FACULTY OF CIVIL ENGINEERING

SUBJECT CARD

Name in English:	**Theory of elasticity and plasticity**
Name in Polish:	**Teoria sprężystości i plastyczności**
Main field of study (if applicable):	***Civil Engineering***
Specialization (if applicable):	**Civil Engineering**
Level and form of studies:	**~~1st /~~ 2nd level*, full-time ~~/ part-time~~***
Kind of subject:	**obligatory / ~~optional / university-wide~~***
Subject code:	**CEB008361**
Group of courses:	**~~YES~~ / NO***

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	**30**	**15**			
Number of hours of total student workload (CNPS)	**60**	**60**			
Form of crediting	~~Examination~~ / crediting with grade *	~~Examination~~ / crediting with grade *	Examination~~-~~/ crediting with grade *	Examination / crediting with grade *	Examination~~-~~/ crediting with grade *
For group of courses mark (X) final course					
Number of ECTS points	**2**	**2**			
including number of ECTS points for practical (P) classes		**0,8**			
including number of ECTS points for direct teacher-student contact (BK) classes	**1,1**	**0,6**			

* delete as appropriate

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. The student has necessary knowledge of selected topics of mathematics and physics as a base of structural analysis.
2. The student has knowledge of structural mechanics and strength of materials.
3. The student has knowledge of partial differential equations and Fourier series.

SUBJECT OBJECTIVES

C1. Introduction to three dimensional problem of theory of elasticity
C2. Presentation of physical basis and assumptions in plane problems.
C3. Presentation of assumptions, equations and analytical solutions in Kirchhoff theory of thin plates
C4. Presentation of assumptions, equations and analytical solutions in Kirchhoff-Love theory of thin shells
C5. Introduction to theory of plasticity. Presentation of limit load theory for thin plates.
C6. To set a conviction about necessity of knowledge continuous extension in field of theory of elasticity and plasticity.

SUBJECT EDUCATIONAL EFFECTS	
Relating to knowledge:	
PEK_W01	The student knows and understands the equilibrium, geometrical and physical relations for linear-elastic, isotropic body.
PEK_W02	The student knows and understands the differences between linear and nonlinear descriptions and isotropic anisotropic bodies.
PEK_W03	The student knows and understands assumptions, internal forces definitions and boundary conditions in plates and shells.
PEK_W04	The student knows and understands the differences between bending and membrane shells theories.
PEK_W05	The student knows and understands basic terms of theory of plasticity, definitions and theorems of limit load theory.
Relating to skills:	
PEK_U01	The student recognizes properly plane problems and thin plates or shells issues.
PEK_U02	The student is capable of use analytical solutions for selected discs, plates and membrane shells problems.
PEK_U03	The student is capable of evaluate limit load for plates using kinematic approach.
Relating to social competences:	
PEK_K01	The student has a conviction about necessity of knowledge continuous extension in field of theory of elasticity and plasticity.

PROGRAMME CONTENT		
Form of classes - lecture		**Number of hours**
Lec1	Introduction. Index notation. Stress tensor: differential equilibrium equation	2
Lec2	Stresses tensor (cont.): kinetic boundary conditions, transformation, invariants, principal stresses and directions.	2
Lec3	Continuous body motion: Lagrange and Euler description, strain tensors, compatibility equations. Linear elastic material models. General Hooke's law. Theory of elasticity equations set. Lame and Beltrami-Mitchell equations.	2
Lec4	Elastic strain energy. Total potential energy. Virtual work principle. Lagrange theorem. Stable and unstable equilibrium.	2
Lec5	Plane problems. Airy stress function for plane stress.	2
Lec6	Plane problem in polar coordinates – application of Airy stress function, third order differential equation for axial symmetry case.	2
Lec7	Thin plates. Kirchhoff theory: assumptions, stresses and internal forces, equilibrium equations, boundary conditions.	2
Lec8	Analytical solutions for plates. Rectangular plate – Navier approach.	2
Lec9	Plate stability. Second order bending theory.	2
Lec10	Annular plates. Fourth and third order differential equations for axial symmetry case.	2
Lec11	Thin shells. Assumptions. Geometrical description. Stresses distribution and internal forces. Bending theory application for cylindrical container.	2
Lec12	Membrane theory for shells of revolution. Equilibrium equations. Analytical solutions for spherical and conical geometry and axis-symmetrical load.	2
Lec13	Basis of theory of plasticity: plastic body models, general plasticity conditions, plasticity conditions for plates, Definitions and theorems of limit load theory.	2
Lec14	Lecture summary. Examples of test tasks.	2
Lec15	Test	2
	Total hours	**30**

