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CONTENT

COMPARISON OF THERMAL CONDUCTIVITY OF FOAMED GEOPOLYMERS CONTAINING PHASE CHANGE MATERIALS

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Abstract. The aim of this work was to investigate the effect of Phase Change Materials on the insulation properties – thermal conductivity coefficient [λ], of fabricated foamed geopolymer panels. Phase Change Materials have been widely reported in the public literature, making them increasingly popular in recent times. PCMs have the ability to accumulate heat, which they can absorb or release due to thermal transformation, which contributes to energy efficiency. This paper presents the results of research on geopolymers based on fly ash with the addition of microencapsulated and macroencapsulated phase change materials (PCMs). Geopolymer composites were prepared by adding 0%, 5%, 10% and 15% PCM and the curing process was carried out at 60°C. Three different phase change materials with melting points of 28°C (MicroCapsPCM28 (Slovenia)) and 25°C and 42°C (PX25 and GR42 (Germany), respectively) were used. All the phase change materials used belong to the paraffin group. The obtained composite sheets were subjected to thermal conductivity tests in 3 temperature ranges (0–20°C; 20–40°C; 30–50°C). The paper also presents the density results of the foamed composites investigated, as well as the visual evaluation and the morphology of the porous structure using scanning electron microscopy. As a result of the study, it was found that foamed geopolymer composites without PCM addition have lambda coefficient values of 0.06–0.07 [W/m*K], while with the addition of phase change materials 0.07–0.085 [W/m*K]. The obtained test results give the potential to use these materials in construction as insulating materials. The use of these substances in building partitions results in the decrease of daily temperature amplitudes inside the building, as well as in the phase shift of the time of release of stored heat.

EVALUATION OF HEATING AND COOLING LOADS FOR A WELL-INSULATED SINGLE-FAMILY HOUSE UNDER VARIABLE CLIMATE PATTERN

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Abstract. Single family houses consume substantially more thermal energy per floor area compared to multi-apartment buildings to satisfy space heating or cooling demand. Over the past decades there has been an undisputed evidence of a temperature rise across the world, that has led to a growing concern of more extreme weather patterns and regular seasonal heat waves globally. As such, building occupants are at a continuously growing risk to overheating exposure inside the premises. Within the framework of this study a single-family house was examined with respect to its thermal performance in warm and cold seasons. A simulation model was developed in IDA-ICE software to evaluate annual thermal energy demand for a reference scenario, 3 shading scenarios and for an optimized scenario. At an optimized scenario that incorporates mechanical ventilation with a heat recovery unit and enhanced thermal performance of the external building elements, the annual thermal energy demand in the proposed single-family house was reduced by 39.5% compared to the reference scenario, which is a significant step towards meeting nearly zero energy building criteria.

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OPTIMAL SENSOR PLACEMENT IN COMPOSITE CIRCULAR CYLINDRICAL SHELLS FOR STRUCTURAL HEALTH MONITORING

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Abstract. Laminated composite cylindrical shells are widely used as structural elements in many engineering fields such as aerospace, automotive, marine, civil and mechanical engineering due to their superior stiffness and strength properties. However, these advantages are balanced by a lower damage tolerance. External mechanical and cyclic loads as well as varying environmental conditions can induce damage in composite structures, which can heavily degrade their mechanical properties and load carrying capability. Structural damage can initiate failure and disintegration leading to undesirable consequences and losses. Thus, structural health monitoring (SHM) and damage detection is one of the most important tools for maintaining the integrity and safety of the composite structures. The aim of SHM is to detect, locate and assess various defects in composites at the earliest stage possible to ensure their safety and durable service life. One of the best solutions for this purpose is to integrate a sensor network in composites for periodic or continuous monitoring and evaluation of structural state. The quality of monitoring and damage identification greatly depends on the data received from sensors. Therefore, optimal sensor placement in composites is very important task for obtaining accurate and reliable information.

This work presents an approach for optimal placement of strain sensors in composite circular cylindrical shells. The approach uses numerical strain values in longitudinal and transverse directions extracted from the top surface of the thin-walled composite cylindrical shell. Numerical model of composite cylindrical shell was modelled using the FE commercial solver ANSYS. The modal analysis with the Lanczos eigensolver was performed to determine the first 11 eigenvalues and corresponding eigenvectors. Number of sensors and their location were obtained taking into account different loading conditions of the composite shell, physical constraints of strain sensors and optimisation strategies.

BIOINSPIRED COMPOSITES: ADVANCED MATERIALS' FUTURE

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Abstract. Billions of years of evolution allowed biological materials to evolve powerful strategies. Therefore, natural materials have an excellent mechanical performance, achieving an ideal unification between architecture and its properties (Zhang, 2016). The ubiquity presented by the combination of toughness and strength (Jiang et al., 2020), for example, makes them very attractive for Engineering purposes through a biomimetic approach. In this sense, the Bioinspired Engineering field emerges to study ways to translate these strategies into the development of optimized synthetic materials (Eder, 2018).

Nowadays, bioinspired composites can be seen as a promising proposal for materials science improvement, capable to promote a disruptive path in various industry fields. Within this framework, this research characterizes the design principles and fundamental parameters for the design of bioinspired composites. For that, relevant biological materials (like nacre, bone, spider silk, and lotus leaf) characteristics and structural applications are highlighted in this work.

We also discuss the main challenges to be overcome in the design of bioinspired composites and indicate experimental studies that illustrate their mechanical principles' applications. In addition, a future outlook is presented with a glimpse of smart materials and complex structures fabrication/prototyping through the so-called Additive Manufacturing innovative technologies (Alshahrani, 2021).

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THERMAL MODIFICATION OF TUNGSTEN COATINGS FOR DETECTION BY INFRARED SPECTROMETRY METHOD

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Abstract. Physical vapor deposition (PVD) of metallic thin films is used extensively in the fabrication of semiconductor technology devices – the use as of lately for them have grown. Tungsten (W) is a low resistivity, refractory metal that is often deposited by PVD methods for use as a gate contact to semiconductor devices and due to the low work function and high thermal stability, W can be used for the fabrication of field emitters in microelectronics [1–3]. In order to monitor quality of the synthesized thin films by magnetron sputtering method, it is necessary to develop methodology suitable for the analysis of these thin films.

Infrared spectrometry is a sensitive method for the analysis of chemical bonds, but W thin films contain weakly polar and non-polar bonds, that cannot be directly detected by infrared spectrometry, therefore oxidation of W is selected as thermal modification method for detecting oxidizes products of such thin films.

Infrared spectra of W 50–60 nm thin films, deposited by magnetron sputtering on Si/SiO_2 substrate, were recorded prior and after oxidation. The samples were heated up to 600 °C with a heating rate of 10 °C/min in a Muffle furnace and then were allowed to cool down to room temperature. Infrared spectra were recorded using Bruker Fourier transform infrared (FTIR) spectrometer Vertex 70v in the range of 400–4000 cm^{-1}, with resolution of ±2 cm^{-1}, and in vacuum 2.95 hPa. Surface morphology was characterized by scanning electron microscopy; element content – by energy dispersion X-ray spectrometry. The results obtained are to be implemented in further research regarding oxidation of W thin films.

It is possible, that in parallel oxidation of the W thin films, oxidation of the substrate could also be achieved, in both – oxidation of Si and recombination of already existing oxide bonds in SiO_2, that should be considered for developing methodology. Although WO_x is a promising interfacial material metal-oxide-semiconductor devices because of also its remarkable electrical, optical, thermal and chemical stability compared to other oxide-type materials [3], which could be taken into account for further projects and researches.

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BIQUADRATIC TRANSFORMATIONS OF THE PLANE GENERATED BY A BINARY MAPPING OF TWO SECOND-ORDER LINEAR HYPERBOLIC SURFACES

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Abstract. The abstract of the paper considers the definition of biquadratic transformations of the plane generated by the binary mapping of linear hyperbolic surfaces of 2nd order. Scientific works on the development of graphical models of biquadratic transformations of the plane are investigated. The spatial scheme of establishing a biquadratic transformation of the plane between two non-adjacent planes is considered. The essence of the method is as follows: given two intersecting second-order algebraic surfaces in Euclidean space and two non-coincident projection planes. We rotate the second second-order surface around the axis by 90^0 so that the positive direction of the axis coincides with the negative direction of the axis. The obtained new position of the linear hyperbolic surface of the second order and the points on the surfaces corresponding to the points of the other surface. Based on the above, the theory and consequences of the biquadratic transformation of the plane are formed. The paper also considers the simulation of biquadratic transformations of the plane, when the combination of binary mapped surfaces of the second order are linear surfaces of the 2nd order, and as surfaces are taken three single-band hyperboloids and four hyperbolic cylinders on three axes. The study showed that the combination of binary second-order mapped surfaces allows to obtain four kinds of biquadratic transformations of the plane. The algorithm developed in the article also allowed to determine mathematical models of biquadratic transformations of the plane, which is necessary for their practical application. A new quadratic type of graphical models of biquadratic transformations of the plane is considered. Thus, a new way of solving engineering problems and a scientific direction in applied geometry have been discovered.

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HYGROTHERMAL PERFORMANCE OF HEMP BLOCK IN A MULTI-LAYER WALL

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Abstract. Hempcrete is a promising and modern self-bearing thermal insulation material, as it has low thermal conductivity and can provide negative CO_2 emissions, i.e. more CO2 is stored in the material than generated during its production. It is used in the construction of new buildings, but it is accepted to believe that it can also be used in the renovation of existing and historical buildings, for example, insulating wooden buildings from the inside, because their hygrothermal properties are well compatible with wooden construction. The following study was conducted to assess such compatibility both experimentally and through modeling. A wooden multi-story building built in 1936 was used, which was insulated from the inside with experimentally made hemp blocks, relative humidity, temperature at different wall depths, as well as heat flow through the structure were measured with sensors, the data was used for modeling validation and mold growth risk assessment. The structure consists of cement-lime plaster, pine, lime plaster and hempcrete. Due to the fact that the transfer of moisture and heat in the wall construction of the building are closely related, sensors were placed in the wall construction that collected data on humidity and temperature at the relevant points. The design model used in the experiment was created in the numerical modeling software WUFI. One-dimensional models were developed and the finite volume method was used. Experiments were performed to validate the numerical model and obtain indoor/outdoor temperature boundary conditions. The experiment was performed from 2017. April 9 to 2019. April 27 or ~ 2 years. The numerical model for the temperature and humidity transport in wall insulation structure with hempcrete has given results that are good enough with experimental observations. In addition, the mold risk forecast, which is only derived from the numerical modeling results, coincides with the actual observations – that is, in both cases no mold risk was detected, and no mold was observed when looking at the design itself. This shows that the model of hempcrete material created in the constructions with other materials is adequate, which means that it can be used in other cases when the climatic conditions in Latvia are close enough to the observers.

PILOT STUDY ON SHRINKAGE AND FRACTURE OF MATERIALS BASED ON THE ALKALI-ACTIVATED SLAG: INFLUENCE OF CURING REGIME

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Abstract. Materials based on the alkali-activated slag (AAS) show great potential for the production of cement-free concrete with high compressive strength and durability, low hydration heat, and lower CO_2 footprint compared to the ordinary concrete based on Portland cement. Despite the extensive research of AAS materials that has been very dynamic during the last thirty years, some of the issues related to their behaviour have not been fully explored yet.

The understanding of the complexity of the shrinkage process and the cracking tendency of AAS materials is still a challenging problem which remains in the focus of many researchers over the world. In contrast to Portland cement concretes, the shrinkage and cracking of AAS materials is more strongly affected by factors related to their composition (e.g. the nature of the activator and its concentration, liquid-binder ratio, aggregate grain size, aggregate-binder ratio, etc.) and also by the curing regime.

The paper presents the results of a pilot study focused on the shrinkage process and fracture parameters of two fine-grained materials prepared from ground granulated blast furnace slag and silica sand. Two different activators were used for manufacturing – liquid sodium silicate and sodium hydroxide. The components ratio and the activator concentration were the same for both materials and were as follows: activator dose of 6% Na_2O with respect to the slag weight, 1% of lignosulfonate plasticizer, and the ratio of slag:water:sand of 1:0.45:3.

All specimens matured at room temperature. For each material, four curing regimes were designed with respect to the potential application on-site (especially different upper surface treatment and demoulding time). The shrinkage measurement lasted more than 2.5 years, after which fracture tests were performed on the same sets of specimens.

Although only a slight nuance was in designed curing conditions, the results showed different sensitivity of investigated materials and monitored parameters to the particular curing regimes.

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3D/4D PRINTING OF NATURAL FIBRE COMPOSITES

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Abstract. This work relates materials science and additive manufacturing to propose an overview of the role of natural fibres in composites for 3D and 4D printing. Recent trends pushing toward green and sustainable manufacturing are moving the composites field away from traditional human-made materials and getting it closer to biocomposites that use natural, renewable and/or biodegradable supplies. In this sense, there has been an accelerated growth in research and innovation in natural fibres [1]. In general, natural fibres are used in composites as reinforcement in polymeric matrices, such as PLA, ABS and PCL to improve mechanical properties and biodegradability. Interest in natural fibres is growing for many reasons mainly due to their potential to replace the synthetic ones, with improved sustainability, lower cost, reduced environmental footprint, alternative end-of-life management, and great energy advantage over traditional reinforcing fibres such as glass and carbon fibre [1, 2]. Regarding the mechanical properties, natural fibres show low density and reasonable specific strength and stiffness/ Young's modulus. Further, another advantage of natural fibres is their availability, there is a vast range of them commercially accessible, such as sisal, flax, hemp, kenaf, cotton, jute, coir, grass, bamboo and wood [1, 2]. However, the challenge with them is that specific knowledge of their microstructure and composition related properties is required to select them properly, aiming the achievement of synergetic properties during the composite formulation and processing. In this sense, this work provides the state-of-the-art of the use of various types of natural fibres in additive manufacturing technologies, mainly to enhance mechanical and structural properties and biocompatibility of 3D printed polymeric parts [1, 2]. Furthermore, natural fibres' high moisture sensitivity is a valuable property for 4D printing because it can trigger actuation in stimuli-responsive structures. In 4D printing, the fourth dimension arises from the ability of the 3D printed structure to change its shape, functionality and/or properties along a predictable and predefined time when exposed to a given environmental stimulus (e.g., temperature, light, humidity, pressure, pH, vibration), during its post-printed lifetime [3]. Therefore, natural fibres' hygroscopic properties combined with the anisotropic shrinkage/swelling response upon moisture variation, and the possibility of alignment during printing, enable the use of natural fibres in 4D

printing, for the development of specialized shape-changing behaviour and self-assembly through different design strategies, adding technological maturity and innovation to the bio-based composites field.

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THE INFLUENCE OF THE HORNIFICATION ON THE MECHANICAL PROPERTIES OF THE HEMP FIBRE REINFORCED FLY ASH-BASED GEOPOLYMER MORTAR

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Abstract. The aim of this study was to investigate the influence of the fibres hornification (10 and 15 wetting/drying cycles) on the mechanical properties of hemp fibre reinforced fly-ash based geopolymer mortars. The geopolymer mortars were reinforced with 10mm long hemp (*Cannabis sativa L*) fibres in the dosage of 1.0 vol%. Their compressive and flexural strengths, as well as energy absorption capacity were measured at the age of 28 days.

It was shown that the hornification of the fibres led to the fibres' separation (fibrillation) and fibres' cleaner surfaces. This probably led to fibres' better distribution through the matrix, which consequently led to less porous and denser mortars. All this influenced the increase in all tested mechanical properties of the fibre reinforced geopolymer mortars, after the fibres hornification. The difference of the hornification number (either 10 or 15) showed no significant influence on the fibre reinforced mortar's mechanical properties.

Since this method of fibres treatment is easy to apply and financially and environmentally justified, it is highly recommended to be used for the future natural fibre reinforced mortars' investigation.

