



ADDOPTML2024

1st ADDitively Manufactured OPTimized Structures by means of Machine Learning



OPTARC-2024

2nd International Conference on Optimization Driven Architectural Design

OPT-ii2024

2nd Engineering and Applied Sciences Optimization

Irbid-Jordan, October 1st - 4th 2024

BOOK OF ABSTRACTS

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**1st ADDitively Manufactured OPTimized
Structures by means of Machine Learning:
2nd International Conference on Optimization
Driven Architectural Design:
2nd Engineering and Applied Sciences
Optimization:**

Irbid-Jordan, October 1st - 4th, 2024

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Preface

The rapid expansion of the architectural, engineering, and construction industry (AECI) worldwide is contributing to large waste generation, high energy consumption, and serious environmental pollution. The European Green Deal impels the AECI to minimize the use of materials and waste. Additive manufacturing (AM) is a flexible and automated process that can produce complex geometry objects, reducing the production time. The ADDOPTML2024 will develop a comprehensive machine learning-based design manufacturing process for civil structures. It will encourage synergies between multidisciplinary academic experts. It will rely on the advancement of AM technologies, including recycled consumables, addressing the shortage of hospital units during the COVID-19 pandemic.

The principal aim of OPTARCH2024 is to create and test methodologies for the application of optimization techniques in different design phases of civil structures by developing strong synergies among a multi-disciplinary team of academic experts. The first goal of OPTARCH2024 is to exploit the use of shape and topology optimization techniques in computer-aided architectural design. Moreover, the Network wants to exchange ideas, propose formulations that correspond to real-life applications, and develop solutions for optimal multi-disciplinary architectural design. Of particular interest is the combination of criteria deriving from structural mechanics, eco-design, bioclimatic design, and acoustic performance.

The proposed OPT-ii2024 special interest conference will facilitate the exchange of ideas on topics of mutual interest and can serve as a platform for establishing links between research groups with complementary activities. Thus, the communities of Mathematical Programming and Nature-Inspired Search Algorithms will become more familiar with important application areas with great social impact, arising from real-world problems. These areas range from practical applications in structural, aerospace, mechanical, civil, chemical, naval, and bio-engineering to applied problems in economics, physics, and biology. Moreover, communities of Applied Sciences and Engineering will benefit from this interaction, since they will be exposed to advanced computational methods and software tools which can highly assist in tackling combinatorial optimization problems.

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Optimizing the Flexural Behavior of Reinforced Concrete Beams with hybrid ECC Jackets

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ABSTRACT

The flexural strength of reinforced concrete (RC) beams is required to be upgraded due to many situations where additional loading is induced and strengthening becomes a must. The nonlinear finite element modeling was used in this study to fulfill the objective of flexural strengthening using an innovative system. The new system is a hybrid technique where steel fibers are mixed with polyvinyl-alcohol fiber-reinforced engineered cementitious composite (SPF-ECC) with steel reinforcing rebars. The SPF-ECC layer was applied with 50 mm thickness on three sides of the conventional RC beams (U-shaped). The optimization of strengthening system was optimized using different values of sensitive parameters, including the effect of beam depth (200, 275, and 350) mm, the presence of the strengthening system (with and without), and the steel reinforcement within the SPF-ECC layer (without, 2Ø16, and 4Ø16). Results were presented in terms of strength, serviceability, and failure modes for all stages (cracking, yielding, and ultimate) with detailed results presentation. In conclusion, the performance of the RC beams could be significantly upgraded even in the presence of space limitations using a simple combination of the material properties and the geometrical dimensions.

* The asterisk denotes the presenting author.



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Integration of 3D Printing and Machine Learning in Sustainable Construction: Feasibility and Challenges

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ABSTRACT

In recent years, three-dimensional (3D) printing and machine learning applications in sustainable construction have evolved. Recent innovations in 3D printing technology have led to its integration in a variety of industries, including buildings and constructions. It is a technology for creating 3D objects layer by layer using a computer-generated design through machine learning depending on pre-identified parameters and the desired output. This paper aims to provide a review about the current practices of the 3D printing and machine learning in sustainable construction and useful suggestions to increase its popularity and potential. Several countries started using 3D printing in construction by creating small-scale prototypes of steel or concrete that can allow for actual printing of full-scale structural systems. The advantages of this technology range from being environmentally friendly to reducing the overall weight of the individual structural elements without affecting their capacities and performance. However, the technology is still facing some major challenges that need to be resolved in order to consider the 3D printing as a competitive and effective technology in the construction industry with optimized shapes, reduced materials, and maintained sustainability criteria.

Keywords: 3D printing; construction industry; machine learning; sustainability.

* The asterisk denotes the presenting author.



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Motion Sequence Optimization of a Reconfigurable Building to Increase its Energy Efficiency

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ABSTRACT

Reconfigurable structures pave new paths for contemporary architecture. The synergy of robotics applications and structural engineering principles can unlock significant potential for new, smart buildings, which will adapt to transient environmental, societal and architectural requirements. To comply with contemporary needs for sustainability though, measures to mitigate the energy consumption of reconfiguration of such structures are necessary. At the same time, actuation during reconfigurations should not compromise its durability. To this end, the present study deals with the optimization of the motion sequence for a reconfigurable research pavilion. The investigated structure is designed as a lightweight system comprising a central actuated telescopic pillar and eight sets of bar linkages arranged axisymmetrically around it. The vertical effective crank-slider approach as discussed in Phocas et al. [1] is applied to facilitate the desired reconfigurability of the structure. In any feasible motion sequence, a generic 1-DOF mechanism is defined through employment of stepwise selective releases of one intermediate joint on either side of the vertical slider, while the pin joints at the supports always remain unlocked. As each bar linkage system consists of 8 bars and 9 nodes, $7! = 5040$ motion sequences are possible for transforming the structure to a new configuration.

In the framework of the present study, an optimization algorithm that computes all possible motion sequences from a given initial to a final configuration based on Euclidian geometry principles is developed. Subsequently, the optimized sequence is indicated by the algorithm aiming at minimization of the actuation during reconfiguration based on the vertical effective crank-slider concept, as well as of the wear of the reconfigurable mechanism during the life cycle of the structure. Moreover, conclusions based on the computational findings that can lead to strategic decisions during the conceptual design of such structures in general are drawn and recommendations for future work are presented.

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Form-finding and Automated Fabrication of GFRP Panels with Double Curvate for a Canopy Structure

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ABSTRACT

Developments in digital design technology currently applied in the architectural and engineering fields enable the extension of design processes from the conceptual phase to detailed design stage and fabrication. Non-conventional structures with complex architectural forms are often realized through technology transfer and material advancements and characterized with enhanced geometrical and mechanical features. In this framework, architectural form, structure and material comprise an indispensable, homogenized unity in the development of the prototype. Along these lines, the current paper refers to the design and automated fabrication process of a canopy structure of steel members with glass-fiber polymer (GFRP) panels of double curvature. The canopy structure serves as roof element for an electricity changing station and is located in a public parking area. The preliminary design of the structure succeeded in parametric associative design environment. The adopted final shape derived from a form-finding process of the respective adaptive system of cables actuated bending-active steel members stabilized by the prefabricated GFRP panels. Following fabrication of the steel members, the member structure was assembled and erected indoors and 3D-scanned for redefinition of the exact geometries of the panels. The latter were then 3D-printed in series by an industrial robot (6-axis KUKA KR2700). Following erection of the member structure in place, the GFRP panels have been assembled. The digital design and automated manufacture process serves as case example of a nonlinear interdisciplinary approach followed in achieving a non-conventional lightweight structure with double curvature that was derived from a form-finding simulation process of the respective adaptive system.



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Overcoming Platform Dependency: The Role of WebAssembly and Pyodide in Civil Engineering Tools Transition

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ABSTRACT

In the dynamic digital landscape, the demand for accessible, efficient, and robust computational tools for civil engineers is at its peak. However, the power of traditional desktop-based applications is often overshadowed by a significant drawback—platform dependency, a particularly pressing issue in civil engineering. This limitation, coupled with challenges like real-time collaboration, version control, and updates, underscores the need for a solution. Though a complex task, the shift from desktop to web applications is necessary. This is especially true for many existing tools, including those used by civil engineers, written in Python, a language not natively supported in the browser environment. This poses a significant hurdle to the transition, necessitating substantial re-engineering of these tools. WebAssembly [1] and Pyodide [2] are instrumental in facilitating the transition. WebAssembly offers a binary instruction format for a stack-based virtual machine, enabling high-performance applications on web pages. Pyodide, conversely, brings the Python runtime to the browser via WebAssembly, enabling Python scripts to run directly in the browser. Leveraging WebAssembly and Pyodide, we can seamlessly port existing Python-based computational tools for civil engineers to web applications without significant rewrites. This approach ensures the robustness and efficiency of the original Python code and brings the advantages of web applications, such as accessibility, collaboration, and seamless updates, to the forefront.

During our secondment in IDEA 75 within ADDOPTML in 2021 (Fragkoudakis, Karampatsis), we put our proposed approach into practice by developing a Python library. This library was designed to determine the outer shell of a unit cube complex, serving as the final step in an optimization process that aims to use as little material as possible while maintaining the construction's stability. The optimization process resulted in a dense STL construct, and the need to determine the outer shell of the construct became apparent. We rigorously tested our library for various corner cases before applying it to a confirmed case of a concrete bridge. The results were promising, and the logical next step is to disseminate the tool to as many potential users as possible through a web application. Furthermore, we have plans to lay the groundwork for porting several other civil engineering tools to the web.

The integration of WebAssembly and Pyodide presents a compelling pathway to bring various computational tools for civil engineers to the web and holds immense potential for the field. This approach, by preserving the robustness and efficiency of the original Python code while bringing the benefits of web applications, such as accessibility, collaboration, and seamless updates, paves the way for a new era in civil engineering tools. Further research and development in this area are warranted to exploit this potential and thoroughly drive innovation in the field.

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Enhancing the Mix Design in 3D Concrete Printing through Systematic Optimization Process

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ABSTRACT

3D printing of concrete has emerged as a promising technology in the construction industry, offering faster and more efficient building processes. However, the mix design heavily influences the success of 3D-printed concrete. The mix design of the concrete has a direct impact on the printed structure's printability, mechanical properties, and overall quality. A comprehensive understanding of different mix designs is crucial for optimizing 3D printing processes and achieving high-performance concrete structures. The major challenge in concrete printing is to identify and maintain the mixture characteristics suitable for printing and stacking up in layers. The mix design includes the selection of suitable materials, proportions, and additives to achieve the desired rheological properties that facilitate extrusion and layering during the printing process. Different mix designs may vary in terms of their composition, particle size distribution, water-to-cement ratio, admixtures, and curing methods. A comprehensive search in the literature was conducted to identify various mix designs that could be employed when printing cementitious materials. The literature review revealed that mix designs for 3D printing of concrete can vary significantly in terms of their composition and properties. Some mix designs use traditional materials such as Portland cement, sand, and aggregates, while others incorporate innovative materials like silica fume or fly ash to improve strength and durability. Furthermore, the use of admixtures such as superplasticizers can enhance the workability of the concrete mixture, allowing for easier extrusion and improved rheological properties. In addition to the composition and materials used, the proportions of each component also play a crucial role in the mix design. The water-to-cement ratio is an important parameter that affects the workability and strength of the printed concrete. Different mix designs may have varying water-to-cement ratios to achieve the desired consistency for printing. Moreover, the particle size distribution of the aggregates and fillers can also impact the flowability and packing density of the concrete mixture. Comparing different mix designs, it can be observed that mix designs incorporating silica fume and superplasticizer have been found to exhibit favorable rheological properties for 3D printing of concrete. These mix designs have shown improved workability, reduced viscosity, and enhanced printability compared to traditional mix designs.



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Significance of Nozzle Dimensions for 3D Printing of concrete

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ABSTRACT

Nozzles play a crucial role in the 3D printing process as they are responsible for depositing the material onto the build surface in order (i.e. layer by layer). In 3D concrete printing nozzle determines the final form of the concrete as it directly influences the deposition of each layer. The size of the nozzle not only determines the proportions of the extruded concrete, such as its height and width, but also significantly affects the accuracy, resolution, and aesthetic value of the final outcome. Increasing the diameter of the nozzle increases the volume of concrete flow, leading to a faster construction process. This can greatly reduce the time required to print a structure. Nevertheless, there is a compromise in terms of a coarser surface texture and a possible decrease in the precision needed for intricate and complex building components. The coarseness of the finish may be unacceptable for certain designs where a sleek, smooth surface detailing is of utmost importance. Alternatively, using a narrower nozzle diameter can improve the 3D-printed concrete's resolution, allowing for the acquisition of finer details and the creation of more elaborate, accurate patterns and textures. This can lead to a significantly smoother and more visually appealing surface. Nevertheless, the reduced dimensions can impede the movement of concrete, resulting in a deceleration of the printing pace and perhaps prolonging the time of the construction process. The geometrical configuration of the printing nozzle is a determinant factor in the 3D concrete printing process as it significantly affects the mechanisms of compaction and adhesion, which are vital for the construction of each layer. The shape of the nozzle has to be meticulously designed to guide the concrete deposition in a way that promotes optimal compaction. This is essential to eliminate voids or air pockets within the extruded material. These air gaps, if not addressed, can lead to a reduction in the overall density and strength of the concrete, making it more susceptible to mechanical failure and degradation over time. Additionally, the nozzle's design (dimensions) governs the interface where new concrete meets already-deposited layers, playing a pivotal role in ensuring that each layer adheres firmly to the previous one. Strong interlayer bonding is not merely beneficial but imperative for structural integrity. The nozzle must be engineered to optimize all of these qualities, guaranteeing that every layer is effectively bonded to the adjacent one, resulting in a robust, cohesive structure that fulfills both functional and aesthetic requirements.



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Innovative Hybrid Reinforced ECC Strengthening of RC Beams: Reinforcement and Geometrical Interaction

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ABSTRACT

The necessity for strengthening structural members has increased recently with many challenges that engineers face, including the available space, required improvement, and construction cost. Many methods were proposed in the literature for upgrading the flexural performance of reinforced concrete (RC) beams with limited improvement extent and ductility reduction issues. This study introduces an innovative flexural strengthening method where the ductility and strength capacities of the RC beams were improved using the combination of steel fibers and the polyvinyl-alcohol engineered cementitious material (PV-ECC), forming the hybrid SPH-ECC reinforced jacketing system. The interaction between the unstrengthened RC beam main flexural reinforcement and the strengthening jackets' geometrical properties was introduced with a proper comparison between the two beam sets. The role of the flexural reinforcement was addressed using the interaction between the beam (3Ø16, 3Ø20, 3Ø25) and the SPH-ECC reinforcement (2Ø16). In addition, the geometrical interaction was examined using three strengthening layer thicknesses (30, 50, and 70) mm while keeping the beam depth at a constant value (325 mm). Results were promising and gave a wide vision of the extent of efficiency of the new hybrid strengthening system.

* The asterisk denotes the presenting author.



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Enhancing 3D Printed Concrete through Waste Fly Ash: A Comprehensive Approach to Sustainable and Efficient Mix Design

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ABSTRACT

The significance of replacing sand with waste fly ash (WFA) in the mix design of concrete for 3D printing applications extends beyond just one or two attributes; it encompasses environmental, economic, and structural considerations. WFA, recognized for its pozzolanic properties, actively participates in the chemical reactions during cement hydration. This interaction leads to the formation of additional cementitious materials, which contribute positively to the concrete's durability and compressive strength. WFA reduces the dependence on naturally occurring sand, conserves natural resources, and mitigates ecological disturbances caused by sand extraction. The inclusion of WFA in concrete can reduce permeability and increase the solidified material's long-term strength. WFA imparts enhanced qualities to printed concrete, such as reduced permeability and improved long-term strength, which are critical for the structure's durability and lifespan. As 3D printing rapidly constructs structures layer by layer, early-age strength is particularly crucial to ensuring that the structure can support itself during the printing process. This is where admixtures come into play, moderating factors like setting time and aiding in achieving the desired rheological properties that ensure the printability of concrete. Admixtures serve to fine-tune the mix design, offering control over the setting time, which, if delayed, can hinder the printing process's speed and efficiency. They also enhance the bonding between layers and improve overall workability, which is essential for achieving the dimensional accuracy and fidelity required by complex 3D-printed designs. The measurement of the early-age compressive strength of concrete offers a window into the material's initial phase of solidification and the rate at which it gains strength. This property is a critical indicator of the concrete's ability to reach a state of rigidity capable of withstanding loads, which is particularly vital in the context of 3D-printed structures where the printing process is continuous and rapid. The integrity of each successive layer depends on the sturdy foundation provided by the preceding segment. Higher early-age strength ensures that the construction process can proceed promptly without the risk of structural failure or deformity. The 28-day strength is regarded as the benchmark for assessing the excellence and maximum load-carrying capability of the concrete. In the context of 3D printing, it is crucial to verify that the layered structure will satisfy the necessary service requirements and structural standards, which frequently depend on the 28-day strength values.



