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24TH INTERNATIONAL CONFERENCE MODELLING IN MECHANICS 2026



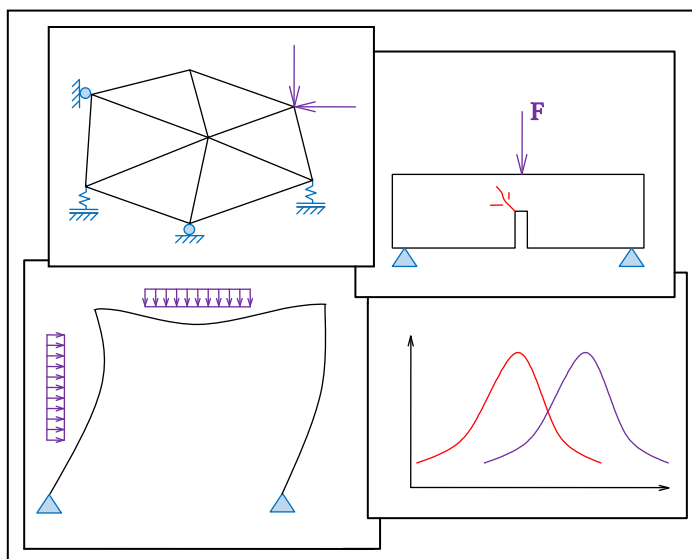
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Case Study: Flat Roof Retrofit on a Prefabricated Building with BIM Libraries as Output

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Initiatives based on the European Directive on the Energy Performance of Buildings focus on renovating buildings with the worst energy performance, which probably includes prefabricated residential buildings constructed during the communist era. In line with current trends in improving the quality of the urban environment, renovation should also include green systems such as green roofs and facades. The study presented in this paper is based on standard design documentation for the P1.14 prefabricated system, which is one of the most widespread types in Slovakia and the Czech Republic. Alternative roof compositions with the application of a vegetation layer were designed for the flat roof of this building, with the designs optimized with regard to the maximum allowable additional load on the existing supporting structure. After a static assessment, which is the subject of a separate article, the individual variants were implemented in the BIM environment in the form of a library of system roof structures. Each composition contains defined material layers and a set of parameters including surface weight, thermal properties, and additional information useful for project documentation and other phases of the building's life cycle. The output is a recommended BIM library suitable for the current design of the renovation of prefabricated apartment buildings.

Non-Invasive Monitoring of Retaining Wall Deformations Using Terrestrial Laser Scanning and FEM Analysis

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This paper presents the results of research on monitoring and analysing the deformation of a retaining wall using non-invasive methods. The main objective of the study was to develop an effective diagnostic procedure enabling the identification of displacements, deformations, and potential zones of structural weakness without interfering with the structure itself. The research employed terrestrial laser scanning (TLS), digital photogrammetry, and numerical analysis based on the finite element method (FEM). The acquired point clouds allowed for the development of an accurate geometric model of the retaining wall and enabled comparative time-based analysis. The use of spatial data made it possible to determine the distribution of horizontal and vertical displacements and to identify local surface deformations. The obtained results confirm the high effectiveness of non-invasive methods in the monitoring of retaining structures, particularly in the case of existing and historic objects, where destructive testing is limited. The proposed approach enables early detection of adverse geometric changes, supporting structural safety assessment and the planning of remedial measures. The presented methodology demonstrates the integration of advanced measurement techniques with engineering analysis in structural mechanics modelling.

Optimisation of the Material Composition of Wall Structures Using Automated Data Export from the BIM Environment to Analytical Tools

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This article explores a methodology for streamlining the assessment and optimisation of building envelope components through the integration of Autodesk Revit, Dynamo, and Microsoft Excel. The primary objective is to present an automated workflow that enables the direct export of technical wall parameters, such as layer thicknesses and thermal conductivity coefficients, from a Building Information Model (BIM) into a specialised analytical tool. The process utilises visual programming within the Dynamo environment to extract data. Exported data is then automatically organised in Excel, where the calculated heat transfer coefficient is compared against the national regulatory standards of specific countries. A key contribution of this solution is the multi-criteria optimisation module, which allows users to identify ideal material compositions based on weighted priorities between purchase price and carbon footprint. This approach provides designers with rapid feedback on energy standard compliance while facilitating environmentally and economically responsible decision-making during the early stages of design.

Elasto-Plastic Shape and Size Optimization of Truss Structures Using Genetic Algorithm

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This study introduces an automated optimization framework for steel truss structures exhibiting elasto-plastic behavior, with the objective of achieving material-efficient solutions while maintaining structural performance requirements. The structural response is evaluated using nonlinear finite element analysis that consistently accounts for both geometric and material nonlinearities. Inelastic behavior is characterized through the complementary strain energy associated with residual forces, which serves as an indicator of the evolution and control of plastic deformation. The optimization process simultaneously addresses shape and size design by considering nodal positions and member cross-sectional areas as design variables. A genetic algorithm is employed as the primary search strategy to handle the nonconvexity and discontinuities inherent in elasto-plastic structural optimization. Constraint handling is achieved through penalty-based formulations to enforce admissible plastic deformation and load-carrying capacity requirements. The proposed methodology is demonstrated through benchmark truss examples, where the optimized solutions exhibit reduced structural weight and controlled plastic engagement compared to reference designs. The results underline the importance of incorporating material nonlinearity directly into the optimization process and confirm the suitability of genetic algorithms for solving complex elasto-plastic shape and size optimization problems in truss structures.

Impact of Additional Weight from Thermal Insulation of Prefabricated Building on Resistance of Elements

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In the construction of industrial, warehouse, commercial, and residential buildings and halls, prefabricated concrete structures have always been preferred, both in the past and today. This is mainly because, compared to monolithic concrete structures, they can be designed more courageous and, above all, they can be built faster. In the case of precast elements, higher quality materials are usually used – higher strength of concrete and higher quality of reinforcement. At the same time, prefabricated structures also place higher demands on the precision of production and assembly. Panel (prefabricated walls/slabs) systems are prefabricated structures that were often used in the past for the construction of residential buildings. In the recent past and still today, there is an effort to continue using these buildings for housing, even though their planned lifetime is coming to an end. This is being addressed by projects that are mainly based on insulating the perimeter envelope and replacing the roof structure. However, this involves additional weight that is not taken into account, as static assessments are not usually performed. This paper addresses this issue – how new loads affect the current condition of the building and the need for static recalculation.