INFLUENCE OF ALKALINE ACTIVATOR SOLUTION RATIO ON THE PROPERTIES OF BIOMASS FLY ASH-BASED ALKALI-ACTIVATED MATERIALS

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Abstract. This study investigated the use of untreated high carbon biomass fly ash (BFA) and less alkaline Na_2CO_3 as an activator to produce alkali-activated materials (AAM). This paper examined how the Na_2CO_3/Na_2SiO_3 (SC/SS) ratio of alkaline activator solution (AAS) affected the setting time, structure development, and physical-mechanical characteristics of the BFA-based AAM pastes cured at ambient temperature. The initial and final setting times of AAM pastes decrease, respectively, with an increase in the SC/SS ratio. The AAM sample with the smallest SC/SS ratio possesses the lowest density and UPV value, and the highest water absorption. After 7 days of curing, the compressive strength of AAM samples decreased as the SC/SS ratio rose. Nevertheless, the compressive strength of AAM samples increased with increasing SC/SS ratio after 28 days of curing. The SEM studies supported the results for density, water absorption, and UPV, showing that as the SC/SS ratio grows, the structure of the samples becomes denser and more homogenous, consistent with the higher compressive strength of the samples.

Keywords: biomass fly ash, alkali-activated materials, alkaline activator solution ratio, compressive strength, structure development.

DEVELOPMENT OF INNOVATIVE INSULATION MATERIALS FROM PLANT ORIGIN FIBRES

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Abstract. Agricultural and wooden based waste products (different hemp shives, flax shives, oat husk, wood chips) were used to develop eco-materials with low thermal conductivity (density around 200 kg/m3, specific heat capacity 1100–2000 J/(kg*K). The bio-based fillers were tested and used together with mineral (gypsum and activated alumosilicates) and organic binders (potato starch) for the production of innovative insulation eco-materials by using pressure moulding, thus increasing the stability of the samples. Tests of mechanical properties of the developed eco-materials were performed on a Zwick Z100 universal testing machine, according to LVS EN 826. The thermal conductivity and specific heat capacity of the materials were determined using the LaserComp heat meter FOX600 and Netzsch HFM 446 Lambda Small according to the guidelines of Standard LVS EN 12667. The microstructure was analysed by micro-tomography, compatibility between fibres and binder were tested by FTIR, but physical properties were determined according to LV standards.

Micro-encapsulated PCM slurry Microcaps PCM25-S50 was used to increase thermal properties of experimental developed eco-materials. In this case, micro-capsules were introduced in the structure of the material during the production stage. The bio-based materials were experimentally developed with different amounts of micro-encapsulated PCMs to improve their properties.

As a conclusion plant origin fibers are possible to use for development of the insulation materials with properties similar to the commercial materials obtained in the market. The novel materials correspond to the European Green Deal and the 2030 Climate Target Plan. The European Commission has recommended that the EU have to reduce its greenhouse gas emissions by at least –55% by 2030 (relative to 1990 levels) and achieve climate neutrality by 2050.

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INFLUENCE OF NATURAL AGING ON THE CHEMICAL COMPOSITION OF HEMP MORTAR

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Abstract. In recent years, bio-based building materials have become increasingly popular in the field of low-carbon construction. Different bio-based solutions are being adopted because of their advantageous hygrothermal properties and low economic and environmental costs.

One such bio-based solution is hemp mortar, which is used in France and other countries for various construction purposes, such as thermal insulation for interior and exterior walls. However, the use of hemp mortars is hampered by insufficient data on their durability and risk of degradation due to natural aging cycles. Indeed, hemp mortar is hygroscopic, heterogeneous and anisotropic, which makes it difficult to study this material.

Therefore, the main objective of this work is to study the effect of natural aging on the chemical composition of hemp mortar. XRD and thermogravimetric analyses of hemp mortar samples were performed experimentally. The effects of two different compositions and sample depths were also investigated. All experimental results were compared with the results of reference samples treated under laboratory conditions. In general, the results showed a higher degree of degradation of the mineral matrix of hemp mortar during natural aging due to carbonation and hygrothermal stresses.

Keywords: hemp mortar, chemical composition, natural aging, XRD analysis, thermogravimetric analysis.

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INFLUENCE OF SLUDGE FROM RESIDUAL CONCRETE RECYCING SYSTEMS ON FRESH AND HARDENED CEMENT PASTE

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Abstract. As the volume of the concrete production industry increases, more waste is generated at concrete production plants. One of these wastes forms when concrete mixes come back from the job sites, or just washing ready mix concrete truck drums after work. After the aggregates are washed out, from other residual substances liquid sludge and dry sludge is formed, whose use is not possible in the manufacture of concrete without knowing how such waste affects the properties of the cement stone.

The purpose of this paper is to use the waste generated and to determine the effect of liquid sludge and dried sludge on the properties of fresh and hardened cement paste. The pH of the liquid sludge, the density of the dried concrete sludge, thermogravimetric studies, chemical and mineralogical composition were determined.

Samples of two different compositions were prepared. Cement mixtures were made from cement, superplasticizer, liquid sludge, dried concrete sludge and clean water. In compositions with dried concrete sludge, the cement was replaced with dried concrete sludge in different amounts – 0%, 5%, 10%, 15%, 20%, 25%, 30%. In the compositions with liquid sludge, the cement content was kept constant, but clean water was partially replaced with liquid sludge, reducing clean water content by varying amounts – 0%, 10%, 20%, 30%, 40%, 50%, 60%. The slump and setting time of cement paste was tested with different contents of dried concrete sludge and liquid sludge. For hardened cement paste the density, compressive and flexural strengths and water absorption were determined. It has been found that reducing the cement content in the samples, i.e. increasing the amount of dried concrete sludge, degrades both the technological and mechanical properties of the samples, but changing the samples up to 5% does not drastically affect the properties. In mixtures with liquid sludge, an increase in strength and density is observed.

Taking into account all the test results obtained for cement paste, it can be concluded that dry concrete sludge can replace a small amount of cement, up to 5%, and the amount of liquid sludge used to replace clean water is optimal up to 20%.

ORDINARY GYPSUM PLASTERBOARD AND KNAUF TORRO GYPSUM PLASTERBOARD BULLET-PROOFING

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Abstract. Bullet-proof walls are recently attractive also outside of specialized areas with the most threat of attack. Nevertheless, an average wall cannot protect us from an intentional or stray bullet. Therefore, five stands were made of gypsum wall panels, ordinary plasterboard, and Knauf bullet-proof plasterboard, fired with two different calibers of weapons. The results were documented through photography. The test results show the ballistic resistance of enhanced materials, not ordinary plasterboard. The obtained results are compared with the technical information. The aim was to test whether plasterboard, the most used material in construction, is comparable to bullet-proof structures. These results will be used to complement the standard LVS 1061 ''Gypsum boards and board systems. Design and use rules'', as well as for individual use in protection against external bullet threats or to prevent ricochets.

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CU-AL-AG COMPOSITE TARGET FOR PVD PROTECTIVE COATINGS FOR MAGNESIUM MADE BY POWDER METALLURGY TECHNIQUE

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Abstract. A new composite metal target for physical vapor deposition (PVD) coating on Mg alloys was produced using powder metallurgy (PM) technique. The ternary Cu-Al-Ag composite metal targets were produced in three different compositions with Cu content fixed at 80 wt. % and varying Al/Ag ratios of 1, 1.5 and 7, respectively, resulting in composition Cu-80 wt. % Al-X wt.% and Ag-Y wt.% (X=10.0, 15.0,17.5, and Y=10.0, 5.0, 2.5). Target plates in the chosen composition were synthesized using powder compaction method. Effect of powder mixing time and compaction load on the density and strength of green parts was studied. The effect of powder mixing time, compaction force and silver addition on microstructural and mechanical properties of PVD targets investigated.

1. Introduction

Over the past decades, fuel prices have been steadily rising and a has led to a growing emphasis on the need for weight reduction of products and components in industries such as aircraft [1]and automotive [2], [3], ceramics [4], [5], composites [6]–[8] and concrete [9], [10]. Aluminum alloys, which have good mechanical and anti-corrosion properties, have been extensively used for various applications for decades[11]. However, densities of these alloys range between 2,640 to 2,810 kg m^{-3}, which cannot keep up with the current need for lightweight structures. A good alternative to Al alloys is Mg alloys, with densities ranging between 1,760 and 1,810 kg m^{-3}, making it more attractive alternative for stiffness driven applications due to its high specific stiffness (GPa kg^{-1} m^3) [12]. However, one of the major obstacles to the widespread application of magnesium alloys is its low corrosion resistance [9]– [11]. One of the cheapest and most effective methods for increasing corrosion resistance is by creating protective coatings through galvanic method. However, in the case of magnesium, this is problematic due to the extremely large potential difference between the base magnesium metal and the newly applied coating. To overcome this obstacle, we proposed to create a dual layer barrier with

intermetallic ($MgAl_{intermetallic}$) on the inside and a brass like Cu-Al-Ag layer on the outside that acts as the primary copper substrate for further galvanic process.

Such multicomponent PVD coatings have been successfully developed as demonstrated by Smolik et. al. [16] having Mg—$MgAl_{intermetallic}$—TiN and Mg—$MgAl_{intermetallic}$—Al_2O_3 layer structure. PVD is clean and effective method for manufacturing of thin metal coatings on all kinds of the surfaces, even complex shapes, and powder materials [17], [18]. Powder metallurgy (PM) route is one of the easiest ways to make alloys and meta mixtures, especially in case of poor constituent solubility and/or significant difference in the densities of the alloying metals [19]–[21]

The goal of this study is to study the effects of PM process parameters, powder mixing time and compaction pressure on the production of ternary Cu-Al-Ag composite metal targets for the PVD process.

2. Materials and methods

The constituent metal powders used in this study were gas atomized Al 99.9% powder FLPG8.5 (Henan Yuanyang Powder Technology Ltd., China), Cu 99.95% powder HC Cu (Osprey Sandvis AB, Sweden), and Ag 99.99% powder (Sigma Aldrich, Germany). The particle sizes of the powders are given by d_{90} value of 5–10μm, 5–15μm and 10–45 μm for Al, Cu and Ag, respectively. SEM micrographs of the powder are shown in Figure 1. It can be seen that the particles have a moderate degree of sphericity, and the surface is not smooth and uniform.

A planetary ball mill with Al_2O_3 balls was used for milling and mixing of powders. Powders were ground at 200 rpm in three batches for 1, 2 and 5 hours in the presence of isopropanol (Sigma Aldrich, Germany) as lubricant to prevent powder lumping and induce adequate mixing leading to homogenous distribution of each component. Powder mixture was cold compacted to form green parts in a stainless-steel die using a 100-ton hydraulic press under uniaxial compressive load of 100, 150 and 200 MPa for 5 min. The compacted specimens were dried at

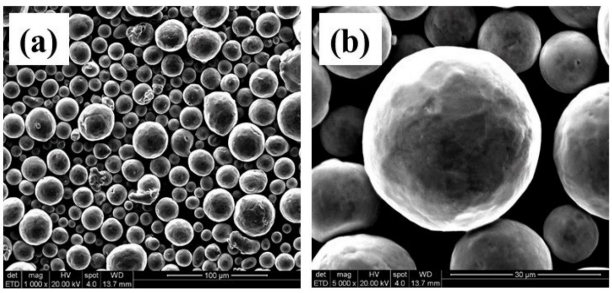

Figure 1. Scanning electronic microscopy images of the Cu powder at magnification a) 1000x times and b) 5000x times.

85 °C for 5 h to get rid of the isopropanol. After cold compaction, round plates with 90 mm diameter and 10 mm height were obtained.

Strength of the plates was obtained by performing three-point bending test on an Instron 8801 Universal Testing Machine at room temperature and 0.01 mm s^{-1} rate of deformation. 5 specimens were tested for each type. Average value and standard deviation of the flexural load until fracture were reported.

The homogeneity of powder mixture was examined using optical digital microscope (Keyence, VHX 2000) at 150x and 200x magnifications. Powder mixtures produced at several different mixing times were examined under an optical microscope and it was determined that 2 hours of mixing produces a homogenous powder mixture with no visible signs of powder agglomeration.

3. Results and discussion

Upon compaction, the targets are inspected for surface quality and structural integrity. The obtained targets shown on the figure 2.

The powders are compacted by mechanically pressing them in dies that results in densified powder mass with sufficient structural integrity to sustain handling loads. The processes during the compaction are depicted in Figure 3, where the entire green compact parts are brought together at ambient temperature in several stages. Stage 1 is where the particles are rearranged under the increasing load and densification occurs due to the filling up of pores between particles and an increase in number of contacts is seen. In stage 2, porosity decreases due to formation of localized agglomeration of particles, leading to secondary and tertiary structures. Stage 3 is characterized by an increase in the contact area between the particles accompanied by elastic deformation and finally in stage 4, contact enlargement and plastic deformation lead to final compaction. This phenomenon is well documented in literature [22]–[24].

The values of flexural load until fracture for the compacted plates of the three compositions at different mixing time and compaction load are summarized in Table 1. Since PVD targets do not have to withstand significant mechanical loads, the criterion for adequate compaction and part strength was defined as sustaining 100 N load without developing a crack. This was determined from previous experimental work on round plates of 90 mm diameter and 10 mm height and

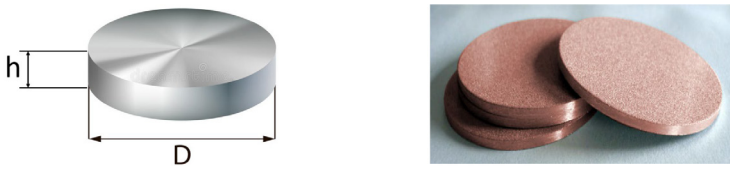

Figure 2. The schematic (a) and compacted Cu-Al-Ag (b) disc, where D=90.0 mm and h=10±0.5 mm.

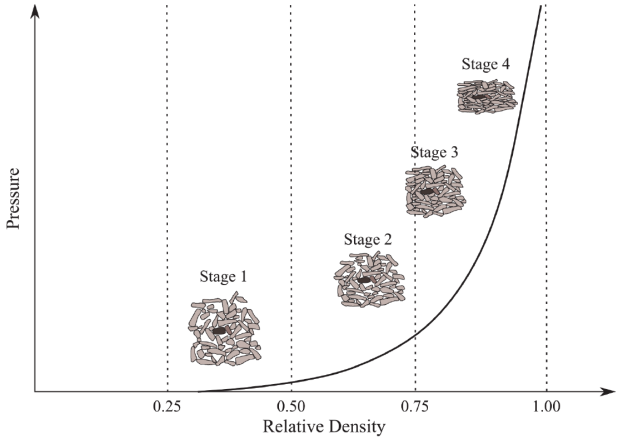

Figure 3. Pictorial representation of the powder compaction process and the different stages that are obtained [20].

is deemed sufficient for target plates during handling and mounting in the PVD device. The effect of Al content on the flexure load until failure is evident from the results in Table 1.

A decrease in flexure load is seen with increase in Al powder content in the compacted plates. A decrease of up to 33 %, 26 % and 20 % in the flexure load values is observed in specimen compacted at 100, 150 and 200 MPa, respectively, between the compositions with lowest and highest Al content. Since the parts are only compacted powders and not sintered, structural strength is only attained from compaction and inter particle friction. Al particles are smallest in size and higher percentage of these particles changes the particle size distribution that leads to

Table 1. Load until fracture and density values of targets for different compaction loads and compositions.