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Advancing the Field of 3D Concrete Printing by Exploring the use of Eco-Friendly Mortars

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ABSTRACT

Employing eco-friendly mortar for 3D concrete printing offers multiple benefits that align with environmental protection, cost reduction, and enhancing the longevity of the constructed structure. This type of mortar typically incorporates by-products from industrial processes, such as waste fly ash (WFA) or bottom ash (BA), as substitutes for traditional sand. WFA, a finer powder-like substance with the ability to undergo a pozzolanic reaction with lime and water, forms additional binding, adding benefits such as ease of mixing, lowered water consumption, and long-term strength. Its fine granularity can also lead to a more compact material structure and potentially superior structural strengths. Nonetheless, the composition of WFA can vary widely, which may influence the uniformity and reliability of the mortar's characteristics. Excessive amounts of WFA might slow down the hardening process, posing challenges for the swift stacking (i.e., layer by layer construction) necessary in 3D printing. On the other hand, BA stands out due to its relatively larger grain size. It has the capacity to enhance the mortar's resistance to heat and often entails less pre-use treatment than WFA. The inconsistent particle shape of BA, though, may lead to reduced mix fluidity, possibly necessitating more water or substances to modify the mixture for printing. In terms of sustainability, WFA and BA both limit the consumption of unprocessed resources and contribute to a decrease in overall greenhouse gas emissions from concrete manufacturing. Due to its reactive properties and minute particle size, WFA tends to produce a more robust and long-lasting mortar. When judged solely on strength, WFA tends to outperform due to its material-enhancing pozzolanic activities suitable for the demands of 3D-printed constructions. Nevertheless, the best option between WFA and BA depends on the application's specific requirements, resource accessibility, financial considerations, and ecological policies. If a strong early development of strength is required to enable quick, undistorted layering, WFA would be the preferred option. Conversely, BA could be the preferred material if printing requires a rougher aggregate texture or if broader sustainability objectives demand a more comprehensive waste management approach. Both waste products contribute positively to the eco-friendliness of 3D-printed concrete structures.



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The Impact of Using Mixed Assessments in AHP-TOPSIS MCDM on the Final Selection of Contractor

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ABSTRACT

The use of Multi-Criteria Decision Making (MCDM) methods in contractor selection within the construction industry has gained significant traction. This is due to the fact that contractor selection is a multifaceted problem that is complex in nature. The choice of the MCDM method can significantly influence the ranking of contractors in construction projects. Each MCDM technique has its unique approach to evaluating and prioritizing alternatives based on the various criteria, leading to potential variations in the final rankings. For instance, while analytic hierarchy process (AHP) is based on pairwise comparisons to determine the relative importance of criteria and the performance of each contractor, the technique for order preference by similarity to ideal solution (TOPSIS) focuses on the geometric distance of each contractor from a positive- and a negative-ideal solution. Consequently, mixing different MCDM techniques must account for differences among the methods in evaluating alternative criteria and contractors. This paper tests the mixed AHP-TOPSIS MCDM technique under various scoring evaluations. The paper investigates the change in the final contractors' rankings using AHP and AHP-TOPSIS with various methods of contractor evaluations per benefit and cost criteria. The paper utilized a case-study from literature for validation. Results obtained clearly show that changing the MCDM technique and/or changing the evaluation method contributed to significant change in the rankings of the contractors. Compared to the case-study, results show that the case-study's selected contractor came fifth using AHP only, and they came forth and fifth using AHP-TOPSIS with different evaluations methods of crisp values.

* The asterisk denotes the presenting author.

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The Flexural Behavior of Engineered Cementitious Composites (ECC) One-Way 3D Printed Slabs made of Solid and Hollow Sections

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ABSTRACT

In light of the recent development and the reduction in the available natural resources, the interest in searching for sustainable and efficient construction and resources has increased. Therefore, the method of 3D concrete printing takes place as a type of construction where forms are not required to shape the required structural element. In contrast, the 3D printing method suffers from a major deficiency related to the reinforcement method of the printed members where challenges exist in finding a practical and efficient method. Consequently, scientists work on the printed concrete properties where types of self-reinforced mixes were utilized such as the Engineered Cementitious Composites (ECC). In addition, the production of lightweight sections is also a major concern which could be achieved using a combination of hollow and solid sections. This study adopts the method of nonlinear finite analysis to investigate the flexural performance of one-way ECC slabs composed of a combination of solid and hollow rectangular sections. Different overall slab thicknesses and solid-to-hollow section areas were examined in terms of the flexural performance measures, such as the ultimate load, deflection, serviceability limit, stiffness, toughness, and flexural strength. Mathematical relationships were introduced based on the slab depth and the hollow volume percentage with high correlation values.

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A Design Framework for Carport-integrated Solar Panels

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ABSTRACT

The expansion of urban areas in Gulf Cooperation Council (GCC) countries, featuring extensive open parking lots in the vicinity of shopping centers, malls, commercial buildings, institutional buildings, and universities, presents a unique opportunity for sustainable energy initiatives through the installation of ground-mounted solar panels configured as carports. These installations offer dual benefits, providing vehicle shading and harnessing solar energy for community energy resilience. However, the design of solar carports in such settings faces specific aerodynamic challenges. The examination of wind loads on solar panel structures has recently intensified, driven by the growing demands of solar industry professionals to establish design guidelines for such installations. This increasing focus has led to significant contributions to the literature, influencing the formulation of current design provisions within some widely recognized wind codes and standards. These provisions are integral to professional practice, providing design wind loadings for two primary types of solar panel installations, namely ground-mounted (referred to solar farms) and rooftop-mounted. Despite similarities in structural geometry, solar carport installations possess distinct aerodynamic features compared to ground-mounted solar arrays, possibly rendering the existing wind design provisions for ground-mounted solar arrays inadequate for solar carport structures. Ground-mounted solar arrays are typically situated in open, flat fields with minimal surrounding obstructions. In contrast, solar panels installed in parking lots frequently encounter a set of wind design challenges due to their urban settings. These installations are often surrounded by buildings and other structures that significantly disrupt wind patterns, introducing turbulence and shielding effects. The presence of such buildings may also lead to wind channeling effects, which can produce high wind speeds and increased turbulence, thereby impacting the wind loads on the solar panels. Recognizing these challenges, this study aims to develop a comprehensive design framework for wind loads on carport-integrated solar panels. The proposed framework will review and potentially adapt design wind pressure coefficients from various international wind codes and standards of practice currently available for a wide range of structure shapes and configurations. The goal is to establish refined guidelines that can be integrated into existing design standards and codes of practice.



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Characterizing Shape Changes in 4D-Printed ABS Beams Under Thermal Stimuli

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ABSTRACT

The present study focuses on the shape morphing behaviour of 3D-printed beams manufactured using Acrylonitrile Butadiene Styrene (ABS) filament subjected to thermal stimulus. The aim of this study is to explore the impact of various printing parameters, that is, printing speed, layer height, layer width, and nozzle temperature, on the shape transformation of ABS beams.

The beams were printed using a standard Fused Deposition Modeling (FDM) printer and then subjected to thermal stimulus (in a thermal chamber). The level of deformation of the beams was quantified by taking the following measurements: chord of deformed structure, height of arc, and internal arc length.

Increased bending deformation was observed when the printing speed, layer height, and layer width were higher. On the other hand, bending responses decreased with an increase in nozzle temperature. The shape transformation was also temperature dependent. ANOVA (Analysis of Variance) was performed accordingly to confirm the statistically significant influence of these parameters on the transformation of shape. Also, Finite Element Analysis (FEA) simulations confirmed the experimentally observed behaviours.

This study concludes that the printing parameters can control the response behaviour of the printed ABS beams. The reported work provides important contributions to the optimization of printing parameters towards desired thermal response properties of ABS structures. Such results could have huge implications for a wide range of applications where controlled shape changes are necessary.

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Thermal-Induced Morphing Behavior of 4D-Printed PETG Beams

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ABSTRACT

The present study focuses on the shape morphing behaviour of 3D-printed beams manufactured using Polyethylene terephthalate glycol (PETG) filament subjected to thermal stimulus. The aim of this study is to explore the impact of various printing parameters, that is, printing speed, layer height, layer width, and nozzle temperature, on the shape transformation of PETG beams.

The beams were printed using a standard Fused Deposition Modeling (FDM) printer and then subjected to thermal stimulus (in a water bath). The level of deformation of the beams was quantified by taking the following measurements: chord of deformed structure, height of arc, and internal arc length.

The deformation varied with different levels of the printing parameters. The shape transformation was also temperature dependent. ANOVA (Analysis of Variance) was performed accordingly to confirm the statistically significant influence of these parameters on the transformation of shape. Also, Finite Element Analysis (FEA) simulations confirmed the experimentally observed behaviours.

This study concludes that the printing parameters can control the response behaviour of the printed PETG beams. The reported work provides important contributions to the optimization of 3D printing parameters towards desired thermal response properties of PETG structures. Such results could have huge implications for a wide range of applications where controlled shape changes are necessary.

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Implementation of Brucite in Alkali-activated Materials Intended for 3D Printed Structures: A Fractional Factorial Design Approach

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ABSTRACT

This study demonstrates the effectiveness of employing a fractional factorial design-of-experiment (DOE) methodology in the development and analysis of alkali-activated Ground Granulated Blast-furnace Slag (GGBS) pastes; activated using a combination of sodium silicate and Brucite slurry. Addressing the pressing need to reduce greenhouse gas emissions from Portland cement production and diverging from conventional studies that employ strong alkaline activators such as sodium and potassium hydroxides, this investigation introduces a pioneering Brucite slurry as an alternative activator. Although Brucite slurry is a stable hydroxide, preliminary findings of this study reveal that the material solidifies within one day of curing, suggesting its potential for enhanced strength characteristics upon further exploration. The research employs the Taguchi design of experiment approach, specifically utilizing the L9 orthogonal array with three factors; each at three levels, resulting in nine experimental setups. The investigated factors include: the sodium silicate-to-Brucite slurry ratio (F1), Brucite slurry concentration (F2), and the elevated heat curing temperature (F3). By systematically varying these parameters, the study aims to identify the optimal conditions for maximizing compressive strength. Analysis of variance (ANOVA) is used to assess the compressive strength data obtained from the various mixes. The optimization of compressive strength is pursued using signal-to-noise (S/N) ratios with the Larger-is-Better criterion; a key feature of the Taguchi method. This approach not only helps in identifying the optimum mix design, but also ensures robustness against variability in the experimental conditions. The significance of this study lies in its novel approach toward sustainable construction practices that can be integrated in 3D printed structures. By eliminating the use of traditional Portland cement and instead of utilizing more environmentally friendly approaches, the Taguchi DOE method, is expected to lead to the optimum performance of the designed mixes, endorsing new practices towards sustainable construction. The insights gained from this study could potentially revolutionize the field, offering a viable path forward for reducing the carbon footprint associated with concrete production. To the knowledge of the authors, this study represents the first documented use of Brucite slurry in the activation of GGBS pastes.



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A Modified bin-packing-based heuristic to solve the heterogeneous multi-attribute generalized assignment problem using Excel

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ABSTRACT

The general assignment problem (GAP) involves allocating tasks to available agents to minimize the total cost of the assignment. GAP has applications in the various industrial and service fields due to its potential to enhance productivity and optimize the use of resources. Bin-packing is a basic optimization problem that aims to minimize the number of bins required to house inserts while at the same time preventing exceeding bin's capacity. This study uses Excel to present a heuristic to solve the GAP by means of a modified first-fit-decreasing bin-backing heuristic. The proposed algorithm assigns N -heterogeneous jobs to M -heterogeneous machines, $N \gg M$, to enhance fairness among machines. This heuristic sets the number of bins equal to the number of machines and the number of inserts equal to the number of jobs. The proposed heuristic accounts for single and multiple dimensions bin-backing where each dimension is associated with a job/machine attribute of significance to the decision maker. Unlike bin-backing, the heuristic allows over capacitating bins while preserving fairness. The paper presents a case study of a two-dimensional nature where time and power limitations are key to the assignment. In this scenario, decision makers try to optimize over-time and over-power to get the job done while minimizing associated costs. Results obtained from the study illustrate the simplicity of the proposed algorithm while at the same time shows the significance of weights of the two attributes on the final results.

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The Extent Effect of the Relative Material Properties on the Flexural Performance of SPH-ECC Jacketed Beams

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ABSTRACT

The overall strength, serviceability, and durability characteristics of structural systems are a combination of the interaction of their constitutive materials. Therefore, this study examines the flexural behavior of reinforced concrete (RC) beams jacketed using a new strengthening system with a hybrid combination between the steel fibers and the polyvinyl-alcohol-engineered cementitious composites (PV-ECC). Simply supported beams with 325 mm depth, 200 mm width, and 3500 mm length were numerically simulated with SPH-ECC jackets using ABAQUS software after being well-validated using experimental results from the literature. The extent effect of the material properties was addressed using three conventional concrete strength values (20, 40, and 60) MPa and three SPH-ECC compressive strength values (60, 80, and 100) MPa. Results were addressed and introduced in terms of the relative strength ratios between the original system and the strengthening layers with proper justifications on the observed phenomenon of the interaction between low and high-strength concretes.

* The asterisk denotes the presenting author.



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Integrating Finite Element Method and Terrestrial Laser Scanning for Structural Analysis and Conservation of the Amman Citadel

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ABSTRACT

The finite element method is highly recommended for destructive structural analysis and inspection due to its accuracy and efficiency. The main goal of this study is to combine laser scanning and structural analysis to assess the condition of walls at the Amman Citadel, a cultural site in Jordan. The research delves into both the properties and static behavior of the structure using detailed modeling to capture material behavior through proper modeling techniques. The aim is to show that valuable information on integrity can be obtained through analysis alone without physical inspections. The analysis results uncovered an instability in the structure highlighting the need for remedial actions. This instability is attributed to events, neglect and a lack of experts in preservation all contributing to the deterioration of the Citadels walls. In light of these findings urgent conservation efforts are emphasized in this study. It lays the groundwork for developing a conservation plan tailored to address the needs of this cultural site.

The combination of cutting-edge technologies, like terrestrial laser scanning along with FEM offers a foundation for monitoring and conserving historical buildings guaranteeing their endurance for the succeeding generations.

Keywords: Finite element method (FEM), Terrestrial Laser Scanning (TLS), Structural Analysis, Conservation Plan, Historical Building Information Modeling (HBIM)

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Prediction of Mechanical Properties in Thermally Exposed Recycled Aggregate Concrete Using Artificial Neural Networks

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ABSTRACT

This study aims to explore how recycled aggregate concrete (RAC) behaves when exposed to heat to help engineers in designing durable structures using sustainable materials. The research focuses on using machine learning algorithms, particularly artificial neural networks (ANN), to predict the mechanical properties of RAC under thermal conditions. By incorporating factors such as aggregate properties, recycled content percentage, mix proportions, concrete age, and specific thermal exposure parameters, ANN is used to enhance accuracy in predicting the reduction of the mechanical properties, particularly the compressive strength and elastic modulus, in RAC due to elevated temperatures. This study utilizes a dataset collected from previous experiments to train and validate the ANN models. It also investigates the coupling effect of some significant parameters to improve understanding the thermal behavior of RAC specimens. The results from the ANN models and the coupling effect study are used to create useful design equations. Results show the effectiveness of the ANN models in predicting RAC's mechanical behavior under varying thermal conditions, with outcomes indicating high accuracy and low error rates compared to established empirical formulas. This research offers practical implications for the construction industry, providing engineers and practitioners with a predictive tool for assessing RAC performance under different thermal environments. This will promote the use of RAC in structures vulnerable to high temperatures such as chimneys and help structural engineers in evaluating repair strategies for RAC constructions post-elevated heat exposure.

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Predicting the Thermal Properties of Travertine Rock: A Comparison of Machine Learning Techniques and Multivariate Regression

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ABSTRACT

Travertine rock is widely used in various engineering applications, particularly as a construction material for building facades and columns, due to its desirable properties, such as hardness, thermal insulation, and aesthetic view. However, there have been limited studies evaluating the physical engineering properties of Travertine stone, especially concerning its thermal properties. This research paper aims to present the thermal properties of Travertine building stone through direct measurements. While direct measurements are essential for accurate data, the process is laborious, requiring detailed procedures to ensure precision, and time-consuming, often involving extended periods for sample preparation, testing, and data analysis. Therefore, this paper proposes using regression and machine learning techniques to develop a validated model that indirectly predicts Travertine rock's thermal properties indirectly through easy, simple, inexpensive, and non-destructive tests. The performance of these machine learning techniques in predicting the thermal properties of Travertine rock is compared to that of Multivariate Regression. The results from this study are expected to provide valuable insights into the thermal behavior of Travertine rock and demonstrate the efficiency of machine learning techniques in predicting these properties.

Keywords: Travertine rock; buildings stones; Thermal Properties; Machine Learning; Multivariate Regression (MVR)

* The asterisk denotes the presenting author.