Preliminary Parametric Modelling and Structural Analysis of Concrete Structure

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The proposed research is aimed at the development of a tool for the preparation of a parametric model of a concrete precast residential building suitable for structural and/or thermal analysis. The objective is to create a model of a selected structure based on predefined geometry and the repetition of typical patterns, such as the number of storeys or the number of panels in the case of a precast residential building. The typical geometric characteristics will be taken from the 3D model of existing building. The model will be developed to enable export to IFC format and/or a format suitable to selected finite element system or further processing. The feasibility of the proposed solution will be evaluated with regard to the integration of a CAD system for construction model preparation. Furthermore, the automation of data transfer from drawing software to the software for the next analysis step such as FEA software will be implemented and discussed.

Assessment of the Building Envelope of the T06B Panel System Using Thermographic Measurements

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Massive construction of precast buildings began after the end of the Second World War and continued until the late 1990s in the V4 countries, which are affected most by large-scale precast building estates. Renovations of precast residential buildings were started in the 1980s and focused mainly on improving the thermal technical properties of the external wall using the ETICS system, which is now insufficient in thickness, and on replacing windows, which are also no longer sufficient today. Nowadays, we often encounter surface condensation in the interiors of precast buildings, leading to the formation of mold on the inner surfaces of structures. For a proper revitalization plan, it is first necessary to identify the cause, which may not be immediately apparent. One way to identify the causes is to determine locations with increased heat flow using thermographic measurements. Thermal bridges and their severity can be detected using a thermal camera, which we used to assess the external wall of a selected T06B precast building in Ostrava. Under clear skies and an outdoor temperature of -9°C , we took measurements from both the exterior and interior in the most critical areas and in places where surface condensation occurred. Several defects were found in the implementation of the ETICS system on the exterior walls, as well as poor quality of the existing windows, including their installation.

The Influence of a Waterproofing Admixture on the Durability of Lightweight Concrete Based on Sintered Fly Ash Aggregate

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Lightweight concrete is a porous material, significantly more so than ordinary concrete, which is related to the porosity of lightweight aggregates. The quality of the microstructure, including the quantity and distribution of pores, affects the permeability of the concrete, which directly translates to durability. The aim of the research was to determine the influence of the sealing admixture on properties related to durability. As part of the research, four series of concretes were prepared: control concrete and concretes with a crystalline admixture in amounts of 0.5, 1.0 and 2.0 kg/m³. The concretes were tested for water absorption, water permeability under pressure, and resistance to freeze–thaw cycles. Concretes modified with the sealing admixture, despite a slight increase in water absorption (from 10.4% to a maximum of 11.4%), showed a lower degree of water penetration into the samples compared to the control concrete. This value decreased with increasing admixture dosage from 45 mm for the control concrete to 32 mm for the concrete with 2.0 kg/m³ of admixture.

Use of Selected Waste Materials in Cement Bound Granular Mixtures for Road Pavement Layers

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Cement Bound Granular Mixtures (CBGM) are construction materials of relatively low strength that are mainly used in the lower layers of pavement structures and in improved subgrade layers. Due to the relatively low strength requirements and the large volume of material used, these layers create an opportunity for the effective utilization of various waste materials and industrial by-products. This approach is consistent with the principles of the circular economy and the reduction of natural mineral resource consumption. This paper presents the results of preliminary studies on the possibility of using selected waste materials as components of cement bound granular mixtures. Among the materials used in the study were recycled concrete aggregate obtained from the demolition of structural elements, crushed brick from ceramic waste, and fine-grained sand of the 0/1 mm fraction, which is a by-product of the production of road aggregates. These materials were used as partial or complete replacements for natural aggregate in the designed mixtures. The conducted research included the evaluation of the basic properties of the mixtures, in particular compressive strength, bulk density, and selected technological parameters. The obtained results indicate that the use of waste materials in cement bound granular mixtures is feasible and in many cases does not lead to a significant deterioration of the mechanical properties of the material. At the same time, the use of such materials may contribute to reducing the amount of construction waste and decreasing the consumption of natural aggregates.

Numerical Design of a Friction-Based Clamping System for Temporary Antenna Support on the Žižkov Television Tower

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During the reconstruction of the upper steel shaft of the Žižkov television tower, a temporary structural solution was required to support four television antennas for a period of three months without interfering with the primary load-carrying structure. The concept consisted of a segmented steel clamping collar assembled around the tubular shaft. Individual segments were connected using preloaded bolts. Vertical loads from the antennas and supporting brackets were transferred through friction generated between the collar and the tower surface by bolt pretension. The paper focuses on the numerical design of this friction-based connection and the determination of the required bolt preload to ensure sufficient shear resistance and prevent slippage. A three-dimensional finite element model was developed, incorporating geometric nonlinearity, contact interaction, and explicit simulation of bolt pretension. Load combinations included self-weight and wind effects. The study resulted in a practical design methodology for determining the minimum required bolt preload considering contact pressure redistribution and friction coefficient variability.

Parametric study of numerical models of tensile tests of thin-walled steel specimens

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This study presents a parametric finite element numerical analysis of tensile tests performed on thin-walled steel specimens with two geometric configurations and five thicknesses. Models were carried out in the ANSYS software. The data set includes specimens made of new S390GD steel with thicknesses of 1.5 mm, 2 mm, and 3 mm, as well as specimens with thicknesses of 1.89 mm and 2.89 mm taken from a 10-year-old structural member to capture potential changes in mechanical response caused by long-term aging of the material. A simple parameterized modeling framework was developed to enable automatic control of specimen geometry. This approach ensured consistent model generation and enabled systematic investigation of thickness-dependent effects without manually redefining the model topology. The simulations provided detailed distributions of von Mises stress, equivalent strain, and global strain for all ten configurations. The presented models and results proved ideal for defining critical areas and will serve as a basis for further research. The models will be used to prepare experiments and subsequently validated. The presented part belongs to the broad research of non-traditional fasteners for thin-walled cold-formed profiles used in construction.

Influence of Biochar on the Durability of Low-Carbon Cementitious Materials for 3D Concrete Printing

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This paper examines the influence of biochar on selected mechanical and durability properties of lowcarbon cementitious materials developed for 3D concrete printing. Biochar was used as a partial replacement of cement in the range from 0 to 10% by volume. The mixes were designed to meet the requirements of printability, shape retention, and layer stability. The experimental program focused on the effect of biochar addition on strength development and durability-related parameters. Compressive strength and flexural strength were tested on specimens produced by extrusion-based 3D printing. The testing protocol allowed evaluation of strength evolution and directional behavior related to the printing process. Durability assessment included freeze—thaw resistance, total porosity, and drying shrinkage. Freeze—thaw performance was investigated using cyclic freezing and thawing of printed specimens. Porosity was determined to characterize the internal structure of the cementitious matrix modified with biochar. Drying shrinkage was measured to evaluate volumetric stability over time. The study provides a comprehensive experimental framework for assessing the role of biochar as a cement substitute in low-carbon materials for 3D concrete printing. The selected test methods allow analysis of both mechanical performance and durability aspects relevant to additively manufactured concrete elements.