Mix time (hours)	Target composition (wt. %)	Compaction pressure					
		100MPa		150MPa		200MPa	
	Cu–Al–Ag	Flexure load (N)	Density**	Flexure load (N)	Density**	Flexure load (N)	Density**
2	80–10–10	85±3	73±2 %	117±5	79±2 %	161±3	88±2 %
	80–15–5	61±6	71±3 %	102±4	78±3 %	132±3	87±7 %
	80–17.5–2.5	57±5	72±1 %	87±9	77±4 %	129±4	86±5 %
5	80–10–10	87±3	74±5 %	128±6	82±3 %	183±8	88±1 %
	80–15–5	68±6	72±2 %	109±4	81±4 %	161±5	88±2 %
	80–17.5–2.5	59±3	72±3 %	91±1	80±3 %	149±6	86±2 %

* three-point bending test until fracture for disk-shape compacted powder.
** from theoretically calculated density

inefficient packing of the particles. The results show that 100 MPa compaction load is not sufficient to produce strong parts irrespective of composition and mixing time. For 150 MPa, only the composition with 17.5 wt. % Al fails the required criteria. Whereas all parts produced under application of 200 MPa compaction load have sufficient strength for all compositions.

Density of the parts as a percentage of the theoretical density of the compositions is also shown in Table 1. Density does not vary significantly with the composition but an increasing trend with compaction load is observed. Effect of Al content on density could be explained by lower plasticity of Al in comparison to Cu and Ag, which leads to less deformation of Al particles and higher interparticle voids. Therefore, higher compaction loads overcome this limitation and leads to higher density. Another explanation is the presence of a thin Al_2O_3 layer on the Al particles which reduces its adhesion of Cu and Ag particles during the compaction. Higher mixing time of the powders leads to superior mechanical properties. This can be attributed to the fact that the grinding and mixing action produced by Al_2O_3 milling balls in iso-propanol media leads to breaking up of the oxide layer on Al, that exposes pristine Al surface for better adhesion of the other two metals.

4. Conclusions

Inclusion of Ag in the mixture at 5 and 10 wt. % ensures good mechanical strength (over 100 MPa) at mixing time 2 hours and compaction force 150 MPa, even for composition with high Al powder content (up to 17.5%). For the compaction of Cu–Al–Ag PVD target with sufficient strength at Ag loading 2.5 wt.% with high Al powder content (up to 17.5%), 200 MPa compaction force and mixing time 2 hours is required . In case of future scaling-up and to obtain larger PVD targets by employing lower loads, a solution for achieving of good-enough mechanical strength of Cu–Al–Ag PVD target is to apply 5 hours ball-mill mixing time.

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THE EFFECTS OF 3D PRINTING ON DURABILITY OF CONCRETE

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Abstract. 3DCP is becoming more common in the construction industry nowadays, however, the aspects of durability of printed concrete are not well-studied yet. This paper focuses on determining how frost-thaw cycles as well as sulfate attacks affect printed concrete samples, compared to cast samples of the same concrete mix and whether the conventional concrete frost resistance tests can be applied for 3D printed concrete samples. Two different concrete mixes were both printed and cast – first one was a ready-made mix provided by a dry concrete mix manufacturer and was used for reference, where-as the other mix was prepared at the lab. First, 7 and 28-day compressive and flexural strength as well as density were determined to establish the difference between mechanical and material properties of both printed and cast concrete samples that were intended to be used for durability tests. Next, both printed and cast samples of both mixes were subject to a total of 56 freeze-thaw cycles while submerged in NaCl solution, allowing to determine mass loss of each sample after a certain amount of frost cycles. Also, both printed and cast samples were tested for sulfate resistance. To conclude, the obtained results enable the authors to evaluate how 3D printing affects concrete resistance to frost/thaw cycles and sulfates compared to conventionally cast concrete as well as the possible causes for this. Further research is needed to improve both the design mix of concrete as well as the printing and testing technology which would allow for increase of durability of 3D printed concrete leading it to become more widely used in the construction industry.

Keywords: 3DCP, Durability, Limestone powder, Frost resistance

LIGHTWEIGHT EPS – GYPSUM COMPOSITE FOR 3D PRINTING

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Abstract. 3D printing is becoming more common in the construction industry nowadays, therefore, it is vital to explore new building materials suited for use in this process. EPS-gypsum composite is a perspective candidate for 3D printing as it allows to obtain a building material with insulating properties while using recycled gypsum products from the construction industry as binder. This paper focuses on developing a 3D printable material by finding the most suitable ratio for EPS, gypsum binder and water for the mix. Five different mixes were tested to find the most suited one for printing, three of them contained retarding additives as well. Several fresh state properties of the printed material were tested, for instance, extrudability, buildability, rheology, setting time and fresh state density; tests with different printheads/nozzles and varying printing speeds were also carried out. Physical properties, such as moisture content and density of the cast and printed samples were determined. In addition, mechanical properties like flexural and compressive strength of the printed samples were tested. The obtained results enable the authors to evaluate the applicability of EPS-gypsum in the process of 3D printing. Further research is needed to improve both the design mix of this mix as well as the printing and testing technology which would allow to increase the quality of printed composite as well as explore its use as an insulating material in the construction industry.

Keywords: 3D Printing, Additive Manufacturing, Gypsum, EPS, Composite, Thermal Insulation

DEVELOPMENT OF A STATIC PLATE TEST FINITE ELEMENT CALCULATION MODEL AND ANALYSIS OF THE OBTAINED DATA USING GEOTECHNICAL RESEARCH FIELD DATA AND FINITE ELEMENT CALCULATIONS

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Abstract. In the last few years as the budget for the road sector has been decreasing in Latvia, the number of road pavement construction reinforcement design and construction objects has been increasing. Without providing a complete reconstruction of the road structure, it is possible to reduce construction costs and make maximum use of existing road construction materials. However, in order to ensure the long-term viability of the road and the safety of road users, it is necessary to assess the load-bearing capacity of the existing road and the subsoil. One of the most accurate ways to determine the bearing capacity of existing road structural layers is the static plate test. During the geotechnical research, the load-bearing capacity of the existing foundation under the asphalt concrete structure is assessed. However, the accuracy of the results is strongly influenced by the thickness of the existing asphalt concrete structure layer and the size of the dismantled asphalt area, as well as the fact that the load-bearing capacity of the existing foundation is determined at a certain depth. In order to determine the load-bearing capacity of the existing foundation in the deeper layers, the engineer performs a subjective experience-based interpretation that is not based on mathematical calculations. With the development of geotechnical survey equipment and engineers' understanding of the bearing capacity of the existing soil, it is also possible to use other field research methods, such as probing and interpretation of their data. Various calculation software's for soil calculations have been developed worldwide. With the help of software's, it is possible to evaluate the properties of soil layers, predict deformations and develop reinforcement solutions, however, the obtained results do not reflect the basic bearing capacity, which is expressed in MPa units. It is planned to develop a FEM simulation of static plate test based on the values of the soil layer parameters obtained from the interpretations of the probe data and to compare the results of the theoretical calculation with the results of the static plate performed on site in the study area. The aim of the study is to determine whether the load-bearing capacity of the existing base can be accurately determined by finite element calculations – a simulation of a static plate test based on the physical-mechanical properties of the soil determined during the geotechnical survey.

ENVIRONMENT RISK MANAGEMENT OF WAREHOUSE AND PRODUCTION HALL INVESTMENT PROJECTS

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Abstract. Planning, implementation and operation of buildings and related outdoor areas in accordance with the principle of sustainable construction is currently a very current topic.

Important elements of sustainability include the environmental impact assessment of construction works, which may include CO_2 emissions. Warehouse and production halls are significant environmental polluters and emitters of CO_2. The management of industrial companies seeks to manage this environmental risk and find ways to reduce it within the framework of sustainable development.

The article deals with the management of environmental risks in general, their identification, assessment methods, development of the countermeasures to reduce or eliminate them. An important component of their management is the continious monitoring and control of the functioning of the measures. An analysis of a research sample of warehouse and production hall projects located in industrial zones shows that if companies fail to continuously reduce emissions, they may face secondary risks , which may relate to the company's social impact, sales or reputation of the company affecting, for example, their share prices.

The output of the research work presented in this article is a list of initiatives to reduce the environmental risks (especially CO_2) of warehouses and production halls, determine the costs associated with them on the one hand and assess the socio-economic impacts (benefits to society) on the other. The research work serves as another step in determining the overall socio-economic effectiveness of these measures.

PRODUCTION TECHNOLOGY OF ECOLOGICAL HIGH-PERFORMANCE FIBRE COMPOSITE CONSTRUCTION MATERIALS

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Abstract. The production of traditional construction materials based on Portland cement, mineral fillers and synthetic resins, requires a significant amount of energy and CO_2 emissions for their production. Eco materials derived from natural plant fibers and mineral binders are an alternative solution for modern ecological construction.

This research work is devoted to the development of production technology of ecological high-performance fibre composite materials based on hemp fibers and magnesium binder. The technological scheme consists of preparing raw materials, manufacturing hemp composite boards, assembling a wooden structural frame, and filling an internal space with a lightweight thermal insulation composite.

The proposed composite wall structures consist of outer envelope layers made from dense hemp composite and middle insulation layer made from a light-weight insulation hemp composite. In the course of previous studies, it was elaborated laboratory samples of a composition of magnesium oxychloride cement (MOC) binder and hemp fibers, which have required mechanical and thermal properties. At the same time, testing of the developed composition in real operating conditions revealed some disadvantages that are associated with increased sensitivity to moisture.

The tasks of this study are the testing of experimental compositions in real production conditions, the study of the influence of technological parameters on material properties and the investigation of hydrothermal properties. Within the framework of the experimental part, a composite was made in which 20% magnesium oxide was replaced as an alternative binder such as metakaolin and fly ash. It was found the general factors that play an important role in the formation of material structure, such as the moisture content in the mixture, pressing parameters, as well as binder content and composition.

LIGHTWEIGT POROUS GEOPOLYMERS FROM WASTE RED BRICK PRECURSOR AND SYNTHETIC FOAMING AGENT

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Abstract. Geopolymers are associated with a high potential in replacement of traditional Portland cement. Metakaolin and fly ash are proved to be suitable precursor to produce alkali cements, called geopolymers [1,2]. Their properties are widely researched and their efficiency has been proved, while the limited availability and price of these precursors limits their application. Up to now, research on alternative precursors with wide availability, low cost, and low environmental impact is followed. Attention is paid to ashes, industrial by-products, and construction and demolition waste [3,4]. Waste red brick is such material that proved to be a suitable precursor to produce geopolymers [5]. To prepare material with high additional value, the new geopolymer should be developed to sophisticated material. In this paper, the waste red brick is used as a precursor to produce geopolymer and moreover, highly porous geopolymer system are represented. Porous geopolymers proved to be suitable in different applications, such as civil engineering, as a construction material, water treatment as a sorbent of pollutants and pH controllers in bio-gas production [6,7]. Here, for the first time porous geopolymers on waste brick precursor and synthetic foaming agent were developed. Red waste brick was ground to powder particles and activated with NaOH. Porous structure was obtained by pre-foaming technique where geopolymer slurry was mixed in the foams. Physical and mechanical properties were evaluated depending on mixture composition and foaming agent content. Porous geopolymers with density from 240 to 718 kg/m^3 were obtained. The pore structure of obtained materials was characterized. Compressive strength of such materials was from 50 to 800 kPa. Further application testing in different industries should be performed to bring the maximal efficiency of such alkali-activated porous geopolymers based on the waste red brick precursor.

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THE EFFECT OF RUBBER MICROGRANULES ON THE PHYSICAL-MECHANICAL PROPERTIES OF CONCRETE (FROM RECYCLED TYRES).

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Abstract. Recycling of end-of-life car tyres is still a pressing issue around the world and especially in Latvia. The introduction of rubber additives into concrete is quite well studied worldwide. It is known that the introduction of rubber crumb in large quantities (> 5 % by volume) reduces the mechanical strength of the material and the modulus of elasticity. This study focuses on the use of rubber admixture at low doses of less than 3 % by volume. The production technology for rubber grains involves initial tyre separation, shredding, disintegration, fractionation and subsequent devulcanization to obtain specific properties that can potentially improve the durability properties of concrete and other cementitious composites. It is assumed that the rubber additive can be used as an alternative to air entraining additives to improve frost resistance.

The effect of a rubber granule additive on the mechanical properties and frost resistance of different classes of concrete compositions produced in-house is investigated.

The following mix formulations were produced: standard mixes, mixes with rubber microbeads and mixes with commercially available flexible microspheres.

It was found that the water absorption of the mixtures with the different additives (Figure 1) did not differ significantly from the reference mixtures. At the same

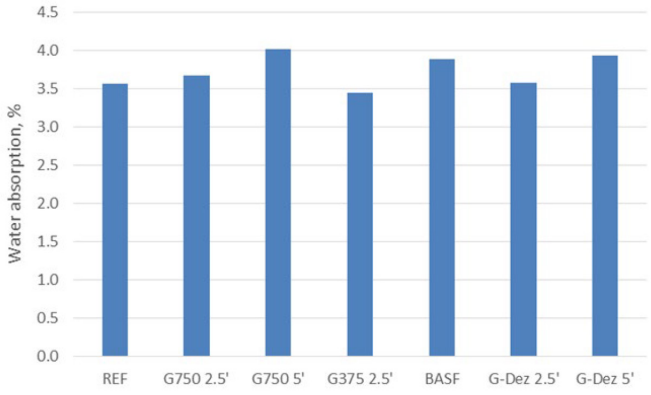

Fig.1.

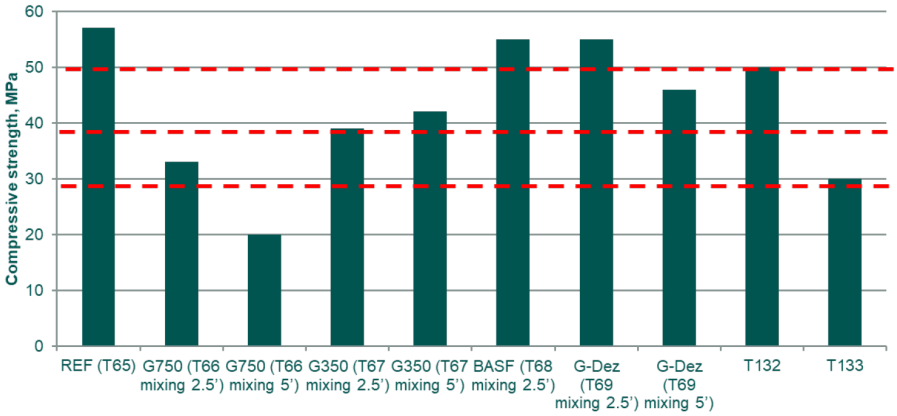

Fig.2.

time, the strength of the concrete (Figure 2) depends not only on the amount of additive added but also on the mixing time. To compensate for the decrease in concrete strength, it is suggested to limit the amount of rubber admixture and to use a water-reducing admixture to control the water/cement ratio.

LIMESTONE FILLER AS SCM ADDITIVE IN BINDERS FOR 3D CONCRETE PRINTING

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Abstract. This paper concentrates on usage of fine-ground limestone filler (R0) from Rakke Limestone production (Estonia) as SCM for partly replacing OPC in 3D Concrete Printing (3DCP) mixes. Important technological parameters like flowability, extrudability and buildability of the mixes are discussed and examined. Two opposing material properties have to be balanced in order to successfully implement them in 3DCP. A) The mix must be pumpable enough in order to deliver it by the hose from the mixer to the nozzle and B) after extrusion maintain its shape without any supporting formwork while carrying the load from subsequent filaments.

Experimental mixes with different OPC replacement have been prepared by MIRA Ehitustooted OÜ, which have been printed on a gantry printer in Tallinn University of Applied Sciences. Comparison with industrial mixes from Weber Saint-Gobain - Beamix 145-2 and ESL has been carried out. It has been shown that despite of the increased water demand LP improves printability of mixes. This can be attributed to additional finely dispersed flocculation centres provided by LP additive.

