
- acquisition of skills for effective performance of different types of professional activities;
- the use of procedures and methods of evaluation, which fix the formation of professional competencies.

Methodological recommendations for the organization of independent work

1. Self-work while working through the literature.

Review the lecture notes immediately after class. Mark the material in the lecture notes that is difficult to understand.

Try to find answers to difficult questions using the literature.

If you are unable to understand the material on your own, formulate questions and ask the instructor for help at the next lecture.

Every week it is recommended to set aside time to repeat the material, checking your knowledge, skills and abilities by control questions.

2. Independent work on making an outline.

1. Collect literature on the topic. Study the source where it is presented in the most complete and up-to-date manner.

2. Based on this source, make a detailed outline, indicating the pages of the book that relate to a particular point in the outline.

3. Study other sources. If they contain material on the already existing point of the plan, write in the plan and the new source with the indication of pages. If the other source covers the topic from a different perspective, add another paragraph to the plan.

4. Having analyzed all the literature collected on the topic, you will get a final plan, on which you can write an outline, combining the material from different sources.

5. Edit your outline, read it carefully and think about: - whether you are satisfied with its general plan; - whether the semantic and logical connection between the individual elements of the content is well perceived; - whether it is successful; - whether the outline is well organized; - whether it is well organized; - whether it is well organized.

3. Preparation for laboratory classes

The purpose of laboratory classes is to deepen and elaborate the theoretical material of the subject through regular and systematic independent work of students throughout the course. Directly conducting a laboratory class involves: solving

problems and exercises according to the sample; analyzing the results; systematizing the material and preparing a report on the work done.

Instructions:

Study normative documents, mandatory and additional literature on the issue under consideration.

Read the lecture notes on the topic.

Carefully study the order of individual practical work or the algorithm presented by the teacher.

4. Preparation for the exam

Carefully read the material from the lecture notes prepared at the class.

Read the same material from the textbook, study guide.

Try to understand the unclear, in particular new terms. Often ignorance of terminology prevents students from perceiving the material in the classroom at the proper level.

Answer the self-check questions in the textbook.

Briefly retell the content of the studied material "in your own words".

Memorize "working definitions" of basic concepts and laws.

Having mastered the theoretical material, proceed to the performance of tasks, exercises, solving problems, calculations on individual tasks, etc.

Approximate list of questions for the exam

1. Types of fundamental and applied problems of modern geomechanics. Examples.
2. Place of geomechanics as a branch in modern mechanics and connection to other mechanical disciplines.
3. Main mechanical characteristics and properties of rocks and rock masses. Classification of geomaterials according to the nature of deformation.
4. Finite deformations and fracture diagrams under uniaxial compression and tension
5. Some basic concepts of stress-strain state theory. Stress and strain tensors. Deformation vector.
6. Basic systems of equations describing the stress-strain state of deformable solids and applications in geomechanics.
7. Constitutive relations for solids and geomaterials.
8. On the stress state of rock masses. Natural stress state of rock strata.
9. Rock pressure in rock masses.
10. Mathematical statement of geomechanical problems within the framework of continuum mechanics and discrete media mechanics.
11. Statement of model problems of underground geomechanics.
12. Solution of the stress-strain determination problems for rock masses in the vicinity of deep underground structures.
13. Examples of analytical solutions of typical geomechanical problems for underground mining excavations.

14. Limit state of rock masses and geotechnical structures.
15. Numerical simulations in geomechanics.
16. Coupled problems of geomechanics.

ПРОТОКОЛ СОГЛАСОВАНИЯ УЧЕБНОЙ ПРОГРАММЫ УО

Название дисциплины, с которой требуется согласование	Название кафедры	Предложения об изменениях в содержании учебной программы по изучаемой учебной дисциплине	Решение, принятое кафедрой, разработавшей учебную программу (с указанием даны и номера протокола
Учебная дисциплина не требует согласования			

Декан механико-
математического факультета
д-р физ.-мат. наук, профессор С.М. Босяков

28 мая 2024

ДОПОЛНЕНИЯ И ИЗМЕНЕНИЯ К УЧЕБНОЙ ПРОГРАММЕ ПО ИЗУЧАЕМОЙ УЧЕБНОЙ ДИСЦИПЛИНЕ

на _____/_____ учебный год

№№ пп	Дополнения и изменения	Основание

Учебная программа пересмотрена и одобрена на заседании кафедры _____(протокол № ____ от _____ 202_ г.)

Заведующий кафедрой

_____ _____

УТВЕРЖДАЮ
Декан факультета

_____ _____