Advancing Sustainable HPC Mixtures with Emerging Volcanic Materials: Rhyolite and Lassenite

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This research investigates the use of natural volcanic materials, specifically rhyolite and lassenite, as supplementary cementitious materials (SCMs) in high-performance concrete (HPC) incorporating Type IL Portland-limestone cement (PLC). The motivation stems from the urgent need to reduce the environmental impact of cement production while enhancing durability performance in transportation infrastructure. The study focuses on durability assessment using electrical resistivity, which serves as a non-destructive indicator of chloride ingress resistance and long-term concrete performance. An experimental program was conducted to evaluate resistivity, compressive strength, and maturity-based strength development under different curing temperatures. The resistivity measurements were interpreted using established durability classification criteria to assess chloride permeability. The results indicate that both rhyolite and lassenite improve durability by reducing ionic conductivity and refining pore structure. Rhyolite mixtures demonstrated more consistent resistivity development and reliable maturity-strength relationships, while lassenite mixtures showed higher later-age strength but increased variability and higher water demand during mixing. The influence of curing temperature on hydration kinetics and durability evolution was significant, with lower temperatures leading to improved long-term resistivity. The findings highlight the importance of accounting for temperature-dependent effects in the evaluation and modeling of material performance. This study demonstrates the potential of regionally available SCMs for developing sustainable, durable concrete and provides insights for optimizing mixture design in performance-based applications.

Comparative Study of Idealized Connections Type for Modeling Clinch of Thin-Walled Steel Sheet

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Modeling clinch joints in thin-walled steel elements is an important task in describing their actual behavior. Accurate numerical simulation of this cold joining technology is complicated by significant plastic deformations and local changes in the microstructure around the joint, which fundamentally affect the stiffness and load-bearing capacity of the detail. In practice, idealized joint models are therefore often used, but their accuracy and reliability have not yet been sufficiently compared for structural steels used in construction applications. This study focuses on comparing different types of idealized numerical joints in the ANSYS software that can be used as a substitute for the geometric model of the clinch itself. Each approach is evaluated in terms of its ability to reproduce the experimentally verified behavior of the joint. At the same time, the computational complexity of the individual models is compared, which is crucial for possible deployment in larger simulations of load-bearing systems. The result is a recommendation for the level of idealization suitable for numerical analyses of clinched structural steel elements, which provides a basis for subsequent modeling of the fatigue behavior and reliability of thin-walled steel structures.

Parametric Study of Mesh Size, Evolutionary Rate, and Filter Radius in Geometrically Nonlinear BESO framework

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Topology optimization based on the Bi-Directional Evolutionary Structural Optimization (BESO) method is widely used for generating efficient structural layouts governed by mechanical performance. Despite its growing application, the influence of numerical discretization and algorithmic parameters becomes increasingly critical when geometrical nonlinearity is taken into account. This contribution presents a parametric framework for investigating the effects of finite element mesh size, evolutionary rate, and filter radius in geometrically nonlinear BESO-based topology optimization. The study employs a finite element formulation incorporating large-displacement kinematics, while the evolutionary material removal and addition strategy of BESO is used to iteratively update the structural layout. Each parameter is examined independently to evaluate its role in numerical stability, convergence behavior, and the physical consistency of the evolving topology. Special attention is given to the interaction between nonlinear structural response and common regularization techniques, such as sensitivity filtering, in order to ensure mesh-independent designs. The proposed framework aims to provide methodological guidance for selecting appropriate discretization and algorithmic settings in nonlinear evolutionary optimization, supporting more robust and reliable application of topology optimization in advanced structural modelling.

Geometric Modelling of Vaults and Arch Structures using B-Splines and Bézier Curves as a Basis for FEM Analysis

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Vaults and arch structures of atypical shapes belong among geometrically demanding objects, where the accuracy of shape description directly affects the reliability of subsequent numerical analysis. Standard linear approximations of the arch axis introduce geometric errors that grow in curved regions, and their reconstruction or design requires a reliable and mathematically consistent geometric model. Classical approaches to modelling within the finite element method (FEM) framework are typically based on linear or quadratic approximations of the element shape. For structures with significant curvature, these approaches require a large number of elements to achieve acceptable geometric accuracy, which increases computational demands and complicates mesh quality control. An alternative is the use of computer-aided geometric design (CAGD) tools — specifically Bézier curves and B-spline representations — which enable an accurate and smooth description of curved shapes while maintaining full mathematical control over the geometry. This approach guarantees consistency between the geometric model and the computational model, thereby eliminating the geometric error that arises during the manual transfer of shape into the FEM environment. The paper presents a methodology for geometric modelling of vaults and arch structures using Bézier curves and B-spline representations, and their direct integration with finite element mesh generation. FEM mesh nodes are generated directly by parametric discretisation of the B-spline curve, thereby eliminating the geometric error associated with shape transfer. The proposed procedure is applicable to a wide class of atypical structures and provides a mathematically consistent basis for subsequent static and dynamic analysis.

Micro-scale Discrete Element Simulation of Permanent Deformation and Fatigue Damage in Sugarcane Bagasse Ash–Modified Asphalt Concrete under Rutting Conditions

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Permanent deformation owing to rutting and fatigue cracking are the dominant distress mechanisms that reduce the service life of asphalt pavements under repeated traffic loading. This study presents a micro-scale numerical investigation of rutting-induced permanent deformation and fatigue damage accumulation in Sugarcane Bagasse Ash (SCBA)-modified asphalt concrete using the Discrete Element Method (DEM) implemented in the Particle Flow Code (PFC) 2D/3D. The asphalt mixture is modeled as a particulate system comprising aggregates and asphalt mastic, with SCBA incorporated into the binder phase to enhance the interparticle bonding behavior. Appropriate contact and bonding models were employed in the PFC to capture viscoelastic deformation, damage evolution, and bond degradation under cyclic loading. Rutting behavior was simulated through repeated loading to quantify permanent strain accumulation, while fatigue damage progression was evaluated by monitoring bond breakage, contact force redistribution, coordination number, and energy dissipation at the microscale. The numerical results show that SCBA-modified asphalt concrete exhibits lower permanent deformation and delayed fatigue damage initiation than conventional mixtures. Enhanced load transfer efficiency and more stable force-chain networks were identified as the primary mechanisms contributing to improved performance. The findings demonstrate that micro-scale DEM analysis provides valuable insights into the rutting and fatigue mechanisms of sustainable asphalt mixtures and confirms the potential of sugarcane bagasse ash as an effective modifier for improving pavement durability. This study contributes to the advancement of performance-based asphalt mixture design and supports the use of agricultural waste materials in sustainable pavement engineering.