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Neural Network-Based Modified Thick-Walled Cylinder Model for Transfer Length in Prestressed Concrete Beams

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ABSTRACT

Accurate prediction of the required transfer length in prestressed reinforced concrete beams is important for both structural effectiveness and economic efficiency in material usage. Recently, several techniques have been developed to predict the necessary transfer length, including artificial neural networks and thick-walled cylinders theory. This study proposes a new technique to predict transfer length by focusing on enhancing the prediction accuracy of the traditional thick-walled cylinders theory by leveraging artificial neural networks. The developed artificial neural network enhances the prediction accuracy by considering more input parameters than those in the thick-walled cylinders theory. A dataset of approximately 300 data points from 16 previous experimental studies from the literature is used to develop the neural network model. The neural network model is trained, tested, and validated using the collected dataset. The developed neural network incorporates 12 input parameters. However, sensitivity analysis is conducted to find the most significant parameters that are employed for the modification. Then, the results obtained from the developed model are used to study how key parameters directly affect transfer length, and to improve the traditional thick-walled cylinder model based on these findings. Among the 12 input parameters, only five modification factors are employed: coating condition, end condition, release condition, corrosion loss percent, and vertical spacing between strands. The developed neural network and modified thick-walled cylinders model show superior performance compared to existing models, with coefficients of variance of approximately 12.3% and 16.3%, respectively.



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Optimization of 3D Printing Parameters on Surface Roughness and Flatness of PLA Using Taguchi Design of Experiments

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ABSTRACT

This study investigates the influence of 3D printing parameters on the surface roughness and flatness of Polylactic Acid (PLA) components using the Taguchi Design of Experiments (DoE) methodology. The primary objective is to identify optimal settings for printing parameters to minimize surface roughness and maximize flatness. Key printing parameters such as layer height, print speed, nozzle temperature, and infill density were systematically varied according to a Taguchi L9 orthogonal array. Surface roughness was measured across multiple orientations (X, Y, Z) and angles (15°, 30°, 45°, 60°, 75°), while flatness was assessed using standard deviation from a reference plane. Analysis of Variance (ANOVA) was conducted to determine the significance of each parameter on the response variables. The results indicate that layer height and print speed have the most substantial impact on surface roughness, whereas nozzle temperature predominantly affects flatness. Optimal printing conditions for achieving both minimal roughness and high flatness were identified, demonstrating the efficacy of the Taguchi method in enhancing the quality of PLA printed parts. These findings provide valuable insights for manufacturers seeking to improve the surface finish and dimensional accuracy of 3D printed components.

* The asterisk denotes the presenting author.



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Synergistic Integration of 3D Printing and Machine Learning for Smart Structural Systems: Overview and Feasibility

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ABSTRACT

This paper explores the integration of 3D printing and machine learning technologies in the development of smart structures, highlighting their potential to transform the design, production, and functionality of intelligent structural systems. By combining these innovative approaches, smart structures can achieve enhanced optimization, adaptability, and intelligence, resulting in substantial improvements in sustainability, performance, and quality across diverse applications. The use of 3D printing allows for the creation of complex geometries and customized components, while machine learning algorithms enable real-time data analysis and decision-making, thus enhanced structural performance. This synergy fosters the development of structures that can monitor their own health, adapt to changing conditions, and optimize their resource use. The paper discusses various case studies and applications where the integration of these technologies has been successfully implemented, demonstrating their feasibility and effectiveness. This work informs researchers, engineers, and industry professionals about the benefits and challenges of using 3D printing and machine learning in smart structures, which highlights advancements and future prospects to support the development of more resilient and efficient built environments.

Keywords: 3D printing; construction industry; machine learning; sustainability.

* The asterisk denotes the presenting author.



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Optimizing the Performance of Expansive Clayey soil as a Landfill Liners

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ABSTRACT

Jordan is considered as one of the countries that has limited natural resources. It has a high population growth rate, including enforced migration of the Syrians, immigration from Gulf wars, enforced immigration of Palestinian people and immigration of Iraqis to Jordan territories. These factors and other factors like economic, political, geographical and cultural factors affect the environment and create a serious environmental threat especially in the places that there is an opportunity for water pollution.

The most important engineering property of the clay liner is its permeability, which is the compacted clay liner capacity to allow the fluids to flow through connected voids in compacted clay liner. In geotechnical engineering, permeability has a dramatic effect on shear strength mobilization as a consequence of drainage and on consolidation characteristics of soil (Sridharan A and Prakash K, 2002).

For optimizing the possibility of using the clayey soil from the southern part of Amman as compacted liners, samples of soil were extracted from Um Al-Amad area – Jordan. The samples of soil were taken from the excavation working for a residential building foundation. The soils were selected based on three factors. firstly, is that their location is near to the main waste landfill in Amman, Al Gabawi landfill, so if the landfill capacity has to be expanded these soils will be easily obtained. Secondly, is that these clays have low hydraulic conductivity which is a requirement for any clay liner. Thirdly, is that these clays are widely extended so that many quantities can be excavated and used.

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Prediction of Layered Soil Permeability through Artificial Intelligence Optimization procedure

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ABSTRACT

Fluids can move from a place of high energy to a point of lower energy through a soil's network of linked voids, which is known as permeability or hydraulic conductivity. A related coefficient called the coefficient of permeability, or k , is typically used to express permeability, an important soil attribute in geotechnical engineering.

In geotechnical analysis, the coefficient of permeability of soil is important when planning and analyzing earth dams, analyzing and managing soil slopes, creating retaining structures, and monitoring and managing groundwater flow and soil settlement. (Das and Sobhan 2013).

Numerous parameters, such as fluid viscosity, fluid polarity, unit weight, particle size and distribution, soil mineralogy, void ratio, soil structure, and saturation level, influence the coefficient of permeability for homogenous soil deposits. (Das and Sobhan 2013; Mesri and Olson 1971).

Machine intelligence is known as artificial intelligence (AI). Artificial intelligence (AI) is a technique for simulating human intellect using a collection of algorithms to create a new computer that can accomplish similar tasks to humans while also performing parallel computing. Machine learning is a subfield of artificial intelligence that paves the way to creating intelligent computers.

In this study, analysis using artificial intelligence is conducted to predict layered soil permeability. Also, this study investigates the permeability of two-layered and three-layered soil systems that constitute either repeated or different soil layers with different perpendicular flow orientations including upward flow, horizontal flow, and downward flow. Towards the end, this study will present an AI empirical approach for the prediction of the experimental permeability of a layered soil system.

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Numerical Assessment on the Flexural Performance of One-Way Geopolymer Concrete Slabs

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ABSTRACT

Construction using sustainable materials has become widespread in the last decades in the building sector where the CO₂ emission transmitted is reduced and the contribution towards sustainability and green buildings are enabled. Geopolymer represents the binder part of the concrete mix through a series of polymeric interactions where the cement utilization was significantly reduced. The flexural behavior of one-way reinforced concrete (RC) slabs with slag and fly-ash-based geopolymer concrete were investigated in this study using the nonlinear finite element analysis (NLFEA) adopted and the structural performance was assessed. Slabs were simply supported with 2100 length, 500 mm width, and 120 mm depth tested with four-point loading. The effect of the slab's depths was examined using three different values (120, 150, and 180) mm, along with the effect of the main flexural reinforcement (2Ø10, 2Ø12, and 2Ø16) using 9 NLFEA models. The strength, durability, and serviceability measurements were all addressed and reported with proper relation to the presence of the geopolymer concrete. Results showed the contribution of the slab depth and the reinforcement ratio toward the slab's flexural performance, including the cracking, yielding, and ultimate stages. The study outcomes promote the use of geopolymer concrete for structural members with dominant flexural behavior.

* The asterisk denotes the presenting author.



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The importance of Incorporating Virtual Reality Training for Renewable Energy Engineering Students at Al Al-Bayt University

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ABSTRACT

Jordan, over the past decade, has consistently exhibited substantial annual growth in renewable installations, particularly in solar and wind energy. The nation's commitment to a sustainable energy landscape is evident, with the share of renewable energy in electricity capacity rising from 0.5% in 2013 to an impressive 39.1% in 2022. The critical need for well trained personnel in the renewable energy sector is apparent amid this transformative landscape. However, challenges faced by public universities, especially in emerging nations like Jordan, necessitate innovative educational strategies. This research advocates for the adoption of Virtual Reality (VR) technology as a cost effective solution to enhance the educational gaps in the training. The Meta Quest 2 VR system that is employed in this research demonstrates to be a game changer in fostering engaging learning experiences. By having a user friendly interface, and by having advanced features enable the creation of a realistic 3D renewable energy applications such as solar photovoltaic (PV) system, enhancing the educational architype. Implementation of a PV system in VR environment at the Renewable Energy Department at Al Al-Bayt University yielded promising results. Through a creative project, students designed and interacted with a VR model by simulating a solar PV system bridging the gap between theoretical knowledge and practical application. Survey results from 87 students affirm the positive impact of VR integration on preparing well trained engineers, and highlight its potential to enhance the learning experience in renewable energy engineering. The study emphasizes the educational innovation achieved through VR technology as a powerful tool for creating immersive and



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realistic educational experiences. Additionally, survey results provide insights into students' perspectives, indicating a positive shift despite initial unfamiliarity with VR technology. Recommendations include expanded VR integration in engineering curricula, continuous engagement efforts, diversified VR applications, and investment in research and development for continuous improvement. The incorporation of VR technology in engineering education presents an exciting avenue for cultivating a generation of well-equipped and innovative renewable energy professionals in Jordan and beyond.



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Evaluating the Structural Performance of 3D Printed FRCC Beams with Anchoring Reinforcement: Material, Geometry, and Loading Perspectives

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ABSTRACT

Increasing attention was paid to three-dimensional (3D) printing technology in the construction, architecture, and medical care sectors. However, the utilization of cementitious composites in 3D concrete printing was increased to upgrade the structural behavior of the printed members. In contrast, difficulties and uncertainties still exist regarding the reinforcement method of the printed members with other induced challenges regarding the cost efficiency and sustainability concerns. This study evaluates the structural performance of 3D printed beams with fiber-reinforced cementitious composite (FRCC) and anchoring reinforcement using the method of finite element analysis (FEA). A total of eighteen beams were simulated with different shear spans (400, 500, and 575 mm), overall depth (120, 200, and 276 mm), and FRCC compressive strengths (23.2 and 43.2 MPa). The behavior was reported for all models in terms of the ultimate load and its corresponding deflection, initial stiffness, toughness, and failure modes. Results were presented as general guidelines to highlight the effect of the examined parameters to provide the scientists and engineers with a wide knowledge of the printing field, mitigating the required time and cost. It was found that increasing the shear span increases the beam's ultimate deflection and reduces its capacity. Moreover, increasing the depth of the beams has various effects on the failure mode and the deflection values where beams with lower depths sustain larger deflections compared to the deeper ones.

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Planning Construction Projects from a System-of-Systems Perspective

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ABSTRACT

Decision-makers within government and industry are overtly facing problems of significant complexity. Managing complex systems, where multiple, heterogeneous, and distributed systems interacting at different levels calls for effective analysis tools that support decision makers. While the tools available for support are plentiful, they cannot be utilized effectively since people who developed such tools all speak different languages. In this context, the purposes of this paper are to introduce the class of problems, termed System-of-Systems, applied to the planning of construction projects, the traits that qualify the industry to be a SOS type, and establish a unifying lexicon to facilitate communication between professions and non-professions. It is found that tackling the construction industry from a System-of-Systems frame of reference is an urgent need since such problem type typically involves interconnections within systems, and more importantly, it accounts for the unintended consequences, in either the success or failure of systems.

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Ground Penetration Radar (GPR) Investigations of Sinkholes at Eastern Dead Sea shoreline

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ABSTRACT

A comprehensive ground-penetrating radar (GPR) study conducted along the eastern shore of the Dead Sea has revealed the dynamic subsurface geology and hydrogeology in stunning detail. Using a multi-line approach including GPR lines 1, 2, and 3, this study has revealed a wealth of geological features and the distribution of vital freshwater resources within this unique landscape. A recurring theme running through this study is the compelling interaction between freshwater aquifers and subsurface cavity formation. This dynamic interaction underscores the ever-changing nature of the subsurface world, with freshwater intrusion triggering processes such as dissolution, subsidence, and cavity formation, each of which exhibits distinct dimensions and characteristics. This interaction is a dramatic testament to the dynamic and ever-evolving nature of subsurface environments.

GPR line 1, which spans 700 meters, revealed freshwater aquifers at depths ranging from 6 to 6.5 meters below the surface, with a variety of cavity formations identified. This recurring pattern persisted across all ten carefully examined sections along Line 1, highlighting the interconnected geological and hydrogeological nuances in each section. Extending our exploration to the 1,000-meter-long GPR Line 2, we examined the changes in elevation and their intriguing associations with freshwater reservoirs. Of particular note were the observations in Sections 1 and 2, which indicated a dynamic subsurface flow pattern and suggested the presence of complex groundwater movement pathways that warrant further exploration



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and analysis. Furthermore, GPR Line 3, a 600-meter-long line running west to east, revealed a series of gaps, some of them of considerable size, along with extensive freshwater saturation within the subsurface layers. This section clearly demonstrated the profound relationship between water infiltration, subsurface stability, and gap formation, greatly enriching our understanding of the geological processes occurring.



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Treated Wastewater as Groundwater Recharge in Jordan

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ABSTRACT

Limited water resources: Jordan is among the most water-scarce countries in the world, with per capita water availability well above the international water poverty line. The country relies heavily on over-depleted groundwater resources and limited surface water resources, making it highly vulnerable to water shortages.

Groundwater recharge using treated wastewater has become a sustainable solution to meet the growing demand for freshwater resources. This process involves the deliberate infiltration of treated wastewater into aquifers to replenish groundwater reserves, thereby enhancing water availability for various uses including drinking water, agriculture, and industrial processes. Reusing wastewater to recharge groundwater not only helps alleviate water scarcity, but also provides environmental benefits such as reducing discharge of treated wastewater to surface water bodies, reducing pollution, and supporting healthy ecosystems. However, implementing this approach requires careful consideration of factors such as the quality of treated wastewater, aquifer characteristics, and potential risks to human health and the environment. This brief reviews the potential and challenges of using wastewater as a source of groundwater recharge, emphasizing the importance of advanced treatment technologies, stringent monitoring systems, and regulatory frameworks to ensure safe and effective implementation.



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Innovative Application of Basalt Fiber Reinforced Polymer Bars (BFRP) in Bridge Deck Construction: Sustainable Approach to Infrastructure Longevity

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ABSTRACT

Basalt Fiber-Reinforced Polymer (BFRP) bars are gaining attention in structural applications due to their high tensile strength, lightweight nature, and environmental advantages compared to conventional steel reinforcement. BFRP bars are four times stronger and 3.5 times lighter than steel, making them a promising alternative for concrete structures, particularly in harsh environmental conditions. This study investigates the mechanical and durability properties of BFRP bars, focusing on the effects of bar size. Three bar sizes (12.7 mm, 15.9 mm, and 19 mm in nominal diameter) were examined to evaluate their performance under various conditions. Durability tests involved conditioning the bars in an alkaline solution for 1, 2, 3, and 6 months at 60°C and subjecting them to 100 freeze-thaw cycles between -20°C and 23°C. The results revealed that bar size significantly affects tensile and bond strengths, with larger bars showing reduced performance. However, unconditioned BFRP bars exhibited high tensile and moderate bond strength with concrete. Conditioned bars demonstrated good resistance to alkaline environments, particularly the No. 6 bar, which retained 54% of its tensile strength after six months of exposure and showed excellent resistance to freeze-thaw cycles. Notably, the modulus of elasticity remained unaffected by the durability tests. Based on these findings, a predictive model for long-term tensile strength was also proposed.

In addition to material properties, this study explores the structural behavior and serviceability performance of concrete bridge decks reinforced with BFRP bars. Concrete bridge decks are highly susceptible to deterioration, especially in severe weather conditions where deicing salts are used, making durable reinforcement critical. The research involved casting and testing four full-scale single-span slabs (3 m long x 1.2-m wide x 20-cm deep) and two continuous two-span bridge decks (5.5 m long x 3 m wide x 20 cm deep) under static loading. The study examined the impact of bar size, spacing, and continuity on the flexural behavior of the bridge decks. The results, which include data on deflection, crack width, strains in concrete and BFRP bars, ultimate flexural-shear capacity, and flexural-shear failure modes, led to the development of a new empirical model for evaluating the flexural shear strength of bridge decks reinforced with FRP bars. Although BFRP bars have a lower modulus of elasticity than steel, they are suitable for applications where deflection is not a primary concern, such as bridge decks, offering a durable and efficient alternative to traditional reinforcement methods.

Based on the findings of this research project, the Illinois Tollway Authority planned to make two bridges using BFRP in Chicagoland, Illinois, where Professor Mohsen Issa signed a contract to be the project's quality control and quality assurance.

In addition to this research project, Dr. Issa will talk about other full-scale research projects on infrastructure.



