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The 6th International Conference on Innovative Materials, Structures and Technologies (IMST2025) takes place on 10–12 September 2025 in Riga, Latvia, organised by the Faculty of Civil and Mechanical Engineering of Riga Technical University. The conference aims to promote and discuss recent achievements in sustainable and innovative building materials, advanced structures, structural health monitoring, 3D printing, bio-based solutions, and circular economy approaches in the construction sector.

IMST2025 provides a platform for researchers, engineers, industry representatives, managers, and students to exchange knowledge, present results, and address current challenges. The event brings together over 150 participants from 20 countries, featuring keynote lectures, oral and poster sessions, and networking opportunities. We wish all participants to gain new knowledge, build fruitful collaborations, and enjoy the vibrant atmosphere of Riga and Latvian culture.

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PRODUCTION AND USE OF LIGHTWEIGHT ARTIFICIAL AGGREGATES IN 3D BUILDING TECHNOLOGY

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This study explores the development and application of lightweight artificial aggregates (LAA) in 3D printing-based construction, addressing environmental concerns and aiming to reduce carbon emissions in the building industry. Aggregates were produced via granulation using charcoal and hydrated lime, followed by air drying and carbonation. The microstructure was examined using SEM/EDS, revealing tight bonding and minimal impurities. Experimental 3D printing mixtures were prepared with varying aggregate proportions and tested for compressive and flexural strength in accordance with EN standards. Results indicated that mixtures without aggregates achieved the highest strength, while the inclusion of coarse fillers decreased compressive strength by approximately 11 %. This research demonstrates the potential of LAA in 3D construction applications while highlighting the critical influence of aggregate size on mechanical performance.

PERFORMANCE EVALUATION OF STARCH-STRAW BIOCOMPOSITES FOR 3D PRINTING IN CONSTRUCTION

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Construction materials contribute significantly to environmental degradation, highlighting the need for eco-efficient alternatives derived from renewable resources. Biocomposites made from agricultural byproducts offer a promising substitute for conventional synthetic composites. In parallel, the growing emphasis on automation and digitalisation in construction has led to increased interest in 3D printing technologies. While 3D printed concrete has seen substantial development, the application of 3D printed biocomposites in construction remains underexplored. This study investigates the potential of starch-based biocomposites reinforced with barley straw for 3D printing applications. Two forms of barley straw, ground and chopped, individually and in combination, are used with starch as a binder. Samples were prepared and tested for key properties, including density, compressive strength, flexural strength, water absorption, and swelling. The extrudability of the biocomposites is examined using an extruder gun, which is of particular importance in determining applicability in 3D printing. The results indicate that biocomposites containing ground barley straw demonstrate superior mechanical strength and lower water absorption, while chopped straw contributes to reduced material density. Extrusion tests further confirm that ground straw composites exhibit favourable extrudability, making them suitable for 3D printing of construction elements. Overall, this study establishes the feasibility of using starch-barley straw biocomposites in 3D printing for construction. Further mix design optimisation is recommended to enhance performance and printing quality. This research provides an essential step toward integrating renewable agricultural waste into advanced manufacturing processes, contributing to the development of low-carbon, circular construction materials.

ENHANCING PERFORMANCE AND ADVANCING SUSTAINABLE CONCRETE PRODUCTION THROUGH BIO-TREATMENT OF RECYCLED CONCRETE AGGREGATES USING MICP

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The construction industry generates large volumes of waste through various activities and heavily relies on natural resources; therefore, it faces increasing pressure to reduce its environmental footprint and adopt circular economy strategies. Recycled Concrete Aggregates (RCA), derived from construction and demolition waste, offer a potential solution; however, compared to natural aggregates, RCA's inferior quality, including high porosity, weak mechanical properties, and poor durability, limits their widespread use. Inspired by the emerging self-healing concrete, this study introduces a bio-based treatment method using Microbially Induced Calcium Carbonate Precipitation (MICP) to enhance RCA quality and promote its practical application. Two bacterial strains, Lysinibacillus sphaericus and Priestia megaterium, were tested using various concentrations and treatment methods. The treated RCA showed notable improvements: mass gain reached up to 6 %, water absorption was reduced by as much as 88 %, and resistance to impact and abrasion increased by 58 %. Scanning electron microscopy and X-ray diffraction confirmed surface deposition of calcite on the surface of the treated RCA. Among the tested conditions, soaking treatments outperformed spraying methods, and P. megaterium delivered slightly better results than L. sphaericus. Concrete mixes with treated RCA exhibited increased workability, up to 15 % higher compressive strength, and improved durability compared to those made with untreated RCA or natural aggregates. Partial replacement of natural aggregates with treated RCA (50 %) yielded better performance than the complete replacement (100 %). These enhancements were linked to the bacterial type, treatment method, and replacement ratio. Future research will focus on optimising treatment protocols, testing alternative bacterial strains, and combining MICP with established RCA enhancement techniques to maximise performance. A full-scale life cycle assessment will be conducted to evaluate feasibility, and scale-up studies will explore the practical implementation of this approach in concrete production. This research supports the development of high-performance, sustainable alternatives to conventional aggregates, thus promoting the circular economy in the construction industry.

COMBINING EXPERIMENTAL ANALYSIS AND MACHINE LEARNING FOR LONG-TERM DURABILITY ASSESSMENT OF HYDRAULIC LIME MORTARS

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This study presents an integrated experimental–computational framework for assessing the durability of lime-based mortars subjected to acidic environments, with a particular focus on predictive modelling using machine learning. While the degradation of lime-based mortars under aggressive exposures remains insufficiently addressed in the literature, this work bridges that gap by combining a systematic experimental campaign with a robust data-driven modelling approach. Mortar specimens formulated with commercial hydraulic lime were exposed to controlled ageing regimes, including immersion in acidic solution (pH 3.0), distilled water, and dry storage, for durations of 1000, 3000, and 5000 hours. Mechanical degradation was monitored via flexural testing. To predict the long-term mechanical behaviour, an extreme gradient boosting (XGBoost) algorithm was trained on the experimental dataset using input features such as exposure duration, density, moisture content, and corrosion indicators. The output variable was defined as the full stress–displacement response under flexure. The machine learning model demonstrated high predictive accuracy and generalisation capacity (R^2 = 0.984; RMSE = 0.116, 4-fold cross-validation), capturing complex nonlinear dependencies within the ageing dataset. Notably, the model identified the 3000-hour mark as a critical transition point for mortar performance under acidic attack, followed by a progressive degradation phase. Comparative trends from control environments (dry and water) highlighted distinct evolution pathways, further validating the model's capability to differentiate environmental effects. The results confirm the potential of ML-assisted frameworks as powerful tools for forecasting durability and mechanical performance in heritage-compatible lime-based systems under long-term exposure.

POTENTIAL APPLICATIONS OF NATURAL ZEOLITE IN 3D PRINTING TECHNOLOGY OF FINE-GRAINED CONCRETE

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3D printing of concrete is a promising construction technology that has recently attracted growing interest in both scientific and industrial fields. This innovative construction method enables the development of individually tailored and unique structural solutions while reducing waste generation, minimising labour requirements, significantly shortening construction time, and decreasing the risk of design errors. Although considerable research has been conducted in this field in recent years, 3D printing of concrete still presents numerous challenges, particularly related to the interaction of various rheological properties over time.

This study investigates the influence of natural zeolite on the 3D printing properties of fine-grained concrete. Rheological tests were conducted on fine-grained concrete mixtures using a rotational rheometer Rheotest RN 4.1 with coaxial cylinders. In the experiments, CEM I 42.5R Portland cement was used as the binder, washed sand (fraction 0/2 mm) as the fine aggregate, and natural zeolite as the mineral additive. The binder was partially replaced with natural zeolite in amounts ranging from 0 % to 9 %, in 3 % increments. The flow curves, shear stress, plastic viscosity, and thixotropy/dilatancy indices of the mixtures were determined immediately after mixing and after 60 minutes.

The results showed that natural zeolite increases the yield shear stress of fine-grained concrete mixtures and improves buildability during 3D printing, while plastic viscosity remains nearly constant. The thixotropy/dilatancy index remained almost unchanged both immediately after mixing and after 60 minutes as the shear rate increased, indicating the stability of the mixture's thixotropic behaviour.

PLYWOOD WALL FOR BULLETPROOF MODULAR BUILDINGS

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Perforation data for laminated birch plywood material samples with a thickness of 28 mm (comprising 1, 2, and 3 layers) have been collected and analysed at a real shooting range. The aim is to ensure acceptable conditions within modular houses while providing protection against external threats in accordance with protection class BR2/FB2 according to Standards EN 1063 and UL 752. The residual velocities of the ogive-shaped bullets after perforating the plywood specimen or the penetration depth were measured. The Poncelet formula was employed to determine the coefficients that help to alternate between classes FB1-FB4. These parameters specify the maximum penetration depth or the minimum wall thickness (experimentally 76 mm, theoretically 93 mm guaranteed) for birch plywood material when subjected to handguns, within the protection classes BR1-BR4/FB1-FB4, at initial bullet velocity ranging from 330 m/s to 450 m/s and bullet masses from 2.5 g to 15.7 g. A case study is presented in the article. A graph illustrating the results would facilitate understanding of each layer's ability to stop a bullet with an initial velocity of 340 m/s, especially when combining plywood with other materials. Currently, there is no existing formula for the maximum penetration depth of different material layers. Optimisation of the results indicated that an ideal plywood wall thickness of 105.7 mm would provide the maximum protective capability, based on the mathematical analysis.

EFFECT OF CHEMICALLY DIVERSE WASTE GLASS ON BINDER PROPERTIES

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The global production of glass encompasses a diverse range of products, including packaging materials, household appliances, optical devices, and solar panels, each possessing unique properties. As both glass production and consumption continue to increase annually, there is a corresponding increase in the generation of glass waste [1]. While simple household glass can be separated and recycled, a significant part of other glass waste remains challenging to recycle sustainably due to the cost and time-consuming nature of the recycling process [2]. The glass must undergo processing at temperatures ranging from 1200 °C to 1400 °C to remove impurities such as dirt and rust from the final product [3]. However, improper sorting of glass waste can lead to contamination, hindering its reuse and negatively impacting the quality of the final product. Studies [4] have indicated that up to 75 % of all glass waste produced is landfilled, resulting in a comparatively low recycling rate compared to other solid waste streams. Research is ongoing worldwide to explore the recycling of non-containerised waste glass for various applications, including asphalt pavement aggregates, concrete production aggregates, cement replacement, glass tile production and glass fibre insulation materials [5]. However, the chemical composition of various types of glass waste, such as those derived from fluorescent lamps, television screens (cathode ray tubes), and liquid crystal displays, could also be utilised as a substitute for part of the cement.

In this work, the influence of the chemical composition of different glass wastes on cement hydration, physical and mechanical properties after 7, 28 and 90 days of curing of samples is analysed. The statistical analysis showed that the most significant oxides in glass composition improving the compressive strength of binder are SiO_2 and CaO, and oxides that decrease the strength are BaO, SrO and $Na_2O + K_2O$. The compressive strength of the binder samples with the highest amount of SiO2 is 10 % higher compared to the control sample (about 97 MPa at 90 days), and the binder with the highest amount of BaO, SrO and $Na_2O + K_2O$ has the lowest compressive strength (about 66 MPa at 90 days). Additionally, glass with the highest amount of SiO_2 accelerates cement hydration and with the lowest amount of SiO_2 retards.

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THE EFFECT OF MINERAL STONE WOOL PRODUCTION WASTE ON THE RESEARCH OF REFRACTORY COMPOSITE

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The necessity to decrease pollution in modern construction and other industrial sectors is becoming increasingly clear, especially in the context of rising CO_2 emissions and the impacts of climate change. Consequently, it is essential to find efficient ways to utilise the waste generated by industrial sectors, thus creating a secondary use for this waste and promoting sustainability and the circular economy [1]. A notable industrial byproduct is the dust resulting from the production process of mineral stone wool, which is also referred to as cupola dust [2]. General mineral wool waste generation in the European Union amounts to approximately 2.54 million tons per year and is expected to increase up to 2.82 million tons by 2030 [3]. Notably, this material is not recycled back into the production cycle but rather sent to landfill. Their chemical composition, which is rich in SiO_2, Al_2O_3, CaO and MgO compounds, can make them valuable as active components in composite materials.

The initial stage of the study aims at the mechanical treatment of these dusts by granulation in order to utilise the large amount of dust and to give the dust a larger reaction surface with the cementitious materials. The granulation process is seen as a preparatory step for pellet incorporation into composite systems, using the granules as a filler in refractories. This step focuses on the formation of granules. The resulting pellets are heated up to 1000 °C to determine the chemical, physical and mechanical changes of the pellets due to the high temperature. The experimental findings are obtained using chemical composition, pH, electrical conductivity and SEM to determine the influence of the pellets on the hydration, microstructure and other properties of aluminate cement.

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SYSTEM IDENTIFICATION OF AN EXISTING BRIDGE BEFORE AND AFTER RETROFIT MEASURES

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In this study, we present the results of the dynamic identification of a reinforced concrete (RC) arch bridge before and after a critical intervention in which the hangers of the bridge were replaced. The investigation focuses on the analysis of the natural frequency fluctuations caused by the changes in the anchor point geometry and the length of the anchors made during the replacement. The reason for the replacement was the need to ensure the structural integrity and longevity of the bridge. At the same time, it was an opportunity to investigate the effects of the changed geometric conditions on the dynamic behaviour of the bridge. Originally, it was assumed that the natural frequencies would remain relatively unchanged, provided that the free length of the hangers, which is directly influenced by the anchor points, was consistent with the original design. However, dynamic identification after the intervention revealed a more complex scenario. Our results show that the change in anchor point geometry led to shifts in the natural frequencies of the bridge due to the changes in the actual free length of the hangers. In particular, changing the anchorage points changed the boundary conditions, which in turn affected the overall stiffness distribution and the dynamic response of the bridge. To carry out this study, dynamic tests were performed before and after the replacement of the hangers, which allowed the extraction of natural frequencies and mode shapes.

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EFFECTIVENESS INCREASE OF TIMBER AND TIMBER-CONCRETE COMPOSITE PANELS

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As an environmentally friendly building material, timber aligns with government strategies for sustainable development and climate change mitigation. Enhancing the efficiency and load-bearing capacity of timber structures is a current and pressing concern. European and North American markets have seen a rapidly growing popularity and demand for CLT (cross-laminated timber) panels [1].

Since the usage of CLT in construction projects has significantly increased, this material has been chosen as the base material for the research. While CLT walls are quite robust and capable of withstanding bigger loads, there is rarely a need for a load-bearing CLT wall that is thicker than 120 mm. The same cannot be said about slab elements. To increase efficiency and save material, the CLT slab performance could be improved by adding other materials or structural elements, such as GLT (glue-laminated timber) longitudinal beams to the cross-sectional tensile area or a concrete layer to the compressive area.

Rib CLT panels could successfully be used for long-span floors and roofs where high load-bearing capacity and low self-weight are required, also adding to the aesthetic of the building altogether.

Also, combining timber with materials that have superior mechanical properties, such as concrete, can improve the load-carrying capacity and other characteristics of timber structures, creating TCC (timber concrete composite) [2].

Investigations in this study are oriented in two main directions. The first direction involves evaluating the potential to increase the load-carrying capacity; the second direction of this investigation focuses on improving the connection between CLT and added structures or materials, reducing the brittleness of adhesive timber-to-concrete connections. Some laboratory experiments have been done containing TCC elements, for example, there were several CLT (tCLT = 100 mm, 5-layer) with added concrete layer (tconcrete = 50 mm), laboratory specimens prepared for testing with a span of 1400 mm. A simplified design method based on the transformed section method and the γ-method outlined in Annex B of EN 1995-1-1 for mechanically jointed beams was considered for behaviour analysis of the structure [3].