Simplified Method for Determining the Calcium Hydroxide Content in Low-Emission Cementitious Composites

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The development of a simplified method for determining calcium hydroxide content in low-emission cementitious composites constitutes an important step in assessing their durability and degree of hydration. Conventional techniques are typically based on the analysis of cement pastes and neglect the influence of aggregates, which limits their applicability to real mortars and concretes. The aim of this study is to extend a method based on controlled thermal treatment of samples in a muffle furnace, taking into account the impact of different aggregate types on measurement accuracy. The study focused on mass changes occurring within the temperature range corresponding to the dehydroxylation of Ca(OH)_2 (400–600 ° C), as well as disturbances caused by aggregate mass loss. Mortars containing quartz aggregate, river sand, and thermally stable magnetite were evaluated, together with low-emission binders incorporating mineral additives such as fly ash and calcined clays. The results were compared with reference thermogravimetric analysis (TGA) measurements. The outcome of the study is an optimized and practical method enabling reliable determination of Ca(OH)_2 content in real cementitious composites, enhanced by a correction procedure accounting for aggregate properties. This work was supported by Rector of the West Pomeranian University of Technology in Szczecin for PhD students of the Doctoral School: ZUT/12/2025/Anna Jagiełło.

Using 3D Printing for Geometric Verification of Numerical Models of Clinch Joints

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In recent years, additive manufacturing has become a common part of the design, testing, and presentation processes for mechanical joints. This paper focuses on a practical demonstration of how 3D printing using PC filament can be effectively applied to the study of the geometry of clinch joints in thin-walled sheets. The aim is not to replace real metal samples in terms of their mechanical properties, but to create an accurate geometric copy of the resulting deformation obtained by numerical simulation or experimental measurement. This approach allows for quick visual and spatial verification of FEM model results, especially the shape of the lock, material overflow, and minimum remaining thickness. Printed models provide an advantage in communication within design teams, in presentations of results, or during tool design. They enable physical collision checks, visual assessment of the effect of clinching parameters, and rapid demonstration of different joint shapes depending on changes in material or tools. The paper presents the complete procedure from exporting the results of the numerical model to a printable format to the actual production of the physical model. The limitations of the method and its potential contribution to the verification of numerical forming simulations are also discussed.

Limitations of Surface Hydrophobization in Improving the Frost Resistance of Concrete - A Case Study

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The durability of engineering structures in a temperate climate is largely determined by the resistance of concrete to water ingress and cyclic freezing and thawing. Therefore, quality control of concrete is of key importance, both prior to its placement and during construction. In the case of unsatisfactory frost resistance test results obtained from specimens taken from ongoing deliveries of fresh concrete mix, it becomes necessary to perform additional testing on cores extracted from completed structural elements. This paper presents a case study of a structure in which insufficient frost resistance of the in-place concrete was identified. In order to improve durability, surface impregnation using a hydrophobic agent approved for use in construction was proposed. The frost resistance was evaluated in accordance with PN-B-06265:2022-08 using core specimens extracted from the structure before and after impregnation. The test results demonstrated that the applied hydrophobic treatment did not ensure the required resistance of concrete to cyclic freezing and thawing. The conducted analysis indicated that the negative assessment was primarily caused by an improper microstructure of the concrete, in particular an unfavorable air-void system, determining its low durability under frost action. Therefore, the obtained results indicate the limited effectiveness of the applied hydrophobic agent, representing surface protection methods, in the case of concrete with inadequate internal parameters.

Size and Shape Optimization of Geometrically Imperfect Steel Trusses Using a Genetic Algorithm

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This scientific research investigates size and shape optimization for steel trusses, considering geometric imperfections using a developed genetic algorithm. The primary objective is to minimize structural weight while maintaining allowable stress, stability, and displacement constraints. The proposed method is based on a Python algorithm directly coupled with commercial finite element software ABAQUS, which facilitates the automatic modification of a parametrically built geometry, the execution of analyses, and the evaluation of the obtained results. Size optimization modifies the cross-sections of the truss members selected from a predefined cross-section library, while shape optimization varies the nodal positions within a strictly defined range. The combination of these two methods leads to enhanced structural performance and a reduction in the required structural weight. The results highlight the importance of taking geometric imperfections into consideration, as traditional optimization often leads to imperfection-sensitive designs that underperform in reality. Furthermore, the simultaneous optimization of nodal positions and cross-sections leads to robust designs that maintain stability conditions. This method secures safer and more reliable structural behavior while achieving favorable material usage and improved structural performance. These findings support the development of future lightweight structural designs, leading to cost-effective and sustainable solutions.

Comparative Analysis of Piezoelectric Material Response Using the Finite Element Method

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This study evaluates the electromechanical response of a two-layer cantilever beam using the finite element method (FEM). The beam consists of a passive lower elastic layer and an active upper piezoelectric layer. Ten different piezoelectric materials were analysed for the active layer. The numerical results show that the maximum electric field occurs in the z-direction, while the highest normal stresses develop along the x-axis; responses in other directions are considerably smaller. Among the investigated materials, the highest voltage and electric field values are obtained when using the PZT-4 material, while the lowest values of voltage and electric fields are achieved when using PVDF. The highest stress values occur when using PZT-4 material, and the lowest stress values occur when using PVDF material. Overall, the results confirm that the choice of piezoelectric material significantly affects the performance of the cantilever system and is a key factor in optimizing piezoelectric devices. These findings highlight the strong influence of piezoelectric material selection on the overall harvester performance and provide guidance for optimizing cantilever-based piezoelectric energy harvesting devices. With the continuous advancement of modern technology, further development of piezoelectric materials and their applications is expected. The materials research continues to progress, leading to materials with increasingly efficient mechanical-to-electrical energy conversion.

Dynamic Analysis of Frame Structures Under Periodic Loading

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This paper presents a dynamic analysis of frame structures subjected to time-varying loading. It is assumed that the loading is periodic. The periodic loading is converted into harmonic components using a Fourier series, i.e., the periodic load is converted into a sum of simple sine and cosine functions. A discrete computational model with a finite number of degrees of freedom is created. The equations of motion are formulated. The natural frequencies and corresponding mode shapes of the structures are determined numerically by solving the associated eigenvalue problem. The solution procedure based on modal superposition is applied. The external load vector is decomposed into modal contributions according to the mode shapes. This approach transforms the coupled system of equations into a set of independent modal equations that can be solved. The study focuses on the dynamic response of multi-story frames, and it analyzes the influence of the number of stories and the number of columns per story on displacements and overall structural behavior.