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Optimized Finite Element Analysis and Strengthening Assessment of the Segmental Concrete Bridges Utilizing Proof Load Testing

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ABSTRACT

Many countries worldwide face a common problem with the aging bridge infrastructure that is being demanded to carry increasing loads. With the cost and the difficulties associated with replacing and rehabilitating these bridges, it is necessary to make the most efficient use of the existing infrastructure. Proof Load Testing (PLT) proved to be a reliable non-destructive method to assess the bridge and reflect its actual behavior, especially the old bridges. The advancement of the Internet of Things (IoT) technology concerning sensors and data acquisition systems for sensing, collecting, and storing the data in conjunction with Finite Element Modeling has resulted in combining analytical models and field test results for better assessment of the bridge condition. It would be insightful to combine the field-testing data with Finite Element Modeling to optimize the outcomes from Proof Load Tests. In this paper, the case of the I-39 Kishwaukee, a five-span twin post-tensioned segmental concrete box girder bridge, has been studied. Kishwaukee Bridge was built in 1970. Several retrofits were carried out on the structure to solve the cracks and slippage at the shear key between the pier segment and the adjacent cantilever segment caused by non-hardened epoxy at the joint during the time of construction. In 2006, The Illinois Department of Transportation investigate the structural behavior of the bridge and determined that the crack growth along the webs is caused by principal tensile stresses higher than the code limits. Using the FEA, the model shows an estimated permanent strain of $85 \mu\epsilon$ caused by the dead load only at the shear key. This strain added to the strain caused by the HS20 truck live load led to a total strain of $180 \mu\epsilon$ higher than the strain corresponding to the modulus of rupture of the concrete ($135 \mu\epsilon$). A total estimated deflection of 3.84 in. at the midspan of Span #3 caused by the HS20 truck live load exceeded the AASHTO allowable limit for deflection (3.74 in). Since the bridge was deficient, IDOT decided to strengthen the structure using four-12 strands, 15 mm external post-tensioning tendons placed inside the box girders to reduce the shear forces acting across the webs. This paper illustrates a Proof of four different trucks loading weights of 76 tons (167 k), 90 tons (200 k), 122 tons (268 k), and 136 tons (300 k) conducted on the bridge. Nine testing scenarios were successfully completed with a maximum of two testing trucks of approximately 136 tons (300 k). The data obtained from the field test (Measured strains near the pier, where shear and negative moment are critical, and at midspan, where the positive moment is crucial, and measured deflection



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profiles) were used to optimize a non-linear finite element model for the bridge. This paper provides a comprehensive guide on how to conduct load rating assessments based on the AASHTO MBE method for PLT. It outlines a step-by-step procedure for conducting field operations, implementing instrumentation, and interpreting test results. The data obtained from the field test is used to develop a Finite Element Model showing the impact of the recently introduced external post-tensioning tendons on the structural performance of the bridge. In conjunction with the FEA, this research demonstrated that the rehabilitation of the Kishwaukee I39 bridge using the post-tensioning system reduced the deflection by 88.72 %, and minimized the principal tensile strain of the shear key by $80\mu\epsilon$. Based on these findings, this paper provided a significant allowance for accommodating future traffic load increases on the Kishwaukee I-39 River bridge.



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Experimental Study on the Optimization of Metakaolin-Based Geopolymer Concrete (GPC) for Prestressed Railroad Concrete Crossties

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ABSTRACT

Future technology focuses on preserving the earth's natural resources and reducing pollution; unfortunately, the cement industry is responsible for about 5 to 7% of total carbon dioxide (CO₂) emissions. In terms of global warming, geo-polymer technology could significantly reduce the CO₂ emission to the atmosphere caused by the cement industries. Studies show that geopolymers have excellent physical properties, high early strength, and low shrinkage. Geopolymers are majorly produced from metakaolin, fly ash, kaolin, and slag. Metakaolin-based Geopolymers have remarkable strength, excellent mechanical properties, and high resistance against acid and alkali corrosion. In addition, the problem of corrosion, especially in steel reinforcement, is an issue that needs to be addressed. Basalt fiber-reinforced polymer (BFRP) rebars is an environmentally friendly material with better corrosion resistance and freeze and thaw cycles than conventional steel reinforcement, attracting attention to use this material in special structures. Using BFRP and GPC can result in more durable, corrosion-resistant, and strong structures. Within the scope of this study, fifteen different GPC mixes were investigated to analyze the influence of coarse and fine aggregate, Water Glass (WG)/Cementitious (CM) ratio variation, fly ash substitution effect on metakaolin as well as curing temperature and fiber effect on the compressive and flexural strength of the GPC. This study showed that curing the sample by heating at 60 degrees Fahrenheit increases the compressive strength during its early age, while heating at a higher temperature can cause porosity and voids in the specimens. Also, a low-shear mixer was used to mix metakaolin with waterglass for 10 minutes before adding the aggregates to ensure the GPC mix matrix was homogenous. In addition, a 20% fly ash replacement by weight of cementitious material and the usage of river gravel yielded better workability. The study produced excellent physical properties of GPC with compressive and flexural strength reaching 9,400 psi and 800 psi, respectively. Prestressed concrete crossties are considered a more sustainable and durable substitute for conventional wooden ties in current railroad construction projects. Using Basalt Fiber Reinforced Polymer Bars (BFRP) as prestressing material has been considered to avoid corrosion in harsh environmental conditions. Multiple geopolymer concrete crossties, reinforced with #3 BFRP rebar



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reinforcement, were cast with different reinforcement configurations. The testing results of the cast crossies show excellent behavior in terms of ultimate strength capacity. In Addition, multiple geopolymers concrete crossies were installed at McAlester Army Ammunition Plant in McAlester, Oklahoma, and are under investigation and testing on a real-life rail track.



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Finite Element Analysis of Mechanical Vibrations in Fiber-Reinforced Laminated Nanocomposite Beams under Hygro-Thermo-Mechanical Conditions

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ABSTRACT

In the present work, a multiscale method is developed to predict the hygro-thermo-mechanical vibration response of laminated nanocomposite beams. The study determines the mechanical properties of the CNT-based epoxy matrix, by using the modified Halpin-Tsai model, which is incorporating the impacts of CNT agglomeration, orientation, waviness and CNT size-dependent characteristics. In addition, the Chamis micromechanical model is employed to evaluate the six independent elastic constants of the nanocomposite lamina, taking into account environmental factors such as temperature and humidity. Finally, Finite Element Method (FEM) is used to evaluate the vibration behavior of neat and CNT-based laminated composite beams.

The investigation explores various parameters involved in the design process, such as the influence of CNT microstructural characteristics and environmental factors on the vibration performance of nanocomposite beams. The outcomes of the present multiscale modeling are in compliance with experimental data available in open literature.

It could be assumed that while CNT inclusion enhances the mechanical properties of nanocomposite laminas, the natural frequencies of the composite beams are affected by variations in temperature and moisture content. In addition, CNT microstructural characteristics remain of critical concern in the design of effective nanocomposite structures. The developed multiscale modeling procedure offers significant potential in the design optimization of CNT-based composite structures for future industrial applications.

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Experimental and Numerical Investigation of Integral Abutment Bridges: Single and Group Pile Behavior

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ABSTRACT

Integral Abutment Bridges (IABs) have become a popular solution for reducing maintenance costs associated with conventional bridges in the United States and neighboring countries. However, the absence of standardized design procedures and a comprehensive understanding of abutment-pile behavior under combined axial and lateral loads pose significant challenges to their widespread implementation. This research aims to address these challenges by conducting full-scale experimental testing and numerical simulations to evaluate the performance of steel H-piles and concrete-filled tube (CFT) piles in IABs. The study investigates the low-cycle fatigue behavior, lateral displacement capacity, and pile-structure interaction under various loading conditions. Two distinct pile configurations will be tested: individual piles and group piles, focusing on parameters such as pile ductility, connection details, and orientation. A specialized testing setup is being designed for full-scale testing to conduct experimental investigation of integral abutments, applying both axial and cyclic lateral loads to the steel piles. The experimental results will inform the development of an analytical approach to predict lateral pile capacity and validate current design assumptions. In addition, this research will provide information into the behavior of abutment-pile systems in IABs and establish a set of minimum design requirements and recommendations for their safe and efficient design and construction.



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Framework for managing the stability of agricultural landscapes

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ABSTRACT

The sustainability of agricultural lands in the world is constantly declining due to the catastrophic load associated with the ever-increasing need for products, raw materials, and feed. Modern trends in increasing the productivity of agricultural crops are mainly related to fertilizers, seeds, robotization of production, artificial intelligence, etc. Assessment of the natural potential of the territory is often not among the priorities under study, although it is the basis for the sustainability of agricultural landscapes.

It was established that the sustainability of agricultural landscapes depends on physical-geographical, natural-climatic, geomorphological, soil conditions, natural and anthropogenic factors, which must be digitized for use in modern GIS. It was determined that the GIS framework for managing the sustainability of agricultural landscapes at the level of an agricultural enterprise must necessarily include the following elements: maps - landscape, soil, slope steepness, erosion, types of terrain, natural boundaries, at a scale of 1:10000 or 1:25000, as well as a geomorphological profile of the territory [1,2].

Based on the conducted assessment, models (low-, medium-, high-resource-intensive, ecologically balanced, equilibrium, soil-protective, medically balanced) of agricultural land use were developed, taking into account the limiting conditions and factors affecting the sustainability of agricultural landscapes. Each of the proposed models has various environmental, economic and social indicators that should be taken into account when designing and organizing agricultural land. The proposed framework is universal and can be used in the design of sustainable agricultural landscapes in all natural zones where agricultural crops are grown.

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Towards the Sustainability of Geopolymer Concrete Slabs with Fiber-Reinforced Polymers

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ABSTRACT

Concrete is a widely utilized material in the construction industry with cement as the binder components. The production of cement contributes to one ton of emitted CO₂ per produced ton of cement. Therefore, there was a need to find a suitable alternative binder using available resources and chemical reactions, such as the geopolymer concrete. This study investigates the flexural behavior of geopolymer concrete slabs reinforced with different types of reinforcement rebars, forming a successful step toward sustainability and green construction principles. The superior properties of the fiber-reinforced polymers (FRP) were also included using various types of reinforcements, such as carbon (CFRP) and basalt (BFRP) where their high tensile strength contributes to the slab's flexural performance. Slabs with different geopolymer concrete strengths (20, 40, and 60) MPa and different internal reinforcement rebars (steel, CFRP, and BFRP) were simulated using ABAQUS software. Results revealed that the presence of geopolymer concrete with higher strength increased the induced cracking severity and reduced the slab's ductility. In addition, the strength was significantly upgraded using FRP reinforcement with the optimal combination with lower geopolymer concrete grades.

* The asterisk denotes the presenting author.



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Conceptual Design of a Transformable Shelter in Philippines

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ABSTRACT

This paper presents a conceptual design of a lightweight shelter inspired by the traditional Filipino house, Bahay Kubo, aiming to meet sheltering needs after a natural disaster in the Philippines. The transitional shelter aims to provide an architectural and engineering solution for post-disaster shelters in the Philippines, facilitating the transition to more permanent structures. To tackle environmental conditions, the proposed shelter alters its form in two different spatial configurations to accommodate the Philippines' rainy and dry seasons. For instance, during the rainy season, the shelter features a steep roof and a raised floor (vertically elliptical in shape) to protect against rain and flooding. During the dry season, the shelter can be configured to have a wider layout (horizontally elliptical in shape). Using locally available materials for the shelters' structural and envelope system, such as bamboo beams, amakan wall panels (woven panels of bamboo) and nipa palm leaves using the pawid thatching technique for the roof, this approach not only reduces the environmental impact of the shelter but also supports the local economy.

Additionally, the design incorporates S-joints, which have been analyzed using the Finite Element Method, and an adjustable ring to connect the bamboo beams with the joints in avoiding using bolted connections. Auger anchors are used to support and ensure the shelter's stability. 3D printing technology is employed to maximize the potential of S-joints while also considering manufacturing complexity when joining multiple links. Finally, the paper presents the structural analysis, joint stress analysis, and a bending test of one selected joint. A prototype in scale 1:6 demonstrates the shelter's transformation from the rainy season to the dry season configuration.

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Polymer-Metal Hybrid Application in Road Infrastructure for Increased Crashworthiness

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ABSTRACT

In the modern day, road transport is the major mode of personal and commercial transport the world over with an excess of 1 billion vehicles traversing the world's roads every day and moving at higher speeds for greater efficiency and effectiveness of travel and transportation the aspects of road design need to adjust for adequacy in aspects of road marking lighting and barricading for the safety of drivers, passengers, pedestrians and goods. As has been shown in several researches, the infrastructure used in roadside infrastructure contributes significantly to the severity of accidents along the road. As such, this paper focuses on macrostructural employment of polymer-metal hybrid (PMH) material to design the material for long lasting transient load sustainability enhancing crashworthiness properties of roadside infrastructure material that will provide minimum damage to the colliding vehicle. Research has mostly been focused on trying to find technologies and materials that can make motor vehicles more crashworthy. On the converse side of things however, little has been done for crashworthiness of road furniture and the other obstacles; whereas Crashworthiness is generally defined as the ability of a structure to protect its occupants during an impact; in general, this term is not directly used to explain the crash behaviour of structures that are not carrying anything to be protected. For purposes of this paper however we will use this term to describe the crash behaviour of structures that are generally the barriers in a collision with the interest in designing them in aiding the safety of the occupants and cargo of the colliding vehicles. In general, solid and very rigid structures are used in roadside infrastructure with the major advantage being that they're not frequently replaced. On the other hand, PMH materials promise the ability to have flexibility to design a material specifically for the task at hand as they give the ability to choose options specific to materials and how they interact. Reasonable research has gone into the manner of which these materials are designed and how best they can be utilised. Work has been done by several researchers such as Grujicic, Ramani and Huang etc. with the general findings that using the right methods for the right applications PMH materials can give impressive results. PMH materials have been successfully applied for use in motor vehicle Body in White components in some researches from Grujicic et.al. and Mahoso et.al. For this research, The PMH material is designed for large format application as most road infrastructure is of an appreciably large size. For PMH material design there are a particular design considerations to be made for their application in road infrastructure i.e. constituent material availability, adhesion technique between constituent materials, the ribbing structure of the polymer to support the metal and polymer behaviour in relation to the elements all which have been shown that they can be manufactured with specific characteristics advantageous to the use case using generative AI for the ribbing design as well as additive manufacturing for the assembly. With these factors in cognizance, we can thus proceed to perform the material selection and specific customised mechanical configurations with comparable design and application.



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Mitigation of Energy Crisis Worldwide Using 3D-Printed Concrete with Phase Change Materials

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ABSTRACT

The energy crisis presents a challenging concern for many international organizations in different areas around the world. Conventional construction methods allow thermal radiation to enter buildings in all its forms, which in turn consumes more energy. Structural buildings consume about 40% of global energy for daily consumption, especially consumption related to cooling or heating. Therefore, it was necessary to innovate new constructional systems and utilize new materials that could effectively improve the thermal energy storage capability of the structural system. Additive manufacturing is a digital construction method where the construction of complex geometries is enabled with less time and cost compared to traditional building methods. Phase change materials offer a suitable solution for overcoming the thermal and energy efficiency problems of the built structure. Therefore, this paper reviews the main characteristics of the PCMs and their combination with the 3D printing technology, highlighting the possible challenges, applications, and methods to overcome and improve. However, the available properties could fulfill the essential building construction requirements, but with inadequate effectiveness which increases the need for further investigation and improvements.

* The asterisk denotes the presenting author.



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Enhancing Onshore Wind Tower Foundations: A Comprehensive Automated Design Approach

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ABSTRACT

The need for green energy production and involvement in structures implementation is in constant flux and increasing demand, receiving considerable attention from all parties involved into minimizing environmental impact of structures, reducing their costs, and developing them so as they are aligned with the scientific and operational needs.

While wind energy research has extensively focused on optimizing the parts of the onshore wind turbines like the tower, hub and blades to reach the maximum efficiency while keeping their cost low, limited scientific approach has been found to the wind tower foundations despite the fact that the last considerably contribute to the whole wind turbine – foundation system cost.

This study introduces and analyses an innovative approach targeting at optimizing onshore wind tower foundation systems, emphasizing both engineering, functional and financial feasibility. The approach involves a comprehensive analysis of design load cases, particularly emphasizing resistance against overturn, while ensuring compliance with Eurocode and regulation guidelines and at the same time taking into consideration the soil conditions, the wind turbine characteristics, the wind conditions and the field allocation of the wind turbines. The foundation system is conceptualized as a beam slab with voids filled by soil material, either excavated or brought to the construction site from designated soil deposit areas. The challenges met and confronted are also analysed while mentioning the importance of overcoming them and meanwhile comparison with prior proposed optimization methods are presented and analysed.

Furthermore, as a future trend, the study aims to integrate the new foundation system with steel 3D printing technology in the manufacturing process of the wind tower's structural elements. This integration is expected to enhance the precision and customization of the superstructure-foundation system, thereby improving overall performance and efficiency.