Also, the finite element models were developed to verify the results obtained by the simplified design method and test results. Firstly, the software ANSYS (student version) was used for the development of simpler FEM (finite element method) models. The SHELL element type was used for modelling the TCC specimens, a linear isotropic material model for concrete and a linear orthotropic material model for CLT layers. Connections between all the layers of the FEM models were modelled as rigid ones.

To obtain more precise results and further investigate the behaviour of the connection between structural timber and concrete components, and behaviour of the composite panel, altogether more detailed and advanced FEM (finite element method) models of tested samples were made by using newly developed Verisim software.

In conclusion, it was stated that the addition of a concrete layer with a thickness of 50 mm and mechanical properties close to C25/30 strength class concrete results in a notable increase in the load-carrying capacity of the CLT panels with dimensions 1400 mm × 400 mm × 100 mm by up to 40 %. The possibility of decreasing the brittleness of the structure failure by adding polypropylene microfibres was stated. It was shown that the addition of microfibres MAPEI PP-FIBER M6 to the concrete surface layer changes its behaviour under the failure load; the beam-type panels did not collapse brittle, and in some specimens, the concrete layer did not disintegrate at all but rather delaminated from the CLT section. It can be concluded that the addition of the polypropylene microfibres increases the maximum vertical displacements of the specimens, causing a decrease in the modulus of elasticity of the concrete layer.

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ANALYSIS OF THERMAL BRIDGES IN THE WALLS MADE OF INNOVATIVE WOOD WASTE PANELS

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Wood waste is a common problem in the construction sector. It is generated during the cutting of wooden elements, formwork, and during building demolition. This paper concerns the use of wood waste from the construction and production processes of CEWOOD Sp. z o.o. production plant [1] in multilayer wall panels with thermal insulation properties. These panels are made from wood waste and a cement binder, to which reactivated, partially hydrated cement is added. This cement is a by-product of fibreboard production. Pilot studies on the recycling of production waste to obtain a reactivated binder are presented in a scientific article [2]. The panels also contain a low-density insulating middle layer based on wood waste from the CEWOOD panel production line and hemp shives, which are commonly used in hempcrete. In one of the mixtures, hemp shives were used as a partial replacement for wood waste at a ratio of 50 % by weight. The panel structure is a wooden frame. The cross-section of wooden elements in a panel, as well as panel joints, corner joints, and the window-panel frame connection, can create thermal bridges. These thermally weaker areas present a greater risk of condensation and mould growth. This issue is important when designing walls made of organic materials. This article presents a two-dimensional (2D) heat transfer analysis based on the finite element method using THERM software. Several variants of external walls with different layer configurations and timber frame solutions were analysed to find the most effective way to reduce thermal bridges. The thermal parameters of the biocomposites forming the panel layers were obtained from our own research. It was demonstrated that partially replacing wood waste with hemp shives significantly reduced the thermal conductivity of the biofiller, positively affecting the overall thermal performance of walls made from the developed panels. The analysis results were presented in the form of heat transfer coefficient values and the linear heat transfer coefficient equivalent to the timber structure. The temperature distribution in the wall and nodes was also presented graphically as isotherms and isotherms filled with colour. The calculations and analyses performed can be helpful in designing energy-efficient houses using biocomposite panels.

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FLOOD-SHAB: A SMART FLOOD EVENT-DRIVEN BRIDGE MONITORING CONCEPT WITH AI-POWERED DEBRIS DETECTION

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Bridges are highly vulnerable to extreme hydraulic events such as floods, where debris accumulation, scouring, and rapid water level changes can compromise structural integrity. Traditional structural health monitoring (SHM) often relies on continuous high-frequency logging, which, while effective, generates large data volumes, increases energy consumption, and limits scalability for long-term use.

This paper presents a conceptual event-driven, multi-sensor monitoring solution developed within the MSCA-PF project, Structural Health Assessment of Bridges during and after FLOOD events (FLOOD-SHAB). The system operates in a dual-mode strategy, switching from periodic baseline monitoring to continuous recording when hydraulic or structural anomalies are detected. It integrates 3D sensors for vibration and tilt tracking, radar-based water level sensors for hydraulic detection, and closed-circuit television (CCTV) cameras supported by artificial intelligence (AI)-based object detection for monitoring debris accumulation.

A key feature of the concept is an AI-powered debris detection model, trained on both synthetic and real images, which currently shows strong preliminary performance. This capability enables automated alerts and timely interventions, such as debris removal. By combining smart sensing, AI analytics, and adaptive event-driven logic, this approach offers a scalable and energy-efficient pathway for improving bridge resilience during extreme flood events.

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DRILLING RESISTANCE AS A NON-DESTRUCTIVE INDICATOR OF IN-DEPTH STRENGTH OF CONCRETE

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In modern structural diagnostics, non-destructive testing (NDT) methods play a vital role in evaluating concrete integrity without compromising its functionality or serviceability. As the demand for rapid, reliable, and minimally invasive assessment techniques increases – particularly in ageing infrastructure, heritage conservation, and marine environments – NDT becomes indispensable for ensuring safety and guiding maintenance strategies. Traditional methods such as rebound hammer (ReH) testing and ultrasonic pulse velocity (UPV) have been widely adopted for estimating surface hardness and internal compactness, respectively. However, these techniques are often limited in their ability to detect localised heterogeneities or to assess mechanical properties beyond the surface layer, especially when the concrete is affected by variable moisture content.

This study introduces and evaluates the application of drilling resistance (DR) testing as a novel complementary NDT approach aimed at capturing the internal mechanical response of concrete with greater depth resolution. DR testing measures the rotational speed and power required to penetrate the material, offering valuable insights into its hardness, density, aggregate bonding, and the presence of microstructural anomalies. Unlike surface-based methods, DR provides a depth-profiled resistance curve, enabling detection of strength gradients and assessing changes in internal structure due to factors such as curing conditions, water ingress, or material ageing. When used in tandem with ReH and UPV, the DR method enriches diagnostic reliability by correlating surface hardness and wave propagation results with actual drilling performance.

Experimental analysis of drilling resistance in standard concrete using a 600 W hand power drill mounted on a universal testing machine (UTM) under controlled laboratory conditions was conducted. The research aimed to correlate rotational speed (RPM) fluctuations with feed rate and concrete type to characterise concrete drillability and evaluate energy response under load. Drilling penetration speed of 20 mm/min and 1800 RPM of rotational speed was used. While UPV and ReH methods provided surface-level strength estimations, DR enabled in-depth profiling across a 30 mm drilled section. Unlike surface-dependent readings from ReH or wave-dependent interpretations in UPV, DR captured localised resistance changes due to aggregates and microstructural transitions. This makes DR particularly suitable for identifying density gradients, evaluating strength evolution with depth, and confirming uniformity.

In conclusion, DR testing provides a valuable complementary NDT method to assess concrete strength, moisture effects, and internal consistency. The study confirms that higher concrete strength correlates with lower RPM and higher energy demand during drilling. As a minimally invasive method, DR can enhance multi-method diagnostics and improve the reliability of strength estimation in concrete structures – particularly those exposed to fluctuating environmental conditions such as bridges, foundations, or marine piers.

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DETERMINATION OF FREEZE RESISTANCE OF 3D-PRINTED CONCRETE

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The surface freezing of 3D-printed concrete is a relevant topic in construction and materials engineering, as this process can significantly impact the properties, mechanical strength, and durability of concrete. Due to the layered structure and heterogeneous microstructure of printed concrete, additional challenges related to heat exchange processes and potential defect formation may arise during freezing.

The issue arises from the fact that freezing an uneven printed concrete surface, compared to a cut surface of the same concrete mixture, results in more unfavourable outcomes, specifically on the uneven side. This may be attributed to uneven heat exchange intensity, varying moisture distribution on the surface, and the dynamics of the freezing process. An irregular surface can create conditions for uneven frost penetration, leading to the formation of microcracks and overall structural weakening.

Furthermore, the layered printing technology creates different concrete density distribution patterns, which can influence the final resistance to freeze-thaw cycles. This is particularly important in cold climates, where 3D-printed concrete may be used in both residential and infrastructure projects.

Methods for determining the freeze resistance of 3D-printed concrete include both laboratory and field tests. The most commonly used methods involve freeze-thaw cycle testing, which assesses resistance to mechanical damage, moisture absorption, and microstructural changes. Additionally, scanning electron microscopy (SEM) analyses are conducted to identify potential microstructural defects.

Possible solutions for improving the freeze resistance of 3D-printed concrete could include optimising the concrete mixture composition, incorporating special additives to enhance freeze resistance, or adjusting printing parameters. Surface treatment technologies could also be beneficial in improving surface uniformity and reducing structural damage.

HYGRO-THERMAL PROPERTIES OF WOOD WASTE CONTAINING COMPOSITES

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This study presents the results of measurements of selected thermal and hygric properties of newly developed building materials made of recycled wood and binder. These composite materials, in the form of wood wool cement boards, were produced using bio-fillers and cementitious binders. Such boards are typically used for acoustic or thermal insulation in commercial buildings. However, this research considers their use in building envelopes. Five compositions were investigated: production-line waste combined with standard Portland cement (with and without compression), production-line waste with a Portland cement and sanding dust mixture (with compression), and production-line waste with an alternative binder (with and without compression). The densities and porosities of the composites were key parameters affecting the mechanical, acoustic, and, most importantly, hygrothermal properties of the materials. True density was determined using a helium pycnometer. Geometric density was measured using the Archimedes method, allowing the calculation of total, closed, and open porosity. Thermal conductivity was evaluated using the guarded hot plate method. Heat capacity, measured in the 24–70 °C range and extrapolated to lower temperatures, was obtained using a NETZSCH DSC 404 F1 apparatus. Sorption curves were determined using the desiccator method, and water vapour permeability was measured using the novel "box-in-box" method described in the literature. The results were analysed to reveal the relationships between the density, porosity, thermal conductivity, and hygric properties of the composites.

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COMBINED EFFECT OF TEMPERATURE AND HUMIDITY OF ELECTRICALLY CONDUCTIVE MORTARS ON THEIR CONDUCTIVE PROPERTIES

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Cement composites are the most widely used material in the construction industry and are constantly undergoing intensive technological development. One of the newer variants is their electrically conductive version, which brings several other new possibilities. For now, however, they are more in the laboratory development phase than in wider use in practice. Thanks to their electrical conductivity, which also depends on certain internal and external conditions, it is possible to monitor their properties and current states. For this reason, it is called self-sensing concrete. The variability of electrical conductivity allows monitoring the load on the structure, the development of internal cracks and, last but not least, these structures can be heated. Another advantage is the fact that production costs are only minimally higher compared to conventional composites. By partially substituting conventional aggregate with electrically conductive fillers, a reduction in the electrical resistivity of the resulting concrete or mortar can be achieved.

This study was focused on the combined effect of temperature and humidity of electrically conductive mortars on their conductive properties. The formulation of the test specimens was designed to approximate standard mortar as closely as possible, with the addition of varying amounts of graphite in particle sizes of 1–3 mm, 500 µm, and 3 µm. Measurements were conducted on 40 mm × 40 mm × 80 mm specimens equipped with embedded pairs of electrodes. The primary objective of this study was to investigate the effect of temperature changes between +20 °C and –20 °C on the resistivity of both dry and water-saturated specimens. The resistivity of samples previously conditioned under laboratory conditions exhibited a trend that closely mirrored the temperature profile. Moist mortars maintained a relatively constant resistivity at positive temperatures; however, upon reaching the freezing point, a sharp increase in resistivity was observed. This phenomenon is attributed to the phase transition of the conductive liquid within the pore structure into a solid insulating state. Upon reheating, the conductive properties of the material return to their original state.

COMPARISON OF GEDIMINAS HILL SLOPES BEHAVIOUR UNDER ENVIRONMENTAL AND FIREWORKS CONDITIONS

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This paper presents the findings from three-dimensional finite element analyses for Gediminas Hill, including its buildings and the construction remains of the Upper and Lower Castles in Vilnius. The aim of this research is to evaluate the current stability of Gediminas Hill's slopes by applying a safety reduction factor and to identify potential worst-case scenarios, taking into account its structures and construction remains. The behaviour of Gediminas Hill was determined under dynamic loading, also. The self-weight of soil layers, technogenic soil, gabions, buildings, remains, and pedestrian pathway were evaluated as static loading and fireworks exploding like dynamic loads. The strength reduction analysis of the technogenic soil layer allowed for the determination of areas with the highest concentrations of displacements, which are compared with dynamic loading results.

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3D PRINTING CONCRETE OPTIMISATION FOR SUSTAINABILITY AND DURABILITY

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Nowadays, the reduction of CO_2 emissions is becoming increasingly important in the construction industry. Production of different building materials creates a CO_2 impact; therefore, it is necessary to optimise the materials to be used. Concrete is distinctive among all building materials in terms of carbon footprint. As the composition of the cement is not changed during the elaboration process of concrete, the only opportunity to reduce CO_2 is by replacing the aggregates, for instance, by integrating and storing CO_2 in the concrete itself. This can be done with aggregates being in a solid form. In the study process, different natural aggregates will be tested and improved in the concrete mixture. Since not all natural substances can be used as concrete aggregates, the study will examine and analyse various recyclable materials obtained from various construction waste.

During the course of the study, the aim is not to lose the mechanical properties of concrete by improving them as much as possible and not to worsen the workability of the material with 3D printing. In order to compare these mechanical properties of the material, several concrete specimens will be produced and tested in the laboratory using the compression test method. Based on the fact that the properties of concrete depend on its composition, specimens' chemical properties will be studied in-depth.

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EFFECTS OF ALUMINOSILICATE-RICH MATERIALS ON ALKALI-ACTIVATED WOOD ASH

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Portland cement (PC)-based concrete is widely used as the primary building and construction material. Nonetheless, PC production is responsible for large global anthropogenic emissions of greenhouse gases and industrial energy consumption. Meanwhile, the intensive demand for natural aggregates exerts significant stress on non-renewable resource conservation. In this context, developing alkali-activated materials based on industrial and agricultural waste as an alternative to traditional PC-based materials is a sustainable approach.

As a clean energy source, biofuel energy derived from wood combustion is increasingly welcomed around the globe, especially in forestry countries like Lithuania, which generates a significant amount of wood biomass waste. According to the reports (Teker Ercan et al., 2023; Zhu et al., 2024), the global yearly generation of wood biomass is approximated to be 4600 million tons, which is predicted to grow threefold by 2035. This exerts great pressure on the land resources and environmental conservation. To investigate a sustainable application of this waste at a large quantity in producing alkali-activated materials (AAMs), wood ash (WA) containing wood fly ash (WFA) and wood bottom ash (WBBA) was recycled as precursors, and recycled sand (RS) was valorised as fine aggregates. Sodium hydroxide (SH) at a concentration of 7 mol/L, calcium hydroxide (CH) at 10 % by the total precursor mass, and sodium silicate (SS) at an SS to SH mass ratio of 1 were ternarily used as alkaline activators. One challenge of WA utilisation in building and construction materials is its low chemical reactivity, which limits the development of the mechanical properties (Du et al., 2024). Taking it into account, aluminosilicate-rich materials, including metakaolin (MK), natural zeolite (NZ) and coal fly ash (FA), were introduced as a binary precursor to provide extra aluminosilicates at the content of 10 %, 20 %, 30 % and 40 % by precursor weight. Compressive strength, physical properties, and microstructural analysis (SEM-EDS, XRD FTIR, and TG-DTA) were tested to assess the mechanical properties and reaction kinetics, plus a cradle-to-gate lifecycle assessment (LCA) to evaluate the environmental impacts of the produced AAMs.

