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Abstracts of the scientific and practical conference «Mathematical modeling and experimental studies of civil and mechanical engineering problems»

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Part I

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of Abstracts of the Scientific and Practical Conference
"Mathematical Modeling and Experimental Studies of Civil and Mechanical Engineering Problems"
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PLENARY LECTURES

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The Effect of Vibrations on the Tightness of Flange Joints in a Piping System

Bolt joints are essential in various industries for joining components and ensuring tightness under different loads. However, loss of bolt pretension due to vibration can lead to joint leakage and loosening. This paper investigates effective methods to prevent vibration-induced loosening in bolt joints, focusing on an M12 threaded bolt under transverse vibration. Using finite element analysis, the study examines the impact of factors like friction coefficients, thread pitches, and bolt pretension on joint vibration resistance.

This research aims to improve the safety and reliability of bolted joints in applications susceptible to vibration e.g. in petrochemical plants.

Keywords: bolt joint, transversal vibration, preload decrease, self-loosening, piping system.

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Agricultural Waste to Insulation: Laboratory Study of Mycelium-Stabilized Straw Composites

The increasing demand for sustainable abd available materials has driven interest in bio-based composites for construction applications. The presented study is focused on the development of insulation composites made from agricultural waste, specifically straw, bound with mycelium—a natural fungal binder. Straw serves as renewable resource, while mycelium offers a low-energy, biodegradable bonding mechanism.

Laboratory experiments dedicated to the fabrication process and characterization of the resulting composite's thermal insulation and durability. Key findings reveal that mycelium-stabilized straw composites exhibit favorable thermal conductivity and sufficient mechanical integrity, making them viable candidates for sustainable insulation.

The study also highlights the potential to valorize agricultural residues, reduce waste, and contribute to circular economy practices. These results demonstrate the feasibility of mycelium-straw composites as a sustainable alternative to conventional insulation materials, paving the way for innovative, eco-conscious solutions in building design.

Keywords: bio-based materials, straw, insulation, mycelium.

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Particle swarm optimization for the rational design of earthquake resistant buildings with friction dampers

The paper is devoted to the prediction of rational locations of friction dampers in multi-storey buildings to enhance their resistance to seismic and dynamic loads using the methods of swarm intelligence. For this aim, the method of particle swarm optimization is employed.

Analytical models describing the dynamic behavior of multi-storey frame buildings with dry friction dampers are developed. A 2D model of a six-storey reinforced concrete frame building is considered. The calculation model is adopted in a form of a vertical cantilever rod with lumped masses. Let us note that the presence of dry friction dampers involves a significant nonlinearity into the input problem. The governing equations of motions are integrated numerically by the Runge-Kutta method.

In order to justify the applicability of the proposed analytical model, its natural frequencies are compared with the results of the modal analysis of the original structure performed in LIRA-SAPR. The obtained analytical and numerical solutions are in a good agreement. The analysis of the displacement patterns of the lowest six normal modes evaluated in LIRA-SAPR confirms the validity of the basic physical assumptions of the lumped mass model.

The problem of a rational location of friction dampers in the six-storey frame building using the proposed lumped mass model is considered. A design solution with three dampers installed as braces in the central span of the building is adopted. There are two types of objective functions that need to be minimized: 1) the maximal displacements of the floors and 2) the maximal inter-storey drifts.

The case of a periodic load with a frequency equal to the fundamental frequency of the structure is considered. The rational locations of the dampers are predicted using the method of particle swarm optimization with a population of 16 particles. The same solution is obtained for the both objective functions implying the installation of the all three dampers at the floor 1.

Mathematical models of seismic loads are developed. The seismic acceleration is simulated by a stochastic Gaussian process as a superposition of harmonic waves with discrete frequencies and random phases. The spectral energy density of the earthquake is described by the empirical Kanai-Taimi model. Based on the proposed model, accelerograms for different types of soils are developed.

Non-stationary vibrations of the six-storey frame building under the seismic load are investigated. Using the method of particle swarm optimization, the population of 16 particles is employed to predict the rational locations of friction dampers. The minimal displacements are achieved installing the dampers at the floors 1, 3, 4, whereas the minimal inter-storey drifts require installation of the dampers at the floors 1, 2, 3. The latter solution provides also the minimal accelerations of the building.

The developed dynamic models and the methods of simulation can be used in the design of houses and structures with enhanced resistance to seismic and dynamic impacts, as well as for the reconstruction of existing buildings to increase their seismic protection.

Keywords: earthquake engineering, dry friction dampers, dynamic loads, non-stationary vibrations, collective artificial intelligence, particle swarm optimization.