Fatigue Crack Growth in Concrete: Linking Paris Law, Acoustic Emission, and Fractography

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This study investigates fatigue crack propagation in concrete beams with notches under three-point bending, subjected to cyclic loading using a servohydraulic testing machine operating at 10 Hz. Crack growth rates were analysed using Paris law measured from CMOD (Crack Mouth Opening Displacement), while Acoustic Emission (AE) monitoring captures real-time microcracking activity. Fractographic analysis of fracture surfaces provided insight into crack initiation and propagation mechanisms, including microcracking, aggregate bridging, and fracture surface roughness evolution. All analyses were performed for different stress levels, corresponding to varying fatigue lifetimes, allowing comparison of crack growth behaviour across Paris law, AE, and fractography analysis. By correlating Paris law parameters with AE signals and fracture morphology, the study establishes a direct link between different methods of crack growth observations. The integrated approach provides an understanding of interactions between material heterogeneity, loading, and crack evolution, supporting improved assessment and design strategies for concrete structures under cyclic loading.

Nonlinear Analysis of a Container Falling on the Reactor Hall Floor During Fuel Transport

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One The International Atomic Energy Agency (IAEA) initiated a program in 1990 to assist the countries of Eastern Europe and the Soviet Union in evaluating the safety of their first generation WWER-440/230 nuclear power plants. The main objectives of the program were: to identify major design and operational safety issues, to establish an international consensus on priorities for safety improvements, and to provide assistance in the review of the completeness and adequacy of safety improvement programs. One significant accident is a possible drop of the container during the replacement of the nuclear fuel in the reactor shaft. This accident can arise due to the failure of the crane hanger. It is necessary to remark that this operation is carried out during a technological pause. The reinforced concrete structure of the NPP containment can be penetrated as a consequence of the container's drop. In the case of extreme accident scenarios, the IAEA's requirement is that there should be no leakage of radioactivity from the hermetic zone, and therefore, the failure of part of the NPP structures is permitted. The impact load from the container drop was considered based on the NPP documentation for container handling and possible transport corridors. In the case of a container drop onto the concrete structure, dynamic impact loading was considered. Three different container drop heights were considered: 200mm, 1000mm, 4000mm. Two routes were selected. The aim was to avoid weak spots with holes in the ceiling, places with steam generator hangers, and to determine the maximum length of the route above existing walls under the ceiling. The nonlinear material model was based on the "Drucker-Prager" model for concrete layers on the SHELL181 layered element and the "Generalized Hill" material model for the layers of blurred reinforcement, taking into account the orientation of the reinforcement in the given element according to the design documentation. The nonlinear geometric model was based on the theory of large deformations of SHELL181 shell elements. The extreme location was analysed in the LS DYNA software for the container falling through the ceiling. The methodology and results of these analyses will be presented in the paper.

Numerical Analysis and Mesh Optimization of Clinch-Joined Thin-Walled C-Profiles under Three-Point Bending

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This article focuses on the development and optimization of a numerical model for the three-point bending of a slender beam composed of thin-walled cold-formed steel elements. The model, developed in Ansys, aims to accurately capture the mechanical behavior of a built-up cross-section formed by two clinch-joined C-profiles (300 mm in height). Given the 2 m span and the susceptibility of thin-walled members to local instabilities, various finite element meshing strategies were investigated to balance computational efficiency with the accuracy of predicted deformations and stresses. The study evaluates multiple mesh refinement schemes in critical regions, particularly around the clinch joints, where local stiffness and interaction significantly influence the global response. Furthermore, the selection of an appropriate material model is discussed regarding the nonlinear behavior of cold-formed steel. The findings offer practical recommendations for mesh density, element formulation, and material representation, providing a framework for the efficient and reliable FEM modeling of similar structural members.

Experimental Evaluation of Shear Strength in Asymmetric Timber–Concrete Specimens Using a Modified Test Setup

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This paper focuses on the development and validation of a novel method for testing the shear strength of an asymmetric timber–concrete specimen with a bonded joint, which forms part of timber–concrete composite (TCC) panels. Since most test specimens were cut directly from TCC panels, it was not possible to prepare the symmetrical specimens recommended in existing testing methodologies. For this reason, an experimental procedure complying with the requirements of EN 14080 was proposed. During the tests, the maximum shear force and the strain distribution at the timber–concrete interface were recorded using the digital image correlation (DIC) method. Initial tests performed using the original test set-up revealed a non-uniform distribution of shear stresses, with the upper part of the bonded joint subjected to significant tensile stresses. This led to undesirable failure mechanisms and, in some cases, failure occurring within the timber element outside the bonded interface. Based on these observations, a modified test set-up incorporating a massive welded steel element was designed and implemented to simulate symmetric load application. Validation of the modified configuration through analysis of horizontal strains at the timber–concrete interface confirmed a more uniform shear stress distribution and improved reproducibility of failure modes. The proposed method therefore represents a suitable approach for the experimental evaluation of the shear strength of asymmetric bonded joints in timber–concrete composite structures.

Numerical Modeling of 3D Printed Steel Components

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3D metal printing, also known as additive manufacturing, is a revolutionary technology that is already replacing traditional manufacturing methods such as milling and welding in certain fields such as medicine and the automotive industry. It is an innovative approach that uses digital models to create complex metal structures layer by layer. The main advantages of this technology include the ability to create complex geometries, reduce material waste, and shorten production cycles. One of the methods used for 3D printing of metal alloys is SLM, or Selective Laser Melting, which uses a high-power laser to gradually melt metal powder layer by layer in a powder bed. The SLM method represents a different approach to the production of complex components with a high degree of material and geometric optimization. However, the resulting 3D-printed components exhibit complex mechanical properties that depend on the orientation of the component during printing. The article focuses on the creation of numerical models of test specimens in a static software environment based on the finite element method, taking into account the orientation of the print. Modeling enables the simulation of stress-strain behavior, which is part of static loading, taking into account the selected material and its anisotropy. With growing interest in sustainability and production efficiency, 3D metal printing is expected to play a key role in the future of industrial production and penetrate deeper into structural applications.

Effect of Wind Direction and Traffic Intensity on the Dispersion of Aerosol Particles

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De-icing salts applied in winter contribute to the formation of aerosols near roadways. This study assesses the influence of wind direction and traffic intensity on the dispersion of aerosol particles originating from de-icing salts using numerical simulations of turbulent flow in ANSYS Fluent. The computational model is based on the real topography of the expressway in the vicinity of Ostrava. Particle deposition is monitored on sampling planes at varying distances from the road. The article analyzes two wind-direction scenarios and two traffic-intensity configurations. In both scenarios, the wind approaches from the left side of the vehicle: one case corresponds to flow in the direction of travel, and the other against it; in both cases, the wind is inclined at 60° relative to the vehicle axis. Traffic load is represented by the passage of one or two vehicles. The simulation results confirm that higher traffic intensity leads to a greater amount of deposited particles and also demonstrate its effect on their spatial distribution. The vertical extent of the particles is generally comparable; however, under specific wind conditions, the height of the aerosol cloud increases significantly. Wind direction also influences the nature of particle deposition, altering the distribution of particle capture on the monitored sampling planes.