According to the results, the addition of FA, MK, and NZ effectively improves the strength by 47.18 %, 33.12 %, and 57.62 %, respectively, with the highest value attaining 22.71 MPa, 20.54 MPa, and 24.33 MPa. This indicates that NZ was the most effective in improving the mechanical properties of alkali-activated wood ash (AAWA). From SEM images, the usage of binary precursors densified the microstructure of AAMs by introducing more closed pores and decreasing micro-cracks, and based on the EDS, NASH gels were produced, co-existing with C(A)SH. In the TG-DTG analysis, greater weight loss associated with the activation products was observed for samples with FA, MK, and NZ, which was further confirmed in the XRD patterns, with higher intensity in peaks aligned with C(A)SH were identified. In FTIR spectra, the transition of the Si-O-Si and Si-O-Al bands confirmed the production of the hydrates and geopolymeric gels. This indicates that adding an aluminosilicate-rich precursor accelerates the alkaline activation and enhances its degree, favouring the development of mechanical and microstructural properties. In terms of LCA, binary precursors increased the environmental impacts of the production of AAWA, especially NZ, which accounted for a threefold increment in the greenhouse gas emissions due to its energy-intensive mining and processing procedures. Considering the influences on both the engineering performance and environmental impacts, CFA was the most effective among the three materials when used together with WA.

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FRESH AND MECHANICAL PROPERTIES OF GREEN MORTARS

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Reducing CO_2 emissions in the construction sector remains a critical challenge, with cement production – particularly the thermal processing of clinker – being one of the largest contributors. Among the various strategies to mitigate emissions, the partial replacement of cement with supplementary cementitious materials (SCMs) is widely recognised and promoted.

Significant quantities of industrial by-products (e.g., fly ash, metallurgical slags), quarry residues (such as marble and dolomite), and construction and demolition waste (e.g., glass, concrete, bricks) have been explored as alternative binders in cement-based materials, including pastes, mortars, and concrete.

This study focuses on the development of green mortars by partially replacing cement with recycled glass, dolomite waste from marble processing, and mechanically activated fly ash sourced from thermal power plants [1]. The primary objective was to assess the influence of these alternative materials on the fresh properties (density, permeability, consistency, and setting time) and hardened mechanical properties (flexural and compressive strength) of the resulting mortars.

The substitution of cement with recycled glass and mechanically activated dolomite significantly prolonged the setting time, in contrast to the use of mechanically activated fly ash. However, despite these differences in fresh properties, all green mortars exhibited mechanical strengths that are comparable to those of conventional mortars.

This research supports the implementation of circular economy principles in the Republic of North Macedonia and aligns with the national Smart Specialisation Strategy (S3), particularly in the domain of Sustainable Materials and Smart Buildings.

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ACCELERATING MATERIALS INNOVATION THROUGH INFORMATICS: DISSEMINATING COST ACTION CA22143 – EUROPEAN MATERIALS INFORMATICS NETWORK

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COST Action CA22143 – EuMINe (European Network for Materials Informatics) aims to enhance the European research and innovation capacity in the field of materials development and engineering through the integration of materials informatics (MI), artificial intelligence (AI), and data-centric technologies. The Action is structured across five dedicated working groups (WGs) addressing both research coordination and capacity-building objectives across interdisciplinary domains.

The collective efforts in the frame of EuMINe are to generate novel datasets and develop advanced data- and AI/ML-driven methods for designing and engineering the materials, including the adaptation of cutting-edge technologies such as computer vision, automated reasoning, and generative models to the materials science domain. By targeting transversal socioeconomic challenges, including the Sustainable Development Goals and the European Green Deal, the Action focuses on diverse material classes relevant to energy (production and storage), low-dimensional systems, molecular materials, structural materials (alloys, concrete, composites), and biomaterials.

To date, based on COST networking tools, EuMINe has facilitated a substantial number of targeted training schools and workshops aimed at early-career researchers, focusing on the application of materials informatics, artificial intelligence, and data-centric technologies to diverse classes of materials. Additionally, several short-term scientific missions (STSMs) have been implemented to foster interinstitutional collaboration and knowledge exchange. These activities support the development of domain-specific datasets, relevant to different materials, and the deployment of AI/ML frameworks for predicting and optimising their performance. A representative example is the realised STSM that can exemplify the transformative potential of machine learning (ML) in structural material design, i.e., on the prediction of high-temperature mechanical behaviour of high-strength steels (HSS) [1]. Advanced ML models were trained on an extensive experimental dataset through tensile testing of HSS specimens with varying thicknesses and temperatures, further expanded with over 450 additional data points covering a diverse range of material conditions. The gradient boosting (GB) model outperformed traditional empirical approaches, achieving an $R^2 > 0.98$, demonstrating exceptional capability to capture complex, nonlinear material responses. The proposed ML-based framework not only enhances predictive accuracy but also plays a crucial role in ensuring the safe design of these materials under extreme conditions, such as during fire exposure.

By translating the EuMINe framework to the construction industry, similar ML-driven approaches can be applied to predict and optimise the performance of cementitious composites, recycled aggregates, and novel low-carbon building materials, including those derived from industrial by-products. Such synergy underscores the role of EuMINe in bridging data science and engineering to foster innovation through the development of sustainable, high-performance materials and smarter, data-driven infrastructure solutions.

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DEFORMATION MEASUREMENTS IN SELF-STRESSING SFRC USING DISTRIBUTED FIBRE OPTICAL SENSING

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The construction of industrial floor slabs traditionally involves large volumes of concrete and steel mesh reinforcement, significant labour demands, and common durability issues such as shrinkage-induced cracking, joint openings, and curling. This project investigates the use of self-stressing steel fibre-reinforced concrete (ssSFRC) with expansive additives as an alternative, aiming to achieve a chemically induced prestressing effect that mitigates shrinkage deformations and enhances structural performance. A state-of-the-art distributed fibre optic sensing (FOS) system has been used in laboratory investigations and deployed in field tests to monitor micrometre-scale deformations with high spatial resolution.

The assessment of expansive deformations and the quantification of the inherent compressive stress generated within the self-stressing SFRC due to restrained expansion are presented, and implications on structural design and the potential reduction in slab thickness are introduced. The presentation will give an overview of the novel features of this sensing technique and illustrate the findings from the experimental investigation. The work aims to develop predictive models for the long-term behaviour of self-stressed SFRC floor slabs under service conditions. By integrating advanced sensing technologies and material innovations, this research contributes to the design of more efficient, durable, and resource-saving industrial floor systems.

FIBRE INCORPORATION INFLUENCE ON RESISTANCE INCREASE TO DYNAMIC FATIGUE TESTING IN TENSION OF FLY ASH-BASED GEOPOLYMER COMPOSITE

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In recent decades, the interest in alternative binders to Portland cement has increased significantly. It has been fueled not only by the increased cost of natural resources but also by legislative measures targeting CO_2 emission reduction. One of the found alternatives is geopolymers. There has been thorough research work done mostly towards different waste material applications as constituents in the geopolymer matrix. These mix designs have been made, optimised, and in most cases, basic mechanical properties assessed. While in many cases such things as strength in certain stress states are enough to characterise materials' role as structural material, it does not provide any hard evidence on how it would act in service life over long design stages, assuming service periods.

This research evaluates the effect of fibre incorporation to increase resistance to dynamic loading in tension. Specimens for this research are made from fly ash-based geopolymer composite. The fatigue test specimens are compact tension (CT) specimens and are designed according to ASTM E647-15. Specimens are subjected to 100,000 load cycles. The tests are run in two ways: with fixed load amplitude and with fixed displacement amplitude.

While steel fibre incorporation into the geopolymer mortar reduces tensile strength by 15 % to nearly 20 % depending on the fibre amount, it significantly reduces the deviation of the displacement values when the loading is done with fixed load amplitude. The displacement value deviation is reduced from 56 % to 88 %. Furthermore, depending on the load amplitude, the achieved displacement differs significantly. For instance, if the pre-load of the specimen is 0.7 from its strength and amplitude +/–0.1 from its strength, then the achieved displacement values are 92 %, 86 % and 93 % lower than plain, 1 % steel fibre, and 2 % steel fibre reinforced specimens pre-loaded with 0.5 and with a load amplitude of +/–0.2 of strength.

When specimens are tested with fixed displacement and the testing amplitude is fixed, the necessary load to achieve the displacement, there is no significant difference linking the load derivative (top and bottom load difference) and different amounts of fibre reinforcement. As for the applied load to achieve displacement boundary conditions, the specimens without any reinforcement exhibit an early peak load, and during testing from 500th to 100,000 cycles, the necessary load amount slightly decreases. The same characteristic is exhibited by 1 % steel fibre reinforced specimens, but 2 % steel fibre reinforced specimens show a stable or slight increase in the necessary load value.

REDUCTION OF VOC EMISSIONS THROUGH THE USE OF OPEN-CELL CASTING MOULDS MANUFACTURED USING BINDER JETTING 3D SAND PRINTING TECHNOLOGY

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Additive manufacturing (3D printing) has seen rapid development in recent years and is increasingly being applied across various industrial sectors. In foundry engineering, it enables the production of complex moulds and cores that are challenging or even impossible to obtain using conventional methods. This technology not only shortens the lead time for production but also opens new possibilities for improving the environmental sustainability of metal casting processes.

One of the critical challenges in contemporary foundries is the emission of volatile organic compounds (VOCs) during the pouring of molten metal into moulds containing organic binders. The thermal decomposition of these binders releases harmful substances such as benzene, toluene, ethylbenzene, and xylenes (BTEX), as well as polycyclic aromatic hydrocarbons (PAHs). These compounds contribute to environmental pollution and pose significant health risks to workers. Consequently, the industry is striving to reduce gas emissions and meet increasingly stringent environmental and occupational safety standards.

The presented study investigates the gas generation of three types of moulding sands:

1) a conventional sand with an organic binder used in classical moulding processes,
2) an inorganic geopolymer-bonded sand, and
3) a 3D-printed sand produced via Binder Jetting using a furan resin binder.

Furthermore, the study explores the potential of open-cell (lattice) moulds, made possible by 3D printing, to enhance gas evacuation during casting. Such geometries reduce gas entrapment and significantly lower the emission of harmful compounds into the atmosphere.

The results confirm that 3D-printed open-cell moulds offer a promising pathway towards more environmentally sustainable and safer foundry processes. Combining Binder Jetting with innovative mould design can not only minimise the environmental footprint of metal casting but also improve working conditions by reducing workers' exposure to toxic gases.

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LIFECYCLE APPROACHES IN CIRCULAR BUSINESS MODEL ECOSYSTEMS

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The real estate sector operates within a predominantly linear economic model, characterised by resource extraction, construction, utilisation, and eventual demolition, leading to significant waste and environmental impact. The concept of a circular economy (CE) offers a transformative alternative, aiming to decouple economic growth from finite resource consumption by keeping materials and products in use for as long as possible, thereby reducing waste and the demand for virgin resources.

This paradigm shift has gained increasing traction within the built environment, recognising the urgent need for sustainable practices to mitigate environmental degradation and enhance long-term value.

This research explores the field of circular economy business models (CEBMs) within the real estate industry, examining their potential to drive sustainability, foster value creation, and reshape traditional practices through the lens of relevant case studies and emerging frameworks. The transition towards circularity in real estate is not merely an environmental imperative but also presents substantial economic and social opportunities.

This research employs a methodology based on a comprehensive review and synthesis of existing literature and industry reports pertaining to the circular economy in the real estate sector. The analysis draws primarily from the provided sources, including academic articles, industry publications, and collaborative reports from organisations such as the Ellen MacArthur Foundation and Arup [1]–[5]. The approach involves identifying key concepts, frameworks, and case studies related to CEBMs in real estate. Specifically, the paper examines proposed business models, real-world examples of their application through case study analysis and testbeds, and discussions of their potential financial, environmental, and social impacts. The abductive research approach, which uses empirical data to infer how 'circular' value has been realised from the concept of 'building blocks', as discussed in one of the sources, provides a relevant lens for analysing the practical examples. This synthesis aims to provide a structured overview of the current landscape of CEBMs in real estate and their implications for the industry's future. Based on these findings, a classification of circular ecosystems is proposed, and the most prominent success factors for circular ecosystems are presented.

The research reveals a growing recognition of the potential of circular economy principles to transform the real estate sector through the implementation of innovative business models. The increasing adoption of circular economy business models holds significant implications for the real estate sector, driving a shift towards greater sustainability and value creation:

- economic transformation,
- environmental sustainability,

- evolving stakeholder roles and collaboration,
- policy and regulation,
- future research directions.

This results in a better understanding of the local ecosystems and proposes a classification of circular ecosystems, as well as presenting the most prominent success factors for circular ecosystems. It demonstrates the feasibility and potential benefits of this transition and presents the most prominent success factors of circular ecosystems. However, realising the full potential of a circular built environment requires a concerted effort involving all stakeholders, supported by enabling policies and continued research to address existing challenges and explore future opportunities of circular ecosystems. By embracing circular thinking and innovative business practices, the real estate industry can significantly reduce its environmental impact and contribute to a more resilient and sustainable future.

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CIRCULARITY IN SMART CITIES – BERLIN, VIENNA, AND ZURICH

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In the contemporary world, digitalisation and technology have been transforming cities. Many technology companies have been collaborating with governments to construct smart cities that promise sustainability. However, sustainability challenges in cities keep rising. In this paper, we focus on and link these two trends: smart cities and sustainability, by focusing on the potentials and barriers to circularity in smart cities. Most of the discussion on circularity in smart cities focuses on techno-centric approaches and solutions. There is a broad literature on how the circular economy is impacted by the use of technology. These discussions are not yet connected directly with sustainability or smart cities. In this study, we build on the literature that links sustainability and urban quality of life in cities with circularity to investigate how far current smart city strategies address circularity and the circular economy. Using content analysis, the study addresses the following issues: What are the current discourses and narratives relating to circularity in smart city visions? How is circularity represented in smart cities's strategies? Does this representation contribute to a better urban quality of life, or do they (re-)produce or (re)enforce existing sustainability challenges? Broadly, we raise questions about the quality of sustainable living in smart cities.

HARD COATING MATERIALS AND DEVELOPMENT OF MANUFACTURING SYSTEMS FOR POLYMERIC WASTE

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Circularity (CE) is a powerful instrument to achieve sustainability. Current research discovers advanced technological solutions for the operational implementation of CE in polymeric manufacturing industries. Based on spectroscopic characterisation, mechanical testing, tribological investigations, Python-based computation, and PyCharm machine learning algorithms, the traditional, engineering, high-performance, and ultra-high-performance manufacturing systems are developed, fundamentally relying on the coefficient of friction (COF), wear rates, plastic deformation, and fracture mechanism. The designed COF values of strategic, conventional, and domestic manufacturing systems are standardised in the range of 0.03–0.09, 0.10–0.22, and 0.30–0.47, respectively. Experimental manufacturing systems are employed in the fabrication of polypropylene-based composites with facilities of Vickers hardness and thermal stability in the ranges of 1000–1800 HV10 and 400–2400 °C. Tensile, bending, and impact tests are standardised according to American standards for industrial production and commercialisation. The conceptual framework of silicon nitride, zirconia, tungsten carbide, steel, alumina hard materials, titanium aluminium nitride, and titanium carbo-nitride coatings manufacturing systems is proposed to process all possible polymers and waste. Additionally, diversity in experimental and computational results can be introduced for automation, digitalisation, implementation of the concept of circularity, and sustainability in view of reverse engineering concepts.

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STUDY OF THE EFFECT OF DIVERSE MINERAL OILS ON THE PHYSICAL PROPERTIES OF CONCRETE

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Mineral oils are widely used in industry and transportation, but their properties change under the influence of temperature, mechanics, chemistry, and as a result of accidents [1]. During operation, leaks can occur that get on concrete and reinforced concrete surfaces. Oils penetrate into the pores of concrete, reducing its strength and water resistance, especially if they are waste fluids with impurities [2]. Contact with oils leads to both a change in the structure of the concrete stone and a change in its mechanical characteristics. A possible decrease in the strength of the structural material at the operational stage requires an assessment of the residual resource of the bearing capacity of the structure. The impact of oils on reinforced concrete has not been sufficiently studied. The purpose of the study is to evaluate how six types of oils change the weight and strength of the samples and what risks this poses to structures. Concrete specimens of 100 mm ×100 mm in size were used in the study, made of Portland cement PC II/A-B-500R-N (SEM II/A-LL 42.5 R) of class C 32/40, which is the main structural material due to its high strength, durability and availability [3]. Three types of mineral oils were used to test the concrete: transformer oil T-1500, motor oil 10W-40, and industrial oil IGP-30. The tests were conducted under standard conditions, and the oils were applied by dipping and brushing.