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Optimal Design of a Truss Structure Under Uncertainty

The influence of errors, inaccuracies, and deviations on the behavior of real technical systems, as well as their impact on modeling results, can vary in degree, determining the system's sensitivity. Modern approaches to assessing such sensitivity range from the simplest methods, based on partial derivatives when analytical formulas are available, to more complex ones grounded in probability theory, the theory of rough sets, and the theory of fuzzy sets. Given the diverse nature of uncertainty, approaches that combine different theories are of particular interest.

For the tasks of this study is the development of approaches for modeling technical systems under uncertainty. Using the example of finding optimal solutions for a truss consisting of four elements under fuzzy data conditions, specific applications of models such as dependent-chance programming, models with fuzzy-random and randomly-fuzzy data, expected value model and fuzzy modeling are demonstrated.

The approaches outlined in this work facilitate the conceptual modeling of technical systems in the absence of sufficient sample data. They enable the assessment of the impact of inaccuracies and the determination of the expected value of the desired quantity. Additionally, the possibility of combining probability theory with fuzzy set theory is demonstrated.

Keywords: fuzzy modeling, dependent-chance programming, expected value model, fuzzy-random and randomly-fuzzy data.

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The Torsion Problem of Finite Cylinder with Different Coupling Conditions Between its Layers

The investigation of finite layered elastic cylinders, both solid and hollow, under

torsion conditions is important in understanding the mechanics of coupled fields in layered composite structures. Such analyses are critical for advancing engineering applications ranging from structural components in aerospace and civil engineering to biomedical implants and soft robotics. The consideration of three types of coupling conditions allow to compare them not only with each other, but also with more complex problems with interfacial cracks and rigid inclusions. It gives possibility to choose more accurate model for real-life problems without unnecessary complications. The consideration of ideal, soft and rigid coupling conditions also allows to study how the level of bonding between layers can be selected to meet specific functional requirements in engineering applications.

The use of integral transform method and discontinuous properties of Green's function allow to construct the exact analytical solutions for each type of coupling conditions. It allows to make various numerical investigations and gives the possibility to compare numerical solving methods with derived analytical results.

Keywords: torsion problem, elastic cylinder, soft contact, rigid contact, ideal contact.

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AXISYMMETRIC THERMOELASTIC PROBLEM FOR A CONE TRUNCATED TWICE BY SPHERICAL SURFACES

In the field of mechanical engineering and construction, thermoelasticity problems have a significant impact on the development of new structures. This is due to the fact that stress state issues caused by non-uniform heating are of great importance for the strength and structures' proper functioning analysis. The presence of thermal stress can result in the formation of cracks and the development of plastic deformations, which can ultimately lead to complete or progressive failure.

In this paper, an axisymmetric thermoelastic problem for a cone truncated twice by spherical surfaces is considered. The cone is depicted in the spherical coordinate system. It is assumed that both spherical surfaces are fixed, and the cylindrical surface is under smooth contact conditions. The temperature distribution is specified on one of the spherical surfaces, while the remaining surface of the cone is assumed to be thermally insulated. The mathematical formulation of the problem consists of boundary value problems for finding the temperature distribution inside the cone,

and a system of equations for determination the cone points' displacements as a function of temperature. The solution of this problem is derived in the explicit form. The stress arising at the cone boundaries are calculated. The resultant zones of compressive and tensile stress are identified.

Keywords: twice truncated cone, thermoelasticity, exact solution.

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Numerical analysis character of conical shells buckling problem and effect of geometry deviations

The study of the character and properties of the numerical solutions of the buckling problem of smooth shallow closed conical shells is the well-known actual problem. In presented work the analysis of the numerical solutions of the studied problems of the buckling of closed shallow conical shells is carried out. The dependences of dangerous pressure on thin-wall parameter are obtained in a practically interesting wide range change of the values of the slope angle of generator line to the base of the cone.

The obtained dependences are useful in designing of studied structures. Also, the effect of initial imperfections in the geometry of the middle surface on the buckling of the studied shells was additionally researched. The influence on the buckling of axisymmetric deviations of the geometry with one half-wave along the generator line with both negative and positive Gaussian curvature is considered for shells with average values of the slope angle of the generator line to the base of the cone. The values of the critical and limiting pressures were established in depends of the amplitude of the deviation. These dependences decreased by more than 10 times with a negative curvature in the case of an increase of deviation, and increased up to three times with a positive curvature. At the same time the dangerous linear buckling model, typical for small deviations was replaced by a geometrically nonlinear model.

Keywords: conical shallow shell, buckling, external pressure, numerical analysis.

YOUNG RESEARCHER LECTURES

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Determination of the Load-Bearing Capacity of Flat Sandwich Panels

The report presents the results of determining the load-bearing capacity of flat sandwich panels. The main objective is predicting the load-bearing capacity of wall panels depending on the span length, because in our country there are no such normative calculation methods. Laboratory tests included single-span, double-span and triple-span panels.