Form of classes - class		Number of hours
Cl1	Index notation – application examples.	1
Cl2	Stress tensor components transformation. Invariants, principal stresses and directions calculation.	2
Cl3	Application of Airy stress function in solution of plane stress problems.	2
Cl4	Plane problem in polar coordinates – stress concentration caused by a circular hole.	2
Cl5	Navier solution for plates.	2
Cl6	Hyperboloid membrane shell – different geometry parameterization	2
Cl7	Kinematic approach to limit load evaluation for rectangular and circular plates.	2
Cl8	Test.	2
	Total hours	**15**

Form of classes - laboratory		Number of hours
Lab1		
...		
	Total hours	

Form of classes - project		Number of hours
Proj1		
…		
	Total hours	

Form of classes - seminar		Number of hours
Sem1		
…		
	Total hours	

TEACHING TOOLS USED	
N1.	Lecture: traditional form.
N2.	Classes: analytical solutions of lecture related problems.
N3.	Office hours.

EVALUATION OF SUBJECT EDUCATIONAL EFFECTS ACHIEVEMENT		
Evaluation (F – forming (during semester), P – concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
P (classes)	PEK_W01, PEK_W03, PEK_W05, PEK_U01 PEK_U02, PEK_U03.	test
P (lecture)	PEK_W01, PEK_W03, PEK_W05, PEK_U01	test

	PEK_U02, PEK_U03.	

PRIMARY AND SECONDARY LITERATURE
PRIMARY LITERATURE: 1. Stephen P. Timoshenko and J.N. Goodier, Theory of Elasticity, McGraw-Hill, 1970. 2. A.I. Lurie and A.K. Belyaev, Theory of Elasticity (Foundations of Engineering Mechanics), Springer, 2005. **SECONDARY LITERATURE:** 1. Y. C. Fung, Foundation of Solid Mechanics, Prentice-Hall, New Jersey 1965. 2. Kyuichiro Washizu, Variational methods in elasticity and plasticity, Pergamon Press, 1982.

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MATRIX OF CORRELATION BETWEEN EDUCATIONAL EFFECTS FOR SUBJECT
Theory of elasticity and plasticity
AND EDUCATIONAL EFFECTS FOR MAIN FIELD OF STUDY ***Civil Engineering***
AND SPECIALIZATION **Civil Engineering**

Subject educational effect	Correlation between subject educational effect and educational effects defined for main field of study and specialization (if applicable)**	Subject objectives ***	Programme content ***	Teaching tool number ***
Knowledge				
PEK_W01	K2_W01, K2_W02, K2_W04, K2S_CEB_W16	C1, C2, C6	Lec1 ÷ Lec6 Cl1 ÷ Cl4	N1, N2, N3
PEK_W02	K2_W01, K2_W02, K2_W04, K2S_CEB_W16	C1, C6	Lec3, Lec4, Lec9	N1, N3
PEK_W03	K2_W01, K2_W02, K2_W04, K2S_CEB_W16	C3, C4	Lec7 ÷ Lec12, Cl5, Cl6	N1, N2, N3
PEK_W04	K2_W01, K2_W02, K2_W04, K2S_CEB_W16	C4, C6	Lec11, Lec12	N1, N3
PEK_W05	K2_W01, K2_W02, K2_W04, K2S_CEB_W16	C5, C6	Lec13, Cl7	N1, N2, N3
Skills				
PEK_U01	K2_U02, K2_U04, K2_U08, K2S_CEB_U19, K2S_CEB_U23	C2, C3, C4	Lec5 ÷ Lec12, Cl3 ÷ Cl6	N1, N2, N3
PEK_U02	K2_U02, K2_U06, K2_U08, K2S_CEB_U19, K2S_CEB_U23	C2, C3, C4	Lec5, Lec10, Lec12, Cl3 ÷ Cl6	N1, N2, N3
PEK_U03	K2_U02, K2_U06, K2_U08, K2S_CEB_U19, K2S_CEB_U23	C5	Cl7	N2, N3
Social competence				
PEK_K01	K2_K01	C6	Lec1, Lec3, Lec4, Lec9, Lec11, Lec13 ÷ Lec15, Cl1, Cl6, Cl8	N1, N2, N3

** - enter symbols for main-field-of-study/specialization educational effects
*** - from table above