Main subjects of the complex exam

In the theoretical part of the complex exam held at the end of the fourth semester of the PhD-program in the Pál Vásárhelyi Doctoral School of Civil Engineering and Earth Sciences, starting the fall semester of the school year 2018/19 applicants must take an exam from a main and a secondary subject.

Main subjects of the complex exam in the program of Structural Civil Engineering:

Sz1. Structures

Sz2. Dynamics and Earthquake Analysis

Sz3. Construction materials and Building construction

Sz4. Geotechnics and Engineering Geology

Main subjects of the complex exam in the program of Infrastructure Civil Engineering:

I1. Hydrodynamics

I2. Management of rural and urban waters

I3. Water quality

I4. Road and railways infrastructure

Main subjects of the complex exam in the program of Surveying and Geoinformatics Engineering:

G1. Mathematical Geosciences

Detailed topics and the recommended literature of the main subjects are listed in the following pages.

Main subject of the complex exam in the program of Structural Civil Engineering:

Sz1. Structures

Introduction to elasticity. Stresses and strains; material-, geometrical- and equilibrium equations; failure and yield criteria; plane stress and plane strain condition; Airy stress function, analytical solutions in 2D; stress concentration.

Principles of energy and work. Principle of virtual displacements, reciprocal theorems, Castigliano's theorems, stationarity of potential energy, principles based on complementary energy; Rayleigh-Ritz-method, Galerkin-method, basis of FEM.

Statically indeterminate structures. Force- and displacement method; statically indeterminate elastic-plastic structures; lower bound or static theorem of plasticity, upper bound or kinematic theorem of plasticity, shakedown analysis, yield line theory of plates.

Beams and columns. Tension, bending and shear (solid and thin-walled cross sections); torsion (Saint-Venant-torsion and restrained warping, solid and thin-walled cross sections); the Saint-Venant-principle; composite cross sections, cross sections made of materials without tensile strength and elastic-plastic materials, applications for RC and composite cross sections; temperature and other kinematic effects (creep and shrinkage); shear deformation theory of beams (Timoshenko beam theory), shear-lag effect, effective width.

Plates. Material-, geometrical- and equilibrium equations of thin plates, deferential equation of plates, internal forces; orthotropic plates; buckling of plates, local buckling of thin-walled beams, large deflection of plates; vibration of floors due to human activity; ponding; plates on elastic foundation; shear deformation of plates.

Stability analysis and second order effects. In-plane buckling and flexural-torsional buckling of columns, effect of imperfection, the Ayrton-Perry formula, interaction of compression and bending; limit point and bifurcation, summation theorems, energy methods; lateral-torsional buckling, effect of shear deformation on buckling, non-elastic buckling, large deflection of beams, post-critical behavior, analysis of multi degree of freedom structures.

Numerical methods. Rayleigh-Ritz-method, Galerkin-method, FEM; method of load-steps (Euler-method, Newton-Raphson-iteration, load-steps with load corrections).

Analysis of structures. Industrial buildings and their stiffening systems, multi storey buildings, shear center (stiffness center), conceptual design of stiffening systems; trusses and frames; influence lines; shells, membranes and cable-suspended roofs; dynamic effect of wind.

Literature:

Gere, J. and Timoshenko, S.P.: *Mechanics of Materials*. Fourth ed. PWS, Boston, 1997.

Kollár L.P.-és Tarján G.: *Tartószerkezetek elmélete és számítása*, BME, Építőmérnöki Kar, Egyetemi jegyzet, Budapest, 2015. *Mechanics of Civil Engineering Structures*. Manuscript. (To be published in 2020.)

Megson, T.H.G.: *Aircraft structures.* Halsted press, NewYork, 1990.

R. D. Cook, D. S. Malkus, M. E. Plesha, R. J. Witt: Concepts and Applications of Finite Element Analysis, 4th Edition, 2002, John Whiley and Sons, Inc.

Kaliszky S.: *Képlékenységtan. Elmélet és alkalmazások*. Akadémia Kiadó, Budapest, 1975. (Plasticity: Theory and engineering applications, Elsevier Science, 1989.)

Smith, A.L., Hicks, S.J., and Devine, P.J. (2009): *Design of Floors for Vibration: A New Approach.* SCI Publication P354. The Steel Construction Institute, Silwood Park, Ascot.

Timoshenko, S.P. and Woinowsky-Krieger, S.: *Theory of Plates and Shells, 2nd Edition*, McGraw-Hill, 1959.

Kollár L. szerkesztő, (editor): A mérnöki stabilitáselmélet különleges problémái. Akadémiai Kiadó, Budapest, 2006. (*Structural Stability in Engineering Practice*, E & FN Spon, New York, 1999.)