Inverse Determination of Mechanical Fracture Parameters Using Convolutional Neural Networks

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Knowledge of mechanical fracture parameters is essential for modelling the failure of concrete structures virtually. This paper presents a methodology for the inverse determination of these parameters using convolutional neural networks (CNNs), representing an evolution from inverse methods that rely on feed-forward artificial neural networks (ANNs). Unlike traditional ANNs, which process input values independently, CNNs are better suited to recognising spatial features and local dependencies within the data. CNNs utilise convolutional layers that act as automated filters to extract relevant signatures from raw experimental curves. In the context of laboratory three-point bending fracture tests, this enables the network to capture the complex shapes and curvatures of the experimental diagrams more accurately, resulting in more precise parameter identification. The training set for the network is prepared by numerically simulating three-point bending tests using the nonlinear finite element method with randomly generated material parameter values. Once trained, the CNN acts as a highly efficient approximation tool, providing the optimal set of model parameters based on experimental data. The superiority of the CNN-based approach is demonstrated using examples of selected concrete mixtures.

Numerical Assessment of Horizontal Load-Bearing Capacity and Stiffness of a Modular Timber Panel Using Finite Element Modeling

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This article presents a numerical investigation of the horizontal load-bearing capacity and stiffness of a newly designed modular wood panel developed for a new building system for efficient wood buildings. A detailed three-dimensional model of the panel was created in ANSYS, reflecting the exact geometry and material composition of experimentally manufactured panels. The structural system consists of KVH timber elements combined with OSB and DHF sheathing, with the material properties calibrated according to laboratory tests. Two variants were analyzed, differing in the distribution and range of the applied horizontal load. The boundary conditions simulated full anchoring in the base and realistic load transfer through the distribution plates. Both variants were subjected to increasing horizontal forces up to 300 kN to evaluate the deformation behavior, shear stress distribution, and potential failure areas. The results demonstrated high global stability of the panel and clear differences between the two load configurations. Variant 01 exhibited higher local stresses and greater deformation (approximately 36 mm) due to the smaller loaded area, while variant 02 exhibited significantly lower deformation (around 7 mm). Critical shear stress zones were identified primarily in the wooden elements. Numerical analysis confirms the high structural resistance of the panel under horizontal loading and provides important insights for further optimization and experimental verification in the development of a modular building system.

Surface-Aware Dataset Generation from Textured 3D Models for Machine Vision-Based Structural Insection

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The performance of machine vision-based structural inspection systems is fundamentally constrained by the limited availability of large, high-quality annotated datasets, whose acquisition is costly, laborintensive, and often unsafe. This paper introduces a surface-aware dataset generation framework that leverages textured 3D models to produce structurally meaningful and photorealistic synthetic training data. Unlike conventional rendering-based approaches, the proposed method explicitly integrates surface geometry, material properties, and texture-level information into the data generation and annotation pipeline, ensuring defect-level consistency and spatial fidelity across inspection scenarios. The framework enables controlled variability while preserving physically plausible surface characteristics, effectively narrowing the sim-to-real gap. Experimental evaluation demonstrates that models trained on the generated datasets achieve robust performance and improved generalization on real-world structural inspection tasks. The proposed approach establishes a scalable and controllable paradigm for synthetic data generation, significantly reducing dependence on extensive field data collection in structural health monitoring applications.

Design of Pavements under Extreme Loads in Challenging Subsoil Conditions in Port Areas – Case Study of Szczecin and Świnoujście

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This paper addresses the design of pavements subjected to extreme loads in port areas located in Szczecin and Świnoujście, as well as in industrial facilities supporting the offshore wind energy sector. The rapid development of infrastructure dedicated to the storage, handling, and transportation of oversized wind turbine components—such as towers, nacelles, and blades—generates exceptionally high static and dynamic loads transferred to the pavement structure and subsoil during consolidation and transport operations. The specific geotechnical conditions of the analyzed region are characterized by the presence of organic and low-bearing soils, which require the application of advanced ground improvement techniques and carefully optimized structural solutions. The paper presents selected structural configurations of both rigid and flexible pavements designed to meet ultimate and serviceability limit state requirements, including total and differential settlement criteria. Examples of pavement structural calculations and settlement analyses performed using the Finite Element Method (FEM) are provided, incorporating realistic loading schemes corresponding to heavy-duty port operations. The results highlight the critical importance of accurate subsoil investigation and appropriate ground improvement strategies in ensuring the long-term performance, durability, and operational safety of port infrastructure of strategic relevance to the offshore wind industry.

Analysis of Stress Distribution in a Concrete Specimen Involving a System of Steel Anchors

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Structural anchors are commonly used to attach different structural components to a base material, such as concrete. Consequently, recent research has largely concentrated on examining the factors affecting the performance of anchors embedded in the substrate. Anchors are typically exposed to either tensile loading or shear loading. For each case of loading, different behaviour of the anchor can be observed, and various failure modes are spoken about. This work is devoted to the concrete cone failure mode, which is typical for anchors subjected to tensile loading. To design cast-in anchors, numerous both experimental and numerical (finite element simulations etc.) fracture analyses have been performed by many investigators to study the behaviour of such structural elements under various conditions. Investigations on stress distribution in a concrete specimen involving a system of steel anchors are the main topic of this paper. Effects of various parameters of the anchors' system on stress distribution and potential crack propagation are analysed.

Analysis Sustainability Assessment of a Product Utilising Cement-Bonded Particleboard Waste

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This study evaluates the sustainability of structural elements, specifically noise barriers, fabricated from high-performance concrete (HPC) incorporating secondary raw materials. The primary objective is to assess the environmental impact of replacing the finest fraction of natural aggregate with waste generated during the production of cement-bonded particleboards (CETRIS®). Beyond the environmental benefits, the integration of wood-cement filler may enhance the acoustic performance of the elements, particularly in sound absorption, which is a critical parameter for the effective design of noise mitigation barriers. In the experimental phase, the natural aggregate was substituted by this industrial waste at varying replacement levels (0%, 31%, 50%, and 100%). The design of the monolithic structure, cast into removable formwork, is based on mechanical parameters derived from this comprehensive experimental research. Numerical modelling is employed to verify the structural stability of the proposed designs and to optimise material consumption for each mixture variant. A part of the research is a Life Cycle Assessment (LCA), which utilises the calculated material volumes to quantify the environmental footprint of all four concrete mixtures. The results provide a complex evaluation of the synergy between industrial waste recovery, material engineering, and sustainable structural design.