The optimized design not only significantly reduces construction costs by minimizing the quantities of steel and concrete used while certifying the stability and functionality of the wind turbine foundation but also streamlines installation with specific step leading into time saving. Simultaneously, the study enhances the structural behaviour of the wind tower foundation by focusing on elements crucial to its efficiency while making the optimum use of material and eliminating excess of materials that do not actually contribute to the subject studied system.



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Shear Strength of Sandy Soil Stabilized by Eco-Friendly Chemical Solutions

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ABSTRACT

Enhancing sandy soil strength, improving bearing capacity, and reducing erosion, making it suitable for construction projects such as roads and foundations. Various physical and chemical methods are available for sand stabilization; however, they may come with limitations such as high costs, environmental impact, and limited depth penetration. This study stands out for its innovative approach, investigating the potential of sodium silicate and calcium chloride as eco-friendly agents for stabilizing sandy soils. Local Jordanian sand known as Sweileh-sand was stabilized using different mixtures of these agents at varying curing times: 0-day, 1-day, 2-days, and 3-days, using a two-step grouting method. The optimal amounts of sodium silicate and calcium chloride were determined through direct shear tests. This approach demonstrates the treatment's effectiveness in enhancing shear strength and overall soil stability over three days. The test results revealed a significant improvement in shear strength parameters of the stabilized sand.

* The asterisk denotes the presenting author.



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A continuum finite element-based micromechanical approach for the optimal material design of graphene-reinforced composites

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ABSTRACT

The finite element method (FEM) is an essential tool for exploring the complex behaviors of advanced materials and nanocomposites, particularly when experimental analysis is challenging. This study refines the modeling of graphene-reinforced nanocomposites by developing and validating 3D representative volume elements (RVEs) using FEM. The RVE geometry is designed with a sandwich-like structure, which optimizes load distribution and enhances mechanical performance. In these models, graphene is simulated as surface geometry with shell elements, while the matrix and interphase regions are represented as 3D continua, with the interphase modeled at the theoretical thickness of graphene. This approach significantly improves the accuracy of mechanical property predictions by enhancing load transfer mechanisms and minimizing assumptions.

The 3D RVE models were validated against other numerical data and employed to predict key elastic properties, including elastic and shear moduli, across various graphene volume fractions and sizes. Additionally, dynamic simulations were conducted to investigate the material's behavior under impact loads, offering deeper insights into the mechanical performance of the nanocomposites. The results suggest that this modeling approach could be particularly beneficial for applications in industries requiring high-performance materials, such as aerospace and automotive sectors.

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Optimization of an Integrated Design Framework for Post-Disaster Shelter

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ABSTRACT

Given the escalating frequency and severity of natural disasters and the ongoing refugee crisis, innovative and resilient shelter solutions are urgently needed. Hundreds of millions worldwide are affected by natural disasters annually, exacerbated by climate change. Additionally, millions seek refuge from conflict, persecution, and economic hardship.

In post-disaster scenarios, temporary facilities are essential for shelter and education. These must be low-cost, rapidly constructed, and adaptable to diverse sites. An integrated design framework, focusing on optimized and sustainable use of building materials, is proposed to address these needs and align with Sustainable Development Goals (SDGs).

Earthen construction offers significant advantages over traditional solutions like tents, containers, or prefabricated structures. It provides environmental, social, economic, and technical benefits, making it a sustainable and durable choice for emergency shelters.

A comparative study, based on Lesbos' 2015-2018 refugee crisis, examines the effectiveness of earthen shelters. The findings aim to inform future emergency shelter initiatives and promote sustainable, resilient, and inclusive housing solutions.



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Structural Optimization of Additively Manufactured 1U CubeSat Frames

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ABSTRACT

This study presents the design, modeling, analysis, and structural optimization of a 1U CubeSat frame fabricated from Polyether Ether Ketone (PEEK) using additive manufacturing techniques. The primary objective is to minimize the total mass of the CubeSat while ensuring sufficient structural integrity to withstand the mechanical loads encountered during critical phases of launch, including liftoff and stage separations.

Finite Element Method (FEM) simulations were conducted in accordance with the design specifications for 1U CubeSats established by Cal Poly (San Luis Obispo, California) and the specified launch load requirements. Various geometric configurations of the CubeSat's faces were tested to explore structural optimization potentials.

The results of these simulations were analyzed to refine the CubeSat's geometry, achieving significant mass reduction without compromising structural strength. The application of advanced additive manufacturing techniques enabled the production of these optimized structures, regardless of geometric complexity.

This study demonstrates that the integration of FEM processes with cutting-edge 3D printing technologies can yield high-strength, lightweight structures. This approach proves particularly advantageous for 1U CubeSats, where the reduction in structural mass allows for the allocation of additional weight capacity to other systems or subsystems.

* presenter

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Computational Design, Analysis and Experimental Investigation of the Behavior of 4D Printed Airfoils

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ABSTRACT

Since the first appearance of additive manufacturing in the late 1980s, significant advancements have been made in this field. Additive manufacturing (AM), also known as 3D printing, has a wide range of applications, including the production of physical prototypes, functional components, and complex biological structures [1]. In recent years, the spotlight has turned towards smart materials, which have the ability to change shape or properties in response to external stimuli, leading to the emergence of four-dimensional (4D) printing [2].

This work explores the computational design, analysis, and experimental investigation of 4D printed airfoils made from PLA, a shape memory polymer (SMP) [3]. These airfoils can adapt their shape to meet varying aerodynamic conditions and then return to their original form. The study includes an in-depth examination of the potential use of these smart materials in aerospace applications, specifically in the context of sports vehicle aerodynamics.

To validate the design and performance of these adaptive airfoils, a series of computational simulations were conducted using CFD software. The simulations were followed by experimental testing, where the airfoils were produced using Fused Deposition Modeling (FDM) 3D printing technology. The experimental procedure incorporated the Taguchi Design of Experiments (DoE) methodology to systematically investigate the effects of various printing parameters on the aerodynamic performance and shape memory behavior of the airfoils. The results from the experiments were then compared with computational predictions to assess the feasibility and effectiveness of using 4D printed airfoils in real-world applications.

This research demonstrates the potential for significant advancements in the design and functionality of aerodynamic components, paving the way for future innovations in adaptive aerospace structures.

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Introducing T.O.DAY: A Novel Approach to 3D Printed Facade Design

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ABSTRACT

T.O.DAY (Topology Optimization in DAYlight Analysis) is a novel approach to facade design that leverages 3D printing and advanced optimization techniques to maximize daylight penetration. By strategically placing voids within a facade, T.O.DAY can significantly improve the amount of natural light reaching the interior of a building, potentially reducing reliance on artificial lighting and energy consumption. This not only improves daylighting but also introduces daylight analysis into early design stages, allowing for a more holistic design approach.

T.O.DAY's methodology is based on traditional topology optimization, with a key difference: instead of focusing on structural strength, it optimizes daylight metrics. The methodology involves dividing the facade into finite elements and identifying the optimal locations for voids to enhance daylighting while maintaining structural integrity. By combining advanced optimization techniques with the capabilities of 3D printing, T.O.DAY can help create buildings that are both visually appealing and environmentally responsible.

The core benefits of T.O.DAY include optimized daylighting, material efficiency, and customization. T.O.DAY has the potential to revolutionize the design of facades, offering a more sustainable and energy-efficient approach to building construction.

Acknowledgement:

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Improving the interaction between the Encased Composite Beam Parts Using Partial Cellular Steel Sections

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ABSTRACT

Conventional composite beam construction suffers from deficiencies and challenges associated with the interaction between the steel section and the concrete parts and their connection where shear studs and connectors were used. Therefore, there was a necessity to find simple, efficient, and feasible construction methods that satisfy the target requirements and get rid of the shear connection components. This study introduces the flexural behavior of composite beams partially encased with cellular steel sections where the main flexural reinforcement is positioned using the available openings. The nonlinear finite element (NLFEA) simulation was adopted in this study after well validation against experimental tests from the literature. The effect of the concrete compressive strength (20, 35, and 50) MPa was investigated along with the effect of the composite beam width (150, 225, and 300) mm while the depth was kept constant at 300 mm. Results were linked together using the relative ratio between the beam's dimension and the constitutive material properties, providing a wide vision on the improved composite system suitability and abilities. Therefore, outcomes are of major importance for engineers in the industry and academic fields.

* The asterisk denotes the presenting author.



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Analysis, Design and Optimization of Lightweight Lattice Structured Spur Gears using Finite Element Analysis

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ABSTRACT

The present study focuses on the behavior analysis of different lattice structures in spur gears. The aim of this study is to compare the mechanical characteristics of various additively manufactured lattice structures when used as the main body of spur gears, compared to a solid gear body.

Three different lattice structures were designed, simulated and topologically optimized, in order to generate a spur gear that has similar strength characteristics but better strength/weight ratio. Characteristics were quantified by measuring the maximum and mean, stress and deformation and calculating their weight ratios.

Out of the three lattices, two lattices showed exceptional mechanical characteristics for the application. The Octahedral lattice showed the best stress/weight ratio while in the Double Pyramid lattice, the maximum deformation/weight ratio was observed.

This study concludes that lattice structures when used in spur gears can have positive effects in weight reduction but also reveal new characteristics, suited for specific applications. The reported work provides important contributions to the possible applications of lattice structured spur gears. Such results could have huge benefits for a wide range of applications where either the lowest possible stress/weight ratio is required for maximum strength, or a high deformation/weight ratio is required to provide a damping effect for gear transmission applications for which the reduction of vibrations is critical.

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Experimental Investigation of the Mechanical Behavior of PLA Structures Produced by FDM 3D Printing

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ABSTRACT

In the present work, a comprehensive experimental investigation was conducted to explore the mechanical behavior of PLA (Polylactic Acid) structures produced through Fused Deposition Modeling (FDM), one of the most widely used 3D printing techniques. The study aimed to quantify the effects of critical printing parameters, including printing angles, layer heights, and extrusion temperatures, on the mechanical properties of 3D-printed PLA components. Specimens were printed at various angles (0°, 18°, 36°, 54°, 72°, 90°) and subjected to tensile testing to evaluate their performance in terms of tensile strength, elasticity, yield strength, and fracture behavior.

To optimize the experimental design, the Taguchi method was employed, which facilitated the reduction of variability in the data and helped identify the optimal set of printing parameters. The analysis of variance (ANOVA) was utilized to assess the statistical significance of the results, allowing for a detailed comparison between experimental data and theoretical predictions. Additionally, regression models were developed to derive new empirical equations that can accurately predict the mechanical characteristics of PLA based on specific printing conditions.

The outcomes of this research provide a deeper understanding of the mechanical performance of PLA under different manufacturing settings, contributing to the broader field of additive manufacturing. These findings are particularly relevant for industries such as automotive, aerospace, and biomedical engineering, where optimized material properties and precision in 3D-printed components are critical for performance. The study's results also offer a foundation for future developments in the design and application of 3D-printed functional parts, potentially extending the use of PLA in more advanced and high-performance applications.

* Online presenter

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Vehicle crash test simulation using the finite element method

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ABSTRACT

With the rapid development of the industry and the extensive use of vehicles around the world, some adverse consequences appeared in addition to the positive results. One of them is traffic accidents. Because of this, manufacturers were forced to conduct realistic tests (crash tests) on the vehicles to certify their suitability. The purpose of monitoring the extracted results is to study the body's behavior in similar accident conditions. The strength of the construction materials in terms of deformation and absorption of the generated energy is mainly examined. The purpose is to ensure the integrity of the passenger cabin as well as any need to optimize the construction.

In addition to the physical conduct of tests, corresponding tests are also carried out virtually using appropriate programs. More specifically, the detailed design and analysis is carried out with CAD (Computer Aided Design) and CAE (Computer Aided Engineering) programs. After modeling the sample, the required data and elements are entered into the respective program, then the static or dynamic analysis takes place and finally the results are carried out.

In the present work, an extensive reference was made to the characteristics of the body, the passive and active safety of the vehicle, the factors causing traffic accidents and also an explanation of the conduct of crash tests. The analysis and simulation of the collision was done using the Finite Element Method (FEM). This study aims to monitor the produced deformations and stresses, proportional to the speed, construction material, impact angle and other parameters. The ultimate goal is in conclusion the approximation of a safe construction and the drawing of conclusions regarding the evaluation of the various crash conditions.

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A Machine Learning Model for Predicting Building Earthquake Response based on Ambient Vibration Data

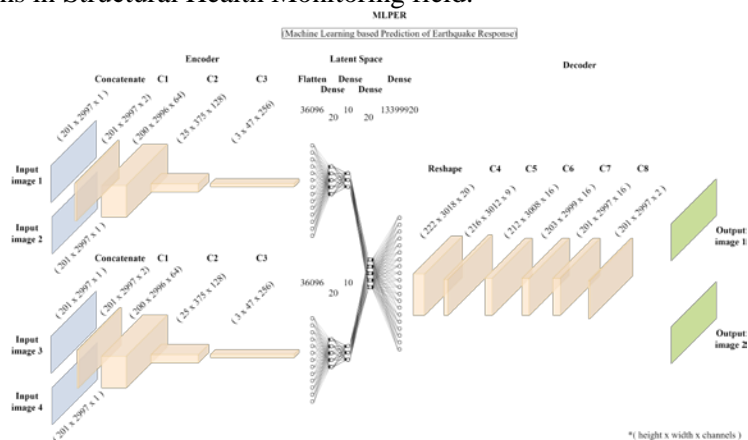
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ABSTRACT

The Deep Neural Networks (DNNs) have been incredible tools to tackle complex regressive challenges under the form of flexible architectures that can be applied across various domains. Meanwhile, in earthquake engineering, there has been an increasing use of Structural Health Monitoring (SHM) in order to include field data into computational models such as simplified models like Single Degree of Freedom (SDOF) or/and Multi Degree of Freedom (MDOF) systems. However, these models in order to describe closely the real case, they have to be modified appropriately. This study aims to utilize ambient vibration (AV) measurements from buildings, alongside earthquake (EQ) time-history data, to develop a predictive model based on a neural network (NN) represented in image format. The goal is to accurately predict a building's seismic response including its nonlinearity nature. The training dataset comprises 1,197 MDOF 2D generated shear models, resulting in a total of 32,319 training samples. To assess the performance of the proposed model various metrics are used, including mean absolute percentage error (MAPE) and mean deviation angle (MDA) for time-domain comparisons, as well as magnitude-squared coherence and phase differences ($\Delta\phi$) for frequency-domain evaluations. This study highlights model's potential as a tool for predicting seismic responses in buildings, taking advantage sensors' data format derived from the growing number of applications in Structural Health Monitoring field.





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Correlation between predictability of extreme wind speeds and wind directionality

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ABSTRACT

Extreme weather events, particularly high wind speeds, present a serious risk to critical infrastructures worldwide, often resulting in severe damage and substantial economic losses. Transportation infrastructure, especially bridges, is particularly vulnerable, where high winds can cause vehicles to overturn, creating life-threatening hazards. Accurate forecasting of these events is crucial for disaster preparedness and infrastructure protection. This research focuses on understanding extreme wind events to develop strategies that reduce their impact and enhance infrastructure resilience.

The study explores the relationship between wind directionality and the imbalance ratio of extreme wind speeds to improve predictability, which is vital for assessing risks like vehicle overturning on bridges. A long short-term memory (LSTM) model is used to predict extreme wind speeds, supported by traditional extreme value analysis to extract these events across various directional sectors. To accomplish this, traditional extreme value analysis is applied to identify and extract extreme wind events across different directional sectors, setting a threshold for classification. This threshold detection is crucial for assessing wind speeds above 20 m/s, which is a critical point in determining the likelihood of truck overturning on bridges [1]. The findings from this research are significant as they provide insights into the nature of extreme winds, ultimately contributing to the development of better prediction models and safety measures for protecting vital infrastructures from these potentially devastating events.

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Modeling the Effective Elastic Modulus and Thickness of Corrugated Boards Using Gaussian Process Regression and Expected Hypervolume Improvement

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ABSTRACT

This work aims to model the hypersurface of the effective elastic modulus ($E_{z,eff}$) and thickness (t_{eff}) in corrugated boards. A Latin Hypercube Sampling (LHS) is followed by Gaussian Process Regression (GP), enhanced by EHVI as a multi-objective acquisition function. Accurate modeling of $E_{z,eff}$ and t_{eff} is critical for optimizing the mechanical properties of corrugated materials in engineering applications. LHS provides an efficient and straightforward approach for an initial sampling of the input space; GP is expected to be able to adapt to the complexity of the response surfaces by incorporating both prediction and uncertainty. Therefore, the next points being generated and evaluated are based on the complexity of the hypersurfaces, and some points, especially those with higher variance, are more exploited and carry more importance. The performance of GP with EHVI is measured by Mean Squared Error (MSE). Prediction of GP resulted in $MSE(E_{z,eff}) = 5.24 \text{ kPa}^2$ and $MSE(t_{eff}) = 1 \text{ mm}^2$. GP possesses then improved accuracy and adaptability for future applications in structural optimization [1].

* The asterisk denotes the presenting author.