Main subject of the complex exam in the program of Structural Civil Engineering:

Sz2. Dynamics and Earthquake Analysis

Basis of vibration. Free and forced vibration of single degree-, multi degree of freedom and continuum structures. Exciting of supports. Effect of moving loads. Pseudo acceleration. Response (modal) analysis (displacement-, acceleration- and pseudo acceleration response spectra). Design spectra. Summation theorems.

Damping. Sources of damping, types of damping. Application of damping devices. Analysis of damped structures. Rayleigh damping. Radiation damping in soil.

Response of structures. Replacement static loads. Time history analysis and numerical methods. Modal analysis, combination of modes. Pushover analysis. Second order effects.

Earthquakes. Sources of earthquakes, intensity and magnitude, wave propagation. Effect on buildings, typical damages.

Design for earthquakes. Requirements, implementations in standards. Elastic design. Capacity design. Limited damage versus failure. Seismic isolation. Design concepts: symmetry, regularity, uniformity, etc.

Aeroelasticity. Velocity and stagnation pressure of the wind. Wind loads of open and closed buildings, structures. Boundary layer, vortex shedding. Aeroelastic instabilities: von Karman vortex streets, galloping, divergence, flattering.

Blasts and impacts. Mechanical effect of a blast. Effect of a vehicle impacting the structure. Dynamic computation of impacting structures.

Literature:

Thomson, W.: *Theory of Vibration with Applications*. Taylor & Francis, 1996.

Chopra, A.K.: *Dynamics of Structures. Theory and Applications to Earthquake Engineering*. Fourth ed. Prentice Hall, Boston, 2012.

Michael Schäfer: *Computational Engineering – Introduction to Numerical Methods*. Springer, Berlin, 2006

Charles E. Needham: *Blast Waves*. Springer, New York, 2010

Main subject of the complex exam in the program of Structural Civil Engineering:

Sz3. Construction materials and Building construction

Construction materials

Physical and chemical basis of material properties [4]
Solids, liquids, gases. Interactional forces in materials. Van der Waals forces. Structure of atoms. Chrystal formation of materials. How material properties are realized and observed. Possibilities and limits in measuring material properties. Stress and strength of materials. Deformations and deformation capacity of materials.

Cements and cementitious materials [5: pp.1-107]
Portland cements. Chemical composition (C_3S, C_2S, CA_3, C_4AF), hydration products, calcium silica hydrates (CSH), fineness of cements and its influence on the cement hydration. Cement types. Cement classes. Strength of cement. Supplementary cementitious materials. Puzzolanas, slag, fly ash, silica fume. Selection of cements for practical applications.

Aggregates [5: pp.108-181]
Classification of natural aggregates, Strength, grading, maximum size and other properties of aggregates, Alkali carbonate reaction. Lightweight aggregates. Heavy weight aggregates.

Concrete properties [3] [5: pp. 182-268]
Fresh concrete. Properties, workability, loss of workability, consistency classes, segregation, bleeding, mixing time, delivery of fresh concrete, placing, vibration.
Admixtures. Purpose of using admixtures. Superplasticizers, water reducing admixtures, accelerating admixtures, retarding admixtures, other admixtures, dosages.

Hardened concrete [3] [5: pp. 269-422] [5: pp. 581-648]
Influencing factors of concrete strength. w/c, porosity, age, bond between components of concrete matrix, curing, Strength, compressive, tensile, multi-axial, fatigue, impact. Concreting in hot or cold weather. Stress-strain relationships. Interrelationship between concrete compressive and tensile strength. Testing and interpretation of compressive as well as tensile strengths.

Long term properties of concrete [5: pp. 423-481]
Shrinkage of concrete. Definition of shrinkage. Types of shrinkage. Drying shrinkage, autogeneous shrinkage, carbonation shrinkage. Shrinkage compensation.
Creep of concrete. Definition of creep, influencing factor. Extent of creep as a function of concrete strength. Creep and creep recovery. Creep and simultaneous shrinkage.

High performance concrete [5: pp. 674-687]
Definitions. Classification. Possible constituents of high performance concrete. Strength, elastic modulus, deformability and durability of high performance concrete. Possible applications. Future of high performance concrete. Tailor made concrete properties.

Lightweight concrete [5: pp. 688-723]
Definitions. Classification. Possible aggregates. Effects of water sorption by lightweight aggregates. Strength, elastic modulus, thermal properties and durability of lightweight concrete. Possible applications. Future of lightweight concrete.

Fibre reinforced concrete [6]
Possible fibres and their properties. Possible matrices and their properties. Bond between fibres and concrete, anchoring capacity of fibres. Durability of fibres. Influences of various fibres on the fresh and hardened concrete properties.

Steel reinforcements, structural steel [2]

Structure of steel. Strength and deformation properties. Ductility. Modification of material properties for cold treatment.
Relaxation. Heat curing and relaxation. Steel corrosion. Influence of inhibitors on the corrosion.