Changes in the physical and mechanical characteristics of concrete samples were recorded after 10- and 30-day contact with the respective oils. The results showed that the impact depends on the type of oil, its condition (new or used), and the application method. When the specimens were immersed in the new T-1500 transformer oil, a steady increase in the weight of the specimens was observed (by 1.14 % on day 10 and by 1.18 % on day 30), indicating capillary absorption of the liquid by the concrete. This was also accompanied by an improvement in strength by 4.14 % after 10 days and by 13.06 % after 30 days, which is likely due to the compaction of the concrete microstructure. Surface application caused minimal weight change but a major strength drop (–48.12 % after 30 days), likely due to uneven oil penetration and cement damage. Immersion in used T-1500 oil increased weight (up to 1.33 %) and slightly improved strength (+2.14 %), though less than with new oil, possibly due to stabiliser loss. Brushing led to a 0.53 % weight gain and a 6.57 % strength drop.

The study of the new IGP-30 oil revealed a positive effect: the weight of the samples increased by 1.12 % on day 30, and the strength increased by 12.19 %, which may indicate the formation of a protective layer that prevents moisture weathering. The effect of surface application was much weaker, with a weight increase of only 0.35 % and a significant decrease in strength to –29.39 % on day 30. Tests of IGP-30 used oil showed less favourable results: when immersed, the strength decreased by –4.88 %, and when applied with a brush, by –84.11 %. This indicates the presence of aggressive oxidising products in the used oil, which can destroy cement stone or dissolve elements of the concrete structure. Immersion in new 10W-40 oil led to variable strength changes: an initial 7.47 % decrease, followed by an 11.41 % increase by day 30, suggesting adaptation. Surface application caused a sharp 63.74 % strength loss. Used oil had little effect on weight but significantly reduced strength – by 11.04 % (immersion) and 55.07 % (surface). Oil impact depends on composition, usage level, and application method.

The experimental study showed that contact of concrete with different types of mineral oils changes its mechanical characteristics, in particular, compressive strength and weight of the samples. Different exposure methods showed different results. The largest decrease in compressive strength was observed when immersed in used transformer oil, while industrial oil had a minimal effect. Also, the weight of the samples confirmed the absorption of oil into the concrete pores during immersion. The greatest destructive effect was found in used engine oils containing aggressive components. The use of new technical fluids can be neutral or even stabilising, depending on the method of application. The results are important for assessing the durability of concrete structures.

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OPTIMISATION OF HEATING SYSTEM POWERED BY AN AIR HEAT PUMP AND A GAS CONDENSING BOILER HYBRID UNIT

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A gas condensing boiler and air-to-water heat pump hybrid unit is an optimal way to introduce renewable energy resources in existing buildings. Two energy sources (gas and electricity) give hybrid unit higher flexibility in comparison to a typical air-to-water heat pump. In a hybrid solution, an air heat pump can be used in locations with low temperature heating seasons. A hybrid unit can output higher heat carrier temperatures; because of this, it can be used in combination with older radiator heating systems.

There are many parameters that can influence the performance of a hybrid heating unit. This paper investigates the influence of heat terminal type, heat carrier temperature, and outdoor switchover temperature setting (outdoor temperature at which the hybrid unit switches from electricity to fossil fuel) on air-to-water heat pump and gas condensing boiler hybrid heating unit performance parameters (total efficiency–ηhybrid and primary energy factor – PEFhhp). The performance of hybrid heating units is evaluated by using a computer model created in the program IDA ice 4.8. The created computer model represents a real building, located in Latvia, that uses the previously mentioned hybrid heating unit. The model is verified by comparing its results with energy meter data from the real building, for the time period from 01.03.2022 to 28.02.2023. The verified model is used to simulate how the performance of hybrid heating units is influenced by changes in heating terminal type, heat carrier temperature and outdoor switchover temperature setting.

According to simulation data, at constant heat carrier temperature, heat terminal type has no influence on the hybrid heating unit's performance parameters. It has been found that increased heating system volume can reduce the hybrid heating unit's run time. In this case, replacing panel radiators with floor heating results in a 33 % reduction in the unit's annual running time. In simulated scenarios, heat carrier temperature reduction by 15 °C increases ηhybrid by 8.7 % and decreases PEFhhp by 17.5 % (at temperature graph 40/35 °C). Switchover temperature increase from –7 °C to 3 °C decreases ηhybrid by 47 % and increases PEFhhp 7 %. Switchover temperature increase also reduces ηhybrid and PEFhhp change magnitude when changing heat carrier temperature graphs. When changing the temperature graph from 40/35 °C to 55/50 °C, the changes are as follows:

- at switchover temperature setting of –7 °C, η_hybrid drops by 14.33 %, but PEFhhp increases by 23.42 %;
- at switchover temperature setting of –7 °C (actual setting), η_hybrid drops by 8.7 %, but PEFhhp increases by 17.51 %;
- at switchover temperature setting of +3 °C, η_hybrid drops by 1.74 %, but PEFhhp increases by 6.45 %.

NON-DESTRUCTIVE EVALUATION AND PREDICTIVE MAINTENANCE: RETHINKING STRUCTURAL LIFETIME MANAGEMENT

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The reliability and long-term operation of engineering structures are crucial for ensuring safety and cost-effectiveness in the most demanding industries such as aerospace, automotive, and civil engineering. The growing complexity of the internal architecture of advanced materials, combined with the increasing demands for safety and sustainability, determines the need for the development of modern approaches to structural integrity assessment. Non-destructive evaluation (NDE) and predictive maintenance play a key role in addressing these challenges by enabling early damage detection and accurate structural lifetime prediction. With the increasing reliance on lightweight composite materials and multifunctional structures, traditional inspection methods are often insufficient, requiring novel approaches that integrate advanced diagnostics, automation, and artificial intelligence.

This study presents recent advancements in the assessment of structural lifetime, with a focus on methodologies developed to enhance NDE based on various testing techniques as well as to evaluate the structural residual life based on NDE and fatigue data. Various non-destructive testing (NDT) techniques are employed to enhance damage detection capabilities and provide a more comprehensive understanding of material degradation mechanisms. The designed algorithms are based on advanced signal and image processing, allowing significant enhancement in the sensitivity of specific NDT techniques to various types of damage. In particular, the developed algorithms for enhancing the D-Sight optical technique allow turning it into a quantitative technique by making it possible to identify corrosion spots on the images resulting from D-Sight inspections [1]–[3]. The developed novel NDT technique, self-heating-based vibrothermography, together with dedicated image processing algorithms, created a possibility of effective testing of composite structures without the need for external thermal excitation [4]–[6], which is especially important for single-side access to a tested structure or inability to use external heat sources. The developed hybrid approach for determining a fatigue limit while simultaneously identifying and monitoring damage propagation in composite structures [7] has made it possible to significantly decrease the duration of tests and inspections of structures containing damage. Finally, the approach that uses a realistic damage geometry reconstructed from ultrasonic inspections makes it possible to predict the structural residual life after the appearance of damage solely based on numerical simulations [8]. The integration of these techniques with advanced signal and image processing methods significantly improves the reliability of damage characterisation and condition monitoring.

By implementing predictive analytics and automated monitoring, the presented approaches enable more precise lifetime estimation and condition-based maintenance, reducing unnecessary inspections and tailoring structural lifetime while improving operational efficiency. The combination of experimental investigations with numerical simulations, advanced signal and image processing, and machine learning enhances the accuracy of structural lifetime prediction, allowing for better-informed maintenance strategies. This shift in structural lifetime management redefines conventional maintenance strategies by introducing adaptive inspection protocols and automated decision-making processes, leading to more sustainable and cost-effective engineering solutions. The ability to anticipate failures and optimise maintenance schedules directly contributes to increased safety and reduced environmental impact, marking a new direction in the field of structural health management.

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ULTRA-HIGH PERFORMANCE FIBRE REINFORCED CONCRETE FOR APPLICATION AS SHOTCRETE

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The technical condition of marine and road infrastructure objects exposed to aggressive environmental impact is a serious problem all over the world and especially in the climate of northern latitudes. Freeze-thaw cycles and exposure to water containing chlorides lead to accelerated reinforcement corrosion and delamination of the concrete surface, which impairs the structural safety and shortens the lifetime of the structures. Within the framework of the research project LACHMAT, it is proposed that the shotcrete application of ultra-high performance fibre-reinforced concrete (UHPFRC) be used for the repair and technical restoration of infrastructure objects. There is still not enough experience in the world of practical application of UHPFRC in shotcrete technology.

The project envisages the development of UHPFRC mixtures that must have specific rheological properties: thixotropy and the ability to adhere to vertical surfaces. This will be achieved by introducing special additives and microfibers. The new material will be characterised with a compressive strength above 120 MPa, a tensile strength of at least 8 MPa, while simultaneously providing high frost resistance in aggressive environments. It is intended to simulate in laboratories the behaviour of material and to investigate the mechanical adhesion between the base concrete and the new coating, as well as to test mechanical properties such as tensile strength, elastic modulus and bending properties of thin plates.

Project-based collaboration includes collaboration between RTU and Empa, training of young scientists and knowledge transfer to the industry. The project involves industrial partners for the joint development of technology for the use of new materials and their practical implementation in renovation and restoration projects of infrastructure objects.

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DEVELOPMENT OF SUSTAINABLE CEMENT-BASED COMPOSITES INCORPORATING GLASS WASTE AND CEMENT KILN DUST

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The growing demand for environmentally friendly construction materials is encouraging the integration of industrial waste into cementitious composites. Among the most promising materials are glass waste, originating from post-consumer or industrial glass, and cement kiln dust (CKD), a by-product of cement manufacturing. Glass waste can be used as a lightweight aggregate or as a finely ground powder, contributing to improved insulation, reduced density, and pozzolanic activity [1]–[4]. CKD, on the other hand, enhances durability and reduces the demand for Portland cement, supporting CO_2 emission reduction and circular economy principles [5], [6]. In the future, cement-based composites can be developed and evaluated that contain both waste glass and CKD. It is important to investigate the synergies between the insulating, pozzolanic, and lightweight properties of waste glass and the cementitious properties of CKD. Experimental tests carried out by researchers include compressive strength, flexural strength, density, thermal conductivity, water absorption and resistance to aggressive environments [7]. The addition of 20 % waste glass can reduce the cost of cement production by up to 14 %, reducing emissions during the cement production process and thus reducing the greenhouse effect and particulate matter [4]. Studies on composites using magnesium oxychloride cement and foam glass have shown a 75 % reduction in thermal conductivity compared to control samples [8]. It is proposed to develop and systematically evaluate cement-based composites containing glass waste and CKD. The aim is to investigate the synergistic effect between the insulating, pozzolanic and lightweight properties of glass waste and the cementitious reactivity of CKD. Preliminary data from previous studies suggest that incorporating up to 10 % glass waste aggregate can reduce the compressive strength of the composite to 21 MPa. However, when 30 % waste glass is used, the coefficient of thermal conductivity is significantly reduced, reaching a value of 0.113 W/mK [1]. Another study showed that the optimum mix composition (2.41 % CKD, 15.22 % GP, 0.35 W/B ratio) showed excellent performance. The 90-day compressive strength of this optimised formulation is 85.32 MPa, 10.3 % higher than the control mix [5]. In recent studies, scientists have shown that CKD and glass powder (GP) can serve as partial substitutes for conventional Portland cement. The optimum variant, consisting of 7.22 % CKD and 5.26 % GP, showed a balance between the properties of fresh mix and hardened concrete [9]. The targeted outcome is a multifunctional, sustainable material tailored for non-load-bearing and thermally efficient building elements. By vaporising two widely available by-products, this approach aims to tackle environmental and structural challenges in 21st-century construction.

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DEVELOPMENT OF CLAY–HEMP–STARCH MATERIALS FOR SUSTAINABLE CONSTRUCTION

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This article presents the development of a fully bio-based composite comprising locally sourced clay, hemp fibres and a retrograded starch hydrogel as a natural modifier. Through rigorous selection, conditioning and integration of the clay, fibres and starch, a homogeneous matrix–reinforcement system was obtained, suitable for both structural and interior applications. The resulting composites exhibit low density (reduced from 1.99 g/cm^3 to 1.30 g/cm^3 compared with clay-only mixtures), adequate linear shrinkage (ranging from 4.1 % to 6.7 %), and compressive strength up to 7.9 MPa, which meets the requirements for non-load-bearing building elements (DIN 18945:2013-08). Hygroscopic testing highlights the composite's ability to buffer indoor moisture, with peak moisture uptake of 220 g/cm^2, underscoring its potential for healthy and comfortable indoor environments. Microstructural analysis reveals a well-integrated hemp fibres network within the clay matrix, while the retrograded starch hydrogel fills pores and stabilises the composite's internal morphology, thereby improving overall structural integrity. By application of agricultural by-products and abundant raw materials, this study outlines a circular-economy approach that lowers embodied carbon and can be adapted to diverse regional resources, marking a significant advance in eco-material design through the incorporation of polysaccharide binders (retrograded starch hydrogel) into clay-based composites without artificial additives.

MECHANICAL AND DURABILITY ASSESSMENT OF 3D-PRINTED CEMENT-GYPSUM-POZZOLAN COMPOSITES INCORPORATING CRUMB RUBBER FROM END-OF-LIFE TYRES

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This study examines the performance and microstructure of end-of-life tyre crumb rubber-modified sustainable cement-gypsum-pozzolan (GCP) composites and potential uses of the new material. This study is focused on the impact of end-of-life tyre crumb rubber on the mechanical properties and durability of 3D-printable GCP materials, specifically freeze-thaw resistance, density characteristics, and water absorption. Composite mixtures of various ratios of crumb rubber were made at a fixed binder content. Mechanical properties included flexural and compressive strength of normal prism test specimens with dimensions 40 mm × 40 mm × 160 mm, and deformation as measured by accurate micrometres to determine the longitudinal strain under long-term curing in water. Water absorption was also evaluated prior to performing durability tests in an effort to determine each mix's pore saturation characteristics. Freeze-thaw durability was tested in two complementary ways. The first was by plate samples being subjected to standardised freeze-thaw cycles according to cement material test standards, where XF1 class was reached. The second method was by ultrasonic pulse velocity (UPV) testing of the 3D-printed sample, which was subjected to frost cycles by measuring diagonally across each face twice to determine internal microstructural change non-destructively with time. The ultrasonic velocity decreased by 50 m/s on average after thermal cycling for 36 days, but later became very stable up to 200 days with negligible cumulative damage. The deformation tests on the prisms also verified negligible length change, which indicated stability in the composite structure dimensions during curing in water. Results indicate that while compression strength can decrease moderately with the incorporation of rubber crumb, it leads to improved flexural performance and higher freeze-thaw stability. There was acceptable water absorption as well, and rubber-modified mixtures exhibited lower ingress due to the hydrophobic tendencies of rubber particles. Overall, the GCP-rubber composite exhibited good 3D printability, interlayer adhesion, and long-term structural stability. This study proves the feasibility of recycling rubber into printable construction materials for facilitating circular economy concepts and improving environmental resilience in cement composites.

GYPSUM-BASED ACOUSTIC PANEL PRODUCED BY 3D PRINTING TECHNOLOGY

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Recent advances in 3D printing technology have enabled the production of customised porous materials in the form of networks and cellular structures at various scales. With additive manufacturing based on particle bed deposition, it is possible to mould such materials with complex designs, which is beneficial for a variety of applications. However, despite technological progress over the last ten years, these possibilities are still hardly utilised.

Moulding cellular materials by 3D printing in a particle bed offers several advantages, such as greater design flexibility, greater versatility, cost efficiency, the ability to create customised powder blends, and reduced time constraints associated with material suitability. This paper presents a digitally designed and manufactured acoustic panel with a different porous structure.