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Behavior of Micropiles Types A and D in Layered Soils

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ABSTRACT

Micropiles, small-diameter drilled and grouted piles are frequently employed to support foundations under difficult ground circumstances. This study aims to comprehend the behavior of two popular micropile types in layered soil profiles: type A (gravity-grouted) and type D (pressure-grouted). Layered soils frequently create complexity because of differences in stiffness, strength, and permeability, which impact load transfer and the interaction between the micropiles and the surrounding soil. Type A micropiles have limited grout penetration into adjacent soils because they rely on gravity to distribute the grout along the drilled hole. On the other hand, Type D micropiles use pressure injection, which results in enhanced skin friction, better grout-soil contact, and a greater capacity to carry loads. The behaviour of these micropiles under axial loads was evaluated, considering factors such as layered soil type effects and thickness, micropiles' diameter, and micropiles' length. The results indicated that Type D micropiles perform better in layered soils than Type A micropiles because they can transfer loads more equally among the various soil layers, particularly in softer soils. However, the characteristics and thickness of each soil layer, micropiles dimensions have a significant impact on the efficiency of both types of micropiles.



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Topology Optimization of Trusses Using reusable software resources under Arbitrary Loads and Constraints

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ABSTRACT

Topology optimization has become an essential tool in structural analysis, allowing for the design of efficient, lightweight structures that meet specific performance requirements. This study focuses on the application of general optimization methods, particularly simulated annealing, in the topology optimization of trusses or other discrete structures. In recent years optimization functions are readily available in packages such as Matlab/Octave, and there is no lack of structural analysis software, often with no optimization capabilities.

Simulated annealing offers the advantage of exploring the design space thoroughly, increasing the likelihood of finding a global minimum solution. This is critical for ensuring that optimized structures can withstand arbitrary loading conditions, such as seismic or dynamic loads. Additional constraints can be imposed, such as limiting the number of distinct cross-sectional sections of the structural elements. These constraints add further complexity to the optimization process but also enhance the practicality of the solutions in real-world applications. With modern computers, topology optimization has become increasingly feasible for structures composed of discrete elements (trusses, frames), where the elements (bars, beams, columns) are prefabricated or even 3D-printed.

This research demonstrates how readily available global optimization techniques can lead to better structural designs by efficiently balancing load-bearing capacity and material use, while adhering to complex constraints [1].

* The asterisk denotes the presenting author.

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Automatic Calibration of the Temperature Parameter in Simulated Annealing Based on Objective Function Statistics

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ABSTRACT

Simulated Annealing (SA) [1] is a widely used optimization technique in which the temperature parameter T plays a crucial role in controlling the acceptance probability of non-improving trial solutions (negative changes) during the search process. Traditionally, the initial value of T is determined by the user, often through trial and error, which can be inefficient and lead to suboptimal performance. In this study, we present an automated method for calibrating the T parameter based on the statistical behavior of the objective function. By leveraging the same sequence of changes (both positive and negative) generated by the SA algorithm, our method dynamically computes an appropriate initial T value, eliminating the need for manual tuning.

Extensive experiments on benchmark and real-world optimization problems demonstrate that our approach yields good results. In particular our approach is successfully applied to the topological optimization of discrete structures made of prefabricated or 3D-printed members.

* The asterisk denotes the presenting author.

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Automated Floor Plan Design with Constraint Optimization Using Simulated Annealing for Architectural Engineering and 3D Printing

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ABSTRACT

In this work, we present a novel method for automated floor plan design in architectural engineering, focusing on the placement of rooms with known dimensions within a rectangular building envelope while adhering to a diverse set of constraints. These constraints include ensuring non-overlapping room placement, providing external openings for rooms, establishing door connections to corridors, and ensuring that corridors lead to external exits. Additionally, compliance with building codes, which restrict the placement of openings on certain sides of the building, is enforced. Special constraints tailored for 3D printing, such as limiting the size of building components, are also considered, along with the flexibility to implement arbitrary design rules.

In contrast to previous methods [1], our method models the floor plan as a discrete grid (raster), with each room converted into a raster representation and placed on this grid. Corridors are treated as unoccupied cells within the grid, connecting the rooms and ensuring access to external exits. Violations of constraints are assigned penalties based on both the nature of the constraint and the extent of the violation. The overall objective is to minimize the total penalty through an optimization approach based on Simulated Annealing.

The method demonstrates robust performance, yielding efficient floor plans that comply with a wide range of practical design requirements. This approach opens new possibilities for further exploration in the realm of automated architectural design, particularly in integrating constraints for emerging technologies like 3D printing.

* The asterisk denotes the presenting author.

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Optimizing the Strength of Lightweight Composite Beams Using Partially Encased Cellular Steel Sections with Various Configurations

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ABSTRACT

Ensuring the composite action in structural members with different components along with optimizing the weight is very challenging and many efforts have been made in this direction in the last decades. This study introduces a new composite beam with partially encased steel sections (PECB) where the shear connectors were mitigated along with superior flexural performance. The innovative connection was done using steel sections with wide flanges and cellular web with circular openings where the section weight was significantly reduced with optimized strength behavior and improved composite action. This study details the flexural performance of PECBs with different cellular configurations. Circular openings were numerically simulated within the steel beam web with different diameters (150, 200, and 250) mm and center-to-center spacing between the two constitutive cells (143, 200, and 250) mm, with a 500 mm constant distance from each of the beam's end. The structural behavior was deeply compared with providing an optimized use of the PECB components to maintain their strength and ductility behavior. Results were promising and believed to provide a wide vision of the improved system's performance.

* The asterisk denotes the presenting author.



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Structural Behavior of Full-Scale Sound-Wall System Based on Large Scale Testing and Non-linear Finite Element Simulation

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ABSTRACT

In civil engineering, large-scale experimental testing is an essential tool for ensuring the performance, safety, and durability of infrastructure projects. It allows for the validation of designs, implementation of innovations, and the delivery of important data for research and development. This study investigated experimentally the structural characteristics of a fully prefabricated noise barrier wall structure. Two large-scale prototypes, each measuring 17 feet high by 11 feet wide, were used to test the system at the University of Illinois at Chicago's High-Bay Structural Laboratory. The system was intended for rapid assembly. About 40 sensors have been placed in each prototype to monitor key aspects like load deflection, load strain, cracking, uplift, and failure modes. The wall system met serviceability and strength limitations and remained structurally stable under high loads, according to the results. The system's wings each withstood a service limit state wind pressure of 15 psf (0.56 kN/m²), and their deflections stayed well within the allowed range. To further reduce the requirement for expensive full-scale testing, a 3D nonlinear finite element analysis (NLFEA) model was developed and calibrated to simulate the behavior of the system. The response of the system under service and strength limitations was accurately predicted by the model. After further refinement for the developed model, it was used to assess the impact of critical parameters, thus allowing for further optimization and improvement of the noise wall barrier.

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Computed tomography for additive manufacturing

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ABSTRACT

X-ray computed tomography (XCT) is a 3D imaging technique that has been increasingly applied as a non-destructive testing method for characterizing the internal structure of various materials at different levels of scale. Additive manufacturing (AM) is the process of fabricating wide range of structures and complex geometries using 3D computer-aided design (CAD) model data. The combination of XCT and AM has become increasingly important in various fields such as engineering and medicine. This paper presents the characteristics of XCT and its combination with AM process, highlighting the benefit and the limitations from this combination. According to the literature, there are two main areas for using XCT and AM which are: dimension measurements and porosity measurements. However, the combined use of XCT and AM is still limited due to the existence of many challenges. This study shows the importance of conducting continuous researches for increasing the use and exploiting the benefits provided by the adoption of XCT in AM.

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Design of transitional spaces in the university campus: the case study of Jordan

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ABSTRACT

Transitional spaces in the university campus are constituted as an inevitable consequence of the design process without a real understanding of the significant role that they play as functional and aesthetic spaces serving students. Therefore, there is a need to examine the characteristics of these places that distinguish them from other facilities to facilitate the construction of a suitable and attractive educational environment. The research aims to investigate the role of transitional spaces in delivering university campuses. The research uses the testing-out approach using a mixed method, where comparative case study areas and a questionnaire survey with students from Jordanian Universities were conducted. Therefore, this study is the first study having this type of transition space on the university campuses in Jordan. This study concludes with a framework consisting of a set of practical recommendations to design transitional spaces within the university campus. It identified the suitable characteristics for the transition spaces within the university campus. This contributes to upgrading the knowledge of the role of in-between spaces in delivering the university campus design, which will help urban and architectural designers in creating successful transitional urban spaces on the university campus.

* The asterisk denotes the presenting author.



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Composite Beams with Partially Encased Steel Section Using Circular Web Openings: Flange and Web Thickness Effect

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ABSTRACT

Structural systems with many components are hard to execute, costly in terms of time and money, and require high caution levels to ensure their composite interaction and optimized performance. Therefore, there is a need to find a simplified and powerful method with reduced construction work and improved actions. This study introduces a modified composite beam construction with a partially encased cellular section and eliminated shear connection parts. The steel sections have wide flanges, cellular webs with systematically arranged circular openings, and encased concrete parts. ABAQUS software was used to numerically assess the extent of the cellular section properties on the flexural behavior of the partially encased cellular beams (PECBs) using different flange thicknesses (3, 6, and 9) mm, and web thickness values (3, 4.5, and 6) mm. The interaction between the two welded horizontal and vertical parts was studied and their effect on the PECBs was introduced. It was found that the new system is innovative with superior properties to ensure favorable strength, lightweight, and ductility characteristics.

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Innovative Synergies in Non-Destructive Testing for Civil Engineering

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ABSTRACT

This paper discusses the use of non-destructive testing techniques in civil engineering applications, offering a summary of commonly used methods that assess structural integrity, detect defects, and monitor infrastructure conditions without causing damage. It also explores the future of hybrid non-destructive testing techniques within the field of civil engineering. By combining two or more methods, such as ground penetration radar and ultrasonic testing, hybrid non-destructive testing enhances the accuracy and efficiency of structural assessments. This approach allows engineers to gain a better understanding of material conditions and identify potential issues more effectively. Additionally, combining image processing techniques with numerical simulation methods, such as finite element and discrete element methods, presents another example of the successful synergies in non-destructive testing. The paper highlights the advantages of these synergies, including improved defect detection, reduced testing times, and superior data quality. Through case studies, the authors illustrate successful applications of hybrid non-destructive testing in real-world projects, which emphasizes its transformative potential in civil engineering. The aim is to inspire further explorations of pioneering non-destructive testing techniques to advance structural and durability assessment practices.

Keywords: Non-destructive Testing; Numerical Simulation; Image Processing; Ground Penetration Radar; Structural Assessment.

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Experimental Mechanical Characterization of 3D Printed Structures Under Bending Loading

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ABSTRACT

In the present work, experiments are conducted to characterize 3D-printed structures under bending loading. Special emphasis is placed on printing with the material PETG (Polyethylene Terephthalate Glycol), known for its excellent mechanical properties, such as impact and puncture resistance, making it a durable and robust material. The selection of PETG is considered significant, as it is suitable for applications requiring strong and long-lasting components.

A key focus of the study is the investigation of how different printing parameters affect the mechanical performance of the printed structures. The experiments are designed and conducted using the Taguchi method, which enables efficient optimization of multiple parameters. PETG structures are printed under varying settings, such as printing angle, layer height, line width, printing temperature and printing speed, following Taguchi's orthogonal array, allowing for a systematic analysis of how these factors influence the material's bending behaviour.

By combining analytical modeling with the experimental results obtained through the Taguchi approach, a deeper understanding is achieved regarding the effects of the 3D printing process on the mechanical properties of PETG-printed structures. This method provides valuable insights into optimizing printing parameters, leading to improved mechanical performance in real-world applications.

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Enhancing Trend-Following Strategies in Financial Markets Using Machine Learning and Time Series Models

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ABSTRACT

The paper explores the integration of machine learning (ML) models into trend-following strategies within trading and investing. Traditional trend-following methods, such as those based on the Ichimoku Cloud, an advanced technical indicator, are enhanced through the use of advanced ML algorithms, including Naive Bayes, K-Nearest Neighbors, Gradient Boosting, Decision Trees, and others. The research backtests these models using currency pair data from 2010 to 2023, evaluating their performance on metrics such as total return, maximum drawdown, and mean return. Results indicate that models like Extreme Gradient Boost (XGB) and Naive Bayes significantly improve returns while reducing risk compared to the base strategy. Additionally, time series models, including Temporal Convolutional Networks (TCNs) and Kalman Filters, are integrated to enhance forecasting accuracy. Both models show substantial improvements in total returns and mean return with lower volatility. The results indicate that time series models significantly outperform the application of machine learning techniques in enhancing the effectiveness of the strategy. The paper highlights the potential of machine learning and time series models to improve the profitability of trend-following strategies and refine decision-making in financial markets and other sectors as well, such as 3D printing.

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Design and Optimization of Stormwater Drainage Pipe Grade Lines for the Aliartos Bypass: A Case Study Using Matlab-Inspired Optimization Procedures

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ABSTRACT

This study presents the design and optimization of the grade line for stormwater drainage pipes installed under the side ditches of Aliartos town bypass road, Greece. The project focuses on optimizing the excavation depth, which is directly related to construction cost, while adhering to constraints on the maximum and minimum allowable pipe depths. The slope of the pipes must be downhill and confined within specified limits to ensure efficient drainage performance.

A custom optimization framework was developed, designed to be compatible with standard optimization routines available in Matlab. The formulation of this problem posed unique challenges due to the multiple constraints and the need for a robust solution methodology. Various optimization algorithms, including Simulated Annealing [1] and Particle Swarm Optimization, were evaluated to identify the most effective and computationally efficient approach.

The proposed method was used on the design of 47 pipes along the Aliartos bypass, resulting in highly satisfactory performance. The optimized pipe grade lines demonstrated significant reductions in excavation depth while ensuring compliance with depth and slope requirements. The results confirm the effectiveness of the chosen optimization technique, offering a reliable and cost-efficient solution for similar stormwater drainage projects.

* The asterisk denotes the presenting author.

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Correlation of process parameters with weld quality and geometry of wire arc additively manufactured steel elements

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ABSTRACT

Wire Arc Additive Manufacturing (WAAM) is a metal 3D printing method that enables the manufacture of geometrically complex metal components with lower cost and higher deposition rates than other metal printing methods, such as powder bed fusion. Although numerous recent studies have recently been conducted on the mechanical properties and physical characteristics of WAAM steel elements, there are still uncertainties regarding the selection of the optimal process parameters when certain mechanical or geometric characteristics are required. Towards addressing this shortcoming, a comprehensive experimental programme has been conducted to investigate the influence of the key process parameters on the mechanical and geometric properties of WAAM wall elements. Following a matrix investigation approach, Numerous combinations of wire feed speeds and travel speeds were considered to investigate the impact of the heat input on the weld quality and geometry of WAAM steel wall elements. The present study was thus carried out in two stages. Firstly, fifty-six combinations of wire feed speeds (between 4 and 16 m/min) and travel speeds (between 5 and 12 mm/s), were employed to produce short WAAM walls; in this manner, heat inputs ranging between 81 J/mm to 1032 J/mm were achieved. Secondly, fifteen tall WAAM walls were printed using the speed combinations from the first investigation that resulted in high quality welds. The second stage investigated the sensitivity of the average layer height to the number of printed layers. The results provide correlations between the heat input and the weld quality and geometric characteristics (namely, wall thickness and average layer height) of the WAAM walls, which can be used to predict the quality and geometry of thin walled WAAM elements based on the heat input of the welding process.

Acknowledgment

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Hydrodynamic Modeling and GIS-Based Mapping of Hypothetical Dam Break Floods

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ABSTRACT

Abstract: This work focuses on simulating flooding under three hypothetical extreme precipitation scenarios by generating a homogenous breach in a concrete dam utilizing a one-dimensional hydraulic model (HEC-RAS) and the Hydrologic Engineering Center's River analysis system (HEC-HMS). Using WorldView-3 stereo pictures, the HEC-GeoRAS tool was used to determine the river geometry terrain model and to create a flood map that showed the affected areas. In the downstream portion of King Talal Dam (KTD), hydraulic parameters such as flow velocity, water level, and flood arrival time were computed over a variety of cross sections. The probable maximum flood (PMF) for overtopping and piping failure scenarios was taken into consideration to estimate the dam breach under changing flow circumstances. Furthermore, the hydraulic conditions downstream at KTD and the breach outflow hydrograph were evaluated using the HEC-RAS. The depletion of the breach hydrographs was guided by means of the dynamic flood wave routing method. After that, breach parameters found by the Froehlich empirical method were simulated using HEC-RAS. Significant flow rates were seen in the area directly downstream of the dam, with overtopping failure resulting in a significantly higher peak flow rate than piping collapse. In the event of an overtopping, this led to larger areas affected by flooding. The flooding that results from the dam break is anticipated to have a significant impact on the communities downstream. The analysis shows that overtopping failures are a more serious risk than piping failures, providing authorities with crucial information for creating efficient flood control and emergency response plans.