Non-metallic reinforcements [7]
Definitions. Possible fibres and their properties. Possible matrices and their properties. Bond between fibres and to concrete. Ductility of non-metallic reinforcement and that of the concrete element. Durability. Application possibilities. Types of possible failure modes.

Durability of concrete [5: pp. 482-580] [5: pp. 649-673]
Meaning and importance of durability. Influencing factors. Transport mechanisms in concrete. Flow, diffusion, absorption. Air and water permeability of concrete. Influence of carbonation on durability. Acid attack. Sulphate attack. Abrasion of concrete. Influencing factors. Cracking induced by loss of durability. Protection level as function of aggressivity and protection layers.
Effects of freezing and thawing and of chlorides. Action of frost. Types of deterioration. Influence of air entrainment. Freeze-thaw resistance. Effects of de-icing salts. Mechanism of chloride-induced corrosion. Ingress of chloride ions. Binding of chloride ions. Influence of blended cements.

Design of durable concrete structures [8] [9]
Durability and sustainability. Sustainable concrete construction. Philosophy of durability design. Through-life care. Through-life performance. Service life. Conceptual design for durability. Mechanics that may cause deterioration or damage to concrete structures. Physical deterioration and damage processes: cracking (plastic shrinkage, thermal, restrained), shrinkage, abrasion, erosion, frost attack, salt crystallisation and scaling. Chemical deterioration processes: sulphate attack, acid attack, leaching and soft (pure) water attack, alkali-silica reaction, secondary and delayed ettringite formation, thaumasite formation. Biological deterioration processes. Corrosion of reinforcement: depassivation, corrosion products, critical chloride content, stress corrosion. Environmental aggressivity, exposure classes. Modelling of deterioration processes.
Possible service life design processes and considerations. Multi-layer protection. Birth certificate. Rebirth certificate. Measures to enhance resistance or avoid reinforcement corrosion: fly ash, slag, silica fume, metakaolin, blended cements, ternary cements. Use of admixtures, inhibitors.
Influence of workmanship on durability.

Service life design [10] [9]
Principles of Service life design. Definition of service life. Definition of rest life. Full probabilistic method. Partial factor method. Deemed to satisfy method. Avoidance of deterioration method. Carbonation induced corrosion-uncracked concrete. Chloride induced corrosion-uncracked concrete. Freeze-thaw attack-without de-icing agents. Freeze-thaw attack with de-icing agents. Influence of execution. Quality management, Maintenance, Condition controls.

Durability – steel, glass, polymers
Durability of steel. Deterioration process. Influencing factors.
Durability of glass. Deterioration process. Influencing factors.
Durability of polymers. Deterioration process. Influencing factors.

Influence of elevated temperature material properties [11] [12] [13]
Definition of fire design. Possible fire scenarios. Purpose of fire design. Requirements. Methods of assessment of fire. Modification of material properties of concrete at elevated temperatures. Reduction of compressive strength. Reduction of tensile strength. Change of thermal coefficient. Influence of mix design. Influences of fire on cement stone, on aggregates and bond. Thermal conductivity. Explosive spalling. How to reduce sensitivity for explosive spalling. Modification of material characteristics of steel at elevated temperatures. Reduction of yield strength, Increase of failure strain and contraction. Accumulation of deformations in a building.

Building construction

Facade systems
Application of industrialised, prefabricated facade systems, conditions of use with regard to the changing building energy requirements.

BIM and information technology
New methods in building design and building constructions (Building Information Modelling, BIM), with a special emphasis on the possibility of simulations (e.g. building energy modelling, fire safety). Potential of information technology to assist building design and realisation, collaboration possibility of participants on a virtual platform.

Sustainable construction materials [15]
Method of environmental Life Cycle Assessment and applications in the construction sector.

Technical value analysis [14]
The analysis of value and the methods of real estate valuation. Obsolescence of buildings, failures affecting the obsolescence of buildings and building constructions. Condition assessment of building constructions, technologies for the preservation of building value.

Building physics and building energy performance, [17-23]
Steady-state and transient heat transport, calculation principles with practical applications. Heat- air- moisture transport, calculation principles and methods, application examples, available tools, possibilities and limitation of tools. Onsite and laboratory building physics measurements of materials and elements, mobile and fix measuring devices, standard measurement methods, innovative possibilities. Building physics behaviour of building materials, building elements, calculation methods (e.g. slab-ground, glass constructions). Whole building dynamic energy simulation, energy balance of buildings, heat losses and gains, calculation principles and methods, available tools, practical applications. Modelling air flows around buildings. Modelling solar radiation, utilisation of passive solar energy, principles and applications (e.g. sunspaces, solar chimneys). Building physics at an urban scale.