Fracture of concrete under various loads: Monotonic static, low-cyclic and high-cycle fatigue

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This contribution focusses on the fracture damage assessment of concrete samples using wide-range experimental data. Within this study, the concrete samples were tested under various loading conditions: static fracture, low-cycle and high cycle fatigue. This allowed us to obtain static load-CMOD, S-N curves for fatigue lifetime assessment, and mainly CMOD-N curves showing the stiffness degradation at high-cycle fatigue load regime. Additionally, acquisition of CMOD during the cyclic loading allowed for evaluation of fatigue crack growth rate by Paris law. The low-cycle fatigue resistance is assessed from stepwise load-CMOD curves or hysteretic loops with increasing CMOD value every step, allowing to analyse damage growth between each load cycle. Moreover, such experimental results provides irreversible CMODIR value, which has similar meaning as the plastic zone in metallic materials. This study investigates the fatigue resistance of concrete samples by combining all of these experimental data and could provide useful recommendation for structural design.

Utilization of Digital Data Acquisition Methods for Geometric Analysis and Asset Inventory of Bridge Structures

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This paper focuses on verifying the applicability of digital surveying methods for the rapid monitoring and asset inventory documentation of bridge structures. The primary objective is to identify actual geometric deviations from design documentation and evaluate the suitability of this approach for routine bridge management within the context of Construction 4.0 and infrastructure digitalization. Data acquisition was performed using an integrated approach combining terrestrial laser scanning (TLS), UAV photogrammetry, and GNSS RTK geodetic surveying. The resulting georeferenced point cloud enables detailed spatial analysis of the structure. The methodology was tested on modern timber footbridges, where an as-built model was generated and subsequently compared with the original design documentation using sectional analysis within a CAD/BIM environment. Particular attention is given to the interpretation of detected deviations, with an emphasis on distinguishing standard construction tolerances from potential structural deformations. The study also discusses the possibilities of repeated measurements for monitoring structural changes over time and the integration of outputs into digital twins and asset management systems. In this context, practical limitations of the method are also considered, such as the influence of vegetation, the visibility of hidden structural elements, and data processing requirements, which represent key aspects for the broader implementation of this approach into routine bridge inspection practice.

Machine Learning–Based Surrogate Modeling for Nonlinear Finite Element Analysis of Cycle-Dependent Deterioration in Composite Bridges

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The durability of transportation infrastructure is strongly influenced by cyclic traffic actions and environmental effects, which progressively reduce structural stiffness and load-carrying capacity over time. Accurately capturing this evolving behavior requires computational models that are both robust and computationally efficient. In this study, a high-fidelity, machine-learning-accelerated modeling framework is developed by coupling geometrically and materially nonlinear finite element simulations with a Neural Network (NN)-based surrogate. The nonlinear finite element model is first calibrated using experimental monitoring data, enabling the identification and incorporation of cycle-dependent degradation mechanisms into the analysis. The comprehensive dataset generated from the calibrated simulations is subsequently employed to train and validate the NN surrogate, which rapidly estimates critical structural response quantities for previously unexamined loading scenarios. The proposed framework is demonstrated on a full-scale composite bridge specimen tested at the Bridge Evaluation and Accelerated Structural Testing laboratory (BEAST®) at Rutgers University's Center for Advanced Infrastructure and Transportation. The results indicate that the NN-enhanced digital model enables efficient evaluation of varying load trajectories and fatigue progression while significantly reducing computational demand. This approach facilitates accelerated parametric investigations and supports informed decision-making for inspection planning, maintenance scheduling, and lifecycle management of composite bridge systems.

Freeze-Thaw Deterioration in Seawater-Mixed Cementitious Systems with Slag, Metakaolin, and Nanoparticles

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The Water-stressed regions in several countries and islands are expected to rise by 2050. Simultaneously, the need to create durable infrastructure in such places can result in increased demand for concrete that requires fresh water for its production. Recent studies focus on identifying the feasibility of using seawater as mixing and curing water for concrete production with the scope of utilizing supplementary cementitious materials (SCMs) and alternative reinforcement. However, the durability of seawater-mixed concretes (SWC) under extreme exposure conditions are limited. This study compares the resistance of 4 mixes of SWCs, and freshwater-mixed concretes made with SCMs such as slag (30%), metakaolin (15%), and nanoparticles (nano-SiO₂, and nano-Al₂O₃) against freeze-thaw action. Specimens are prepared and exposed to freeze-thaw cycles (-20 °C to 20 °C for every 24 hours) conforming to the specifications mentioned in PKN-CEN/TS EN 12390-9:2017-07. Scaled concrete chunks from the surface of exposure were scraped, collected and weighed at 7, 14, 28, 42, and 56 days. At the end of 5 cycles, it is evident that the scaling resistance against the freeze-thaw exposure has improved in the SWCs compared to FWCs due to its improved surface resistivity and porosity at the end of curing.

AutoML-Selected Neural Surrogates for Micro–Macro Mapping in DEM-Based Modeling of Cementitious Composites

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Discrete element modeling (DEM) can capture the nonlinear influence of friction-related microparameters on the macroscopic response of cementitious composites, however, extensive simulation campaigns are computationally costly. This paper presents an Automated Machine Learning (AutoML)-guided surrogate modeling workflow that learns the mapping from DEM inputs, namely bonded friction angle and non-bonded friction coefficient, to macroscopic response indicators extracted from stress-strain curves. A structured set of DEM simulations is generated to cover the relevant friction parameter space while holding non-target settings constant, providing consistent training data for the surrogate. An automated hyperparameter tuning strategy selects an artificial neural network (ANN) configuration that balances prediction accuracy and model complexity, resulting in a compact multi-layer model with strong generalization on unseen cases. The surrogate reproduces nonlinear trends and interaction effects between friction parameters, including changes in peak strength, stiffness, and post-peak softening associated with shifts in failure mechanisms. Once trained, the model enables efficient parametric exploration and sensitivity screening, and it reduces the need for additional DEM runs when new target ranges or mix designs are considered. Overall, the framework offers a reproducible and scalable route for DEM-informed, data-driven characterization of cementitious composites.

Recycled Aggregates for 3D Printed Concrete Structures (Recycl3D) Project - Outcomes and Practical Pointers

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This study presents practical outcomes of the Recycl3D project related to the incorporation of fine recycled aggregates (fRA) and recycled concrete powders (RCP) into mixtures designed for 3D concrete printing. Within the project, it was demonstrated that it is feasible to print composites containing up to 100% fRA as a replacement for natural river sand. Mechanical testing revealed a significant decrease in compressive strength (up to 55%) when both RCP and fRA were introduced into the mixture. Nevertheless, despite the reduction in mechanical performance in certain configurations, all mixtures containing 100% fRA and 10% RCP achieved compressive strengths exceeding 30 MPa, indicating their potential applicability in the construction industry. Additionally, the study presented methods for evaluating the quality of additively manufactured elements using optical measurement techniques such as LiDAR and ground-penetrating radar (GPR). Standard mechanical tests, including pull-off and pull-out methods, were also performed to assess the structural behavior of the printed composites. The results indicate that, when appropriately designed, mixtures containing recycled aggregates can achieve plaster adhesion comparable to that of reference mixtures, regardless of finishing type. Moreover, the LCA results demonstrate the significant environmental benefits of incorporating fRA and RCP derived from concrete waste into additive manufacturing processes.