THE EFFECT OF MWCNTS ON THE STRUCTURE OF LIGHTWEIGHT POROUS COMPOSITE

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Abstract. The problem of reusing or recycling disposed packing tare of expanded polystyrene is relevant in the world. Due to an inert, closed-cell and ultra-light (up to 95% air by volume) and non-water absorbing structure, expanded polystyrene and its aggregates are widely used as packaging materials for many types of goods. However, once the material is used, it is disposed in landfills, where it can remain intact for several generations. Low density (15 kg/m^3) and thermal conductivity coefficient of 0.042 (W/(m·K)) make it possible to use expanded polystyrene aggregates in different formulations of composite materials. The main objective of this study was to carry out more detailed research on the effects of the amount of MWCNTs on the physical and mechanical properties of porous fine aggregate composite based on different fineness crushed expanded polystyrene. The crushed expanded polystyrene aggregates (household packaging), made of local waste, ordinary Portland cement (OPC), plasticizing, air-entraining and MWCNTs (0.00005–0.5% bwoc) admixtures, as well as pozzolanic additive – metakaolin-based waste, were used for the preparation of composite mixtures. The addition of MWCNTs (0.005% bwoc) in interaction with plasticizing and air-entraining admixtures increases the cement stone open porosity, promotes a fine-pore structure and due to the reinforcing effect increases the compressive strength. After 28 days of hardening, the compressive strength and open porosity of cement stone increased by 13.6% and 5%, whereas density decreased by 11%. When different fineness crushed expanded polystyrene was used in composition, the density and compressive strength vary within 830–310 kg/m^3 and 6.5–0.7 MPa range.

Keywords: porous aggregate, ordinary Portland cement, secondary raw materials, macrostructure.

THE INFLUENCE OF MODIFIED BIOPOLYMER ON MECHANICAL, HYGROTHERMAL PROPERTIES AND DURABILITY OF ECOLOGICAL CLAY MATERIALS

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Abstract. In this study, the effect of modified biopolymer (retrograded corn starch) on the mechanical and hygrothermal properties of clay materials was investigated. Also, described the technology of a modified biopolymer preparation. Clay materials were fabricated using different amounts of modified biopolymer. These studies have shown that the addition of modified polymer has a significant effect on the properties and durability of the clay materials. The incorporation of modified polymers into the clay matrix contributed to an increase in compressive strength by 62% (6.8 to 11 MPa). The surface moisture adsorption increased by 29% (from 140 to 180 g/m2). Durability of the clay materials also significantly increased. Also, it was found that the modified polymers had a significant influence on the structure of ecological clay materials.

SOLUTION OF ECONOMIC ANALYSIS OF INVESTMENT PROJECTS FOCUSED ON BROWNFIELD REVITALIZATION

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Abstract. Investment projects focused on brownfield revitalization have significant potential for the economic development of the area, in which they are located (Kadeřábková, Piecha, 2009). The project usually removes the old environmental burden or solves a problem with non-functional or dilapidated buildings (Atkinson et al., 2014). However, a suitably set investment plan, which respects internal territorial economic connections and the character of the near and wider environment, can also offer solutions to other regional problems or the implementation of economically beneficial activities in the commercial and public sector (Finka, 2010). In previous research, several case studies of brownfield revitalization of various nature were identified and analysed in detail (Sabo, Hromádka, 2019–2021). The presented paper aims to synthesize the information obtained on the economic evaluation of individual types of brownfields in order to find a common platform for evaluating of the economic efficiency of investment projects aimed at their revitalization. The output of the paper is a general overview of key inputs for economic analysis, including a proposal for their determination and evaluation, and a proposal of a key method for its implementation. Part of the presented paper is focused on the verification of the functionality of the proposed method for the processing of the economic analysis and the determination of sufficiently robust information for the project implementation decisions.

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INFLUENCE OF HVAC SYSTEMS OPERATING MODES ON OF ENERGY EFFICIENCY

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Abstract. As the most significant rise of constructions volumes in Latvia was registered in a time period from 2005 to the middle of year 2008. Large areas in Riga suburbans were landscaped for building single family type houses. People have been exploiting this property for 15–12 years and by now the challenge for the inhabitants is to find the most efficient way how to maintain a high level of living comfort. As investments in aging systems are necessary, it is in the interest of owners to ensure that the benefits of such investments are maximized and that energy consumption is as low as possible. The results of study can also be applied in a similar matter in other parts of Easters Europe, therefore this study has a particular interest not only for building energy experts but also for the broad public who have chosen private living style. On this study, authors simulated various scenarios where HVAC system's parameters were changed and thermal performance of building structures were improved. It's impact on annual energy consumption, indoor quality and thermal comfort is analysed. Importance of this work is justified with the need to realize and quantify energy efficiency level of the existing single-family houses and to show the amount of required investment to move towards established energy efficiency targets.

Two-storey residential building situated in Mežares parish, in Latvia was designed as the simulation model. The thermal properties, the hourly loads for equipment, occupancy and lighting were set. It is two floors high, with a balcony and a garage.

Computational analyses were carried out using the IDA Indoor Climate and Energy (IDA–ICE) 4.7 software.

Seven scenarios with different activities, such as changes in ventilation operation modes, improvement of building insulation or window change were simulated and analyzed.

Analyzing the model, the problem of overheating in the summer period was highlighted, so the summer period from May 1 to September 30 was considered in detail. Analyzing the relative humidity graph, the actual readings exceed the simulated ones by 20 percent in May and September. Actual and simulated CO_2 readings show a significant difference of 55.82 %.

Regularly opened windows daily throughout the period between June 1st 2020 and September 15th 2020 opening leads to PPM recession is 8.3%, improves the

quality of indoor air, but arises energy consumption sharply. The improvement of external walls insulation is not recommended for such type of buildings for energy saving reasons, and can be applicable in case of insulation damage in particular façade zones.

Installation of mechanical ventilation system decline energy consumption by 7%; the main advantage of AHU installation is PPM recession for 50–51.7 %. This scenario is recommended and guaranteed solution of overheating during summer period and healthy environment throughout the year. Investment payback period is to long, though quality indoor air has a positive impact and a long-term non-material effect on the quality of sleep, life and health of residents of the house.

Validation of the model demonstrate positive results, differences in temperatures for all cases can be explained by difference in outdoor temperature charts and does not influence reliability of the results.

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SHAPING STEEL BUILDING STRUCTURES WITH APPICATION OF VISUAL PROGRAMMING LANGUAGE

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Abstract. The huge development of digital technology has recently made designers, both architects and civil engineers, more and more often use the potential of visual programming language tools. The application of these tools does not require programming knowledge. In relation to this, the aim of the study is to develop an original, and practical approach to the early design stage of steel building structures. It is done using generative design tools working in Rhinoceros 3D environment. The developed approach is exemplified by the several cases of shaping steel bar structures. The elaborated flexible scripts, in order to achieve geometric models of the regular, structural forms are converted into simulation models to perform structural analysis and to evaluate structural behaviour dependently on the models' geometric characteristics'. The performed simulations due to both single and multicriteria optimizations enable one to asses various structural alternatives, as well as to select the optimal design solutions meeting design criteria. The proposed approach to the conceptual design process can drive the design to achieve the favourable geometric and structural forms, which not only follow the design intentions but also target better results. In general, the study shows that visual programming language can be a perfect bridge between architectural and structural design. However, it also discusses its advantages and disadvantages, as well as the directions and the needs of its future development.

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OVERVIEW OF MODERN CONTROL TECHNOLOGIES FOR HVAC SYSTEMS

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Abstract. Air quality has a huge impact on a person's well-being. Air with a lot of volatile pollutants, such as CO2, dust, and organic compounds, reduces human performance and strikes health. To improve air quality, a constant exchange of indoor air is necessary using a ventilation system. The purpose of the project is to create an automatic natural room ventilation system with air composition monitoring. The system will allow to improve air quality and increase the standard of living for humans. Automatization will not distract people from their affairs, which is an unconditional advantage. At the moment following principles are applied to detect human presence and location which can be used for HVAC control -human detection system using IT equipment, human detection system using passive infrared (PIR) sensors, human detection system using wearable sensors or tags, human detection system using vision sensors, human detection using neural network systems. Each of them has some pros and cons and application depends on the necessary precision.

In the scope of the study, it was concluded that it is advisable to use a convolutional neural network (CNN) as a base of computer vision because it's aimed to effectively recognise patterns. It has applications in image and video recognition and can be used in live streams for human detection. As it was found out, one of the most popular and relevant is YOLO (You Only Look Once) and SSD (Single Shot Detector) neural networks based on CNN. YOLO is an easy-to-use network, but SSD is much faster than YOLO. In future studies, it is necessary to study CNN-based networks. From the factory" YOLO neural network comes with a pre-trained neural network. Increasing the performance of the YOLO network requires network learning with more people in the detection-orientated dataset or pre-trained network retraining for specific usage. If the task is to train the neural network from scratch using a custom dataset, it makes sense to train a Single-Shot Detector (SSD) network because of its object detection speed and high accuracy using live stream.

The study showed that in the future it could be advisable to apply HVAC control systems that could determine the human clothing level, and indoor temperature and adjust accordingly. For such a task system that is based on vision sensors coupled with a pre-trained convolutional neural network adopted on MobileNetV2 architecture could be used. Such a system achieved a clothing level determination accuracy of 86% and 90% of the persons served by such a system were satisfied. Another option is to apply computer vision using CNN. It achieved the same

accuracy level and the percentage of occupant's feelings improved by 38%, while the percentage of persons who felt "cooler" decreased by 81%.

Regarding human motion determination systems, the existing studies suggest several strategies. One of them is based on using wireless wearable sensors which are equipped with heart rate sensors and accelerometer. Such solutions provided accuracy of 85% but the usage is limited since persons need to wear a special device. However, the usage of cameras to determine human activity is also developed. It uses a deep neural network with long short-term memory recurrent neural network, which is naturally suited to processing time-series data. The obtained accuracy of such a system to distinguish five activities (running, jogging, walking, handwaving, clapping) was 83%. Another solution would be by capturing heat emissions from humans. Such a system is based on predetermined heat gain profiles and was able to detect activities like standing, sitting, walking, and napping with 81% accuracy.

The described systems can be used for occupants' detection in areas and also for human activity and other human attributes detection. All these facts are highlighting the importance of the application of new technologies as the next evolution stage of HVAC systems. As a result, the modernized control systems have shown advantages over the currently applied typical non-automated systems by providing higher IAQ and reducing unnecessary energy consumption.

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POSSIBILITIES TO USE MUNICIPAL SOLID WASTE INCINERATION BOTTOM ASH IN CEMENTITIOUS MATERIALS

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Abstract. Blended cements whose clinker is partially substituted with other materials have been under intense scrutiny in the last decades. Such binders can provide improved performance regarding consistence, strength, and durability. Moreover, these binders have major environmental advantages such as lower CO_2 emissions, the ability to utilise industrial by-products in the manufacture of binder and their lower cost [1-2].

The aim of this work is to analyse properties of municipal solid waste incineration bottom ash (MSWI BA) and to use it as much as possible for the cement-based road binder composition, at the same without compromising constructional characteristics of the hydraulic binder for roads. The MSWI BA was tested at 6 and 18 months after keeping it in natural conditions and chemical, mineral compositions, pozzolanic activity tests were performed. The best fraction 4/16 of MSWI BA for cement-based road binder was chosen. Additionally, the particle size distribution, density, pH of milled 4/16 MSWI BA were determined. After MSWI BA preparation were formed samples with new binder and analysed swelling problems.

The physical and mechanical properties of these samples at 7, 28 and 56 days were analysed (ultrasound pulse velocity, density, compressive strength). In addition, they are presented calorimetry results of hydration kinetics of cement pastes and SEM analysis of hardened cement-based road binder with milled MSWI BA.

After analysis of results it was concluded, that the most appropriate fraction for binder is 4/16. This fraction characterizes the highest content of SiO_2 and the highest pozzolanic activity. The finesse and compressive strength of cement-based binder with MSWI BA meet the requirements of the rapid hardening hydraulic road binder standard.

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TWO APPROACHES FOR ANALYZING THE DYNAMIC PILE BEARING CAPACITY VIA PILE DRIVING FORMULAS

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Abstract. Piling is considered the most cost-efficient solution in deep foundation structures, and it involves many modern-day solutions in every field, such as modern-day materials and construction equipment. However, analysis of pile bearing capacity that includes evaluating soil conditions and its mechanical properties is relatively new compared to piling itself. Pile bearing capacity depends on two factors – the strength of the structural element itself and the resistance of the soil around the pile. This resistance must be enough to avoid excessive displacements, rotations, and other movements that make the superstructure unstable. The structural strength of the pile itself could be determined, though soil resistance is affected by many factors. One of the pile bearing capacity establishment methods is pile driving formulas – equations that establish pile bearing capacity considering set per blow and hammer impact energy. However, given establishment approach is considered unreliable and out of date, although this approach has several advantages – fast execution and minimum additional equipment required. Paper deals with two approaches for analyzing the dynamic pile bearing capacity via pile driving formulas.

EXPERIENCE IN USING BIM ON THE BASIS OF MAGICAD IN COURSE AND DIPLOMA DESIGN IN THE SPECIALTY "ENGINEERING SYSTEMS AND NETWORKS"

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Abstract. The current stage of development of information systems is characterized by the widespread introduction of BIM (Building Information Modeling) into engineering practice. In the design of engineering networks of a building, the use of 3D modeling is increasingly prevailing, so the study of a new toolkit of software systems is an urgent task in the engineering training of a student. The article discusses the application of the MagiCAD program as the leading BIM solution for the design of internal engineering systems of buildings, which is successfully used by large companies in more than 80 countries around the world. The paper analyzes the advantages of using this program in the course and diploma design of students of the specialty "6B07352 - Engineering Systems and Networks" at the Faculty of Architecture and Civil Engineering at the L.N. Gumilyov.

Keywords: BIM, design, engineering systems and networks

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EXPERIMENTAL ANALYSIS OF TIMBER-CONCRETE COMPOSITE BEHAVIOUR WITH SYNTHETIC FIBRES

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Abstract. With the growing importance of the principles of sustainable construction, the use of load-bearing timber structures is becoming increasingly popular. Timber-concrete composite offers wider possibilities for the use of timber in construction, especially for large span structures. The greatest benefit from the combination of these materials can be obtained by providing a rigid connection between the timber and concrete layers, what can be obtained by adhesive connection. The use of such a solution in practice is often associated with fears of a fragile collapse. Therefore, issue how to increase a safety factor of the proposed material is topical now. The experimental investigation is made to determine the effect of the synthetic fibres use on timber-concrete composite behaviour, by testing a series of timber-concrete composite specimens with and without fibres in the concrete layer. The obtained results show that addition of 0.5% of synthetic macro fibres prevents the formation of large cracks in concrete and prevents the disintegration of the concrete layer in case of collapse, in addition, an increase in the stiffness of the composite material is observed, which improve energy absorption and load-bearing capacity of the material.

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EXPERIMENTAL VERIFICATION OF CONDITIONS WITHIN THE CUPS IN THE CUP METHOD OF WATER VAPOR PERMEABILITY MEASUREMENT

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Abstract. The vapor transmission of building materials can be determined using the cup (dish) method. It has been described in the standards ISO 12572 [1] and ASTM E96 [2]. This method involves placing a desiccant or a saturated salt solution in the cup to maintain a certain relative humidity inside it. The cups are covered with a material whose vapor transmission is to be determined, tightly sealed, and placed in a climate chamber that maintains specific relative humidity and temperature. Based on the changes in the mass of the cup, vapor transmission coefficients of the tested material may be obtained.