Special attention is also paid to the development of the blend. So, from the selection of the materials themselves, the characterisation of the raw materials, the characterisation of the blends, to the characterisation of the printed samples. A large part will be dedicated to methods such as particle size distribution, XRD, isothermal calorimetry, mechanical properties and X-ray microtomography.

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INCREASING THE STRENGTH PROPERTIES OF TIRE RUBBER CEMENT COMPOSITE BY THE TREATMENT OF RUBBER CRUMBS

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The enhancement of mechanical properties in tire rubber cement composites through the treatment of rubber crumbs is an evolving area of research, underscored by various experimental studies that demonstrate the potential of modified rubber to significantly influence the performance and durability of cement-based materials.

The adhesion between rubber particles and cement paste is inherently weaker compared to traditional aggregates, primarily due to the non-polar nature of rubber, which diminishes the interfacial bond strength. Previous studies have shown that pre-treatment of rubber crumbs can notably enhance this bond, thereby improving the performance of rubberised concrete composites. It has been demonstrated that treating rubber crumbs with cement paste to enhance bonding strength resulted in improved compressive strength metrics and overall material durability. The mechanical strength of composites can be improved via a pretreatment process, which increases the contact surface area and facilitates better adhesion between the rubber and the cement matrix [2].

The positive effects of varying proportions of treated rubber crumbs on the properties of rubberised concrete has been evaluated. A study indicated that substituting up to 30 % of conventional aggregates with pre-treated rubber leads to optimal improvements in strength and workability [3]. Specifically, the effective incorporation of these modified rubber particles resulted in slight improvements in compressive strengths compared to untreated rubber counterparts, addressing a longstanding challenge of strength loss associated with rubber addition in concrete mixtures [4].

Further comparative studies focused on the mechanical characteristics of rubberised concrete composites reinforced with treated rubber have emphasised flexural strength and ductility improvements. It has been noted that while increased rubber content initially leads to strength reductions, optimal treatment and mixing methods can counteract these drawbacks, resulting in composites that possess desirable mechanical attributes for construction applications [5], [6].

The introduction of additives or modifiers alongside pre-treated rubber crumbs has also proved to be a method to enhance the overall performance of cement composites, expanding their applicability in sustainable construction practices.

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THE INFLUENCE OF ARCHITECTURAL COMPOSITION OF A BUILDING ON ITS SURVIVABILITY UNDER DYNAMIC LOADS

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In modern construction, increasing attention is being paid to the study of the dynamic characteristics of buildings and structures, since their sensitivity to variable loads determines the safety and durability of buildings [1]. The correlation between the stiffnesses and inertial characteristics of load-bearing elements significantly affects the modal characteristics, but the geometric configuration of the structure as a whole makes significant changes in the forms of the structure's movements. Thus, there is a need for a comprehensive analysis of the impact of architectural solutions on the engineering parameters of the structure.

Architectural design determines the general appearance, geometry, and functional zoning of a building. In turn, this directly affects the distribution of masses and stiffnesses. The engineering component of the design should take these parameters into account in modelling and calculations to ensure proper operation of structures under dynamic loads.

Thus, the purpose of the study is to analyse changes in dynamic characteristics under the condition of changing the configuration of a multi-storey reinforced concrete frame building. This analysis will reveal the relationship between architectural and engineering solutions, ensuring an optimal balance between aesthetics, functionality, and safety of the building.

To perform this analysis, two design schemes of a multi-storey reinforced concrete frame building were created [2]. In each of them, the spatial stiffness is determined by two stiffness cores. However, in the first model, the stiffness cores are located inside the building, and in the second model, they are located outside. Each of the considered configurations of the design scheme has its advantages. The location of stiffness cores inside the building is a traditional engineering solution that ensures symmetrical distribution of stiffness and equal vibrations. The external location of the stiffening cores has certain architectural and functional advantages: shafts and staircases are located outside the main volume of the building, which reduces energy consumption, frees up internal space and increases the usable area of the building.

The analysis of the vibration forms of two schemes of a multi-storey reinforced concrete frame building with different locations of stiffening cores revealed certain patterns. The most significant advantage of the scheme with external arrangement of stiffening cores is the delayed occurrence of bending vibrations in the vertical plane, which may indicate greater spatial stiffness and greater stability. In particular, in the scheme with external stiffening cores, a displacement of the centre of symmetry is observed. The analysis of the chart of frequency changes showed a decrease in the frequency value for the scheme with external shafts compared to the scheme where the stiffening cores are located inside. In some shapes, the frequency reduction can reach 20 %, except for the 3rd shape, where the oscillation frequency in the scheme with external stiffening cores exceeded the value from the second scheme. From the graph of eigenvalues, it can be concluded that in the scheme with stiffening cores inside the building, the value of eigenvalues exceeds the eigenvalues of the second scheme in all forms except the third.

The study of the dynamic characteristics of the reinforced concrete frame building confirmed the significant influence of the geometric configuration on the dynamic behaviour. The analysis of the results showed that the placement of stiffening cores from the outside helps to delay the occurrence of dangerous bending vibrations in the vertical plane. This is an important factor in ensuring spatial stiffness and increasing the seismic resistance of the structure. Despite the reduction in frequency values, the scheme with external stiffening cores also has the advantage of optimising internal space and energy efficiency.

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ECONOMIC BENEFITS OF CIRCULAR CONSTRUCTION: A CONCEPTUAL FRAMEWORK FOR COST SAVINGS AND REVENUE GENERATION

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The construction sector remains a significant consumer of raw materials and a major producer of waste globally, posing substantial challenges to sustainable development and resource conservation. With increasing urbanisation and infrastructure demands, traditional linear construction practices contribute heavily to environmental degradation, resource depletion, and increased greenhouse gas emissions. Circular construction methodologies, encompassing strategies such as material reuse, recycling, modular design, and waste minimisation, represent promising approaches to mitigate these environmental impacts while simultaneously delivering tangible economic advantages. However, despite growing recognition of their potential, the financial implications and economic feasibility of adopting circular practices remain insufficiently understood, particularly in emerging economies where regulatory frameworks and market incentives may be less developed.

This paper proposes a comprehensive conceptual framework designed to evaluate how circular construction approaches can generate considerable cost savings by reducing reliance on virgin raw materials and diminishing waste management and disposal expenditures. Additionally, the framework identifies potential revenue streams arising from the resale or reuse of reclaimed building materials, including crushed concrete, deconstructed timber, recycled steel, and other industrial by-products. The adoption of modular construction techniques further facilitates the repurposing of building components across multiple projects, thereby enhancing material efficiency and reducing capital costs. The economic rationale is further strengthened through extended building lifespans enabled by circular design principles and increased participation in emerging circular economy marketplaces, which open new business models and value chains.

Drawing upon a variety of international case studies, including the successful reutilization of precast concrete elements in renovation projects throughout Europe and innovative modular timber construction in Nordic countries, this framework delineates critical enablers for the successful implementation of circular construction. These include integrated and transparent supply chains, the incorporation of design for disassembly and adaptability principles during the early stages of building design, and the establishment of supportive regulatory environments that provide financial incentives, certification schemes, and standardised quality controls for reused materials. The framework also critically addresses key barriers, such as the significant upfront capital expenditures associated with circular technologies, challenges related to the technical validation and certification of the performance and durability of reclaimed materials, as well as the lack of universally accepted valuation methodologies and accounting standards for circular assets.

By integrating recent advances in building materials science, structural engineering innovations, and economic cost-benefit analyses, this study offers strategic insights for engineers, architects, policymakers, and industry stakeholders seeking to advance circular economy principles within the built environment. It thereby provides a robust foundation for subsequent empirical research and the development of evidence-based policies that facilitate the transition from linear to circular construction paradigms. Ultimately, this research advocates for a transformative shift in construction practices, demonstrating that environmental sustainability and economic viability are not only compatible but mutually reinforcing objectives. This alignment is essential to achieving resilient, resource-efficient, and climate-friendly construction industries, which are indispensable to the global effort toward sustainable development and a circular economy.

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THE IMPACT OF THE MARINE ENVIRONMENT ON THE SUSTAINABILITY OF CONCRETE ELEMENTS IN PORT PIERS

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Port infrastructure plays a critical role in ensuring the efficiency and safety of global maritime logistics, yet it is persistently exposed to one of the harshest natural environments – the sea. This research investigates the influence of the marine environment on the long-term performance and sustainability of concrete elements in port protective structures, with a case study focused on the Southern Pier of Ventspils Port, Latvia.

The study explores the multifactorial degradation of concrete under marine exposure, including chemical, physical, and biological impacts. These range from chloride-induced corrosion and carbonation to freeze-thaw cycles, salt crystallisation, and bio-corrosion from algae, fungi, and bacteria. In the context of the relatively low-salinity yet dynamically changing Baltic Sea environment, these processes collectively compromise the structural integrity and service life of port piers.

The methodology combined field and laboratory non-destructive testing (NDT) to evaluate the condition of tetrapods and block elements forming the Ventspils Southern Pier. Sclerometric testing (rebound hammer) and ultrasonic pulse velocity measurements were carried out to assess the surface strength and internal homogeneity of concrete structures, both in situ and on core samples drilled from twelve test locations. The experimental analysis further included depth profiling for carbonation and strength variation using phenolphthalein indicators and layered hardness assessments. A key focus of the experimental analysis was the layered assessment of concrete quality and strength. Measurements showed a significant decrease in strength and homogeneity with increasing depth from the surface, indicating progressive internal degradation. The phenolphthalein carbonation test revealed variable depths of carbonation, with some core samples showing neutralised zones exceeding 30 mm, a clear sign of compromised passive protection for embedded reinforcement. The rebound hardness values also diminished by up to 25 % between the outer surface and the mid-depth layers, suggesting long-term environmental fatigue. Ultrasonic testing results further supported these findings, identifying regions of reduced pulse velocity corresponding to areas of increased porosity or microcracking. These insights confirm that surface inspections alone are insufficient to fully assess the degradation state of concrete in marine structures – layered, depth–resolved diagnostics are essential for accurate condition assessments.

Findings confirmed that the marine environment accelerates deterioration not only at the surface but within the deeper structural layers of concrete. Sclerometric results exhibited variations correlating with surface weathering and exposure gradients, while ultrasonic testing revealed zones of reduced homogeneity indicative of internal cracking or microstructural degradation. The effects of carbonation and chloride penetration

were especially prominent in older sections of the pier, highlighting the importance of preventive diagnostics.

The study emphasises that regular, comprehensive non-destructive monitoring can significantly improve decision-making related to port infrastructure maintenance. Based on the data, practical recommendations are offered, including periodic diagnostic intervals, the use of sulfate- and chloride-resistant cementitious materials, and targeted rehabilitation techniques.

This research contributes to the broader understanding of sustainable port asset management and underlines the necessity of tailored diagnostics in marine engineering. As climate change accelerates environmental stressors such as sea level rise and extreme weather events, ensuring the sustainability of coastal infrastructure becomes increasingly vital.

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THE APPLICATION OF WOOD BIOMASS ASH IN CEMENT MORTARS

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In recent years, the circular economy has been studied in various sectors, including the construction industry. Portland cement is one of the most used materials in the concrete industry. The cement industry is a major contributor to global CO_2 emissions and consumes vast amounts of natural resources. The manufacturing of Portland cement is highly energy-intensive and is among the largest contributors to anthropogenic CO_2 emissions. The cement industry alone accounts for 9 % of global anthropogenic CO_2 emissions. In this context, the reuse of wood biomass ash, a by-product of biomass combustion, has drawn attention as a sustainable cement replacement in cement mortars, which should be thoroughly investigated. Although it is possible to apply raw wood biomass ash in cement mortars, the mechanical properties of hardened mortar samples containing wood biomass ash can be improved if the wood biomass ash is pre-treated.

The task of this study was to assess the application of wood biomass ash as a Portland cement replacement. The early-age mechanical properties of hardened mortar samples containing wood biomass ash were determined. During the early age, the pozzolanic properties of the wood biomass ash were not observed. Further investigation is needed to determine the later-age mechanical properties of hardened mortar samples and the potential pozzolanic reactivity of the wood biomass ash.

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THE INFLUENCE OF ELECTRONIC AND HOUSEHOLD GLASS WASTE ON CEMENT MICROSTRUCTURE AND STRENGTH

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The need to develop a binder with reduced cement content by utilising hard-to-recycle electronic and household glass waste arose due to climate change, pollution issues, and the ever-increasing global energy demand. According to the United Nations Environment Programme Report, in 2020, building construction and operation accounted for 36 % of global energy demand and 37 % of global CO_2 emissions. To this day, the largest source of greenhouse gas emissions is associated with the production of building materials and the operation of buildings. For example, the production of widely used Portland cement alone accounts for about 8 % of total global CO_2 emissions [1]. Another growing concern is the increasing amount of electronic and household glass waste worldwide. As the amount of such glass waste continues to increase, the recycling rate decreases, making glass recycling one of the ongoing challenges for sustainable development. The construction industry, as one of the largest global sectors [2], [3], presents significant potential for the incorporation of electronic waste glass into building materials. Finely crushed glass waste can be integrated with cementitious composites, contributing to the reduction of cement and natural aggregate consumption [4], [5].

The study analyses the influence of electronic and household glass waste on the development of cement stone microstructure and strength. For the tests, three types of glass waste in the form of dispersive powder were used with different particle morphologies and amorphous phase content. Scanning electron microscopy (SEM) analysis revealed that for TV glass, angular particles of irregular shape are typical, whereas particles of lamp (L) and washing machine (W) glass are more sharp-edged and partially crystallised, with needle-shaped crystals visible in the SEM images, especially for the W-type glass. The cement samples were prepared by replacing up to 30 % of the cement with glass waste, and SEM analysis was carried out after 7, 28, and 90 days. It was found that due to the high dispersity of the glass, the particles agglomerate, and the primary cause of strength reduction is the formation of agglomerates throughout the sample, which significantly increases porosity in these areas. This effect is particularly noticeable after 7 days of cure, but remains even after 90 days, although some pores are already filled with cement hydration products.

X-ray diffraction analysis showed that the different glass wastes do not significantly alter the mineral composition of cement stone, but rather change the quantities of the compounds formed. Thermal analysis indicated that mass losses in the temperature range of 110–320 °C, especially in samples with W-type glass, are almost identical to those of the control (pure cement) sample. The portlandite content in glass-containing samples decreases as a result of the reduced cement content. However, after recalculating the results to an equal cement content, a higher amount of portlandite was observed in the samples with a W-type and L-type glass after 7 days compared to the control samples. After 28 days, the portlandite content decreased below that of the control samples, with the lowest amount found in the W-type glass samples. These samples also exhibited the highest compressive strength, indicating that the pozzolanic reaction was most intense with this type of glass waste.

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POSSIBLE SUBSTITUTIONS OF TRADITIONAL BINDERS IN AUTOCLAVED AERATED CONCRETE

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Increasing global demands for energy-efficient and low-carbon construction materials shift the importance of the search for environmentally and economically sustainable alternatives to conventional Portland cement and lime in all fields of the building industry. These primary binder components also play a key role in autoclaved aerated concrete (AAC) technology, particularly in stabilising the pore structure and providing mechanical strength. The presented study investigates the feasibility of substituting traditional binders with mixed cements and alternative lime types, aiming to reduce the environmental footprint of AAC while maintaining or enhancing its functional properties.

The research is divided into two phases. In the first phase, a series of mixed cements, namely CEM II/A-S 42.5 R, CEM II/A-S 52.5 R, CEM II/B-S 32.5 R, CEM II/B-M (V-LL) 32.5 R, and CEM III/B 32.5 L-LH/SR, were evaluated as potential substitutes for pure Portland cement. These cements, differing in clinker content and supplementary cementitious materials, were assessed for their effects on the consistency and reactivity of the fresh AAC mixture, as well as on the physical and mechanical properties of the hardened material. In the second phase, the study explored the role of various lime types in mitigating undesirable effects introduced by pollutants present in the mixed cements, aiming to ensure phase stability and effective tobermorite formation.