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Variational Solution of a Catenary Using Repeated Integrals

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Cable structures are typically modeled based on the theory of elastic fibers. For simple structural systems, analytical solutions can be used; however, such structures are usually solved numerically—through nonlinear FEM analysis. For more complex loading conditions or for additional loading of an existing structure, the computation requires satisfying two or more differential equations simultaneously. In such cases, the use of FEM can be quite complicated, and alternative solution approaches must be sought. This paper applies a modification of the Galerkin–Petrov variational method to solve the problem of a loaded cable structure of a circular building. The method provides a relatively simple way to solve systems of nonlinear differential equations—in this case, a specially additionally loaded catenary. The solution consists in calculating the deviations from the exact solution for the selected values of the coefficients of the standard basis function at the Gaussian points of the numerical quadrature and multiplying the matrix of weight coefficients (constants) for individual repetitions of the cubature by these values, thus obtaining the deviations of individual integrals. The proposal of adjusted coefficient values for the next step of the calculation is determined using any numerical method for solving systems of nonlinear equations.

Non-Contact Strain Measurement by Digital Image Correlation

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Accurate determination of Young's modulus of elasticity requires precise measurement of both stress and strain within the elastic region of material behavior. Stress is calculated as the ratio of the applied force to the original cross-sectional area of the specimen, while strain represents the relative deformation produced by the applied load. Traditionally, strain has been measured using contact extensometers attached directly to the specimen. However, recent advances in optical measurement techniques have introduced Digital Image Correlation (DIC) as a reliable non-contact alternative. Digital Image Correlation is an optical method that tracks the displacement of randomly distributed surface patterns across a sequence of digital images or video frames recorded during loading. By analyzing the movement of selected subsets within the monitored area, full-field displacement and strain distributions can be determined with high spatial resolution. This paper presents the application of DIC in standardized tensile testing of steel specimens for the purpose of determining Young's modulus. The experimental procedure, including specimen preparation, loading conditions, camera setup and DIC software parameters, is described in detail. The measured strain data obtained from DIC are evaluated and discussed. The results confirm that DIC represents a suitable and effective alternative to conventional extensometers in elastic modulus determination.

Comparison of Modal Analysis Results in ANSYS and Scia Engineer Software Environments Using for Case Study of a Historical Building

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The article deals with the comparison of numerical modeling of a historical sacral building – a church in the village of Turie – using ANSYS and SCIA Engineer software. The aim of the study is to assess the differences in the prediction of dynamic parameters of the structure, in particular natural frequencies, natural vibration modes, and damping. A simplified spatial model based on the actual geometry of the object was created in both programs, with ANSYS using higher-order 3D volume elements, while SCIA Engineer works with frame-wall elements with a simplified description of spatial behavior. The material parameters and boundary conditions were based on data on historical stone masonry, wooden structural elements, and the geological conditions of the site. The results from both software programs were compared. However, ANSYS provided a more detailed description of local modes, higher accuracy in torsional shapes, and better sensitivity to changes in structural stiffness. SCIA Engineer excelled in faster model creation and effective focus on global structural behavior, but with lower accuracy for higher modal shapes.

Fully Probabilistic Design of Shear Strength: Comparison of Nonlinear Numerical Model and Code Formulas

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This paper evaluates the shear strength of concrete beams reinforced with steel or GFRP using a fully probabilistic approach that considers model uncertainty. The aim of this study is to compare the results obtained from a nonlinear numerical model (ATENA) with analytical model (design) codes (ACI 318, EN 1992-1-1 and fib Model Code 2010 for steel reinforcement and ACI 440, mEN 1992-1-1, EC 2 and fib Model Code 2010 for GFRP reinforcement). Design values corresponding to a probability of failure 0.0012 are determined with and without considering model uncertainty according to appropriate formula. The comparison is based on a fully probabilistic design values obtained from the nonlinear numerical model and analytical model codes. The analysis is performed on experimental data and evaluates the agreement between numerical approaches. The results show the importance of considering model uncertainty in the fully probabilistic evaluation of shear strength and in the case of fib MC 2010 provides good agreement between design values and nonlinear numerical model. The paper contributes to the reliability assessment of numerical and analytical approaches for the design of elements failing by shear.

Computational Model for Fracture in Timber Structures Exposed to Moisture

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The paper introduces a computational model developed to simulate brittle fracture caused by mechanical loading and by moisture variations in structures containing orthotropic and hygroscopic materials. Typically, timber shows significant modifications of its mechanical properties when exposed to environment with changing humidity. This leads to stress evolution and potentially provokes crack initiation and propagation. Experimental studies on structures composed of timber and concrete have proven that moisture fluctuations can considerably affect internal stressing and global structural operation. Such coupled hygro-mechanical effects are analysed by the proposed computational model integrating moisture transport, hygro-expansion, and fracture mechanics. The fracture approach employs a phase-field and interface damage formulation to represent crack initiation and growth as a continuous degradation process. The hygric part of the model includes bound and vapour water transport, sorption effects, and the degradation of material stiffness ultimately leading to moisture-induced fracture. A simplified structural element is studied in an in-house MATLAB code to illustrate interactions of moisture diffusion, stress and deformation, and fracture propagation.

Can Seawater Mitigate Early Strength Development in Low-Carbon Cementitious Systems?

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The use of seawater as a mixing solution for low-carbon cementitious binders has recently gained attention due to growing interest in resource-efficient construction and the need to reduce freshwater consumption in coastal regions. Existing research calcined clay-limestone cements, and blended systems with supplementary cementitious materials (SCMs) indicates that ionic composition of mixing water can significantly influence early hydration kinetics. In this study a cementitious systems containing 3 types of low-grade calcined clays (illitic clays) were developed and evaluated in scope of hydration and strength development. Isothermal calorimetry studies confirmed that elevated concentrations of chlorides, sulfates, magnesium, and alkali ions, interact with clinker phases and SCMs resulting in higher hydration heat. Strength activity index (SAI) studies confirmed that at early ages seawater has extremely beneficial effect on strength development, while after 28 days effect is comparable to freshwater systems. Study confirmed that proposed cementitious systems based on low-grade illitic clay meets the EN 450-1 SAI criteria to be applied in cement-based composites.

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