The method principle is simple, and it is widely used, but it is known to be subject to problems. First of all, it depends on the steady flow condition, but buildings operate in dynamically-changing conditions which makes the utilization of obtained mass transport coefficients questionable. Secondly, verification experiments have shown that a wide range of permeability values were obtained in different laboratories under identical conditions, for the same materials [3]. Lastly, there are problems regarding the discrepancy between assumed and real values of relative humidity inside the cups. This concerns especially dry cups in which desiccants are expected to produce relative humidity close to 0%. The standard [1] instructs to supply the 0% value to the formulas enabling water vapor transmission coefficients' calculation. Recent study [4] reported much greater values. In case of highly permeable material (gypsum board) and popular desiccants, i.e. $CaCl_2$ and silica gel, the initial relative humidities within the cups were reported as approx.15% and increased during the measurement, exceeding 20% just after 5 days. In this work, the same topic is investigated experimentally for cups filled with calcium chloride ($CaCl_2$), and saturated aqueous solution of potassium nitride (KNO_3) and covered with hemp-lime composite samples, which may be considered highly permeable. Present study confirms earlier reports of great discrepancy between actual and assumed values of relative humidity inside the cups and adds data regarding measurements of water vapor transmission coefficients of hemp-lime concrete.

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EFFECTIVE THERMAL CONDUCTIVITY OF COMPOSITES WITH ANISOTROPIC PARTICLES OF VARIOUS SHAPES EMBEDDED IN AN ISOTROPIC MATRIX

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Abstract. The paper demonstrates a method to calculate effective thermal conductivity in two-phase medium with an isotropic host phase and anisotropic embedded particles. Presented model encompasses various regular shapes of filler particles i.e. infinite plates, finite and infinite cylinders, spheres, prolate and oblate spheroids, ellipsoids and cuboids. Such shapes may approximate wide range of fillers used in heat conduction composites, such as polymers filled with highly conductive metal and ceramic powders, graphite and graphene flakes and nanotubes. Different spatial orientations and sizes of particles may be supplied to the model in the form of probability distributions. Mathematical derivation of effective thermal conductivity tensor is presented, followed by computational examples and comparisons with experimental data and popular effective medium models.

The method is based on analytical approach. Most popular analytical expressions, such as Maxwell, Rayleigh or Bruggeman models [1, 2] does not allow for anisotropic particles. Typical solution in that case is to use numerical heat transfer computations such as finite volume and finite element methods (FVM, FEM) which are resource-demanding. In contrast, the proposed method enables very fast computation and is easy to implement in programming environments. The computations for the present paper were performed in MATLAB.

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APPLICATION OF DIATOMITE AS A SUBSTITUTE FOR FLY ASH IN FOAMED GEOPOLYMERS

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Abstract. In recent years, new climate targets in EU have led to a growing demand for construction materials with a lower carbon footprint. This implies a demand for research on materials with comparable properties and reduced CO_2 emission to replace those currently in use. Geopolymers belong to the group of alkali-activated aluminosilicates, whose advantages include high compressive strength and high corrosion resistance. Examples of aluminosilicate materials used to produce geopolymers are fly ash, metakaolin or volcanic tuff. Recently, there have also been papers discussing the use of diatomite as a replacement for metakaolin in geopolymer materials. The purpose of this work is to investigate the use of diatomite as a fly ash replacement in the production of foamed geopolymers. For this purpose, solid samples based on untreated diatomite and diatomite calcined at 700°C, alone and with the addition of sand in a ratio of 1:1 were first produced to roughly observe material's performance. Then, to observe the microstructure of the produced samples, they were subjected to scanning microscope observations. Compressive strength tests according to EN 12390-3 standard were carried out to check the strength properties after 30 days of curing. Subsequently, fly ash based geopolymer samples with different amounts of diatomite (5%, 10%, 50%) were foamed using hydrogen peroxide as a foaming agent. These samples were analogously also checked for microstructure observation and strength properties. In addition, the thermal conductivity coefficient and water absorption of the samples were investigated to better determine their potential industrial application. The expected result is a change in strength and thermal properties with increasing diatomite content.

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3D CONCRETE PRINTING WITH WASTES FOR BUILDING APPLICATIONS

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Abstract. Study focuses on the benefits of deploying plastic waste and fly ash as a promising alternative to main 3D concrete printing binder. 3D printing technology improvements display that this construction method holds a significant potential by not only finding a globally greener way to developing 3D printing composites but also in researching a more sustainable approach to reducing carbon footprint on the planet, and also becoming one of the possibilities in replacing industrial wastes to ordinary Portland cement.

As an alternative to ordinary Portland cement there are analysed secondary raw materials like fly ashes, plastic waste granules and grinded foam rubber. These chosen materials help to solve two environmentally relevant problems: elimination of industrial waste and CO_2 level reduction in concrete production, meantime enhancing the sustainability of the potential 3D printing concrete mixes that had been modified by wastes.

In paper were analysed modified with wastes, fresh and hardened mixes parameters comparing it to relevant 3D printing mix without changes. It showed that fresh screed with plastic granules is familiar with reference mix. Also one of significant differences were seen that hardening process with plastic wastes were quicker, what is positive feature. Despite the fact that about almost twice lower strength results plastic waste could possibly be used in wall printing constructions because of still enough high strength results. Other advantage what could be done is reducing Portland cement and adding plastic waste into 3D printing mix because of its decrease of deformation which could influence more stable construction. Higher air amount could also implement better wall features for frost resistance.

This experimental studies proved that one of three different mixtures significantly enhanced the stability of the studied features. There could be found favourable solutions in maintaining a cleaner environment with less wastes and reduce the amount of Portland cement in cementitious mixes used in the 3D printing industry. The results have shown that the most promising solution could be a combination of fly ashes and foam rubber as binders in 3D printing concrete in the future.

THE PROPERTIES OF COMPOSITES BASED ON RECYCLED BUILDING MATERIALS

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Abstract. In the past few years, eco-friendly materials have brought a new perspective to the construction industry with its huge popularity. Since technology is improving day by day; construction industry also needs to catch the new era of the construction world. As a matter of fact, increasing awareness regarding using geopolymer concrete in our industry is quite essential for us to prevent the release of a substantial quantity of carbon-dioxide to the atmosphere [1]. Geopolymers, such as high-performance composites and ceramics, have been used in recent years. It is a synthetic aluminum silicate material that can be used instead of cement-based binders in the production of materials. Research shows that using ceramic waste in geopolymers is a more eco-friendly and economic way to use; comparing the using of pozzolanic cements in the construction industry [2]. Also there is research regarding Geopolymer Concrete and its properties which is examined by Vaibhav A. Kalmegh [3]. They showed the strength of Geopolymer Concrete as well as the effect of varied concentration of alkaline solution on the strength of concrete. In article authors will present the physico-mechanical properties of composites based on recycled building materials used as a substitute of natural aggregate or cement.

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MODEL OF RADIANT CAPILLARY HEATING AND COOLING SYSTEM

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Abstract. Capillary heating and cooling system is based on the use of special mesh mats, through which water of the required temperature flows, they are placed on various surfaces, primarily on the ceiling.It has a number of advantages such as:

- Principle of operation due to the radiant energy exchange, which allows it to be distributed more efficiently than in classical convective systems;
- Ability to both heat and cool by one circuit;
- Low operating temperatures (from 18 to 30 °C), which allows saving energy, as well as using its renewable sources.

At the same time, the requirements for the quality of its design increase, since the incorrect location of the capillary mats can lead to the creation of low comfort zones. Thus, the classical method for compiling the heat balance equation for a room is not suitable in this case, since it does not allow estimating the distribution of energy over surfaces.

Computer modeling allows solving this problem, but there are no ready-made packages on the market, and the existing ones use numerical methods that may be redundant for engineering calculations, require specific knowledge not only in physics, but also in the mathematics of processes, and also use significant computing power.In this regard, it was proposed to develop an analytical model, the accuracy of which will be sufficient for engineering calculations, which will not require a large amount of computing resources, and also, in the future, will allow creating application.

Developed model allows to calculate the distribution of energies and temperatures in a room that may contain various openings and capillary mats at the walls, takes into account the influence of additional energy sources such as the sun, electrical appliances and people, and also has a simplified system for accounting for convective heat transfer.

Full paper contains its description, principle of operation, as well as verification based on experimental data, which showed that the deviation in the calculated temperature inside the room does not exceed 8%, in heat energy up to 10%.

PUFJ (POLYURETHANE FLEXIBLE JOINTS) AS AN INNOVATIVE POLYURETHANE SYSTEM FOR STRUCTURAL AND NON STRUCTURAL BONDING OF TIMBER ELEMENTS

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Abstract. PolyUrethane Flexible Joints (PUFJ) as an innovative adhesive system has been developed by a team of researchers from the Cracow University of Technology (CUT) for several years. Initially, the research focused mainly on joining masonry and reinforced concrete elements. Due to environmental concerns and climate changes, further advancement of the PUFJ system was focused on the technology development based on connecting natural materials such as wood and wood-based materials. In 2019, the cooperation of the CUT with a private company resulted in the implementation of the PUFJ system for the construction of innovative connections in a prefabricated timber frame construction of a family house near Cracow. Currently, further research are carried out focused on the complex understanding of behaviour of adhesive bond used in structural and non structural timber bonding, taking into account different species of wood (pine, spruce, beech, douglas fir) and a different thickness of the flexible adhesive layer (from 1 mm to 30 mm). The article contains the properties of the PUFJ system, describes variants of the available applications (wet application in form of liquid substance curing in time or dry application as a prefabricated bonding layers glued to the elements with a thin adhesive layer). Examples of double-lap shear connections and laminated beams made of douglas fir wood of C24 class and Sika®PS polyurethane flexible layer are presented. All specimens were constructed with three various flexible adhesive thicknesses of 1, 2 and 4 mm. The influence of elevated temperature on the load capacity of the connection and on the final deflection was tested. The tests were conducted at four temperature levels (20, 40, 60 and 80°C).

Keywords: polyurethane, flexible adhesive joint, timber, elevated temperature, glass transition.

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COMPRESSIVE AND FLEXURAL BEHAVIOR OF GLASS FIBER-REINFORCED CONCRETE

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Abstract. is the major thing and one of the most frequently used building materials in construction throughout the world. It can be easily moulded into any desired and durable structural shapes. The most common construction material in the building and construction industry is concrete and cement is the main constitute ingredient of it. In our time use of fiber reinforced concrete is still a challenge for modern engineers. Usually is recognized that the mechanical, cracking and fracture, properties of fiber reinforced concrete are far superior comparing to the classical concrete. The addition of fibers into the concrete matrix counteracts its brittleness. Short fibers are usually used in concrete to control cracking due to drying and autogenous shrinkage. Nowadays is possible to note a rapid growth in the use of short alkali resistance glass fibers. The present experimental investigation the has been used to study the effect on compressive and flexural behavior of glass fiber reinforced concrete (GFRC). This paper evaluates the properties of glass fiber reinforced concrete (GFRC) after 7 and 28 days of curing, respectively, so that GFRC can be used in construction. For this purpose, concrete with short alkali resistance glass fibers 36 mm long with a volume fraction (VF) of 1% were used were designed. The experimental results indicated that 28-day mature GFRC of curing, average compressive strength of GFRC is 72.06 MPa. The flexural properties of GFRC are obtained, and it can be stated that the concrete samples average bending strength of GFRC for 7 days is 6.46 MPa and for 28 days is 7.94 MPa, respectively, which means that the GFRC performs well under load conditions.

THE EFFECT OF CONCRETE CONSISTENCY AND PRINTHEAD NOZZLE SIZE ON 3D CONCRETE PRINTING QUALITY

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Abstract. Additive manufacturing or extrusion-based 3D concrete printing (3DCP) is a quickly developing construction method that brings advantages over the above traditional concrete casting [1]. For effective and successful 3DCP, the mixture composition must be carefully selected and adapted to specific printer parameters. Such additives as superplasticizers, viscosity modifiers, supplementart cementitious materials, and inclusions as thixotropic agents, retarders, accelerators, and fibers must be considered [2]. 3DCP technological variables such as water-cement ratio or print-head nozzle size needs to be determined, as they influence the size of the printed object and the total open printing time. Besides that, the properties of the binder itself and its hydration characteristics must be investigated. This all affects rheological aspects and curing dynamics of concrete as well as determine the quality of the printed structure.

A group of models was developed to analyze 3DCP parameters regarding concrete printer print-head nozzle size and consistency of printed concrete. The models were based on 3DCP squares with linear printing patterns. The impact on fresh and hardened concrete properties was tested based on this analysis method. An effort to determine an optimal combination of precise requirements for setting time, fresh concrete consistency, strength and shrinkage was performed. The consistency of fresh material is the key to ensure that initial tests are carried out, which include printing and testing 3D concrete mixtures. The material consistency by table flow method should be between 180 mm and 200 mm to ensure that the mass of 3D concrete is printed with the required mass viscosity to allow its extrusion.The results indicate the change of the mechanical properties regarding the print-head nozzle size and consistency of concrete. Drying shrinkage up to 0.26% was detected at the age of 26 days. Printing quality between top and base layer ratios from 0.53 to 0.98 was reached.

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FOAMED GEOPOLYMERS: A REVIEW OF RECENT STUDIES

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Abstract. Undoubtedly, current environmental trends force scientists to search for a way to reduce carbon dioxide emissions in the production process of building materials. Geopolymers have been called as a potential alternative to traditional concrete for decades, allowing us to obtain more sustainable and durable materials with good thermal and reasonable mechanical properties and solve the problems related to waste materials utilization. Despite the great interest of scientists and the many advantages both in the production process of geopolymers and in terms of material properties, this idea looks unattainable in the near future, so it is worth investigating alternative ways of geopolymer applications.

Thereby this review paper summarizes the recent progress in the field of foamed geopolymers, focusing on the foaming and stabilization processes, material base, and applied treatment techniques, as well as information about the obstacles and challenges that hinder the transition of foamed geopolymers from research laboratories to real application in the civil engineering. This report also describes the density, compressive strength, thermal conductivity, pore size and heat resistance of geopolymer foam concrete are also described in this report. A random sampling method and descriptive analysis were used in the preparation of a review.

EXPERIMENTAL PARAMETER IDENTIFICATION FOR INELASTIC 3D MATERIAL MODEL

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Abstract. Due to global warming, the move toward more sustainable material choices has increased. This has led to significant advancement in the research community to develop many new materials, especially in the field of bio-based material systems. Research on these materials has shown that materials with bio-based origin often exhibit highly nonlinear behavior (e.g., a study done by Almgren et al.). In addition, due to their novelty, the different properties of these materials, especially their long-term behavior, are unknown. Thus, most of these material systems do not go beyond research laboratories. Therefore, if one wants to move the advancement made by research communities worldwide within Industry, more accurate and complex material models must be developed. More importantly, these models must be implemented in easy-use tools. Such a tool would allow anyone to use and predict the nonlinear behavior of materials without understanding the complex mathematics behind the material model.

In addition, structures themselves are becoming more and more geometrically complicated. This also increases the need for different simulation tools, but in this case, the tools need to capture nonlinear behavior in 3D. Most of the nonlinear models are developed for 1D cases. Even if some of the models are developed for 3D cases, methodologies for parameter experimental identification for these models are lacking. In the best-case scenario, there is a theoretical description of how such parameters could be obtained.

In order to simulate time-dependent isotropic material behavior in 3D, the nonlinearity of material has to be studied not only in the loading direction but also in the transverse direction. In the case of anisotropic material, the number of experiments significantly increases because each direction has to be studied separately.

Another challenge for the nonlinear modeling of complex geometrical structures is the need to find the nonlinear functions and parameters for the model in both loading modes - tension and compression. In theory, for some materials, the behavior in tension and compression could be similar, but this has to be experimentally determined.

Schapery has developed a nonlinear viscoelastic material model that has been used in numerous studies with high accuracy. Zapas model has shown good agreement with viscoplastic strain development. In the current work, these two models are used to characterize the nonlinear material behavior. The experimental

parameter identification needed for the 3D material model will be examined, the problems analyzed and solutions proposed. Initial experimental test results from experiments for function and parameter identification of the nonlinear material model (viscoelasticity and viscoelasticity) will be presented.