The results indicate that the choice of binder system significantly influences the final properties of AAC. Optimal binder combinations which provided favourable strength, bulk density, and microstructural characteristics were identified. The findings demonstrate that it is possible to replace a substantial portion of traditional binders with alternative materials without compromising AAC performance, thereby contributing to more sustainable and resource-efficient construction practices.

ALTERNATIVE AERATING AGENTS IN AUTOCLAVED AERATING CONCRETE PREPARATION

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Abstract –Autoclaved aerated concrete (AAC) is a composite material. Nowadays, it is primarily prepared as a mixture of lime, cement, calcium sulphate, siliceous sand, and aluminium powder as an aerating agent. The pore structure is implemented by the reaction between aluminium powder and calcium hydroxide. This reaction generates hydrogen, which is necessary for coherent pore structure formation. For the composite material, it is crucial to obtain compressive strength sufficient for constructive purposes and low bulk density.

This study investigates novel gas generation methodologies involving finely dispersed metal powders with controlled reactivity capable of releasing hydrogen, oxygen, or carbon dioxide. The primary objective is to optimise the coefficient of constructive quality while maintaining the integral strength of the hardened matrix, thereby enabling improved performance without compromising the functional parameters of AAC. Hypothesising that controlled metal-induced foaming can promote uniform pore distribution while supporting a stabilised calcium-silicate-hydrate (C-S-H) network. Several advanced techniques were used: a digital microscope with high resolution for pore structure observation; X-ray diffraction (XRD) and scanning electron microscopy (SEM) to evaluate the crystalline phase arrangement and microstructural integrity. Attention is paid to the genesis and spatial architecture of the C–S–H formation.

The results demonstrate that the strategic incorporation of reactive metals, modulated via particle size and oxide passivation layer, provides a refined pore structure with improved interconnectivity and critical compressive strength thresholds above 3 MPa at target densities below 550 kg·m^{-3}. A correlation is established between metal dosage, gas release kinetics, and the resulting phase assembly stability under hydrothermal treatment in a laboratory autoclave. These findings provide a new model for foaming in AAC systems, combining chemical engineering control with silicate phase optimisation for next-generation high-performance porous building materials.

EVOLUTIONARY OPTIMISATION OF STRAIN SENSOR NETWORKS FOR MACHINE LEARNING-BASED STRUCTURAL STRESS MONITORING

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Structural health monitoring (SHM) systems rely on continuous data acquisition to assess structural integrity by detecting changes in material properties, geometry, boundary conditions, or system connectivity. A critical factor affecting SHM effectiveness is the number and placement of sensors, which significantly influence the quality of the collected data (Hassani & Dackermann, 2023; Wang et al., 2023).

This study addresses the problem of optimisation of sensor networks for structural stress monitoring cases. Building upon previous work where different machine learning models were trained on simulated strain data (generated from experimentally validated, accurate numerical model) to predict loads or stresses in mechanical structures from experimentally acquired strain signals (Mucha, 2020; 2024), this work incorporates a systematic optimisation of sensor locations and orientations into the model development process. A sensor placement optimisation framework is proposed that improves the performance of the prediction models. The proposed method introduces a novel objective function tailored to minimise the difference between measured and maximal strain across multiple load case scenarios. The prediction model works without the knowledge of the load location, where different load cases generate different structural responses.

The optimisation process uses an evolutionary algorithm (EA). EAs are a class of optimisation techniques inspired by the process of natural selection and biological evolution. These algorithms operate by generating a population of candidate solutions, evaluating their performance using a fitness function, and iteratively applying operations such as selection, crossover, and mutation to evolve better solutions over time. EAs are particularly well-suited for complex, nonlinear, and high-dimensional optimisation problems where traditional gradient-based methods may struggle. Because they do not require gradient information or convexity, EAs are highly flexible and robust, making them ideal for applications where the search space is large and the objective function may be highly nonlinear, multimodal, discontinuous, and difficult to find derivatives (Burczyński et al., 2020).

The framework is tested in an example using a composite structure subjected to multiple loading scenarios. Cases involving different numbers of sensors are investigated, with each configuration evaluated for its ability to support machine learning-based predictions of structural quantities such as applied forces or maximal stresses. Statistical validation is provided where both optimised and randomly placed sensors are used as prediction model inputs. Prediction performance is quantified using root mean square error (RMSE). Results consistently show that optimised sensor layouts significantly improve prediction accuracy and reduce variability compared to non-optimised configurations.

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EXPERIMENTAL EVALUATION OF SHEAR STRENGTH OF IRISH SITKA SPRUCE

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Ireland is seeking to expand the use of its native resource of Irish Sitka spruce timber in the construction industry. This timber is classed as C16 timber, which is considered lower in strength compared to most other grades of timber. Ireland thus relies significantly on imported timber for structural applications, highlighting the need to better understand and potentially improve the grading and use of Irish Sitka spruce. To achieve this goal, it is important to understand the mechanical properties of the material for its safe and efficient structural applications in construction. One of the important properties influencing structural performance is the shear strength of timber, particularly in connections. Shear strength properties are important for optimising the design and better grading of the material, both of which are critical for the wider acceptance of the material worldwide. In this study, shear testing of Irish Sitka Spruce is done both in parallel and perpendicular to the grain direction in accordance with Eurocode I.S E.N 1381. The specimens were conditioned at 20 °C and 65 % relative humidity before carrying out testing. The testing on the specimens was performed using a hydraulic testing machine facility available at Technological University Dublin (TU Dublin) using displacement-controlled loading. The results showed that the failure was not affected by the anisotropic behaviour of the timber, with no notable difference in shear strength for the two loading directions. The failure was governed by the sliding out of the staples from the specimen in both directions. This study recommends comparing these results with force-controlled loading in future research. In order to understand the potential of this local timber, the study also proposes that results should be compared against higher-grade C24 timber, which is typically used in structural applications. These efforts will contribute towards sustainability and the economy by promoting the use and wider application of this local resource.

THE EFFECT OF POZZOLANIC WASTE ON THE ALKALI-SILICA REACTION OF SUSTAINABLE CONCRETE

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Alkali-silica reaction is a very relevant issue for most concrete producers. Solving this problem can be achieved in several ways. One such method is to replace cement with supplementary cementitious materials. One of these materials could be very fine glass waste. This waste is obtained in the glass manufacturing industry during glass processing and is separated from process water using special equipment.

The aim of this study is to investigate the effect of this glass processing waste on concrete's alkali corrosion resistance, as well as its physical and mechanical properties. The conducted research involved determining the pozzolanic properties, chemical composition, and mineralogical composition of this waste.

In this study, seven different durable concrete mixes were designed and tested. The mixes included cement, fine and coarse aggregates, a superplasticiser, an air-entraining admixture, concrete sludge, and glass processing waste. The amount of cement was varied, with the glass waste ranging from 0 % to 30 %, and concrete sludge was used to reduce the amount of natural fillers. The water-cement ratio was kept constant across all mixes. The properties of the concrete mixes and key mechanical and physical properties, such as density, compressive strength, and flexural strength, were evaluated. The most focus was placed on testing the alkali-silica reaction and the mechanical and physical properties of the samples after testing.

Based on the experiments and the obtained results, it can be concluded that this glass processing waste increases resistance to alkali corrosion. Specifically, using higher amounts of this waste resulted in smaller length changes of the samples during testing, and there was no significant increase in mass during the process. The research shows that modifying concrete with glass processing waste improves not only its physical and mechanical properties but also enhances its resistance to alkali corrosion. It was found that incorporating up to 15 % of glass processing waste (by replacing cement in the concrete mix) results in more durable and alkali-resistant concrete suitable for construction structures.

POTENTIALITIES IN USING LOAD CELLS FOR THE STATIC AND DYNAMIC MONITORING OF CABLE-STAYED BRIDGES

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This paper presents a novel and cost-effective approach for the structural health monitoring (SHM) of cable-stayed bridges by leveraging load cell recordings on stay cables for both static tension monitoring and vibration-based assessment. By capturing high-frequency force fluctuations, load cells serve a dual purpose: (i) tracking axial force variations in the cables, and (ii) enabling the identification of the bridge dynamic properties through operational modal analysis (OMA). This strategy reduces the number of sensors typically required – such as accelerometers on the deck, streamlining system complexity and data management. A key aspect of the proposed method is the introduction of an optimal sensor placement (OSP) algorithm, designed to identify the most informative stay cables for instrumentation, thereby maximising monitoring efficiency. The methodology is validated through a real-world application to a newly built cable-stayed bridge in Central Italy, equipped with a comprehensive monitoring system. Over almost 3 years of data, including results from proof load testing, are used to compare modal parameters identified via load cells against those obtained from deck-mounted accelerometers. The findings confirm the reliability and accuracy of the load-cell-based approach, highlighting its strong potential for advanced, force-based SHM of cable-stayed bridges.

ADAPTIVE FAÇADE CONCEPTS FOR ENERGY-EFFICIENT BUILDINGS IN BALTIC CLIMATES

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The current study examines the potential of adaptive façade technologies to enhance energy efficiency and indoor environmental quality (IEQ) in buildings across the Baltic region. The research focuses on dynamic building envelope systems capable of adjusting thermal transmittance, solar gain, and ventilation in response to real-time environmental conditions. Initial efforts are directed toward defining key performance criteria – including thermal resistance, acoustic insulation, and moisture regulation – while employing advanced simulation tools (IDA-ICE, COMSOL Multiphysics, TRNSYS) to assess conceptual design scenarios.

While physical prototyping is planned in later development stages, the current work outlines preliminary modular solutions suitable for both retrofit and new construction, incorporating passive strategies and active components such as building-integrated photovoltaics (BIPV) and automated shading systems.

The poster presents the research context, methodological framework, and simulation-driven pathways for the future development of adaptive façade systems adapted to temperate and cold climates, aligned with the EU's energy performance and sustainability targets.

EXPERIMENTAL INVESTIGATION OF LOAD BEARING CAPACITY OF THIN-LAYER FIBER REINFORCED CONCRETE SANDWICH WALLS UNDER ECCENTRIC COMPRESSION

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The construction industry increasingly requires sustainable building solutions that optimise material usage while maintaining structural performance. This research continues previous investigations of thin-layer steel fibre reinforced concrete (SFRC) sandwich walls (SW), where composite action of such walls was analysed (Puzanova & Skadins, 2025). In this study, the load-bearing capacity of thin-layer SW is evaluated experimentally and compared with the previous numerical analysis (Skadins et al., 2023).

The experimental investigation involves six almost full-scale SW specimens (1900 mm × 1000 mm × 270 mm) with 60 mm-thick SFRC wythes and a 150 mm EPS insulation core. Specimens were subjected to eccentric compression loading applied to only one wythe, simulating real-world loading conditions in single-storey buildings. The previously determined level of composite action was 2–18 % (Puzanova & Skadins, 2025), which can be classified as a non or low level of composite action.

Results demonstrate that despite exhibiting nearly non-composite behaviour, the thin-layer SW specimens achieved load-bearing capacity of 2000–3000 kN, which exceeds the buckling load of a single wythe (1800 kN), and most of them were closer to the section capacity of the wythes (3600 kN). None of the specimens failed due to buckling, but rather due to some local effects. The normal strains of the unloaded wythes were close to zero, showing that they were not involved in the load-carrying process directly. However, the obtained values of the load-bearing capacity suggest that the unloaded wythe has an indirect effect on the critical buckling load.

The study suggests that simple connectors providing no or minimal composite action may be sufficient for preventing thin wythes from buckling while maintaining adequate load-bearing capacity. However, attention must be paid to the detailing of the connections of such walls to prevent failure due to any local effects.

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MITIGATING CO IN BUILDING RENOVATION: A BALANCE BETWEEN EMBODIED AND OPERATIONAL CARBON

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Achieving climate neutrality is a central objective of the European Union, with the construction sector playing a key role in meeting this goal. While newly constructed buildings are typically designed as nearly zero-emission buildings, the existing building stock remains energy inefficient. In Latvia, approximately 80 % of residential buildings were constructed before 1980, highlighting the urgent need for large-scale renovation to improve energy performance. This study evaluates the balance between operational and embodied CO_2 emissions resulting from different material choices in building renovation. A life-cycle assessment (LCA) approach was applied to representative residential buildings, comparing renovation scenarios with a baseline scenario of no renovation. The results indicate that embodied emissions from building materials contribute around one-third of total life-cycle emissions; however, unrenovated buildings generate significantly higher operational emissions over their lifetime. Furthermore, the choice of insulation and finishing materials substantially influences the total carbon footprint, with renewable or low-carbon materials offering additional emission savings. The findings demonstrate that renovation remains essential for reducing the overall climate impact of the Latvian housing stock, but careful consideration of embodied carbon is needed to maximise the benefits. These results provide evidence to support the integration of embodied emissions into renovation strategies and national climate policies, in line with EU decarbonization targets.

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NUMERICAL ANALYSIS OF HEAT EXCHANGE PROCESSES IN NEONATAL CARE EQUIPMENT

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In neonatal medical care, it is imperative to provide a stable and appropriate thermal environment and comfort for the patient due to their limited ability to thermoregulate autonomously. For a long time, this has been done using high-temperature radiant heaters (RHW). They consist of the patient's bed, one or more high-temperature infrared heating lamps and a heated mat under the patient. This kind of heater has several advantages, namely that the patient is readily available for medical staff if need be. However, they also present significant drawbacks. The high-intensity radiative heating results in an uneven temperature distribution on the patient's surface, creating regions that are either too hot or too cold for optimal thermal comfort. This can lead to many negative health conditions, for example, accelerated moisture loss through the skin, since newborns have comparatively thinner skin. Given these limitations, there is a need for alternative technologies that ensure safer and more uniform heat delivery.

Therefore, the company Armgate Ltd. is developing a new device (LSW) that replaces the high-intensity heating elements. It consists of a large channel through which flows heated air that in turn heats the plastic surface above the patient. This kind of heater presumably provides a more even, but less intense radiative heating over a larger surface, which can improve the uniformity of skin temperature distribution. The potential improvements have already been experimentally researched by the company that designed the device, with positive results. To analyse the thermal processes of both devices, further numerical calculations were conducted incorporating convective, conductive, and radiative heat transfer.

The finite volume method (FVM) was used, and the 3D geometry of both heaters was used. To simplify the simulations, a steady-state case was considered. The calculations were validated with experimental data obtained by the company. The devices include a patient's analogue – an aluminium cylinder with a comparable surface emissivity to an infant. The metric by which the devices were compared was the standard deviation of heat flux density on the cylinder-air interface surface. This provides a quantitative metric for how homogeneous the heat flux density is on the surface. It was found that when comparing the validation calculation results, the standard deviation of heat flux density is lower by approximately a factor of three for the LSW device compared to the RHW device when the average temperature of the body is similar. This supports the premise that the LSW device provides a more even and appropriate thermal environment for the patient.

The LSW device was studied further to see how different environmental and operational parameters (room temperature and heated surface temperature) could influence the thermal conditions for patients. The reference values for room temperature (23 °C) and heated surface temperature (48 °C) were chosen from standard operational values. Seven values were studied for both parameters with an interval of 12 °C for the ambient temperature and 20 °C for the heated surface temperature. The heat flux density homogeneity on the surface of the LSW device increases when the ambient temperature increases and the heated surface temperature decreases. These findings support the potential of LSW technology as a safer and more efficient alternative for neonatal thermal management.