Keywords: Dam break; flood inundation mapping; structural failure; extreme weather events; hydrodynamic and hydrological modeling; King Talal Dam



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Bridging Traditional Sculpture Methods with 3D Scanning/Printing

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ABSTRACT

In the ever-evolving landscape of art, the convergence of traditional craftsmanship and state of the art technology has become a dynamic arena for creative exploration. The project at hand delves into this intersection, unraveling the symbiotic relationship between traditional sculpture techniques and state-of-the-art 3D scanning and printing technologies.

This project explores the dynamic intersection of traditional sculpture techniques and the state-of-the-art 3D scanning and 3D printing technology. Two intricate clay sculptures were meticulously crafted by G.-Fivos Sargentis, serving as the initial embodiment of the creative vision. Following this traditional sculpting phase, each model underwent a transformative process, marking a synthesis of classical artistry and modern innovation.

To bridge the analog and digital realms, the clay sculptures were 3D scanned using mobile apps for smartphones, capturing the fine details and nuances of the original handcrafted forms. This digital replication paved the way for further digital sculpture processing and the utilization of 3D printing technology, as the scanned models were recreated in tangible, three-dimensional form. The printed sculptures served as a canvas for the artist's continued exploration, enabling a unique dialogue between the physical and the virtual.

The final models were printed in plastic, in resin, resin for casting and wax for casting. Few of them were casted in bronze using lost-wax casting method.

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Do Floods Attack Cities or Cities Invade Flood plains?

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ABSTRACT

During the last century, the increase of global population forced societies to rapid urbanization. However, in most cases, the growth of cities had ignored the collective knowledge that brought the “spirit of the place” (Latin: genius loci). Among other contributions, this knowledge prevented people from building infrastructures within riverbeds and floodplains, as it contained the experience from historical (and sometimes mythical) flood-events and disasters. Exploring the historical evolution of urban sprawl in flood-prone areas, we focus on the case study of Athens in Attica municipality of Greece. Through the assessment of urbanization trends, it is evident that cities have expanded aggressively into floodplains, which were historically avoided due to collective local knowledge about flood risks. As cities continue to grow within these areas, the frequency and severity of flooding events increase, highlighting the fact that urban expansion may be proven a more significant contributor to flood risk than natural flood events.



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The Technological Evolution in Flood Risk Estimation

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ABSTRACT

The advancement of technology has transformed flood risk estimation from rudimentary manual calculations to sophisticated computer-based models. This research traces the evolution of flood risk assessment methods, comparing the analog approaches of the 1970s with modern digital tools. In the past, engineers relied on basic hydrological formulas, manual data collection, and physical models to estimate flood risks, often resulting in limited accuracy. Today, modern software like HEC-RAS, digital elevation models, and satellite imagery have revolutionized this field, providing highly detailed and precise flood hazard maps. In this research, we applied the above tools to the Pikrodafni river in the Attica region as a case study to showcase the impact of technological advancements on flood risk management, emphasizing on how digital tools enable better mitigation strategies and contribute to urban resilience against flood hazards.



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Fast-Track Modeling of the Landscape for Hydraulic Studies, Using Drones and Photogrammetry in Field Research

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ABSTRACT

Hydraulic studies inherently involve assumptions and uncertainties due to the complexity of natural systems. Variations in terrain and surface properties may highly contribute to these, where to properly address them, modern techniques, such as terrain modeling, are employed. Digital terrain models of the landscape play a crucial role in accurately representing the surface where water interacts, capturing elevation, slopes, and features that affect flow. One effective method to minimize uncertainty is taking successive images by drones in order to be processed with photogrammetry, and to finally produce detailed 3D terrain models. These models offer a more precise and comprehensive understanding of the area compared to traditional field research. By incorporating critical parameters, like channel roughness, engineers can have more accurate inputs to calibrate the simulation of the water movement in the terrain. Consequently, combining digital terrain models, water flow parameters, and advanced simulation techniques may strongly enhance the accuracy of hydraulic studies.

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The Use of 3D Printed Models of the Landscape in Hydraulic Studies

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ABSTRACT

Hydraulic infrastructures for flood management are typically designed to operate under a wide range of conditions with multiple roles (dry, little rain, or flood). In this research, we present the capabilities of water flow modeling with physical maquettes created with photogrammetry using successive photos by drone. Digital terrain model can be 3D printed to acquire the maquette of the terrain, and to simulate how a rainfall event transforms into runoff on the maquette. Thus, we can acquire the experimental simulation of how water inundates along the river channel and the flood plain areas. This provides physical characteristics to the study of water flow and the necessary inputs for the principals of the designing process. By capturing water movement and physically observing the simulation of the model, makes it easier to identify potential errors that may arise during the creation of the digital model, and which may not be easily detected otherwise.

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Advanced numerical simulation of a 3D-printed spinal brace

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ABSTRACT

The use of spinal braces is the most common means to address adolescent idiopathic scoliosis by limiting the progression of spinal inclination. From a mechanical point of view, spinal braces are shell-type structures, relying on the fundamental engineering principles of three-point bending and inversion forces. A research project is ongoing to develop a procedure comprising laser scanning, advanced numerical simulation, topology optimization and additive manufacturing, to design and 3D print lightweight, personalized braces. In the present paper recent advances in the numerical simulation procedure are reported.

Finite element simulation of the brace and its interaction with the patient's body is employed, to evaluate the developing deformations and stresses during the brace's use. For that purpose, the brace is modeled with shell finite elements and the body with a mirror surface of appropriate geometry, considering deformability and detachment by means of contact elements with an appropriate pressure – overclosure relation, employing realistic values of human body stiffness at its different parts. The mechanical properties of the brace material employed in the simulation are adopted from experimental tensile tests on 3d-printed Polylactic Acid (PLA) specimens.

From the numerical simulation, von Mises stresses and displacements of the spinal brace are obtained and are used to interpret its structural behavior. To understand how the patient's body is affected by the use of the brace, contact pressures are presented, reflecting the interaction between the brace and the body.

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Numerical Simulation and Nonlinear Finite Element Analysis of 3D-Printed Joints for Deployable Structures

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ABSTRACT

Objective of the present study is the simulation of an experimental process for the design of 3D-printed nodes of a scissor-based deployable shelter for emergency response [1]. The test specimen consists of a 3D-printed node made of Polylactic Acid (PLA) and four aluminum bars with rectangular hollow sections hinged to the node using steel pins. At their other ends the aluminum bars are hinged to a rigid steel base, and the load is applied by a tension rod system to the center of the node.

Geometry and material nonlinear analyses (GMNA) were carried out in Abaqus CAE software Version 2021 [1], where all members of the specimen were simulated through 3D solid finite elements, with the aim of predicting the evolution of the experimental process but also determining the deviations between numerical and experimental findings. Nonlinear material laws were adopted for the joints and the bars, representing PLA [2] and aluminum, respectively, while steel was modeled as linearly elastic. In addition, all possible contacts of the members were simulated through contact elements.

The analysis results demonstrated a high concentration of stresses and material yielding around the bearings of the beams and the node, already at relatively low load levels, while high stresses develop also inside the node at higher loads. Significant margins for optimization of the node topology were established, as inactive areas of the node were observed for the applied loads.

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Measuring and evaluating layer height to width ratio in 3D concrete printing towards higher geometric conformity

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ABSTRACT

Geometric conformity [1] is an essential aspect of 3D Concrete Printing (3DCP) due to its importance in the accurate production of design outcomes. By measuring, predicting and controlling the printing parameters leading to better print quality and geometric accuracy, optimum and desired 3D printed designs [2] can be achieved. Specifically, the height to width ratio influences the geometric accuracy of 3D printed results and lead to higher geometric conformity. Currently, there are few research works that attempt to measure the geometric accuracy of 3D printed products by using scanning or other techniques, comparing the as-design with as-build results. Such techniques require special mechanisms (e.g. scanners) or superior computing time that in some cases is not affordable. This work aims to provide guidelines towards higher geometric accuracy by investigating the height to width ratio of overall and individual layer filaments in 3D printed results through a series of robotic 3DCP sample prototypes using different material mixtures. The results are examined using traditional and automated algorithmic procedures to analyse a series of cross section shapes that are derived from 3D printed samples. This enables the extraction of measurable data that includes among others the height and width of overall cross sections but also of each individual printed filament. In addition, failures occurred during the 3DCP process are recorded and analysed. The collection of data allows comparison between different parameters influencing 3DCP including material mixtures, robotic speed, and adjusted width/height of layer filaments. The results show that printing parameters such as material mixtures and robotic speed play an important role during 3DCP and can be applied to control the process in future design and 3DCP production steps.

* The asterisk denotes the presenting author.

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Driving behavior prediction based on acceleration metrics via machine learning algorithms

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ABSTRACT

Advancement of intelligent transportation systems has placed substantial emphasis on understanding and analyzing driving behavior for establishing improved road safety and traffic management. This work focuses on the application of machine learning algorithms to predict driving behavior based on solely acceleration metrics. With the use of user-recorded datasets, implementation and evaluation of several machine learning models is performed with respect to their ability to accurately classify different driving behaviors: aggressive, passive and normal driving. The results show that acceleration data can provide valuable insights for predicting driving behavior but additional data will be needed for ultimately contributing to safer and more efficient transportation systems.

Driving behavior is a critical factor influencing road safety, fuel efficiency and environmental impact of transportation. With the advancements in sensor technology and data analytics, there is an opportunity to harness machine learning to objectively analyze and classify driving behavior using acceleration metrics. This work investigates the relationship between acceleration patterns and discrete driving behaviors, evaluating how machine learning algorithms can be utilized for prediction.

In the recent past, work has been presented in classifying driving behavior with respect to sensor recorded acceleration data [1,2]. For this study, a dataset collected from user cell phones, comprising acceleration metrics such as longitudinal and lateral acceleration was used in combination to a dataset provided in the work of Cojocararu et al [2]. The data was gathered from a diverse range of drivers over various road conditions, capturing a wide spectrum of driving behaviors. Preprocessing involving removal of outliers and noise, normalization and feature engineering was performed in the data set. Regarding feature augmentation, features such as moving average and data grouping over a defined time window to facilitate more meaningful predictions were performed. Following that, a selection of several ML/AI algorithms were tested such as Random Forest, Support Vector Machines and recurrent Neural Networks. The selection of the algorithms was made according to characteristics such as interpretability and robustness against overfitting, accuracy in classification problems, ability to capture complex patterns in high-dimensional data and handling hidden, non-linear correlations. The data sample was separated in train and test samples while k-fold was also incorporated for avoiding overfitting.

The models demonstrated varying degrees of performance across different driving behavior classifications. Table 1 summarizes the results:

Model	Accuracy	Precision	Recall	F1-Score
Support Vector Machines (SVM)	49%	48%	48%	48.12%



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Model	Accuracy	Precision	Recall	F1-Score
Random Forest (RF)	46%	45%	45%	44.98%
Recurrent Neural Networks (RNN)	48%	47%	47%	65.21%

The results emphasize the potential of using acceleration metrics to reliably predict driving behavior. The neural network model outperformed the others, suggesting that deep learning can capture intricate interactions within the data. Moreover, the analysis of feature importance indicates that certain metrics are more indicative of specific behaviors, which could inform driver training programs aimed at reducing aggressive driving patterns. This study demonstrates the feasibility of utilizing machine learning algorithms to predict driving behavior based on acceleration metrics but also the need for recording additional data from more drivers, different roads and additional metrics. The findings suggest that greater emphasis on acceleration patterns could lead to improved models for predicting driver behavior, which in turn may enhance road safety initiatives. Future research could explore the integration of additional data for a more comprehensive analysis of driving behavior.

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Topology Optimization of 3D-printed Spinal Braces

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ABSTRACT

Spinal braces are external support structures designed to help correct the inclination or support the human spine. Their use is often utilized for the treatment of scoliosis, kyphosis or lordosis. The successful treatment of these spinal deformities is very much dependent on their early utilization by the patients. Thus, the use of the spinal brace from a young age is crucial in their effectiveness. Due to the movement restrictions imposed by the spinal brace, young kids are generally not inclined to use them. Therefore, the need for a lightweight optimized spinal brace that imposes only the necessary movement restrictions on the patient is critical in making spinal braces a more attractive treatment.

The design of lightweight spinal braces is achieved through a combination of optimization procedures and the use of 3D printing techniques. In particular, the methodology of Topology Optimization is utilized on an accurate simulation of a spinal brace, producing optimized braces and achieving significant reduction in material. The formulation used in the Topology Optimization procedure was the classic approach, involving the minimization of compliance. Additionally, the future use of 3D printing technology for the construction of the spinal brace enables the minimization of geometry restrictions imposed on the Topology Optimization problem formulation, allowing the optimization algorithm more designing freedom during the optimization procedure.

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Embryo Surface Metrics as a Growth Proxy for Blastocyst Prediction

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ABSTRACT

Previous studies have indicated that cell division timings and morphological features contain predictive information about embryo quality and developmental potential. Traditional assessment methods by embryologists can be subjective and may not capture subtle quantitative changes detectable through advanced image analysis. This retrospective cohort study analysed time-lapse data and embryo classifications from 2,170 embryos cultured for at least 110 hours at a single IVF. An additional 326 embryos were set aside for blind testing to evaluate the model's performance against that of an embryologist. The extraction of these metrics was possible by training a Neural Network (U-Net Architecture) to extract the mask of an embryo in the time-lapse images (TLM). The final machine learning model was trained using extracted data from embryo surface metrics to perform a binary classification task, in order to discriminate between embryos that reached blastocyst stage and those who did not. The machine learning model was able to predict if an embryo will reach blastocyst stage with an AUC of 0.85 [95% CI 0.88–0.93] in a blind test. The model was able to outperform the embryologist's prediction in accuracy by 12% (0.791 vs 0.696) and in F1 Score by 8.5% (0.811 vs 0.742).

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Comparing Different AI Models and Spectral Indexes on Flood Detection Using Satellite Images from Sentinel-2

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ABSTRACT

Floods are catastrophic events that affect nearly every part of the globe, leading to substantial losses of life and causing extensive economic damage. During flood emergencies, one of the primary challenges faced by response teams is accurately identifying the flooded regions to establish access points and determine safe evacuation routes swiftly.

This study compares several artificial intelligence models and spectral indexes for flood detection in Senteinel 2 multispectral images. The proposed methodology combines transfer learning with different models, such as: neural networks, convolutional neural networks, and vision transformers.

A variation of this model is the vision transformer (ViT), which can be applied to image classification tasks. Multispectral Instrument (MSI) images from Sentinel-2 are used which contain images from different bands. Using different combinations of those bands different spectral indexes can be calculated, such as: Normalized Difference Water Index (NDWI), Modified Normalized Difference Water Index (MNDWI), Water Ratio Index (WRI), Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Automated Water Extraction Index (AWEI). By comparing different artificial intelligence models and different spectral indexes the best combination is determined, which can be used for real-time flood detection using Sentinel 2 Multispectral Images.

Acknowledgments:

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Bio-Inspired Innovation: Optimizing Gridshell Structures through the Dolphin Echolocation Algorithm

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ABSTRACT

In an era where sustainability and innovative design are paramount, this study investigates an unexplored method to optimize the gridshell structures, paving the way for more efficient and environmentally friendly solutions. This study aims to employ a bio-inspired optimization technique known as the Dolphin Echolocation Algorithm (DEA) to enhance the design of a grid shell structure focusing on topology optimization and material efficiency. Dolphins employ sonar, a form of vocalization, to detect and discern their desired target. The dolphin modifies its sonar to alter the target's position. This algorithm harnesses the echolocation abilities of dolphins to enhance exploration, optimize utilization, and adapt to changing design requirements. The Dolphin Echolocation Algorithm has the potential to be employed for grid-shell structures to provide material efficiency and cost reduction. The DEA has not been previously employed for this problem and may yield superior solutions compared to other metaheuristic algorithms. To evaluate the accuracy and effectiveness of the DEA, we performed a comparative analysis with other metaheuristic algorithms such as GA, PSO, and ACO in a specific case study. The results indicated that the DEA is efficient and is a high-speed, highly effective method of discrete structural optimization. Integrating DEA into structural design enables engineers to investigate a wider range of design possibilities and improve the designed grid-shell structures. Additionally, the results may catalyze future research on other biological systems, thereby promoting a more profound comprehension of how natural processes can inform innovative engineering solutions in a variety of domains.