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EXPERIMENTAL INVESTIGATION OF HEAT AND MOISTURE TRANSFER IN BIO-BASED BUILDING BLOCK WITH MICROENCAPSULATED PCM

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Abstract. The paper presents the investigation of heat and moisture transfer in hemp shive and magnesia binder composite with microencapsulated phase change material (PCM) to increase the building material's thermal mass. The investigated sample was prepared as a three-layer block of dimensions 600×400×480 mm (length×width×height). External layers of the block had a density of around 500 kg/m^3 and thickness of 50 mm, while the inner layer had a density of around 300kg/m^3 and thickness of 300 mm. The study was performed with a block placed between two specially designed climatic chambers of dimensions 1500×750×1000mm (length×width×height). Temperature and relative humidity in chambers were stabilized by applying glycol heat exchangers working as coolers and dehumidifiers, electric heaters, and ultrasonic humidifiers. 300 mm diameter fans were used to force the flow of air in the system. Additionally, 50 mm wide channels in both chambers were designed close to the sample surfaces and contained matrices of small 50 mm fans to force uniform airflows along both sample surfaces. For parameters control in the chambers, dedicated software in Python, LuaScript, and LabView was written and executed on Raspberry Pi4, LabJack T7Pro, and notebook, respectively. The software allowed setting desired parameters in chambers, including temporal profiles of temperature and relative humidity loaded from the file. Inside the sample, nine temperature and relative humidity sensors (HDC 1080) were placed in the middle and at interfaces of each layer and additionally in the inner layer in 1/4 and 3/4 of its thickness. The sample was also mounted on balance to study weight changes corresponding

with water accumulation. During measurements, the temperature of 20°C and relative humidity of 50% were maintained in one chamber, while in the second one, different conditions were simulated to study the hygro-thermal behavior of the sample.

PROTOTYPE OF AN EXPERIMENTAL STAND FOR INVESTIGATING HEAT AND MOISTURE TRANSFER PHENOMENA IN BUILDING MATERIALS

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Abstract. The prototype of an experimental stand for drying building materials is presented in the paper. The stand is designed to validate a numerical model of heat and moisture transfer in porous media. The experiment was conducted in forced convection conditions. A sample was located in a holder so that only one surface (the top one) had contact with flowing air in the duct. The sample exchanged the heat and moisture with the flowing air through this surface. Two fans at the end of the duct induced the airflow through the vent. The stand was placed in a climatic chamber, stabilizing the temperature (22,5°C) and relative humidity (50%) during the experiment. A tensometric beam was used to measure the temporal variation of the sample mass. A resistance thermometer (PT100) was used to measure the temperature on the sample surface. Four samples (90x90x30mm each) from cellular concrete were prepared. Each sample was dried before the experiment, immersed in water for 24h, then wrapped in the foil and preconditioned (24h) in a climate chamber to equalize the temperature. The samples were dried on the stand for 48 hours. The procedure was repeated twice. Repeatability of results has been achieved. The accuracy of the experimental stand was insufficient. Hence further modifications need to be made.

HEMPCRETE – CO_2 NEUTRAL WALL SOLUTIONS FOR 3D PRINTING

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Abstract. Hempcrete is a bio-based self-bearing envelope and thermal insulation building material that is becoming more popular nowadays and has a low environmental impact, especially CO_2 emissions. This study looks for solutions for hempcrete printing using a custom-built gantry type 3D printer typically used for concrete 3D printing. Preliminary research shows that hempcrete can be printed at a relatively low density of 660 kg / m^3 and achieve adequate buildability and compressive strength for printing individual wall elements. At this density, hempcrete has a thermal conductivity of 0.133 w / (m · K), unable to provide adequate thermal resistance at average wall thickness, so high-density hempcrete should be printed as an outer wall shell (similar to Contour Crafting) and the middle filled with lower density thermal insulation hempcrete. By calculating the CO_2 emissions of such printed 400–620 mm thick walls, it was found that they absorb from 1.21 to 16.7 kg of CO_2 per m^2, thus, such material could reduce the negative environmental impact of the construction industry while improving its productivity through 3D printing.

SHAPING OF ROOFING STRUCTURES BASED ON A HYPERBOLIC PARABOLID

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Abstract. The article presents a comparative analysis of eight roofing structures, the shape of which is based on the surface of a hyperbolic paraboloid. The aim of the research was to select the most optimal option in terms of the adopted criteria.

The structure of the roofing is a square mesh of bars. Each of these structures was created as a result of putting together four individual modules, arranged in different ways. Two basic modules were created, both based on the surface of a hyperbolic paraboloid, from which eight alternative structures were created. The mesh of bars of each of them was created as a result of taking two initial sections, dividing them into the same amount of smaller segments, and then combining suitable pairs of points resulting from the division on both initial sections. In this way, a bar structure was created that was a slice of the surface of the hyperbolic paraboloid.

In accordance with the applicable norms, a static analysis was made, the cross-sections of the bars were selected, and a comparative analysis was performed on the basis of the obtained results. The criteria for comparison were the shape of the formed covering and the possibility of eventual precipitation in the resulting depressions; maximum deflection of the mesh bars while maintaining the smallest possible weight of the structure, as well as the visual attractiveness of the object.

At the very beginning, three structures could be eliminated due to the impractical shape that would cause precipitation to accumulate in the depressions. Then, on the basis of the obtained calculation results, a structure that meets all the assumed criteria was selected.

The creation of the checked structures showed how easy it is to approach shaping a structure based on the shape of a hyperbolic paraboloid and how many positive static and practical features such structures have.

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COMPLEX COATING SYSTEM FOR IMPROVING CORROSION RESISTANCE OF AZ31 MAGNESIUM ALLOY

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Abstract. Nowadays aviation, aeronautics, transport, and construction material industries are searching for light metals and their alloys, that could be used to produce lighter products. Scientists are strongly looking at magnesium and its alloys, because they are up to 30% lighter than now widely used aluminium alloys. However, because of magnesium high chemical activity, it is subjected to corrosion, moreover a dense protective oxide layer does not naturally form on it, as it does in case of aluminium. The most effective corrosion protection for magnesium alloys produces methods, that create barrier layers, such as anodizing, plasma electrolytic oxidation (PEO) or chemical conversion. However, known corrosion protective methods of magnesium alloy do not give satisfying results, they are expensive and harmful to the environment, because they use compounds that contain Cr^{6+} and F^- ions. [1,2]

In this research a new environmentally friendly and cost-effective complex magnesium alloy AZ31 processing method, which includes 3 protective layer creation on the alloy surface, was developed. By using PEO method and a bipolar power source, in a low concentration electrolyte solution, a 7-15µm dense and amorph oxide layer with low porosity was obtained. This layer was at the same time modified with Zr, Si and P to further improve corrosion protective layer durability and mechanical properties.

Because in the PEO process obtained samples are porous and corrosion usually starts in the pores, it is necessary to fill these pores. For this purpose, we chose spray pyrolysis method which allows to cover samples surface with a dense oxide layer, by rapidly evaporating and crystallizing reaction salt solution when it is sprayed on heated magnesium alloy surface. To obtain TiO_2 coating with spray pyrolysis method, titanium isopropoxide solution was used and the processed AZ31 alloy surface was heated to 200°C, that provides proper TiO_2 adhesion properties. The influence of pray pyrolysis process duration on corrosion resistance was investigated.

In the third stage a polyurethane layer was obtained with spray gun that provides additional protection against corrosion. The selected paint system guarantees high adhesion and elasticity that does not allow microcracks to form.

To evaluate samples corrosion resistance properties, obtained samples were immersed in 3% NaCl solution for 168h and after that surface was analyzed by using scanning electron microscope.

It was concluded that the developed protective layer system successfully protects magnesium alloys from corrosion.

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TESTING OF BRITTLENESS FOR SELECTED STAINLESS STEEL GRADES COOLED DOWN AFTER SIMULATED FIRE OCCURENCE

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Abstract. The results of the Authors' research on the post-fire susceptibility to brittle fracture of selected types of stainless steels are presented and extensively discussed. The changes in the value of the breaking energy KV identified after subjecting the samples made of the steels of this kind to episodes of heating in the steady-state heating regime and then cooling in simulated fire conditions were treated as the evaluation criterion. These changes were recorded and compared to the material initial state, based on the instrumented Charpy impact tests. The detailed analysis pertained to steels of varied microstructure, in particular: X20Cr13, X6CrNiTi18-10 and X2CrNiMoN22-5-3 - of martensitic, austenitic and mixed austenitic-ferritic duplex type, respectively. Two different levels of heating temperature have been applied, namely 600oC and 800oC. The first level is to low, while the second one is sufficiently high to induce structural changes expected by the Authors in the material during the exposure to fire temperature. The cooling mode of the test samples had been varied as well. Slow cooling in the open air has been compared in the experiment with rapid cooling in water mist, simulating the results of extinguishing action conducted by fire brigade. The instrumented Charpy impact test was conducted at -20oC and + 20oC to simulate winter and summer conditions. The conducted analysis was aimed at assessing the risk of sudden, catastrophic fracture of load-bearing structure made of steel degraded as a result of a previously surviving a fire with different development scenarios. Detailed analysis of the force – displacement and breaking energy – displacement diagrams, based on the recommendations of the EN ISO 14556 code, yielded basic information regarding the possible brittleness incurred as the result of prolonged heating. The results obtained during the experiment unequivocally indicate, that the fire conditions, in particular the manner of conducting the firefighting action, determine the post-fire steel resistance to brittle crack initiation and unrestrained crack propagation. The capability of the material to spontaneously arrest the initiated crack depends in a way that is no

less important on the internal microstructure of the material observed after fire, and this in turn is conditioned by the changes, which occur (or potentially do not occur) as a result of a fire action.

Keywords: stainless steel, fire, steady-state heating regime, impact test, breaking energy.

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A PRELIMINARY REVIEW OF MECHANICAL TREATMENTS' EFFECT ON THE REACTIVATION OF HYDRATED CEMENT PASTE

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Abstract. More than 4.4 billion metric tons of cement were produced in 2021 [1], making it one of the most common building materials. Unfortunately, excessive cement use brings up several environmental concerns, one being the enormous volumes of CO_{2e} created as a by-product. Reducing CO_2 emissions is crucial in modern cement manufacturing, as 0.9 kg of CO_{2e} is produced for every kg of cement. Cement manufacturing contributed by releasing 3.96 Gt of CO_{2e} into the atmosphere in 2021. This issue is often remedied using recycled raw materials in the fresh concrete mix. Usually, these recycled cementitious materials are ground and thermally activated to regain their reactivity [2–5], but not many researchers characterize ground cement for its properties as a supplementary cementitious binder [6]. The primary outcome of mechanical activation is mineral particle fragmentation, which affects a wide range of physicochemical characteristics of a specific system. The crystal structure of a mineral often becomes disordered during mechanical activation, and the development of crystal lattice defects or other metastable forms can be observed [7]. According to reports, using high-energy mills, such as planetary and vibratory mills, significantly alter solid phase structure and surface characteristics [8]. This study investigated a technique for recycling hydrated cement paste by mechanical treatment method to disintegrate the hydrated cement conglomerate to reveal the unhydrated cement particles [9] that can be used as a supplementary cementitious binder made from processing waste from the production of wood-cement boards. During the quality assessment phase, 1440 m^3 of processing waste a year is produced in one manufacturing plant in Latvia, when the wood-cement boards are cut, prefabricated, polished, and machined for a smoother surface. Processing waste is defined as dust particles no larger than 1 cm containing hydrated and unhydrated cement [10] and spruce wood particles. The developed binder was characterized by mechanical compressive strength. The cement in the waste stream was mechanically processed in a planetary mill to reactivate it and restore its cementitious characteristics.

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HUMAN AND ORGANIZATIONAL FACTORS IMPACT AND IMPORTANCE IN ENGINEERING DESIGN

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Abstract. The impact of Human and Organizational Factors (HOF) on operations and processes is already well known in many industries such as medicine and nuclear power. Ignoring HOF when organizing work with machines and mechanisms increases the possibility of risks that may arise when servicing or working.

To ensure high safety performance and non-accident operation when servicing devices, more attention should be paid to HOF if it was not considered at the design stage. The importance of HOF must be considered at the initial stage of designing as well as during modernization. If HOF was not considered at an sufficient level, then are necessary a corrective measure to reduce the risks that arise when working with equipment.

The paper shows the importance, as well as the main approaches for introducing HOF into the culture of the organization to improve safety performance. Based on the studies carried out by European and world scientists, recommendations are given to ensure the interaction of HOF with existing technical solutions, systems and regulatory with the aim of improve the working environment and increase safety performance.

Keywords: Human and Organizational Factors, safety performance, working environment.

RECYCLED WASTE GLASS USAGE FOR CONSTRUCTION MATERIALS

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Abstract. Recycling glass waste obtained from different industries is an issue in today's economy. One of the ways is to produce lightweight ceramic by applying glass waste, clay, and gasifier as raw materials. The present research has been devoted to evaluate the influences of different clays extracted from two Latvian quarries (Lielauce un Samini) on the properties of lightweight ceramics. The main criteria of applicated clay as raw materials for producing lightweight ceramic are the following: saturation of SiO_2 should be a maximum of 70% and Al_2O_3 minimum of 12%. The aim of the present research was to elaborate a composition for producing glass ceramic from glass waste with minimum energy consumption with/without a gasifier. The most important properties of the final product are thermal conductivity, compression strength, volume density, size, granulometry, and pore distribution. Three parameters of them thermal conductivity, compression strength, and volume density have been tested and analyzed in the present research framework. Burning time is one more important additional parameter, which has been taken into account evaluating the properties of the final product. The obtained volume density is in the range of 226.75 kg/m^3 to 475.78 kg/m^3 depending on the composition.

RESPONSIBILITY FOR MEASURING CONSTRUCTION CONTRACTS IN CZECH CONSTRUCTION COMPANIES

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Abstract. Construction contract measurement systems have proven to be a valuable tool for controlling the efficiency of individual construction contracts. With the pressure to improve efficiency in the construction industry increasing, even smaller companies are now forced to implement complex measurement systems. Correct contract measurement requires companies to designate persons or teams accountable for conducting this task and also to ensure that the measurement data are evaluated correctly. This paper describes contract measurement practices in Czech construction companies, such as whether contracts are measured only after completion or also during execution, who actually conducts the data measurement and who bears the overall responsibility. We also investigated whether and how often ex-post measurement audits are carried out in companies. Information has been collected through an ongoing questionnaire survey, which will also be supplemented by interviews with experts from selected Czech construction companies. Data collection has been conducted since the beginning of 2022 and will be completed during the spring of 2022, after which individual experts will be identified and interviewed. The results of the survey will be evaluated by analysing the frequency of responses. Interim results show that the vast majority of companies measure contracts during and after execution. Measurement is most often the responsibility of the project manager and his/her team or the production preparation team in the company. Almost half of the enterprises then carry out regular audits that examine the measurement and evaluation of construction contracts. Around 20 per cent of the companies do not carry out any measurement audits at all. The main objective of the interviews with experts presented in this paper was to obtain more granular information on why measurement responsibilities differed from one company to another and why some enterprises implemented measurement audits while others did not. These results will further support our long-term research into construction contract measurement practices and the ways in which the currently used systems can be improved to increase overall construction contract efficiency.