Literature:

[1] Palotás L. „Mérnöki szerkezetek anyagtana 1., Általános anyagismeret”, Akadémiai Kiadó, pp. 1-492

[2] Palotás L. „Mérnöki szerkezetek anyagtana 2., Fa-kő-fém-kötőanyagok”, Akadémiai Kiadó, pp. 287-428.

[3] Palotás L. „Mérnöki szerkezetek anyagtana 3., Fa-kő-fém-kötőanyagok”, Akadémiai Kiadó, pp. 19-443.

[4] Mamlouk, M., Zaniewski, J.: „Materials for Civil and Construction Engineers”, 3rd edition, Pearson, pp. 19-102, ISBN 978-0-13-800956-4

[5] Neville, A.M. „Properties of Concrete”, 4th Edition, Longman, 1995, ISBN 0-582-23070-5

[6] Balázs Gy., Balázs L. Gy, „Különleges betonok és betontechnológiák”, 34.1 fejezet „Szálerősítésű beton”, Akadémiai Kiadó 2013, pp. 299-335, 433-443.

[7] Balázs Gy., Balázs L. Gy, „Különleges betonok és betontechnológiák”, 34.2 fejezet „”Nem acél anyagú betétek szerepe a vasbeton szerkezetek korrózió elleni védelmében, pp. 337-443, Akadémiai Kiadó 2013

[8] Matthwes, S.: „Design of durable concrete structures”, IHS BRE Press, 2013, ISBN 978-1-84806-175-0

[9] *fib* Bulletin 53: „Structural Concrete – Textbook on behaviour, design and performance, Vol. 3 – Chaper 5 Design of durable concrete structures”, Lausanne, 2009, ISBN 978-2-88394-093-2, ISSN 1562-3610

[10] *fib* Bulletin 34: „Model Code for Service Life Design”, Lausanne, 2006, ISBN 2-88394-074-6, ISSN 1562-3610

[11] Balázs L. Gy., Horváth L., Kulcsár B., Lublóy É., Maros J., Mészöly T., Sas V., Takács L., Vígh L. G., “Szerkezetek tervezése tűzteherre az MSZ EN szerint (beton, vasbeton, acél, fa)”, *könyv - oktatási segédlet*, *Magyar Mérnöki Kamara*, 2010 ISBN 978-615-5093-02-9, 174 p.

[12] *fib* Bulletin 38: „Fire design of concrete structures – marerials, stuctures and modelling”, Lausanne, 2007, ISBN 978-2-88394-078-9, ISSN 1562-3610

[13] *fib* Bulletin 54: „Structural Concrete – Textbook on behaviour, design and performance, Vol. 4 – Chaper 6 Design of concrete buildings for fire”, Lausanne, 2010, pp. 36ISBN 978-2-88394-094-9, ISSN 1562-3610

[14] TEGoVA (The European Group of Valuers’ Associations) által kibocsátott EVS 2012 (European Valuation Standards-Európai Értékbecslési Szabványok)

[15] Baumann, Henrike; Tillman Anne-Marie: The Hitch Hiker’s Guide to LCA, Studentlitteratur, 2004.

[16] Hauschild, Michael Z., Rosenbaum, Ralph K., Olsen, Stig Irving: Life Cycle Assessment – Theory and Practice. Springer, 2018.

[17] Hens, H.: Applied Building Physics: „Boundary Conditions, Building Performance and Material Properties”, 2010, Ernst & Sohn, p. 319

[18] Hens, H.: „Building Physics: Heat, Air and Moisture, Fundamentals and Engineering Methods with Examples and Exercises”, Ernst & Sohn, 2012, 2nd ed., p. 324

[19] João M.P.Q. Delgado, Eva Barreira, Nuno M.M. Ramos, Vasco Peixoto de Freitas: „Hygrothermal Numerical Simulation Tools Applied to Building Physics”, 2013, Springer, p. 72

[20] Künzel, H.M.: „Hygrothermal Numerical Simulation Tools Applied to Building Physics”, Fraunhofer IRB Verlag, 1995, Stuttgart, p. 65.

[21] Theodore L. Bergman, Adrienne S. Lavine, Frank P. Incropera, David P. DeWitt: „Fundamentals of Heat and Mass Transfer”, 2011, John Wiley & Sons , 7th ed., p. 1076

[22] Clarke, J.A.: „Energy Simulation In Building Design, Butterworth-Heinemann”, Oxford, 2004, ISBN 0 7506 5082 6, p. 362

[23] Hagentoft, C-E.: Introduction to Building Physics, Studentlitteratur AB (January 1, 2011), ISBN13:978-91440 18966, p. 444

Main subject of the complex exam in the program of Structural Civil Engineering:

Sz4. Geotechnics and Engineering Geology

Unsaturated soil mechanics. Basic relationships of unsaturated soil mechanics, stress variables, definition and measurement of soil-water characteristic curve (SWCC), capillary behaviour, permeability, deformation characteristics and strength of unsaturated soils; numerical modelling of unsaturated soil behaviour, practical applications.