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LOW-COST FIRE RESISTANCE TESTING METHOD OF WOOD COMPOSITE PANELS IN INDUSTRIAL SETTINGS: A PROTOTYPE EVALUATION FOR CERTIFICATION READINESS UNDER BS 476 PART 22 AND EN 1634-1

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Fire safety remains a critical concern in the development and application of wood-based materials, especially as global efforts toward sustainability and safe building practices intensify. In both public and private construction sectors, the fire resistance of building elements is essential not only for regulatory compliance but also for the protection of human life and property. The assessment of fire performance is guided by established standards such as BS 476 Part 22 and EN 1634-1, which define procedures for evaluating the fire resistance of non-loadbearing elements, including door panels and composite materials. While accredited laboratory testing is often costly, there is a practical need for low-cost prototype testing methods during product development to assess viability before full certification, and this is the aim of this study.

This study demonstrates a simple and affordable method for fire resistance testing using a test chamber constructed from aerated concrete blocks (300 mm × 200 mm × 600 mm, dry density 425 kg/m^3) and heated with a propane torch (Sievert pro 88 with propane consumption < 6 kg per hour). The system is flexible enough to allow the operator to successfully approximate the ISO 834 time–temperature curve by adjusting the flame and vent gap between the blocks. The temperature within the oven is checked and verified with thermocouples (K-Type) inside the furnace. Surface temperatures of the test panels were monitored using infrared (IR) non-contact thermometers and surface-mounted thermocouples. Preliminary findings indicate that the tightness of the frame-panel interface is the most critical factor in determining fire resistance; loosely assembled panels fail rapidly due to early flame penetration. Additionally, metal hardware accelerates heat transfer, increasing surface temperature and compromising integrity. Surface charring and flame spread can be slowed by applying a magnesite board as the outermost layer, but this does not prevent internal combustion or structural failure of the wood core. Also, the criteria for the outside surface temperature are quickly reached.

Wood, as a natural material, when exposed to extreme heat and flame, has very useful properties. Connected to fact that in normal environment it is not burning before it has lost all its moisture, therefore one of most useful revelation is the fact that it exhibits properties similar phase-change materials where: its surface temperature remains below 100 °C for an extended time due to water leaving wood structure and it evaporating, once all that has finished only then temperature rises sharply, turning surface brown, emitting smoke, and eventually igniting. This natural sequence provides a visible warning before ignition. This study shows that denser and more massive wooden elements perform better, and the method presented offers a viable early-stage testing strategy for eco-friendly composite panels aiming for future compliance with international fire resistance standards.

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ANALYSIS OF THE STATE-OF-THE-ART OF CEMENTLESS UHPC COMPOSITIONS

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Ultra-high-performance concrete (UHPC) is an ordinary Portland cement-based (OPC) construction material differing from its normal strength counterpart by an exceedingly higher (above 150 MPa [1]) compressive strength. The requirement for a higher amount of OPC in the UHPC mix puts a strain on the environment as cement production already considerably contributes to the emission of CO_2, estimated to be 7 % of the world's total [2]. Therefore, for more effective widespread use of UHPC, mixes with low or none-at-all use of OPC should be studied and developed.

This study contributes to the analysis of the approach to cement replacement in UHPC materials in recent years. Mostly encountered approach (over 90 % of papers reviewed) is the partial or total replacement of the binder (OPC) portion with ground granulated blast furnace slag (GGBFS), steel slag powder (SSP) and various SCMs. GGBFS is the main by-product in the iron production, while SSP in iron-to-steel conversion, comprised from varying ratios of alumina, silica, ferrous and other oxides, when finely ground, both exhibit cementitious properties and can be potentially used in concrete production. Due to the rather low hydraulic activity of SCM at their ground state, additional 'activators' are commonly employed in order to promote geopolymerization reactions, which contribute to both initial and final strength of the material. In most cases, these activators include alkali-sourced materials such as sodium and/or potassium hydroxides and/or carbonates with or without a combination of water glass (sodium metasilicate, Na_2SiO_3) [3]. However, due to the hazardous nature associated with alkali use, special attention has been given to the use of alternatives. One such alternative is powdered calcium oxide (CaO) – when applied, it has shown promising results with GGBFS–based cementless binders, with the only drawback being the low early strength of the material [4]. To address this, calcium chloride ($CaCl_2$), a well-known setting accelerator, can be employed. However, due to the chlorine ions it introduces in the mix, it limits its use in concrete with reinforcing metallic components due to the corrosion it causes. To circumvent it, calcium formate ($Ca(HCOO)_2$, CF) can be used instead of chloride, which, although it has lower acceleration potential due to lower solubility in water-based systems, causes little to no corrosion due to the absence of chlorine ions [4].

Finally, to further enhance the strength parameters of the UHPC, fibre additives are commonly used. From these, the employment of steel fibres (with various shapes, sizes and coatings) is reported in more than 50 % of the cases studied. The rest, used either solely or in combination with steel fibre, include new or recycled polymer, glass and/or recycled steel fibre. The latter is more preferred as both the steel and polymer manufacturing are also significant emission sources [5].

Cementless UHCP with GGBFS and CaO/CF cured at 90 °C (for 48 h) shows potential to reach compressive strength up to 187 MPa, giving a promising alternative for construction application [6].

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UTILISING OIL SHALE ASH IN EXTRUSION-BASED 3D PRINTING: A PATH TOWARD SUSTAINABLE MORTAR FORMULATIONS

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The construction industry faces increasing pressure to lower its carbon footprint, particularly in 3D concrete printing, where mortars often contain high amounts of cement and reactive powders to ensure printability. To address this, the current study explores the use of oil shale ash (OSA), an abundant industrial by-product from power plants in the Baltic region, as a sustainable alternative binder. Raw OSA was characterised for its particle size, surface area, reactivity, and morphology. The results indicate strong potential for OSA as a supplementary cementitious material (SCM), with particle size and surface area comparable to cement, and a cumulative heat release of 206.7 J/g, classifying it as reactive. Its rounded morphology further contributes to enhanced workability in fresh mixes.

Three dry-mix mortar formulations were developed, replacing 0 %, 10 %, and 20 % of cement with OSA. Mechanical strength tests showed that up to 20 % substitution resulted in less than a 10 % reduction in 56-day compressive strength. Printability was assessed through yield stress measurements, print quality evaluation, and structural buildability. Mixtures with 10–20 % OSA substitution exhibited favourable rheological behaviour, achieving the target yield stress range (900–1000 Pa) at lower water-to-binder ratios, and showed good buildability and surface quality. These enhancements are attributed to the spherical particle geometry of OSA. Overall, the results demonstrate that OSA is a viable SCM for 3D printed mortars, offering improved workability and potential for carbon footprint reduction. Future work will focus on long-term durability, mix optimisation, and scale-up for industrial application to support circular economy goals in the construction sector.

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MODELLING AND TESTING THE PERFORMANCE OF A STEEL FIBRE-REINFORCED SELF-STRESSING CONCRETE SLAB ON PILES

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This research addresses the issues of predicting the behaviour of steel fibre reinforced self-stressing concrete slab under point loading. A multi-span slab with total dimensions of 15.1 m × 15.9 m and a thickness of 150 mm supported by concrete columns representing piles was produced and tested. The slab contains 60 mm long steel fibres as the only reinforcement without additional reinforcement bars and bar mesh. The slab was tested three times, applying a concentrated load at different positions of the slab spans– at the middle, edge, and corner. Deflection and crack width were recorded at each load step, along with the maximum load values. To simulate slab behaviour, a calculation model was created, and structural analysis was carried out using a commercial finite element method (FEM) software, RFEM 6. To model the nonlinear behaviour of SFRC, an Isotropic Damage material model was used, utilising custom stress-strain diagrams to represent the material's response in both compression and tension. The material constitutive laws for the slab are obtained based on the procedure given in the Eurocode 2, Annex L. Material properties were assessed through various tests on prepared specimens and those extruded from the construction. The predicted results were compared with the test results. The calculated outcomes showed good agreement with the test data for edge and corner slabs. The differences in maximum load do not exceed 5–15 %, and deflection matches range from 93 % to 98 %. The predictions indicate a 50 % higher maximum load capacity and a 24 % higher maximum deformation at the middle span. An important factor affecting the load-bearing capacity is the way the testing frame is fixed to the slab. The load-bearing capacity increases if horizontal restrictions are applied to two columns in the opposite corners of the tested span. The findings of this research offer structural engineers a clearer understanding of how to forecast the behaviour of steel fibre reinforced concrete structures using FEM software.

UTILISING CONSTRUCTION DEMOLITION WASTE AGGREGATES IN CEMENT-FREE CONCRETE FOR 3D PRINTING

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The rising CO_2 emissions released into the atmosphere is a well-known environmental issue, with the construction sector being a major contributor due to the widespread use of concrete. 3D concrete printing (3DCP) is an emerging technology that can minimise material use and waste through optimised geometry. Currently, many 3DCP projects primarily serve as stay-in-place formworks, with load-bearing capacity still provided by traditional reinforced concrete. Most existing 3DCP formulations contain large amounts of cement – a major source of CO_2 emissions. From an environmental perspective, it is crucial to develop mixtures for 3DCP with reduced environmental impact, particularly in applications where lower mechanical properties are sufficient. This can be achieved by reducing cement content or incorporating alternative aggregates.

This study developed and tested multiple 3DCP mixtures that contained industrial waste ash as binder, as well as construction and demolition waste aggregate (CDWA) as aggregate, resulting in a low-CO_2 concrete mix suited for 3DCP. High-calcium oil shale ash (OSA), which exhibits self-cementing properties, was used as a cement replacement. To enhance its binding properties, OSA was combined with a pozzolanic waste material – metakaolin (MK). Two types of CDWA were sourced from different construction and demolition waste landfills and compared to commercially available natural coarse aggregate (NCA) of dolomite to assess performance differences.

First, three series of cement-containing mixtures were formulated using NCA and both types of CDWA, with a binder composition of 60 wt% OPC, 25 wt% OSA, and 15 wt% MK. Then, for each cement-containing mixture, a corresponding cement-free mixture was formulated, in which the binder consisted of 80 wt% OSA and 20 wt% MK. In total, six different series were tested for both cast and 3D-printed specimens. 3DCP was carried out using a gantry-type printer, with each mixture printed into a square-shaped element.

For all series containing cement, the samples reached flexural strengths of approximately 5.5–7.5 MPa, while cement-free mixtures exhibited strengths of around 2.5–4.5 MPa. Surprisingly, the 3D-printed samples consistently outperformed their cast versions by at least 20 % across all mixtures. The compressive strength results showed a significant difference between cement-based and cement-free samples. As expected, the presence of cement led to higher compressive strengths of approximately 50–65 MPa. Despite the absence of cement, the cement-free mixtures still achieved strengths of around 30 MPa, which falls within the range of normal-strength concrete. This suggests that the combination of OSA and MK can provide sufficient structural integrity even without cement.

Although 3DCP samples exhibited approximately 15 % lower compressive strength compared to cast specimens, the cement-free 3DCP mixtures with CDWA still demonstrated unexpectedly high compressive strength. This makes them suitable for various 3DCP applications, such as stay-in-place formwork, non-load-bearing structures, and even low-rise buildings. These results prove that the developed concrete mix, which has significantly lower CO_2 emissions than conventional 3DCP mixes, is suited for a wide range of 3D printing applications in construction.

DEVELOPMENT OF SUSTAINABLE GYPSUM-CEMENT-POZZOLANIC COMPOSITIONS FOR 3D PRINTING

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This study is devoted to the development of sustainable gypsum-cement-pozzolanic (GCP) compositions using various industrial wastes and by-products. An important objective of the research is to adapt the GCP mixtures for 3D printing (3DP) and to ensure the necessary physical and mechanical properties and durability.

Trinary compositions have been developed and practically tested, in which not only commercial materials but also recycled waste were used, such as the product of processing gypsum plasterboard, phosphogypsum, and oil shale ash. As a result of testing, it was revealed that all GCP 3DP compositions have a compressive strength in the range from 20 MPa to 40 MPa, water absorption of no more than 12 % and frost resistance conforming to XF1 concrete environmental class.

Fresh mixes were tested, such as setting times, workability (cone flow method), as well as specially adapted methods for determining fresh properties during 3D printing. Printability and buildability tests include the Slag test and the buildability Buckling test, which show the number of layers that can be printed before the tower is destroyed. It was found that the composition of the filler, water, binder ratios and special additives have a great influence on the stability of the mixture. Using polypropylene microfibers, it was possible to increase the buildability of GCP composition by 35 %.

Portland cement is the most energy-intensive and environmentally impactful component in GCP composition. One of the important objectives of the study is to create a composition with minimal consumption of Portland cement. In GCP compositions without sand, the proportion of cement is 15 % (close to 300 kg/m^3). By adding the optimal amount of sand filler of a defined granulometric composition, it is possible to reduce the proportion of cement to 8.5 %. Further optimising the mix composition and adding oil shale ash (OSA), it became possible to obtain a material with a cement content of 3.8 %, which corresponds to 78 kg/m^3.

Experiments using a laboratory 3D printer have produced prototypes of architectural design elements for practical applications, such as furniture elements, acoustic panels and flower bed elements. It can also be concluded that by improving the technology, it is possible to manufacture low-carbon GCP 3D printed elements for low-loaded building structures.

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DATA-DRIVEN SELF-HEALING CONCRETE MODEL AND ANALYSIS

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The constituents of concrete have a high CO_2 emission impact, especially due to cement. Most of the CO_2 production of the concrete is produced from the burning of fossil fuels to heat up the kiln, and during the calcination process, when the limestone is heated. The main solution for the decarbonisation of concrete involves improving the energy efficiency of kilns, switching from fossil fuel to biomass, carbon capturing and storage, and finally switching to clinker substitutes. At the same time, it is known that the main indicator of a degraded concrete structure is the presence of cracks in the structural elements. The formation of cracks is critical to the life cycle assessment of a concrete structure. Autogenous effect of self-healing concrete is attributed to the calcium hydroxide carbonation, and the swelling of cement and calcium silicate particles from further hydration. The present analysis focuses on the investigation of the self-healing properties provided by fly ash, hydrated lime powder and silica fume on concrete mixes. These fillers provide advantages both in terms of tension strength and healing properties. A classification/regression model is trained on a dataset, and the results are analysed based on the present dataset. Results are verified, providing accuracy and data dispersion on a synthetic dataset reaching allowable accuracy ranges to be considered for practical engineering design purposes.

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EFFECT OF CELLULOSE FIBRE ON CONCRETE PROPERTIES AND SHRINKAGE

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With the rapid growth of the construction sector, the use of secondary raw materials in concrete mixtures is gaining increasing importance to reduce production costs and environmental impact. Cellulose fibre is one such secondary material that can be used in the concrete production industry to improve the deformation properties of concrete. For this purpose, it is necessary to determine the optimal content of cellulose fibre in concrete and assess its influence on the mechanical and physical properties of the concrete mixtures. The aim of this study was to evaluate the effect of cellulose fibre on the properties and shrinkage of concrete.

The study involved eleven batches of concrete specimens, each containing a different amount of cellulose fibre ranging from 0 % to 1 %. The physical and mechanical properties of the specimens were tested after 28 days of curing, while shrinkage measurements were performed over a total period of 190 days. Compared to the control specimens, a 15 % decrease in compressive strength and up to 4.8 % reduction in flexural strength were observed when 1 % cellulose fibre was used in the concrete mixture. The shrinkage of the control specimen after 190 days of curing was 1.53 %, while with 1.0 % cellulose fibre, it decreased to 1.356 %. Therefore, it was found that shrinkage decreases proportionally with increasing cellulose fibre content up to 1.0 %.

The study demonstrated that cellulose fibre has a positive effect on reducing concrete shrinkage, which is important for durability and crack resistance. However, a higher fibre content has a negative effect on compressive and flexural strength, highlighting the importance of optimising the cellulose fibre content in concrete. The optimal cellulose fibre content that reduces shrinkage while maintaining performance was determined to be 1 %. Based on the results, it can be concluded that the use of cellulose fibre in concrete production can reduce shrinkage and improve concrete durability under environmental conditions.