The theoretical part contains calculations predicting the load-bearing capacity depending on the thickness and span length, which provides opportunities for optimizing designs for engineering applications. The factors that have the greatest impact on the load-bearing capacity were identified. The difference between the laboratory and theoretical results is quite small, which indicates the high accuracy of the proposed theoretical calculation method.

Core properties play a dominant role in determining the load-bearing performance of sandwich panels, while cladding thickness has a limited influence.

Keywords: sandwich panels, load-bearing capacity, bending.

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Motion Extraction Technology and Optical Flow Method for Structural Deformation Monitoring in Construction and Civil Engineering

This talk aims to present the application of motion extraction technology and the Optical Flow method for monitoring structural deformations in construction and civil engineering. The study focuses on integrating these advanced techniques into

an accessible workflow via Touch Designer soft, a visual programming platform well-suited for real-time video analysis and post-production. By implementing an Optical Flow algorithm within TouchDesigner, video data of buildings, bridges, and other infrastructure can be analyzed to detect subtle shifts or movements indicative of stress, fatigue, or damage. This non-invasive approach to monitoring reduces the need for expensive and time-consuming physical sensor installations while providing real-time or near-real-time insights into the health of critical structures. The proposed methodology not only enhances safety but also supports preventative maintenance and long-term monitoring in modern construction and civil engineering projects.

Keywords: motion extraction, Optical Flow, structural health monitoring, TouchDesigner, non-invasive approach, real-time analysis.

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Modeling and Experimental Investigation of a Cantilevered Steel Structure

This report presents the findings of a study to determine the load-bearing capacity of a cantilevered steel structure. Technological tests involved a mathematical analysis of the elasticity and strength of the cantilever's components. The theoretical part includes calculations that predict the load-bearing capacity based on the load magnitude and dimensions of the cantilever, providing opportunities for standardizing cantilever components in engineering applications for any reinforced concrete structures. The objective is to develop a universal model of a cantilever to address contemporary challenges in architectural solutions for civil monolithic multi-story buildings. Using a specific construction project as a case study: m. Dnipro, residential complex "MONTBLAN", measurements were taken of the cycle time, including construction and disassembly, and the curing time of the structure. A cost analysis was also conducted comparing this solution with outdated ones, and the advantages and disadvantages of this approach in modern construction were identified.

Keywords: Cantilevered steel structure, load-bearing capacity, elasticity analysis, strength analysis, universal model of a cantilever, curing time, cost analysis.

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Proposal of a permanent formwork block to enhance low-rise building construction

This report introduces a permanent formwork block fabricated from locally sourced or recycled materials as an innovative approach to improving construction techniques for low-rise buildings. Laboratory tests were conducted to assess the mechanical and physical properties of the proposed blocks, demonstrating their suitability for structural applications.

By integrating these formwork blocks, construction processes can be streamlined, labor requirements reduced, and overall sustainability enhanced. The findings suggest that this system offers a cost-effective, resource-efficient solution for low-rise construction projects, potentially transforming traditional building practices and contributing to more environmentally responsible development.

Keywords: permanent formwork, local materials, materials recycling, low-rise buildings, cost analysis.

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Rational Design of an Energy-Efficient Foundation Slab with Void Formers

The presentation is dedicated to the rational design of energy-efficient foundation slabs with void formers, which significantly reduce heat losses through the foundation and enhance the overall energy efficiency of buildings. The use of porous materials or plastic elements (void formers) in the design of foundation slabs helps to reduce their weight and improve thermal insulation properties, ultimately

lowering heating and cooling costs for buildings.

The presentation will address the main principles of rational design for such slabs and their key benefits, including reduced heat losses and energy savings. This allows for the creation of comfortable conditions in buildings while reducing energy costs during operation. Through a rational approach to designing energy-efficient slabs, substantial savings can be achieved during both construction and building operations. This approach enables a reduction in concrete and reinforcement usage, as well as an increase in load-bearing capacity. It also aligns with modern sustainability requirements by lowering energy consumption and minimizing environmental impact.

Keywords: energy efficiency, foundation slabs, void formers, heat loss reduction, energy savings, rational design, sustainable development.

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Development of structural solutions for floors made using 3D printing technology

This work is a continuation of the study of structures made using 3D printing technology, which are subjected to bending and tensile stress. In the course of the work, the previously proposed structural solutions for the floor, which has the form of a shell of positive Gaussian curvature, were improved.

The described improvement of the floor structure will increase the number of automated processes of its construction and improve the bearing capacity of its individual elements. In addition, attempts have been made to practically reproduce the proposed floor structure with plastic on a 3D printer.

Keywords: 3D printing technology, additive technologies.