Soil dynamics. Wave propagation in soils. Characteristics of soils under dynamic loading (strength, deformation parameters, liquefaction); possibilities to obtain these characteristics (laboratory and in situ testing, geophysical seismic tests). Advanced nonlinear material models for numerical anlisys of dynamic behavior. Selection of bedrock earthquake motions, soil behavior during earthquakes and its effect on surface motions.

Special geotechnical structures and technologies. Design and construction of deep excavations (diaphragm walls, pile walls, jet panels, slurry walls). Technologies of soil improvement and soil reinforcement (rigid inclusion, injecting, deep mixing, stone columns, soil stabilization), special design and construction considerations. Design and construction of ground anchors, struts and retaining structures.

Engineering geological modelling. Rock properties and their determination, characteristic input parameters for modelling. Geological structures and their graphic representation. Rock deformations and their description: joints, faults and folds. The dip of rock bed and its graphic representation (stereographic projection, rose diagrams), dip on geological maps. Engineering geological maps and their application in engineering design.

Special engineering geological measurements and their applications. In situ determination of rock mechanical parameters. Rock joints and their on-site measurements. Recording rock stresses in situ. Triaxial test of rocks, role of geofluids, temperature and pressure. Shear-strength test of rocks along discontinuities and its importance in rock engineering. Qualification of rocks, standardized test methods and ISRM suggested methods.

Rock and structure interaction. Fracture system and its role in deep foundations and subsurface openings. Rock excavation methods and their selection. Stability of rock slopes and support systems. The role of environmental conditions in rock slope stability and the effect of joints. Classification of rocks according to their mechanical properties. Analytical and numerical modelling of rock slopes and underground openings (tunnels, cellars, caves etc.).

Suggested references:

Bell, F.G. *Engineering geology*. Butterworth-Heinemann 2007.

Fredlund, D. G., Rahardjo, H., Fredlund, M.D.: *Unsaturated Soil Mechanics in Engineering Practice*, John Wiley & Sons, Inc., 2012.

Hoek E.; Brown E.T. *Underground excavations in rock*. London, Inst. Min. Metall., 1980.

Kempfert, H.G., Gebreselassie, B. *Excavations and Foundations in Soft Soils*. Springer-Verlag Berlin Heidelberg, 2006.

Kramer, S.L.: *Geotechnical Earthquake Engineering.* Prentice-Hall Inc., 1996.

Price, D.G. *Engineering geology: principles and practice*. Springer-Verlag New York, 2009.

Verruijt, A. *Soil Dynamics*. University textbook TU Delft, 2009.

Wyllie, D.C. *Rock Slope Engineering*: *Civil Applications*, CRC Press, 2017.

Zhang L. *Engineering properties of rocks*. Elsevier Geo-Engineering Books, 2005.

Main subject of the complex exam in the program of Infrastructure Civil Engineering:

I1. Hydrodynamics

Fluid mechanics. Motion of a continuous fluid. Eulerian and Lagrangian description. Rotational and irrotational flow. Velocity potential. Interpretation and expression of circulation. Interpretation of the energy of a fluid. Equations of conservation of mass, momentum and energy (Euler, St Venant, Navier-Stokes, Bernoulli). Laminar and turbulent flows. Velocity shear, laminar and turbulent boundary layers. Principle and application of Reynolds time-averaging of the Navier-Stokes equations.

Hydraulics. Uniform and gradually varied open channel flows. Steady-state and unsteady motions. Subcritical and supercritical flow regime, momentum balance of a hydraulic jump. Bed resistance in turbulent flow, relation to the mean velocity. Short and long surface waves. Dispersion, refraction, diffraction and reflection of waves. Progressive and standing waves. Wave phenomena in rivers. Steady-state seepage in porous soils. Interpretation of the Darcy velocity.

Transport. Hydrodynamic interpretation of mixing, advective transport, turbulent diffusion, Fick laws, turbulent dispersion. Vertical and longitudinal dispersion in rivers. Measurement of mixing processes and estimation of the dispersion coefficient. Sediment transport and morphology.

Modelling. Description of flow processes in surface waters and aquifers. Calibration, validation of models, analysis of parameter sensitivity and uncertainty. Principles of grid-based numerical approximations. Finite difference method. Physical similarity and modelling. Governing forces, classical similarity laws. Similarity criteria and invariants. Scale models in hydraulic engineering, scale effects, model distortions.

Literature:

Chanson, H. (2004). *Environmental hydraulics for open channel flows*. Elsevier.

Fischer, H. B., List, J. E., Koh, C. R., Imberger, J., & Brooks, N. H. (2013). *Mixing in inland and coastal waters*. Elsevier.