INFLUENCE OF THE SHIVES ORIENTATION ON SELECTED HYGRO-THERMAL PROPERTIES OF HEMP-MAGNESIUM COMPOSITE

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Abstract. Magnesium binder is an alternative to lime binder in the technology of hemp-based composites. It is a binder made by mixing magnesium oxide with a water solution of magnesium chloride. The advantage of using this binder is an increase in mechanical strength compared to those based on lime. Thanks to this, it is possible to reduce the proportion of binder in relation to the composite. These composites are mainly used as an insulating wall material, as a filling of a wooden frame structure. Hemp shives are pieces of hemp wood obtained from stalk, with a length of several to several dozen millimeters. During compaction, they tend to lay with fibers perpendicular to the compaction direction. The direction of the fibers in the shives, as well as the direction of the capillary pores affect the properties of the composite[1]. The performance characteristics of a building partition insulated with a composite will vary depending on the direction of the shives in relation to the direction of the external factor. The outer wall is exposed to heat flow and water transport, e.g. by capillary action.

The article presents the results of tests of the thermal conductivity coefficient and capillary rise of a composite densified in the direction perpendicular and parallel to the heat flux and moisture flow. Composites samples with a bulk density of about 400 kg/m^3 were tested. Compaction of the mixture in the direction parallel to the heat flow decreased the thermal conductivity. When the composite is used as a monolithic wall insulation, compaction usually occurs in a direction perpendicular to the heat flow. However, due to the reduced value of the thermal conductivity of the composite compacted parallel to the heat flux, such a technique can be used in prefabrication, e.g. in the production of wall blocks. This direction of compaction - perpendicular to the wall surface, and thus to the direction of capillary rise, also reduced the amount of uptaken up water and changed the course of water rising over time. Based on the results, it can be concluded that the targeted orientation of the shives in the wall made of hemp-magnesium composite may bring benefits. It is worth considering the specific direction of compaction depending on the place of application of the composite and the types of external factors affecting the building barrier.

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INVESTIGATIONS OF CEMENT COMPOSITE WITH EXPANDED GLASS FILLER AT HIGH TEMPERATURES

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Abstract. Lightweight refractory composite with expanded glass filler, calcium aluminate cement, additives of metakaolin waste, microsilica and hybrid deflocculants were investigated. The microstructure analysis were performed by using the scanning electron microscope. In addition, the thermal shock resistance, physical and mechanical properties of the composite were deter.ined. Significant changes in microstructure of the composite was caused after firing at the temperature of 1000°C when the expanded glass filler was melted.

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ENGINEERING GRAPHICS AS THE LANGUAGE TOOL FOR COMMUNICATION WITHIN ENGINEERING COMMUNITY

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Abstract. The tools of expression in Engineering Graphics (EG) are graphic representation, figure (image) and drawing specification, which are perceived by the visual and auditory organs (in the case of verbal contact between the writer of a drawing and the reader of a drawing, i.e. the oral form), and represent the means of communication for engineering practice. The requisite elements for the communication model are: sender, receiver, channel, medium and at least a partially overlapping sign repertoire of sender and receiver (Fig. 1.). However, the overlapping part is trivial and already knows to us and its role is merely to establish contact. On the other hand, the more different are languages of communication, the more complicated it is to translate a message expressed in one language into another. This can lead to conflict where communication is obstructed or even impossible. In the present context, we address potential conflict between natural language (words) and (figures) where there continuous dialogue and transmitting of messages from system of signs into another. In this situation it is essential that at

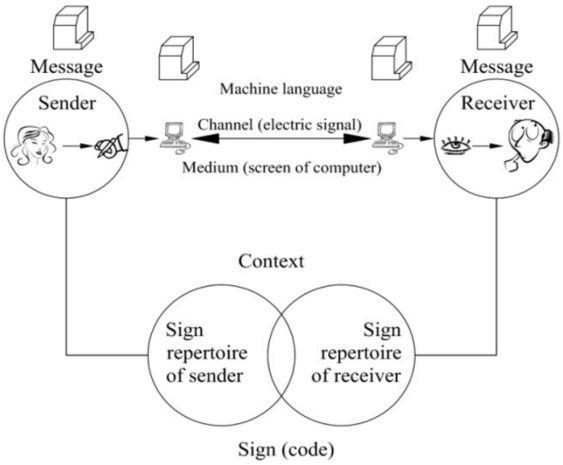

Fig. 1. A communication model involving the use of computers (the model is editorially modified by Tasheva)

least one system of signs is unambiguously understood by both parties – and this is communication by using professional figures, i.e. Engineering Drawings (ED). A successful creating drawings (models) helps to understand the way how the object is constructed in order to transmit it' as a message across languages and cultures.

Signification of engineering imagination (non-existing structure) occurs in the encoding and decoding process within the framework of the communication model (Tasheva, 2012, Fig. 1) as data carrying information must be coded in some way. The ED can be seen as a monomodel in which the visual representation is given in a highly conventional way, expressing the meaning exactly and systematically. ED are prepared using the same design standard, instructions, databases and other documentation. Thus, irrespective of the language, ED are unambiguously understood by all people living e.g. in the Western culture space. Consequently, in engineering specialities, where EG is the basic course, it should be acquired as *lingua franca.*

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ADDRESSING SHRINKAGE STRESSES IN ADMIXTURES AND SURFACE HARDENERS OF CONCRETE FLOORS

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Abstract. Today contemporary construction is evolving rapidly, and main objectives that describe the process are quick, simple, and profitable erecting of buildings. On the opposite, buildings must be built with great durability quality, and sustainability. Using new and innovative materials, e.g. fibre reinforced concrete has many advantages: quick and simple installation, easy maintenance, and fast labour training. Steel fibre reinforced concrete is widely used for building floors and foundations more efficiently, which saves time and money for the investor and the building company. Using several types of floor coatings is a way to reduce the maintenance cost and to prolong the lifetime of floors. Surface hardeners can be applied two ways: into the top layer of fresh concrete and onto the hardened concrete floor. Different physical and chemical processes occur during the hardening of concrete (Holt, 2001), resulting in shrinkage, which in turn leads to cracking of surfaces of floors. To reduce the shrinkage of concrete, various admixtures, fibres, and aftercare methods can be introduced.

The aim of research was to study the effect of various steel and synthetic fibres, and chemical admixtures on concrete shrinkage, and to compare the obtained results with concrete without any additives. The specimens were made and results obtained in accordance with the standard ASTM C490. 26 series of experiments were carried out, each consisting of six to twelve specimens. The shrinkage was determined by measuring length change, and a rig was specially designed and manufactured for this study. Residual stresses were calculated by using Hooke's Law and comparative tests were conducted by hole-drilling method in macro level. The data was analysed by fitting exponential curve and *genfit* function in MathCAD and they coincided well. The results were also compared with shrinkages of different surface hardeners.

The results clearly indicate that the number of fibres in the specimen affect the shrinkage. The less the fibres, the bigger the shrinkage. Orientation of the fibres in the specimen has impact on the shrinkage. Experiments showed that standard concrete shrunk less than the surface hardeners, and the concrete could shrink even less when chemical additives are used.

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IMPACT OF POLYPROPYLENE, STEEL AND PVA FIBRE REINFORCEMENT ON GEOPOLYMER COMPOSITE CREEP AND SHRINKAGE DEFORMATIONS

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Abstract. For the last 40 years, there have been increased interest in geopolymer composite development and their mechanical properties. In the last decades, there have been cases when geopolymer composites have been used for civil engineering purposes, such as buildings and infrastructure projects. The main benefit of geopolymer binder usage is that it has a smaller impact on the environment than the Portland cement binder. Emissions caused by geopolymer manufacturing is at least two times less than emissions caused by Portland cement manufacturing.

As geopolymer polymerization require elevated temperature, it also has a significant moisture evaporation effect that further increases shrinkage. It can lead to increased cracking and reduced service life of the structures. Due to this concern, for long-term strain reduction, such as plastic and drying shrinkage and creep, fibre reinforcement is added to constrain the development of stresses in the material.

This research aims to determine how different fibre reinforcement would impact geopolymer composites creep and shrinkage strains.

Specimens for long-term property testing purposes were prepared with 1% of steel fibres, 1% polypropylene fibres (PP), 0.5% steel and 0.5% polyvinyl alcohol fibres, 5% PP fibres, and without fibres (plain geopolymer). The lowest creep strains are 5% PP fibre specimens followed by 1% PP fibre, plain, 0.5% steel fibre and 0.5% PVA fibre, and 1% steel fibre specimens. The lowest specific creep is to 5% PP fibre reinforced specimens closely followed by 1% PP fibre followed by 0.5% steel and 0.5% PVA fibre, plain and 1% steel fibre reinforced composites. Specimens with 0.5% steel and 0.5 PVA fibre showed the highest compressive strength, followed by 1% PP fibre specimens, plain specimens, 1% steel fibre, and 5% PP fibre reinforced specimens.

Only specimens with 1% PP fibre and 0.5% steel, and a 0.5% PVA fibre inclusion showed improved mechanical properties. Geopolymer concrete mix with 1% PP fibre inclusion and 0.5% steel and 0.5% PVA fibre inclusion have a 4.7% and 11.3% higher compressive strength. All the other fibre inclusion into mixes showed significant decreases in mechanical properties.

MORPHOLOGY AND MECHANICAL PROPERTIES OF PAN NANOFIBER MAT

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Abstract. Nanofibers have acquired greater interest due to their vast variety of possible uses. Nanofibers offer several options to change things physically and chemically during or after the manufacturing process to give them new properties. To exploit the full potential of nanofibers, it is necessary to comprehend the link between the mechanical characteristics, particularly tensile strength, of a nanofiber mat and its morphology. Electrospinning is a rapidly developing polymer processing technology because it provides a simple and effective method for manufacturing nano continuous fibres. This method permits the deposition of nanofibers on revolving collectors. Rotating collectors, such as the drum and electrodes with a gap between them, may readily form oriented fibres. Polyacrylonitrile is a common precursor material for carbon nanofibers (PAN). This research investigates the impact of collector drum's rotation speed on the morphology of the nanofiber mat and discusses the mechanical properties of Polyacrylonitrile (PAN) electro spun nanofiber mats with precisely aligned nanofibers. PAN nanofiber mats have more strength than PA6 nanofiber mats and have less elongation than PA6 nanofiber mats, according to a comparison with previous references studies.

IMPACT OF AMINO ACIDS AS PERFORMANCE-CONTROLLING ADDITIVES ON THE HYDRATION OF REACTIVE MGO

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Abstract. Since reactive magnesia (MgO) is produced at a lower temperature than CaO and is capable of sequestering significant quantities of CO_2, it is considered a more sustainable and technically superior alternative to Portland cement. To obtain maximum carbonation and associated high strengths, a variety of additives are investigated. Using amino acids as an additive is a new concept to control the polymorphism of carbonates. As the hydration of magnesia plays an important role in the magnesia carbonation, this study investigates the impact of amino acids (i.e. L-arginine (L-Arg) and L-aspartic (L- Asp)) on the hydration of magnesia. The results revealed that magnesia hydrated with/without amino acids only formed brucite ($Mg(OH)_2$) as the hydration product. The hydrated composites produced with amino acids were observed to have a lower hydration degree, regardless of the type of amino acids. Specifically, the use of L-Asp not only delayed the hydration of MgO but also reduced the amount of brucite. The increasing amorphousness of brucite with increasing L-Asp concentration was also observed, compared to the control batch. Additionally, Mg^{2+} concentration was increased with the addition of L-Asp, allowing the blends to absorb more CO_2 with a higher concentration of Mg^{2+}.

METHODS FOR MEASURMENT OF THE PLASTIC SHRINKAGE CRACKING OF 3D PRINTED CONCRETE COMPOSITIONS

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Abstract. Developments in the application of the 3D Concrete Printing (3DCP) technology in the construction industry over the past few years are providing a chance to increase productivity and cost efficiency. However, before reaching an industrial stage of the 3DCP technology several hurdles should be overcome. One of the major challenges is to guarantee high durability and long-life cycle of the printed elements. Since 3D printed elements are subjected to very early and fast evaporation of the pore water, accelerated capillary pressure build-up may lead to severe plastic shrinkage and, consequently, a high cracking propensity of the 3D printed elements. Durability and robustness would be severely impaired. Experimental quantification of the plastic shrinkage and related cracking is essential in order to identify appropriate mitigation strategies. The article at hand presents innovative approaches for quantification of the plastic shrinkage and related cracking of the printable cementitious compositions by means of contactless 3D digital image correlation technique. Various experimental setups were presented and their effectiveness for measurement of the plastic shrinkage cracking were analysed.

RADIANT CAPILLARY HEAT EXCHANGERS - POWER CALCULATIONS FOR OPTIMAL HEATING AND COOLING

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Abstract. Due to the recent rise in energy prices in Europe, the issue of switching to renewable energy sources becomes very actual. And it is important not only to change the energy source, but also the reduce the final energy needs by improving the energy efficiency of buildings and usage if highly efficient heating systems.

Heat pumps are the most popular renewable energy source used for heating, whit costs comparable to the gas and central heating. Their high efficiency increases with reducing the temperature difference between the energy source and the heat exchanger installed in the room. The heat carrier in traditional convectors has temperature above 50°C, while use of classical underfloor heating system needs water temperature around 40°C. The most effective are radiant capillary heat exchangers with large surface area, which allows to reduce temperature to 26-30°C providing the same power. Another advantage of radiant capillary heat exchangers is the possibility to operate them in both – heating and cooling modes.

Some studies of widespread used underfloor heating systems showed some more negative effects like discomfort risk due to increased floor surface temperature and intensified floor dust spinning. Mentioned disadvantages are avoided when using radiant capillary heat exchangers with lower temperature, building them into ceiling and/or wall constructions. Unlike the underfloor heating solution, where the role of thermal convection is very important, the built-in systems provide heating or cooling mainly due to thermal radiation.

The advantages of radiant capillary heat exchanger system are:

- energy economy due the less heating / cooling energy need,
- better hygiene conditions due the less air circulation with dust, allergens, and micro-organisms,
- functionality due to combined heating and cooling control system;
- flexibility due to invisible and easy installation, saving space;
- overall efficiency due to fastest room temperature control and possibility to combine with ventilation systems.

This study describes two calculation approaches for determination of needed power and corresponding area/amount of radiant capillary heat exchangers to be installed in rooms to provide necessary heating or cooling power: - simplified and very easy approach, which allows to obtain preliminary estimates required

for design with a minimum amount of input data; - complex and precise approach based on the standard methodology for building's energy performance of buildings.

Calculations were made for some different room types (e.g., small room, room with large glazed facades,) with the help of both approaches. The results obtained have been comprehensively analyzed comparing them to the theoretical radiant heat exchange model for room, as well as with monitoring results for a test room with already installed radiant capillary heat exchanger. The maximally simplified approach gives sufficiently accurate results in most of cases, however, there are some types of rooms (e.g., with a large glazing area), where a more detailed calculation based on the complex modelling approach is required.

This work is supported by the by the European Regional Development Fund project "Development and approbation of complex solutions for optimal inclusion of capillary heat exchangers in nearly zero energy building systems and reduction of primary energy consumption for heating and cooling" (1.1.1.1./19/A/102) and postdoctoral project "Analysis of the actual energy consumption of zero energy buildings and the zevelopment of the necessary energy efficiency improvement solutions" (1.1.1.2/VIAA/3/19/505)

SOCIO-ECONOMIC IMPACTS OF GREENERY AREAS IN URBAN DEVELOPMENT

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Abstract. One of the major themes of sustainable urban development is adaptation to climate change through the protection, maintenance of existing and creation of new green spaces. In the design areas of the municipal master plan, green spaces are designated for specific ecosystem services, which can be divided into 4 basic categories of regulating, cultural, productive, and supporting services related to biodiversity. Thus, green spaces affect human well-being and can serve as a benchmark to assess the quality of human life. Therefore, it can be concluded that the functioning of green space ecosystem services generates socio-economic impacts, benefits, and harms, for the actors in its surroundings. In their article, the authors focus on describing the specific socio-economic impacts generated by different elements of urban green spaces, quantifying their effects in units of measurement, and outlining possible ways of valuing them. The aim of the research in the longer term is to incorporate monetised benefits and impacts of green spaces into the assessment of the economic efficiency of design areas.

CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT IN LATVIA

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Abstract. Since environmental conservation has been mainly critical worldwide, it is crucial to regulate the environmental impact caused by construction activities. The acute problem of utilization and recycling of construction waste, despite enough solutions, is determined by an increase in waste generation and accumulation. To solve this problem, it is necessary to create a comprehensive approach and direct efforts to minimize waste generation and then to develop effective methods for processing construction waste. Nonetheless, existing researches propose that there has been a slow improvement in the market of recycled construction materials. This can be explained by insufficient management of construction waste, it should become an integral part of any project development. Every stakeholder involved in the project, from the owner and architect to contractors and subcontractors, must manage construction waste throughout the project.

The aim of the research was to investigate the construction and demolition waste (CDW) management in Latvia and find causes and effects of it, as well as to find out the barriers of efficient CDW management.

The Ishikawa diagram, also known as "cause-effect diagram," was used to categorize and visualize potential causes of a problem and get to the root cause. All causes related to the problem under this study are detailed within five categories:

- causes related to the method of work;
- machinery and materials -related causes;
- causes related to the person;
- management-related causes;
- external causes.

For visualizing the findings a Problem Suggestion-Benefit diagram has been developed. When developing this diagram, it has been assumed, that the difficulties (Problems) of implementing sustainable waste management will be in the base, as they are the root of causes that hold back the development within this sphere. It is also important to take into account that identification of the potentials problems and finding of the solution to each is recommended at the initial stage of the construction projects and have to be organized as a brainstorming meeting involving the main stakeholders of the project.

According to EU Waste Framework Directive and other foreign practices to reduce the environmental impact of production and consumption waste management,

and to implement environmentally oriented management methods and at the same time solve the most significant economic tasks faced today the following CDW reduction plan can be suggested:

1. Make reduction plan for construction waste
2. Reducing the amount of construction waste in the design of the facility
3. Documents containing requirements to reduce the volume of construction waste
4. Reducing construction waste at the worksite

The contractor may contract with individual recycling firms that handle certain materials in addition to transporting waste. This requires the contractor, subcontractors to separate waste, dispose of it in appropriate containers, and protect it from contamination by other materials. Special attention needs to be paid to increasing awareness and training among the employees.

As it has been studied in this research, waste elimination and minimization can only be addressed only if waste will be perceived as a value. The main problem of addressing waste reduction lies in the different angles of perception of the value of each construction project stakeholder. However, this research also revealed that there are also several significant external and internal barriers, which restrain from having an enabling environment to adopt waste minimization strategies.

To promote recognition of the CDW management system and its benefits, the government, technical agencies, commercial organizations, and certification bodies have to be more active and use mass media and e-commerce to enhance the recycled materials market; introduce price-based customer targeting mechanisms, improve licensed recycled materials and services; VAT mitigation for companies introducing the circular economy concepts.

This research was funded by the FLPP (Fundamental and Applied Research Projects) Programme in Latvia under the research project LZP-2020/1–0010 «Reuse of gypsum and expanded polymers from construction and demolition waste for acoustic and thermal insulation panels».

EFFECT OF FIBRES IN CONCRETE WALLS NEAR POINT LOADS

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Abstract. Concrete walls are one of the structural elements, in which short steel fibres can be effectively utilised. Although the influence of this type of reinforcement to the load bearing capacity is small or even negative, the main effect of fibres is the increased ductility after the maximum load is reached. The effect is somewhat similar to the minimum reinforcement required by the design standards. If walls requiring only minimum reinforcement were reinforced with fibres instead, production time of the elements could be decreased significantly.

However, walls may be subjected to different loading conditions, therefore the evaluation of the fibre effect needs to be done by considering them all. The study is a part of a research project devoted to the evaluation of fibre effect in structural concrete walls. In this study, local crushing near point loads applied on the top of walls is investigated.

Experimental study, in which wall-type concrete elements with four different reinforcement, was conducted. Two groups of specimens were reinforced with steel fibres (d=0.5 mm, l=35 mm) with nominal amount of 40 kg/m^3 and 80 kg/m^3. Two other groups of specimens were made of plain concrete and reinforced with conventional reinforcement as the samples of reference. Two distinct conditions were simulated: 1) the point load applied at the top middle and 2) the point load applied at the top corner of the wall. All together 52 wall specimens were produced and tested in compression.

The results show that the load bearing capacity is related to the failure mode. Both short steel fibres and conventional reinforcement can influence both the maximum load bearing capacity and the post peak residual strength. Negligible effect of fibres was observed for specimens with fibre amount of 40 kg/m^3. However, specimens with nominal fibre amount of 80 kg/m^3 showed noticeable increase of the residual bearing capacity, while the maximum load bearing capacity was smaller than for control specimens. A significant influence of fibre distribution on the residual strength was noticed. This attests the well-known phenomena of FRC that casting technology plays crucial role in the reliability of FRC structures. This is important aspect especially if local crushing is considered, because the locally applied point loads can coincide with local zones of unfavourable fibre distribution.

All the specimens were manufactured by JSC "MB Betons". The research is financially supported by European Regional Development Fund. Project No. 1.1.1.2/VIAA/3/19/487, "Efficiency of fibre reinforced cement composites in structural walls"

EFFECT OF HOLLOW CORUNDUM MICROSPHERES ADDITIVE ON PHYSICAL AND MECHANICAL PROPERTIES AND THERMAL SHOCK RESISTANCE BEHAVIOR OF REFRACTORY CASTABLE

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Abstract. Most high temperature processes in industrial furnaces are combined with cycles of heating and cooling. In these applications, refractory materials are exposed to temperature gradient during operation, which causes thermal stresses and damage to the material. Therefore, the durability of the structures significantly depends on the thermal shock resistance of refractory materials used in thermal units.

This work analyses the effect of hollow corundum microspheres (HCM) on both physicalmechanical properties (density, modulus of elasticity, and compressive strength) and thermal shock resistance behavior of refractory cement based castable with bauxite aggregate. It was found that the replacement of bauxite of 0–0.1 mm fraction by HCM (2.5%, 5%, and 10% by weight of dry mix) had no significant effect on the density and compressive strength of castable, while the modulus of elasticity decreased by 15%. Ultrasonic pulse velocity values and the visual analysis of the samples after thermal cycling showed that a small amount of HCM in composition of refractory castable could reduce the formation and propagation of cracks and thus increase its thermal shock resistance.

ROAD TRAFFIC SAFETY ANALYSIS OF DIFFERENT JUNCTION TYPES ON THE STATE ROADS

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Received day month year; accepted date (use style Received dates, or Alt + Ctrl + R)

Abstract. The highest number of road accidents occurs at junctions. One of the aims of traffic organisation is to improve traffic safety in these areas. Based on a variety of indices – road capacity, points of conflict, number and severity of road traffic accidents – different alternatives for junctions are evaluated. However, the road network has many junctions and roads serve as a means to travel from point "A" to point "B" at a given time. Therefore, one of the most important tasks when addressing the issue of road safety is to find a rational way of improving the safety without losing the importance of the road. The aim of this paper is to analyse the impact of different junctions on the road network and basing on actual data develop a method for the evaluation of different types of junctions with respect to road class.

METHOD AND APPARATUS FOR DYNAMIC TESTING OF STRUCTURAL JOINTS

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Abstract. Dynamic testing is used during the design phase of structures and series production. This type of test evaluates the structural capacity, especially of the assemblies, to withstand different forces and rates of the impact encountered under realistic operational conditions. This study proposes a magnetic impulse actuator for high high-speed impact loading in dynamic tests because of its capability to provide single and repeatable impulse loading over a wide range of forces from 1.0 to 20 kN and pulse durations from 10 to 1000 μs. The method is based on transforming accumulated electrical energy in a capacitor bank into mechanical energy.

For experimental investigations, flat and cylindrical coil inductor devices were used for a capacitor-type pulse current generator. Accelerometers were used to assess the quality of structural connections of structures, providing measurements in 3D spatial directions. The proposed method has been experimentally validated on steel and timber beams in a specified volume of force loading. The technique demonstrated a potential for controlling force and energy parameters. The effect of operating voltage on the coil, the distance from the coil to the investigated object, and the electrical conductivity of the object material on the magnitude of dynamic loading has been investigated. Steel plates fixed on the object at the point of impact were used to improve the efficiency. The technique can be used in experimental studies on models and real objects.

Special attention has been paid to developing a portable, durable and user-friendly device that sets the dynamic loading and a device that acquires and processes the data. Studies have shown that non-linearities in pulse loading occur due to variations in frequency and shape of oscillations, inductor displacements, weight and physicomechanical characteristics of the impactor.

Keywords: dynamic tests of structures, magnetic-pulsed drive, inductor, coil, accelerometer.

AL-TI-MG COMPOSITE TARGET FOR PVD PROTECTIVE COATINGS FOR MAGNESIUM MADE BY POWDER METALLURGY TECHNIQUE

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Abstract. Target metal plates for PVD application made from ternary metal composites of Al, Ti* and Mg were produced by compacting metal powders. Al content was fixed at 70 wt. % and the other two were changed to study the effect of composition on the properties of the plates. Ti* powder, in the form of Ti6Al4V alloy, and pure Mg powder were varied in ratios of 2, 1 and 0.5 by weight. The compositions can be written as Al-70 wt.% Ti*-X wt.% and Mg-Y wt.% (X=20, 15,10, and Y=10, 15, 20). The powders were wet milled and compacted under uniaxial compressive load to form the plates. The strength of the plates was measured by performing 3-point bending tests and load till failure was reported. Effect of cold compaction load, mixing time of the powders and Ti* powder content on the microstructural and mechanical properties was studied.

SEQUENTIAL BENDING CONTROL VIA ORIGAMI WITH MULTI-STABILITY

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Abstract. The sequential actuation control, folding in the case of origami-inspired mechanisms, is an essential feature to achieve more complex geometries avoiding a self-collision between parts during assembly[1] and also allows motion programming. To do that, usually electronic controllers and smart materials can be employed, allowing autonomous action and, in the case of smart materials, with passive energy.

However, adopting a more structure-focused approach can reduce the complexity of the control system and the number of responsive actuators or the need for active control systems[2], which is especially useful in extreme environments where electronics can be affected like, for example, cosmic radiation in space[3]. This work was focused on a structural approach to generate an actuation sequence in origami-inspired mechanisms by using crease patterns that exhibit multi-stability features. There were two main concepts investigated to achieve this goal, both concerning the control of the energy transition barrier between attractors of origami bi-stable systems and by a using set of coupled modules that make up the structure.

On one hand, the geometric method allows the sequential actuation by coupling modules with different energy barriers predetermined by its geometry and smart material in these crease lines[4], so when a stimulus begins to increase it begins to "activate" from the latest barrier energy to bigger one. On the other hand this geometrical driven control does not allow reconfiguration after the making of a module.

The second method is focused on coupling the building blocks to achieve control, that uses the same crease pattern. When coupled these modules interfere in its neighbour energy barriers[5], allowing a conditional activation and reconfiguration after making the module. This also does not depend on increasing stimuli, since the activation of a neighbour can reduce the energy barrier of a module and make it activate in a condition that previously wasn't possible.

Thus the coupling drive control was the main choice to improve a system that exhibits sequential folding. To achieve the self-propelled system there was one more requisite, this actuation need to be periodic and this need of a gradient stimuli. To deal with that was proposed a type of move that produces this gradient.

By rolling movement, and luminous stimuli, one can obtain a structure that projects a shadow in the bottom part, producing a gradient stimulus needed.

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DEVELOPMENT OF PRACTICAL EXERCISES FOR THE ENGINEERING GRAPHICS COURSES INTEGRATED INTO AR MOBILE APPLICATION

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Abstract. In the 21st century, the use of modern technology in teaching is crucial. In addition, in the context of the COVID-19 pandemic, remote learning has become the main form of education in many educational institutions. Students need more time to study subjects independently. In this situation, educators are on the lookout for ways to improve their teaching materials so that students can learn effectively. The ability to comprehend and create technical drawings is a necessary skill for engineering students. In general, students have difficulty constructing and understanding orthographic projections as they have problems with spatial skills. This leads to a misunderstanding of the content of a task, which makes learning very difficult. Augmented reality (AR) has been used in education to improve the students' learning experience, spatial skills, engagement, and competence, especially when compared to traditional didactic methods. This makes the learning materials more effective and maximizes the transfer of knowledge. This article aims to describe the development of a set of practical exercises in engineering graphics subjects integrated into an AR mobile application. With this application, students can visualize and interact with 3D models of objects from the practical exercises. This didactic toolkit was created as part of the project "Contemporary Approach to the Development of Spatial Comprehension through Augmented Reality Content" (SPACAR).

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THE USE OF WASTE POWDERS IN 3D CONCRETE PRINTING

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Abstract. Additive manufacturing with cement-based materials (3D concrete printing) is gaining momentum in the research community and as commercially available printers emerge, it is beginning to establish its place in the construction industry. Nevertheless, many challenges remain to be addressed, one of them being the sustainability of concrete mixes suitable for extrusion-based 3D printing (Flatt and Wangler, 2022).

Concrete is deemed printable if it is flowable enough to be transported through the delivery hose and extruded through the nozzle, while at the same time it needs to be stiff to support the weight of layers stacked on top of each other (Roussel, 2018). An important rheological aspect in achieving these characteristics is sufficient cohesiveness, which prevents segregation, reduces friction, makes the filament smooth and contributes to the stability of extruded layers. Currently, cohesiveness is achieved by adding high quantities of cement, silica fume and fly ash (Jiao et al., 2017). The presented project aims to establish the suitability of inert waste powders for concrete 3D printing with the objective to reduce the use of cementitious materials and thus make printed products more sustainable.

The benchmark mix for this study was based on the mix designed by Kruger et al. (2019). The constituents for 1 m^3 were 660 kg of cement CEM II/B-M (LL-V) 42.5 N, 73 kg of silica fume, 1030 kg of limestone meal, 356 kg of water, 11 kg of superplasticizer and 7 kg of retarder. The latter was used to extend the open time. In the test mix, the quantities of primary components were reduced to 385 kg of cement, 13 kg of silica fume and 485 kg of limestone meal. They were supplemented with 1050 kg of four waste powders, mostly quarry by-products. All powder components were analysed for their particle size distribution (PSD) with *SYNC Microtrac MRB* laser analyser. The proportion of each waste powder in the mix was determined by matching as closely as possible the total PSD of the reference mix. The water content of the test mix was 290 kg, while the superplasticizer and retarder were kept at the same amount. The assessment of printability was performed using a small-scale 3D printer *Delta WASP 2040 Clay*. Four shapes, square and circular tube, zigzag wall and hollow twisted ellipse, were printed in

parallel. The visual assessment of the printed objects and the number of layers successfully printed served for the assessment of printability.

The test mix exhibited reasonably good printability to warrant further research. The extruded filament was smooth and layers supported the weight of subsequent layers without sagging. With both mixes, the printing was stopped because the flowability of the mix was compromised. This manifested in gaps occurring in filament extrusion while on the other hand, the filament was too stiff to break when the print head moved from one object to another – the filament was dragged behind the nozzle and in one case even pulled the printed wall with it thus triggering the collapse. These problems are partially due to the extrusion being gravity-driven since the printer has no pump. However, there is still room for improvement in admixture optimization. Nevertheless, 16 layers were successfully printed with the test mix compared to 20 layers printed with the reference mix.

Further research needs to investigate the ratio between the interlayer bond strength and filament strength. In a well-optimized mix, the former is not significantly smaller compared to the latter. Mixes containing large amounts of cementitious materials (e.g. reference mix) are expected to have a poor strength ratio which could be improved by the introduction of waste powders with suitable PSD.

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