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Impact of column damage on the stability of the reinforced concrete building frame

The problem of preventing the progressive collapse of buildings is becoming increasingly relevant due to the increase in accidents. The aim of the study is to evaluate the contribution of frame elements to the survivability of the building as a whole. The object of study is a damaged structure with changed properties compared to the original model. A computational model of a reinforced concrete frame building was created using the SCAD software package with the application of the finite element method. The results show the importance of taking into account the location of columns and the impact of structural solutions to ensure the reliability of buildings during design.

Keywords: progressive collapse, structural stability, building survivability, multi-storey reinforced concrete buildings, finite element method.

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Analysis of the Elastic Waves Attenuation in Heterogeneous Layered Structures

The study investigates the attenuation of elastic waves in heterogeneous layered structures composed of alternating materials, such as concrete and rubber. These structures exhibit unique dynamic behavior due to the contrasting mechanical properties of their layers. By applying periodic loading, the research explores how the inherent heterogeneity influences wave propagation, energy dissipation, and overall attenuation mechanisms.

Numerical modeling forms the core of the analysis, focusing on the impact of key factors such as material contrast, layer thickness, excitation frequency, and wave interaction at the interfaces. Particular attention is given to understanding how these parameters govern the energy dissipation process as elastic waves traverse the structure.

The results provide important insights into the design and optimization of multilayer systems for practical applications, including energy-dissipating materials, seismic wave mitigation solutions, and structural health monitoring technologies. This work highlights the role of heterogeneity in engineering advanced materials capable of tailored wave attenuation properties.

Keywords: elastic waves, wave attenuation, heterogeneous structures, layered materials, numerical analysis.

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Investigation of the effect of mineral oils on the mechanical characteristics of heavy concrete

The use of mineral oils and petroleum in technological processes is common in industrial buildings. Oily liquids can systematically come into contact with concrete surfaces. Concrete is a composite material and has a certain level of porosity due to the curing conditions of the concrete. As a result of capillary rise and diffusion, oils saturate the concrete matrix. Thus, the structure of the cement stone changes at the molecular level, which leads to a decrease in its density and strength. The penetration of oils into concrete acts as a softener that weakens the adhesion between the components of the material, which leads to a decrease in the compressive and tensile strength of concrete.

Keywords: heavy concrete, mechanical properties, mineral oils, saturation, compressive and tensile strength.

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Modern software for organizational and technological solutions in construction

This talk focuses on the practical application of modern software tools to improve organizational and technological solutions in building construction. By discussing the capabilities of tools like BIM, digital twins, and advanced mathematical models, the session will highlight their impact on optimizing resource use, streamlining project planning, and enhancing workflow efficiency. It was analyzed how these innovations could reduce waste, improve timelines, and drive sustainability, offering a transformative approach to addressing contemporary

challenges in the construction industry.

Keywords: mathematical modelling, construction technology, organizational solutions, BIM, digital twin, resource optimization.

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Investigation of the Impact of Geometric Configuration on Wave Attenuation in a Composite Beam with Circular Inclusions

This study explores the effect of geometric configurations on wave attenuation in composite beams containing circular inclusions. The research emphasizes the interplay between inclusion geometry, material contrast, and excitation frequencies, using numerical modeling to simulate wave propagation in heterogeneous beams. Results highlight the influence of inclusion placement, size, and periodicity on energy dissipation. Special attention is given to optimizing configurations to enhance attenuation properties for applications in vibration isolation. The findings provide insights for designing materials used in seismic mitigation and energy dissipation.

Keywords: wave attenuation, composite beam, circular inclusions, geometric configuration, vibration isolation.

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Drone-Enabled AI for Real-Time Roof Breach Detection and Repair Cost Analysis

This research explores a novel system leveraging drone-based imaging combined with real-time artificial intelligence (AI) analytics to detect and classify breaches in flat roofs. By capitalizing on drone agility and vantage points, high-resolution visual data is captured and fed into machine learning algorithms trained to identify surface defects. The system then provides on-the-fly analysis for the severity and location of breaches, enabling immediate notifications of potential vulnerabilities. In parallel, a cost estimation module utilizes AI-driven quantification to predict repair expenses in real time, helping stakeholders make informed and timely decisions. Preliminary experiments indicate a promising level of detection accuracy and computational efficiency, significantly reducing both labor-intensive manual inspections and lengthy downtime. Future work aims to refine the cost estimation methodology, validate performance across diverse roof materials and environmental conditions, and explore integration with building information modeling (BIM) platforms. This approach showcases the potential of combining drones, AI-based analytics, and cost forecasting to revolutionize roof inspection workflows, ensuring greater safety, enhanced accuracy, and optimized resource allocation.

Keywords: drone inspection, AI-based detection, real-time repair cost, roof maintenance.