Kundu, P. K., Cohen, I. M., & Dowling, D. R. (2016). *Fluid mechanics*. Academic Press.

Novak, P., Guinot, V., Jeffrey, A., & Reeve, D. E. (2010). *Hydraulic modelling – an Introduction*. *Principles, methods and application.* Spon Press.

Main subject of the complex exam in the program of Infrastructure Civil Engineering:

I2. Management of rural and urban waters

Water resources management. Principles of sustainable water resources management. Methods to explore water resources and demands; methods to evaluate them qualitatively and quantitatively. Transitioning from fulfilling water demands to managing water use. Methods of economic analysis, application of the principle of cost recovery.

River basin management. Water management principles based on river basins. Estimating the hydrologic parameters of catchments. Definition of environmental objectives and actions to reach these objectives. Informatics, geoinformatics and mathematical modelling demands of river basin management.

Agricultural water management. Evolution and strategies of agriculture and agricultural water management. Qualitative and quantitative water demand of agriculture. Impact of agriculture on the quality and quantity of water resources. Water-saving and environmentally friendly irrigation methods. Decision support systems for solving agricultural water management problems.

Flood risk management. Flood safety and risk. Structural and non-structural methods of flood risk management. Technical, societal and ecological issues. Flood risk management and spatial development. Economic impacts of floods, economic foundation of improvement measures. Flood risk mapping of river floodplains behind levees. Flood protection and the public, increasing flood awareness in the society.

Urban stormwater management: Interaction of urban areas and its surroundings, impacts of climate change. Water balance and influencing factors of urban catchments. Urban stormwater management and subsystems. Design rainfall. Decentralised solutions of stormwater management.

Water supply systems. Planning of a distribution network: topological, physical and demand models, methods of water demand prediction, stationary and quasi-stationary studies, pressure oscillations. Water withdrawal sources. Basic treatment technologies of drinking water (stripping of iron, manganese, arsenic and ammonia) and treatment plant processes in case of subsurface and surface waters. Ensuring water quality in the distribution network. Corrosion in distribution networks. Water safety plans.

Reconstruction of water utility infrastructure. Statistical and physical methods of state evaluation. Models of failure prediction, decision support methods, structural design. Cleaning of utility network.

Wastewater collection and treatment. Connection of sewer network, wastewater treatment plant and outfall recipient. Structures of mechanical wastewater treatment. Layout and function of activated sludge tanks. Basic reactor linking schemes with respect to nitrogen removal. Biological and chemical phosphorous removal. Design of activated sludge systems. Design of secondary sedimentation tanks. MBR, SBR, biofilm and granulated sludge methods. Operation problems and their solution (floating and suspended sludge). Sludge treatment, reuse and disposal.

Literature:

Loucks, D. P., van Beek, E. (2017). *Water resource systems planning and management: An introduction to methods, models, and applications*. Springer.

Mays, L. W. (2010). *Water resources engineering*. John Wiley & Sons.

Stephenson, D. (2003). *Water resources management*. Balkema.

Metcalf, & Eddy. (2014). *Wastewater Engineering Treatment and Reuse*. New York: McGraw-Hill.
SWMM Applications Manual, Reference Manual Volume I—Hydrology, Volume II—Hydraulics
CARE-S Reports https://www.sintef.no/projectweb/care-s/reports/

Main subject of the complex exam in the program of Infrastructure Civil Engineering:

I3. Water quality

Water chemistry. Acids, bases, salts. Reversible chemical processes and rate equation. Dissociation of water and the concept of pH. Effect of hydrogen bond on physical properties of water. Forms of carbonate ions as a function of pH. Single-component buffer system. Inorganic nitrogen compounds (complex ions), their occurence under different redox conditions, oxidation number. Mineral acids, acidity, proticity. End products of organic matter degradation under oxidative and reductive conditions.

Water quality and classification systems. Quality of natural waters. Typology, reference conditions and assessment of ecological and chemical status of water bodies. Types of water pollution and critical load of rivers. Priority hazardous substances and their occurrence in the aquatic environment. Ecological and human toxicological effects. Measurement of toxicity. Bioaccumulation of pollutants. Pathogenic pollutants and microbiological quality of waters. Drinking water quality. Quantitative and qualitative characteristics of raw and treated wastewater.

Water quality modeling. The DPSIR approach and load response relationships. Descriptive equations for water quality interactions, reaction kinetic models. Time and spatial scaling, Calibration and validation of water quality models. Parametrization, uncertainty analysis. Application of river and lake ecosystem models to describe oxygen household and eutrophication. Modeling of thermal pollution, toxic substances and pathogenic contamination.

Applied ecology. Structures and main processes in ecosystems. Types of aquatic ecosystems and their characteristics. The importance of ecology in water management. Relationships between natural landscape and water. Aquatic habitats and their characteristics. Ecological impacts of engineering activity in aquatic ecosystems (purposes, types, ecological consequences). The role and technics of ecological engineering in order to mitigate the ecological impacts of water management structures. Natural sewage water treatment (types, removal processes and operational characteristics). River bed regulation by using ecotechnology.