Keywords: topology optimization, material efficiency, Dolphin Echolocation Algorithm (DEA), metaheuristic algorithms, Gridshell structures, optimization

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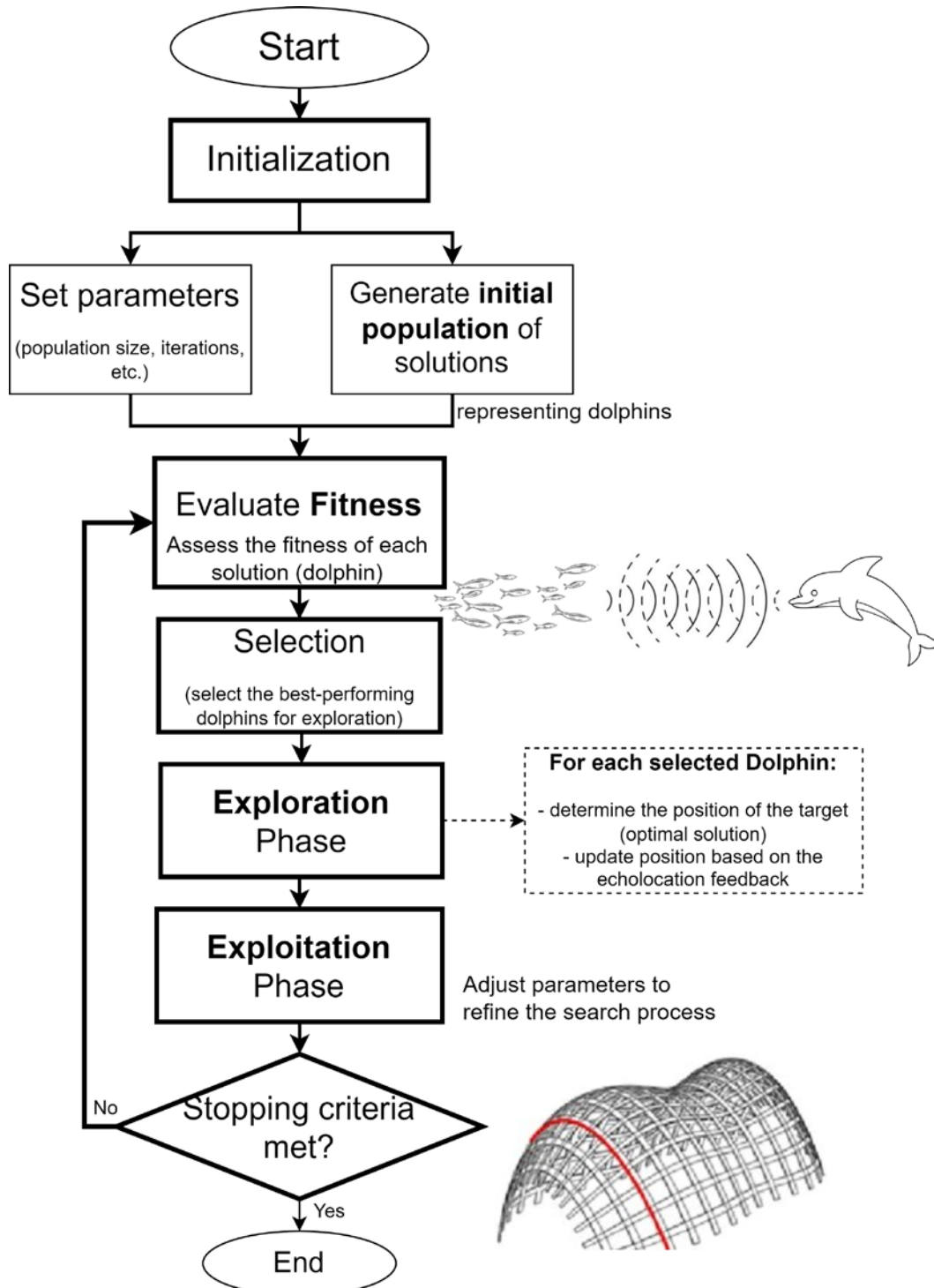


Figure 1 The flowchart of the Dolphin Echolocation Algorithm



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Cost-Effective and Constructible Gridshell Design Through the Fusion of Form-Finding and Evolutionary Algorithms

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ABSTRACT

The construction industry, despite its considerable environmental footprint, represents a crucial segment of the global economy. Consequently, even minor advancements in this field can generate significant global benefits. Structural optimization emerges as a promising strategy for addressing these challenges, particularly in the design of gridshell structures. Gridshells, known for their ability to span large spaces without intermediary supports, offer remarkable structural efficiency. However, their construction complexity has limited their widespread use. Optimization techniques can address this by improving material efficiency and simplifying construction processes. This study introduces an optimization framework for free-form gridshell structures, combining evolutionary algorithms with the enhanced Multi-body Rope Approach (i-MRA) for form-finding [1]. The primary objectives minimize structural components, reduce material consumption, decrease production waste, and ensure compliance with structural standards. This approach provides an innovative and efficient solution for the conceptual design of lightweight and structurally efficient gridshells.

* The asterisk denotes the presenting author.

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The influence of utilizing the 3D Atlas application technology on the athletes' understanding of the anatomy and its mechanisms

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ABSTRACT

This study aimed to identify the effect of using the 3D Atlas application for anatomy on the cognitive outcome of the anatomy course for athletes for first-year students in the Department of Sports Sciences and Physical Activity at Taibah University. The researchers used the experimental method for its suitability to the nature of the study. The size of the study sample was 70 students studying the anatomy curriculum for athletes, divided into two groups, one of which was experimental and numbered 35 students, where the 3D Atlas application for anatomy was used, and the other was a control group and numbered 15 students who used the traditional method of education. The researchers applied the experiment to the study sample during the academic year 2024. The most important results of the study were that the experimental group that used the 3D Atlas application for anatomy was superior to the control group in measuring the cognitive outcome in the anatomy course for athletes, using, and the study recommends the necessity of using the 3D Atlas application Anatomy as an important and helpful factor in guiding the educational process and raising the level of knowledge of students in the anatomy course for athletes, in addition to applying other modern technical means that help raise the level of knowledge of students in other courses.

Keywords: 3D Application; Atlas anatomy; Anatomy for athletes; Sport Sciences.

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Non-conforming Finite Element Discretizations in Small-Deformation Contact Problems with Inelasticity: Overview and Case Studies

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ABSTRACT

This paper provides an overview of finite element analysis of contact problems entailing non-conforming meshes (NCM) in the framework of small-deformation inelasticity. Finite element simulations of solid mechanics frequently utilize NCM to improve accuracy in representing nonlinear behaviors, such as damage and plasticity, without experiencing extra computational costs. When dealing with material nonlinearity and plasticity, higher-order variables are often necessary to effectively represent the nonlinear behavior and material deformation history across non-conforming interfaces. The Enriched Discontinuous Galerkin Approach (EDGA) is a primal method that delivers higher-order kinematic fields at the interface, however, presents the issue of preserving material history at integration points when an increase in integration order is needed. The EDGA is extended to the case of small deformation plasticity by implementing an interface-driven Gauss-Kronrod integration rule to enable adaptive enrichment on the interface while preserving history-dependent material data at existing integration points. This paper discusses various case studies and applications of the method using classical J2 plasticity theory as well as the pressure-dependent Drucker-Prager material model, demonstrating the feasibility and effectiveness in improving algorithmic performance and provide a consistent approach for coupled NCM in inelasticity.

Keywords: Non-conforming meshes, contact problems; inelasticity; small deformation.

* The asterisk denotes the presenting author.



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Advanced Optimization of Geodesic Dome Structures: Minimizing Frame Volume and Structural Complexity through Evolutionary Algorithms

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ABSTRACT

Geodesic domes are efficient hemispherical structures derived from geodesic polyhedrons, typically composed of triangular or polygonal elements that form a stable and rigid shell. This structural system, known for its ability to evenly distribute stresses, enables geodesic domes to support substantial loads relative to their own weight. The unique geometry, based on triangulation principles, grants these domes excellent resistance to external forces, making them suitable for a range of engineering and architectural applications. The first geodesic dome was constructed in 1922 at the Zeiss optics factory in Jena, Germany, serving as a projection surface for a planetarium projector. Later, the work of R. Buckminster Fuller popularized these structures globally, expanding their use into residential buildings, greenhouses, water storage facilities, and exhibition pavilions. Their capacity to maximize enclosed space while minimizing material usage makes them appealing for projects focused on sustainability and cost efficiency.

Despite these advantages, further optimization is often required to refine the design, particularly in terms of reducing material use and simplifying the joints between elements. This study aims to enhance the structural performance of geodesic domes by minimizing both the frame's volume and the complexity of the connections. The base radius is treated as a fixed parameter, representing a shape constraint for the optimization process. By varying the frequency of subdivisions in the polyhedral mesh, the number of frame elements and the structural topology can be adjusted. Through modifications to sectional properties, a range of configurations is explored to achieve an optimal balance between performance and material efficiency. The presented case study considers self-weight and non-uniform loading conditions to evaluate structural behaviour under realistic scenarios, while incorporating practical considerations for the dome's construction and assembly. The optimization strategy employs evolutionary algorithms (EAs) to systematically search for the best configurations. Each candidate solution is evaluated using Finite Element Analysis (FEA) to predict structural responses and assess performance. By integrating FEA results into the optimization process, the approach achieves a more accurate assessment of the design's viability. The findings demonstrate how combining computational optimization techniques with traditional engineering analysis can improve geodesic dome designs, enhancing their potential for modern architectural and structural applications.



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Machine-learning-based constraint handling for particle swarm optimization within structural optimization

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ABSTRACT

Despite their historical roots and formally rigorous mathematical framework, mathematical programming is often not sufficient to effectively deal with real-world complex optimization problems. For instance, focusing on the structural optimization field, heuristic and meta-heuristic computational intelligence methods represented a promising solution for addressing many real-world challenges since their early conception. Several algorithms have been formulated inspired by mimicking natural phenomena, such as Genetic Algorithms or Simulated Annealing, among others. The lack of a strong mathematical basis motivated the idea of always simultaneously implementing different soft-computing techniques both for comparisons and mutual validation, and also because due to the No-Free Lunch, which demonstrated that the perfect algorithm able to solve any optimization problem does not exist. The study of the animal's world behavior, i.e. bird flocking or fish schooling, is the main idea behind one of the nowadays still most widely adopted meta-heuristic algorithms, i.e. the particle swarm optimization (PSO) technique [1]. In the beginning, PSO was formulated to solve unconstrained optimization problems only, and later numerous scholars attempted to introduce some new constraint handling mechanisms in order to exploit the PSO's powerful optimization capabilities even with most likely real-world constrained problems. In this study, the authors focused on the constraint handling problem in PSO for solving structural optimization tasks, by leveraging the nowadays new compelling Machine Learning tools offered by the digital revolution currently in progress [2]. Specifically, the authors formulated a new constraint-handling method based on the support vector machine (SVM) classifier to progressively update the feasible search region while the swarm explores the search space. This novel technique has been tested on a structural optimization conceptual design problem of a Warren truss steel bridge.

* The asterisk denotes the presenting author.

Keywords

Structural optimization, Machine Learning, Meta-heuristic Algorithm, Support Vector Machine

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Performance-Based Optimization of Steel Exoskeletons

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ABSTRACT

This paper presents an innovative approach to the structural optimization of steel exoskeletons, a technique used for the seismic retrofitting of seismically vulnerable buildings. Traditionally, steel exoskeletons have been favored for their ability to reinforce structures externally, thereby avoiding the need for extensive internal strengthening measures. However, despite their benefits, they are not widely adopted due to the large amount of free space required around the building and the restrictive design regulations that enforce strict limits on the stiffness ratio between the exoskeleton and the existing building. These regulations often hinder the potential of exoskeletons, making their implementation less appealing to designers.

This paper proposes a shift in focus, moving from a stiffness-based design approach to a performance-based design methodology. The new approach focuses on optimizing the number, position, and sizing of the exoskeletons, not by adhering strictly to the stiffness ratio but by focusing on inter-story drift as the primary design parameter. Inter-story drift is a critical measure of a building's seismic response, representing the relative horizontal displacement between consecutive floors. This displacement-based approach better reflects the real performance of a structure during seismic events, allowing for more nuanced and effective optimization of the exoskeleton's role in minimizing seismic damage.

Furthermore, the study highlights how the displacement-based methodology encourages more precise control over the building's behavior during seismic events. By focusing on reducing inter-story drift, designers can ensure that the building experiences less horizontal displacement, which is directly linked to structural damage. This performance-driven strategy allows designers to optimize the exoskeleton's positioning and dimensions more effectively, resulting in more sustainable designs both economically and structurally.

By moving away from conventional stiffness-based regulations and embracing performance-based optimization, the new design approach offers a more efficient and cost-effective solution, ensuring the long-term resilience of buildings in seismic-prone areas.

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Data-driven computational mechanics towards structural digital twins

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ABSTRACT

Usage of data for the solution of direct and inverse problems in mechanics and structural analysis has been the topic of various investigations in the last decades. Complexity of neural networks has dramatically increased, leading to deep learning tools, while additional options like differentiation of the neural network metamodel has facilitated the development of physics informed, self-learning versions of them. All these tools have been exploited for the solution of direct and inverse problems in mechanics, see among others the contributions of the authors [1-4].

The previously outlined set of artificial intelligence tools are currently being integrated into finite element modelling codes and are used for the creation of neural network assisted reduced order models in order to support the creation of structural digital twins [5].

The authors will report on their current activity in the field, as well challenges and difficulties for broader usage of this technology in the field of structures and civil engineering. The availability of sensors and Internet of Things promise a digital upgrading of existing structures for efficient structural health monitoring, energy management and other tasks.

* The asterisk denotes the presenting author.

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Stability Analysis of Vault Prototype realized by Additive Manufacturing

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ABSTRACT

Recent interest in masonry structures has highlighted their enduring potential as viable solutions in architecture and engineering. The growing focus on the analysis of ancient masonry vaults, constructed globally throughout history, has revived the need to consider these structures for the roofing of new sustainable and innovative buildings. Concurrently, the stability of both ancient and modern masonry vaults remains a compelling and vital area of research.

This paper examines various funicular structures to facilitate a comparative analysis aimed at identifying the optimal shape and hole configuration. The primary objective is to develop a form-finding design for latticed masonry shells, starting from a defined topology and producing an optimized grid concerning stiffness and stability. The vault shapes are achieved by adjusting key parameters, such as the shallowness ratio (SR) and the hole pattern within the vault [1,2]. A comprehensive structural stability analysis is conducted, varying slenderness and SR across different loading scenarios and constraint conditions [3,4].

In this study, a scaled prototype of the proposed vault typology is fabricated using additive manufacturing techniques. The prototype undergoes various loading conditions and is analysed using Digital Image Correlation (DIC) to observe the deformation patterns as forces are applied. Experimental tests are performed to correlate numerical predictions with empirical data, thereby enhancing the understanding of the vault's behaviour under load.

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An engineered material for optimizing the physical and mechanical properties of building elements produced through an innovative additive manufacturing process

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ABSTRACT

Resource scarcity, rising raw material costs, global population growth, and stricter energy demands are pushing the construction industry to explore innovative solutions capable of addressing future challenges. In this context, the synergy between advanced technologies like additive manufacturing and cutting-edge building materials could play a pivotal role. In this context, this study introduces an innovative material suitable for 3D printing, with density ranging from 80 kg/m³ to 2000 kg/m³. This variation in density leads to significant changes in both mechanical and physical properties. The ability to process this material via 3D printing opens the possibility of dynamically adjusting the density of the extruded layers during the printing process itself, taking the concept of design optimization to a higher level.

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Optimization of hollow-section steel beams through Algorithm-Aided Design

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ABSTRACT

This study deals with the parametric design and the optimization of pedestrian steel structures that are particularly significant in the field of civil engineering. Structural optimization is performed through the use of genetic algorithms (GA). In particular, Grasshopper parametric analysis solver is used, where the Galapagos algorithm is implemented [1]. The optimization is carried out in terms of both weight and shape [2].

Three models of simply-supported beams, with a span equal to 20 metres, are considered: a truss girder, an arch with orthogonal ropes and a network arch. In the first structure, the design variables are represented by the cross-section and the geometric arrangement of the elements constituting the beam. In the case of the arch and the network beams, the design variables are the width of the arch curvature, the cross-section of the different components and the arrangement of internal ropes.

In all optimization procedures the weight of the structure is assumed as the objective function and the attention is focused on hollow circular sections.

The performed analyses show that the network arch represents the optimal model. In fact, it is characterized by normal and bending stresses lower than the other typologies and by the lowest weight and then cost. There is an inverse relationship between the angle of curvature of the top chord and the number of ropes. The cross section of the top chord is bigger than the one of the bottom chord, as well as diagonals are characterized by smaller cross sections, coherently with previous literature studies [2].

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Optimal Design of Arch Bridges

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ABSTRACT

In the last years, many important arch bridges have been built all around the world and particularly in China. Bridge designers rely extensively on the knowledge of previously completed works. This is an efficient process, since a new design concept produced in this way is effectively validated by reference to the previous work.

In meantime the need to build longer and lighter arch bridges requires to develop tools able to help engineers to select the optimal design. It's well known that structural optimization is the subject of achieving the best performance for a structure with various constraints such as a given amount of material, limitation of peak stress and deflection.

Based on the strong demand for lightweight, low-cost and high-performance structures due to the limited material resources and technological competition, the optimal structure design is becoming increasingly important. Benefit from the availability of highspeed computers and the rapid improvements in algorithms, the structural optimization has become in the last decades an important mathematical tool for designers and rapidly becoming an integral part of the structural design process.

The presentation introduces some cases studies showing the benefits of applying such techniques in the conceptual design phase as well as in the detail design of real projects.