THE EFFECT OF BIOMASS BOTTOM ASH AND CHEMICAL ADMIXTURES ON THE CHARACTERISTICS OF CEMENT MATERIALS

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In recent years, the amount of biomass bottom ash waste generated during combustion has increased significantly [1]. Transportation and landfilling of this by-product have negative economic and environmental impacts [2]. Although biomass bottom ash has potential properties that could be used in the production of construction materials [3], [4], its widespread use is challenging due to significant variations in physical and chemical properties that depend on the type of biomass burnt. Another problem is that the consumption of cement is constantly increasing, as it is the primary bonding material in mortar and concrete. This growing demand causes significant damage to ecosystems due to high CO_2 emissions and energy consumption [5]. For this reason, extensive research is being carried out around the world to find alternative materials that could completely or partially replace cement.

The purpose of this study is to evaluate the influence of biofuel bottom ash and chemical admixtures (superplasticiser and crystalline nucleation hardener) on the hydration, physical, and mechanical properties of cementitious materials with biomass bottom ash and to determine their suitability for partial replacement of cement. In this research, cement was partially replaced by 5 % and 10 % by mass of biofuel bottom ash. Calorimetry, X-ray diffraction (XRD), thermogravimetric analysis (TG/DTG), and scanning electron microscopy (SEM) were carried out for the cement paste, as well as compressive strength, density, ultrasonic pulse velocity and drying shrinkage tests were carried out for fine-grade concrete.

The results showed that the bottom ash of the biofuel retards cement hydration; however, when combined with the superplasticiser and hardener, hydration is accelerated, and the resulting cementitious structures become denser. This study demonstrates the potential for waste reuse, particularly the reuse of this type of by-product in mortar production. Research contributes to the development of a circular economy, reduces cement consumption and carbon dioxide emissions, and leads to the production of more sustainable mortars.

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EXPERIMENTAL INVESTIGATION AND NUMERICAL SIMULATIONS OF OUT-OF-PLANE BEHAVIOUR OF RETROFITTED MASONRY WALLS FOR SEISMIC RESISTANCE

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This study investigates the out-of-plane strength of masonry walls retrofitted with different strengthening materials, including basalt fibre grids (BFGs), carbon fibre-reinforced polymers (CFRP), glass fibre-reinforced polymer (GFRP), and ultra-high-performance concrete (UHPC). A combined experimental and numerical approach was employed to evaluate the effectiveness of these retrofitting strategies. Large-scale masonry wall specimens were tested under out-of-plane loading to assess their load capacity. Discrete finite element models were developed and calibrated with experimental data to simulate structural responses under seismic loading. Five specimens were constructed for this study, including one unreinforced masonry wall and four retrofitted walls. The retrofitted walls exhibited significant strength improvements compared to the control specimen: BFG (119.4 %), CFRP (88.6 %), GFRP (259.6 %), and UHPC (172.7 %).

In addition to the experiment, advanced discrete finite element models (DFEM) incorporating a coupled damage-plasticity traction–separation law were developed for the wall specimens and validated against experimental results. Using these validated parameters, bi-directional seismic analyses were performed on the retrofitted masonry structure. The study evaluates their performance through incremental dynamic analysis (IDA) curves, fragility curves, and exceedance probabilities at various drift limit states.

DEEP LEARNING-AIDED SHM FOR FILAMENT-WOUND PRESSURE VESSEL

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Growing use of hydrogen as an alternative to fossil fuels is driving the development of safer means of fuel storage. In most industry applications, high energy density is reached by either high pressure or low temperature, or a combination of the two. Therefore, historically used metal containers have been replaced by composite vessels, which provide significantly higher specific strength and allow for major weight savings. Currently, the most widely used pressure vessels are type IV, which consist of a polymer (high density polyethylene or nylon 6) liner covered by pre-impregnated glass fibre or carbon fibre bands during the filament winding process. Failure mechanisms are much more complex than for homogenous materials due to the anisotropic nature of the composite laminate, and ultimate failure manifests as a hazardous high-energy burst, which demands an effective structural health monitoring (SHM) system. Strain-based monitoring systems are historically the most common, and recently developed novel nano-composite sensors allow for seamless integration between the composite layers. Raw strain measurements are not sufficient for exact and timely damage detection, and processing algorithms are required. Deep learning has been gaining traction in all data processing fields, including structural health monitoring, as deep neural networks can effectively model complex relations observed in large, multi-dimensional datasets. Long-short term memory (LSTM) algorithms have been used specifically for time-series data with the ability to learn short- and long-term features in extensive, high-dimensional datasets. In the present study, a high-fidelity finite element model of filament-wound pressure vessel has been developed, and strain sensor data have been synthesised in nonlinear numerical simulations involving progressive damage of matrix and fibres. Based on the simulated response of the vessel, effective sensor distribution has been found, and a dataset of simulated strain and damage time series has been generated for training and testing of a neural network to capture underlying strain-damage relationships and acquire predictive capability. Methods for normalisation of sensor readings have been proposed with the goal of eliminating the effect of pressure variations and increasing the versatility and flexibility of the algorithm. Development, training and hyperparameter tuning of the neural network have been conducted to obtain high prediction accuracy and the ability to recognise subtle features and nonlinearities in strain measurements caused by structural degradation, which allows early identification of several types of damage, such as matrix cracking and fibre rupture and can be extended for localisation capabilities. Applications in other strain-based structural health monitoring cases can be explored.

DAMAGE DETECTION IN CRACKED PIPELINES THROUGH EXPERIMENTAL MODAL ANALYSIS AND REPAIRING APPROACHES

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Pipelines are critical elements of energy and water distribution systems, where structural integrity must be preserved to guarantee long-term safety and performance. Among the most severe damage mechanisms, cracks can significantly alter the mechanical response, reducing stiffness and potentially leading to leakage or sudden failure.

This study employs experimental modal analysis (EMA) as a non-destructive diagnostic tool to evaluate the dynamic behaviour of cracked pipelines. By extracting modal parameters – natural frequencies, mode shapes, and damping ratios – from measured vibration data, EMA enables the identification and localisation of damage, as well as the assessment of its severity.

The research also investigates the use of fibre reinforced polymer (FRP) patches as a strengthening technique for cracked pipelines. The retrofitting performance is analysed in terms of the pipeline's restored stiffness and improved modal response after repair. The combined application of EMA-based damage detection and FRP reinforcement strategies highlights a promising framework for extending the service life of critical pipeline infrastructure while minimising inspection and maintenance costs.

3D PRINTING OF BIO-BASED BUILDING MATERIALS – MIX DESIGN, PROPERTIES AND LCA

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The high-growth 3D printing industry reduces material waste, labour needs, and environmental impact. Combining bio-based materials with 3D printing, the construction industry can create more sustainable products while improving productivity. In this research, three types of binders – gypsum, magnesia, and calcium sulfoaluminate – and additives were analysed and used for printing with a gantry-type 3D printer.

The suitability of these binders for 3D printing was determined by evaluating the buildability, green strength, and mechanical properties of the mixtures with minimal binder content. A life cycle assessment was conducted to assess the environmental impact of bio-based building materials and the 3D printing process, and comparisons were made with traditional materials.

Results showed that calcium sulfoaluminate samples had the highest strength, followed by magnesia and gypsum samples. Magnesium and calcium sulfoaluminate bio-based building material had higher environmental impacts due to the binder. The printing process had minimal emissions. Calcium sulfoaluminate samples showed high strength but should be used in smaller quantities to reduce environmental impact. Magnesium samples were suitable for bonding bio-based fillers but less suitable for structural compressive materials. Gypsum samples had the lowest environmental impact due to the low calcination temperature of the gypsum binder.

Overall, 3D printing, both independently and in combination with bio-based building materials, demonstrated competitive or even lower environmental impact compared to traditional materials.

INFLUENCE OF VOLCANIC POZZOLANA ON PROPERTIES OF MIXTURES FOR 3D CONCRETE PRINTING

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This paper focuses on the use of volcanic pozzolana (VPI) from Lambfjäll, Iceland, as supplementary cementitious material (SCM) in 3D concrete printing (3DCP) mixtures to partially replace Portland cement (OPC) in the binder. This kind of replacement would be ecologically and economically feasible and meet a global need to reduce CO_2 emissions. Availability at areas of volcanic activity and no CO_2 footprint make volcanic pozzolanas a valuable SCM in concrete technology. Influence of volcanic pozzolana additive on basic properties of fresh 3D printing mortars – flow of Hägermann cone and cone penetration were examined at different VPI percentages in the mixture. Important technical features, such as flowability, extrudability and buildability, were modified by adding superplasticiser (PCE) and viscosity-modifying agent (HPMC) to the dry mixtures before mixing with water. Behaviour of pozzolana in ternary blends with Portland cement (OPC) and limestone filler (LF) was also examined on an experimental mixture from a local industrial producer of dry mixes, MIRA Ehitustooted OÜ. Print of wall elements using a ternary blend containing OPC-LF-VPI in proportions of 50-30-20 as binder was performed on a Gantry-type 3D concrete printer with attended measurement of essential printing parameters. It was found that the pozzolana additive slightly decreases the water demand of the mixture but also decreases the early strength parameters. At later ages, the difference in strength is notably less. When used in 3D concrete printing technology, volcanic pozzolana gives the mixtures extra features by improving their buildability and shape retention.

A CREDIBILITY ASSESSMENT OF A MICRO-SCALE METHOD FOR PREDICTING THE THERMAL CONDUCTIVITY OF BIO-BASED BUILDING MATERIALS

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This study presents a credibility assessment of a method for predicting the thermal conductivity tensor of highly heterogeneous bio-based building composites. This approach involves solving the heat conduction equation at the microscale. Real composite microstructures are accounted for using micro-computed tomography (mCT) data. The method was tested using samples of the wood fibre and cement binder composite used in wood-wool cement boards (WWCBs). These boards are characterised by wood fibres that are oriented in specific directions (i.e., along the width and length of the board), and in practical applications, these fibres are typically perpendicular to the direction of heat transfer (i.e., along the thickness of the board). Therefore, the material exhibits significant anisotropy in thermal conductivity. The developed numerical tool incorporates thresholding, the selection of a representative elementary volume (REV) size, the determination of the physical and thermal properties of composite components, and the model tuning using experimental data. However, the selection of threshold levels to distinguish between different composite constituents is inherently arbitrary and is based on measurement data. In addition, the physical and thermal properties of the composite constituents are often either unknown or highly variable. Therefore, it is essential to assess the extent to which variations in these parameters affect the predicted effective properties of the composite in question. Understanding this is crucial for evaluating the reliability and accuracy of the proposed method.

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STRUCTURAL HEALTH MONITORING OF THE HISTORIC PADERNO D'ADDA BRIDGE (1889)

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San Michele Bridge, also known as the Paderno d'Adda Bridge, is a distinguished example of 19th-century iron architecture of Italian industrial archaeology. Spanning 266 meters across the Adda River in Lombardy, northern Italy, this historic viaduct, completed in 1889 by the Società Nazionale delle Officine di Savigliano, continues to serve as a strategic transportation link within one of Italy's most industrialised regions, supporting both rail and road traffic more than 130 years after its construction. Currently under consideration for inclusion in the UNESCO World Heritage List, the bridge has undergone significant maintenance interventions between 2018 and 2020 to ensure its structural integrity and preserve its historical and architectural value (Ferrari et al. 2020, 2021). As part of ongoing preservation and research efforts, an experimental campaign was carried out in May 2024 to investigate the dynamic behaviour of the bridge under operational conditions. Sensors were deployed on both the bridge and a passing railroad vehicle to capture acceleration data, thereby enabling preliminary evaluation of the bridge's response to vehicle-bridge interaction via finite element modelling. Signal post-processing and structural modelling are currently underway (Ermolli et al., 2025; Guerini et al., 2025; Ferrari et al., 2025). This study forms part of a broader research initiative aimed at establishing a comprehensive structural health monitoring (SHM) platform for the bridge, allowing for efficient, fully digitalised management of this iconic engineering masterpiece.

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TRANSIENT ANALYSIS OF A 3D-PRINTED CANTILEVER COMPOSITE BEAM

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Additive manufacturing is rapidly emerging as a transformative technology in civil engineering, offering the potential for lightweight structural components, material efficiency, and highly tailored geometries that are not achievable with conventional fabrication methods. The ability to integrate advanced materials, such as fibre-reinforced biodegradable polymers, provides opportunities for sustainable and cost-effective solutions in infrastructure. Additionally, 3D printing allows rapid prototyping and testing of structural concepts, enabling a shorter design-to-application cycle. These advantages position additive manufacturing as a promising tool for the future development of engineered structures, including novel beam and panel systems.

This study presents an experimental and numerical methodology for investigating the transient response of a 3D-printed cantilever beam. The beam specimens with nominally unidirectional filament orientation were manufactured using fused deposition modelling (FDM) and subsequently characterised through experimental modal analysis (EMA). A moving modal hammer and a tip-mounted sensor were employed to obtain frequency response functions (FRFs), from which natural frequencies, modal damping ratios, and mode shapes were extracted. Multiple excitation locations were tested to avoid nodal excitation and ensure the reliable identification of bending modes.

Following EMA, impact tests were conducted by striking the beam at mid-span while recording both the impact force–time history with the instrumented hammer and the transient acceleration response at the tip. A lightweight accelerometer with a mass of 0.2 g was used to avoid extra mass loading on the beam. The recorded force signal was subsequently applied as input in the numerical analysis, ensuring direct consistency between experiment and simulation. The finite element (FE) model of the beam was developed in SIMULIA/ABAQUS using classical laminated plate theory (CLPT) with orthotropic elastic layer properties assigned to represent the printed material. The layer stiffness parameters were established in previous study [1] and applied in the present model. The model was built with S4R layered shell elements. A convergence study of the dynamic response was performed to ensure the appropriate number of S4R elements to be used.

Transient response simulations were performed using the modal superposition method, where experimentally determined damping ratios were assigned to the corresponding numerical modes. The influence of the number of modes included in the superposition was controlled by evaluating modal participation factors and effective mass indices, ensuring that the most dynamically significant modes were retained. Simulated responses under the measured impact force were validated against experimental time histories in terms of acceleration at the beam tip. Frequency-domain comparisons of FRFs and time-domain error metrics (normalised root mean square error and maximum absolute error) were employed to assess accuracy.

The methodology demonstrates that 3D-printed beams can be effectively characterised and simulated when experimental modal data and measured impact forces are incorporated into numerical models. The study highlights the importance of realistic boundary condition modelling, accurate damping representation, and proper modal truncation in transient analysis. A key advantage of the present approach is that it enables the prediction of dynamic stresses, strains, and deflections of 3D-printed structural elements within the framework of classical laminated plate theory. Future research will mainly focus on incorporating damping as a result of the strain energy approach and on assessing the threshold of applied initial load beyond which non-linear modelling must be considered. Apart from the present cantilever case, the framework is extendable to more complex 3D-printed structural elements, supporting the integration of additive manufacturing into civil engineering applications where vibration performance is critical.

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RESOURCE EFFICIENCY AND WASTE VALORISATION FOR LOW-CARBON CONSTRUCTION IN THE BALTIC SEA REGION

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Sustainable development in the Baltic Sea region requires innovative approaches to resource management, particularly in the construction sector, which is under pressure to lower its environmental impact. Industrial by-products and wastes, generated in large volumes by mining, energy, manufacturing, and construction activities, represent both a challenge and an opportunity. Rather than being disposed of, these streams can serve as alternative raw materials for building products, contributing to circular economy practices and carbon reduction targets.

The region produces considerable amounts of residues containing silica, calcium, and alumina, essential components in construction materials. Additional sources include glass-, clay-, and cement-derived by-products, all of which hold potential for recycling into new formulations. By evaluating their material properties and processing options, strategies can be designed to reduce reliance on virgin resources, decrease waste volumes, and enhance cost efficiency in construction.

This study reviews the current state of research and practical applications in the Baltic region, highlights promising valorisation pathways, and proposes a roadmap for integrating these materials into sustainable construction practices. Recommendations are also made for advancing research, policy support, and industrial partnerships to fully exploit the potential of industrial by-products as drivers of a more resilient and resource-efficient construction sector.

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