Water- and wastewater treatment technologies. Gas-liquid and solid-liquid separation technologies in drinking water- and wastewater treatment. Sedimentation, filtration, removal of non-settleable particles, chemical coagulation and flocculation. Adsorption. Biological oxidation, nitrification, denitrification, biological and chemical phosphorous elimination. Chemistry of disinfection.

Literature:

Binnie, C., Kimber, M., Smethurst, G. *Basic Water Treatment*. Thomas Telfold Ltd. 2002 (reprint).

Chapman, D. *Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring* – 2nd Edition, 1996 UNESCO/WHO/UNEP

Chapra, Steven C. *Water Quality Modelling*, Waveland Press, 2008.

Somlyódy and van Straten: Modeling and Managing of Shallow Lake Eutrophication. Springer-Verlag, 1986. (ISBN 3-540-16227-5).

Stumm, W., & Morgan, J. J. (2012). *Aquatic chemistry: chemical equilibria and rates in natural waters* (Vol. 126). John Wiley & Sons.

Weiner, E. R. *Applications of Environmental Aquatic Chemistry*. CRC Press, 2007.

Metcalf, & Eddy. (2014). *Wastewater Engineering Treatment and Reuse.* New York: McGraw-Hill.

William J. Mitsch, Sven Erik Jorgensene (2003). *Engineering and Ecosystem Restoration 2nd Edition*. Wiley, ISBN-13: 978-0471332640.

William J. Mitsch, James G. Gosselink, Christopher J. Anderson, Li Zhang (2009). *Wetland Ecosystems*. Wiley, ISBN: 978-0470286302.

Main subject of the complex exam in the program of Infrastructure Civil Engineering:

I4. Road and railways infrastructure

Structure and material of road structures. Requirements for pavement structures. Modelling of asphalt concrete, theory of elastic layer systems. Climatic effects.

Traffic load. Alternative options for design traffic definition. Damage caused by special vehicles

Basis of structural design. Development of international dimensioning procedures, their theoretical background. Basics of analytical pavement design. Stresses and deformations. Material properties and tests of asphalt materials. Type testing, bituminous mixtures, material specifications, quality of asphalt layers. Description of international design methods (German, French, UK, USA). Concrete paving blocks. Pavement design and analysis software, FEM and DEM methods.

Concrete pavement design. Stress and deflections in rigid pavements. Materials, requirements for concrete pavement, concrete testing, design of dowels and joints. Special technologies (white-topping, composite), airport pavements.

Evaluation of Existing Pavements for Rehabilitation. Pavement diagnostics. Types of road pavement damage and causes. Mechanistic–empirical overlay design principle. Material characterisation, fatigue life in number of standard axles, analytical approach.

Innovative road pavements. Review of the use of recycled materials in pavements, noise-reducing asphalt, permeable pavements, „Perpetual Pavement".

Traffic theory: Optimization of traffic flow, linear and network strategies to regulate traffic flow. Manners of traffic regulations. Evaluation of traffic flow, identification and analysis of traffic. Appraisal of behaviour of road users, manners to influence expected behaviour.

Stability of continuously welded rail (CWR) tracks: Technical solutions and conditions of construction of continuously welded rail tracks. Calculation methods of stability of CWR tracks against buckling, parameters infuencing stability. Methods to determine substitutional moment of inertia of track panel. Methods of laboratory and on-site measurements to determine lateral ballast resistance.

Heat expansion of continuously welded rail tracks: Movements of the end of a CW rail, movements in case of pulsing change of temperature. Internal force – displacement diagram of rails, cycle diagrams, without freezing and with effects of freeze-thaw. Internal forces in the rail induced by braking and acceleration. Effects of heat expansion of bridges onto the internal stresses in the CW rails.

Load bearing capacity of the railway tracks: Theoretical background of the Zimmermann-Eisenmann method to calculate the load-bearing capacity of the track. Theory of elastically founded longitudinal beam. Determination of dynamic factor of Eisenmann. Construction of track sections with transition stiffness, their modelling, and methods of construction.

Geometry of railway tracks: Movement characteristics, their determination and calculation. General geometry of transition curves. Geometry of transition curves between a straight and a circular curve, between two compound curves and two reverse curves.

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Dr. Fi István - Dr. Bocz Péter - Dr. Pethő László - Dr. Tóth Csaba: *Útburkolatok méretezése*. 2012. Kiadó: TERC Kft. ISBN: 978 963 9968 34 9

Dr. Gáspár László – Dr. Keleti Imre (Szerk.): *Betonburkolatok*. 2012. Kiadó: Magyar Betonburkolat Egyesület. ISBN: 9789630845854

Yang H. Huang: *Pavement Analysis and Design*. Kiadó: Pearson; 2 edition (2003). ISBN-10: 0131424734

Per Ullidtz: *Modelling Flexible Pavement Response and Performance*. Kiadó: Tech Univ. of Denmark Polytekn. 1998. ISBN-10: 8750208055

Chowdhury, M.A, Sadek, A.: *Fundamentals of Intelligent Transportation Systems Planning*. Artec House, London, 2003

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Vásárhelyi Boldizsár: *Vasúti felépítmény*, Közlekedési Kiadó, Budapest, 1953.

Dr. Nemesdy Ervin: *Vasúti felépítmény, Vasútépítéstan II. kötet*, Tankönyvkiadó, Budapest, 1966.

Dr. Megyeri Jenő: *Vasúti mozgásgeometria*: Műszaki Könyvkiadó, Budapest, 1986. ISBN: 963 10 5978 2

Dr. Megyeri Jenő: *Vasútépítéstan*, KÖZDOK, Budapest, 1991.

Dr. Nemesdy Ervin: A hézagnélküli vasúti pályák gátolt dilatációjának pontos és közelítő számítása, valamint a sínvégek illesztéseinek kialakítása, *Építőipari és Közlekedési Műszaki Egyetem Tudományos Közleményei*, V. kötet, 2-5 szám, különlenyomat, Budapest, 1960.

Coenrad Esveld: *Modern Railway Track*, Digital Edition 2014, version 3.1 ISBN: 978-1-326-05172-3

Dr. Kormos Gyula: Belső súrlódással rendelkező dilatációs készülékek beépítési és fenntartási kérdései különös tekintettel a nyitási táblázatokra, *Nemzetközi Építéstudományi Konferencia*, ÉPKO 2002.

Dr. Kormos Gyula: Síndilatációs szerkezetek titkai, *Nemzetközi Építéstudományi Konferencia*, ÉPKO 2011.

Szabó József: *Az ágyazatragasztási technológiával stabilizált zúzottkőágyazatú vasúti felépítmény statikus és dinamikus terhekre történő viselkedésének vizsgálata és elemzése*, PhD értekezés, BME Út és Vasútépítési Tanszék, Budapest, 2011.

Liegner Nándor: Y-acélaljakkal épített zúzottkőágyazatú folyóvágányok elméleti és üzemi vizsgálata, PhD értekezés, BME Út és Vasútépítési Tanszék, Budapest, 2005.

Main subject of the complex exam in the program of Surveying and Geoinformatics Engineering:

G1. Mathematical Geosciences

Linear Algebra. Vector and matrix norms; conditioning, badly conditioned equations; conditioning of polynomial fitting; Singular Value Decomposition (SVD), its properties and applications in geosciences; Principal Component Analysis (PCA), its connection with SVD.

Statistical methods, estimation. Statistical hypothesis testing, statistical tests; interval estimates, confidence intervals; principle and algorithm of Kalman filtering; link between Kalman filter and least-squares adjustment in groups; basic problem and main formulation of extended Kalman filtering (EKF); how to treat these problems with unscented Kalman filter (UKF); main idea of the unscented transform; principle of kringing and variograms; most important variogram models; Simple and Ordinary Kriging (SK, OK); interpolation from scattered points using kriging; basic idea and main steps of iterative estimation with RANSAC; RANSAC variants; differences between frequentist and bayesian paradigms of statistics; Bayes-theorem, likelihood function, prior and posterior; robust and resistant statistical estimation; maximum likelihood (MLE) and bayesian parameter estimation; problems of bayesian statistics.

Wavelet transform and its applications. Continuous Wavelet Transform (CWT); normalization and significance test of wavelet spectrum, cone of influence; filtering by CWT; Discrete (orthogonal) Wavelet Transform (DWT) and its link with quadrature mirror filters; discrete Haar wavelet transform; principle of multiresolution analysis (MRA); DWT application for data compression and for solving large-scale linear systems; application of wavelet transform for time series analysis.

Stochastic processes. Basics of stochastic processes; characteristics of digital filters, finite impulse response (FIR) and infinite impulse response (IIR) filters; characteristics of digital filters by z-transform; definition and main characteristics of power spectral density (PSD) of continuous stochastic processes; PSD of signals after linear filtering; PSD estimation basics of time series, periodogram estimation and its drawbacks; parametric and nonparametric PSD estimation methods.

Literature:

Awange, J.L., Paláncz, B., Lewis, R.H., Völgyesi, L.: Mathematical Geosciences. Hybrid Symbolic-Numeric Methods. Springer, 2018.

Csernyák L., Hajagos B., Hursán G., Steiner F., Szűcs P., Turai E., 1997. Optimum methods in statistics. Akadémiai Kiadó, Budapest.

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