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SPIS TREŚCI

Foreword

Historically the session is traditionally held by the *Bydgoszcz Branch of the Polish Society of Theoretical and Applied Mechanics* in cooperation with the *Faculty of Mechanical Engineering* and the *Faculty of Civil and Environmental Engineering and Architecture the Bydgoszcz University of Science and Technology.*

The international scientific session of **Applied Mechanics 2024** is held virtual-online at the *Bydgoszcz University of Science and Technology*.

As it seems, the session topic developed further for the last few years triggers interest in the academic community of our University, the scientists of other domestic schools of higher education as well as foreign centres. This year the session is attended by scientists from home and abroad.

The 12th Scientific Session of **Applied Mechanics 2024** takes place 24 years after he first meeting on applied mechanics.

Similarly as two years ago the session organizers ensure that the proceedings in English developed based on the speeches held, having received positive reviews, will be published online as open-access papers by the AIP Publishing (the US). The AIP submits the articles for indexation in such databases e.g. The Conference Proceedings Citation Index (part of Web of Science), Scopus (Elsevier), Inspec etc.

On behalf of the Organization and Scientific Committee of the International Scientific Session of **Applied Mechanics 2024**, we wish to thank all the participants for developing their speeches and taking part in the scientific session at the Bydgoszcz University of Science and Technology.

We wish you fruitful scientific debates.

Chairman of Bydgoszcz PTMTiS Branch
Przemyslaw Strzelecki

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CALCULATION OF THE BUILDING'S STABILITY AGAINST PROGRESSIVE DESTRUCTION ON THE EXAMPLE OF A REAL PROJECT

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Abstract

The problem of progressive collapse has been known to design engineers for a long time and is associated with very sad events in history, the most shocking of which was the collapse of the World Trade Center towers in New York as a result of the terrorist attack on September 11, 2001 (Fig. 1). However, issues related to the phenomenon of progressive collapse have only recently begun to be reflected in design codes around the world.

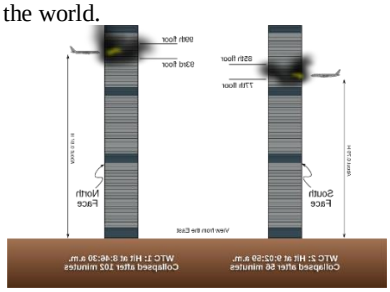

Fig. 1. Aircraft impact points on the south and north towers of the World Trade Center (photo from Wikipedia)

The NIST investigation showed that when the planes hit the towers in different ways, the process of ruining the Pivnichnaya and Pivdennaya towers was disrupted, although the fire was similar. After the impact of the flyers, the internal joints of power were seriously damaged, although the external joints were noticeably weaker. This led to a significant overgrowth of the emphasis between them. The upper structure of the towers played a great role in this reorganization, the weight of which now fell primarily on the peripheral stages, and not on the internal ones [1].

To calculate the stability of buildings against progressive collapse, a spatial calculation model was used, which takes into account the interaction with the soil foundation. The calculation models take into account the possible inclusion in the work of elements that under normal operating conditions of the building are non-load-bearing (for example, hinged external wall panels, parapets, reinforced concrete fences of balconies, partitions, etc.), and in case of local destruction actively participate in the redistribution of forces in the elements of the constructive system.

When calculating structures for resistance against progressive collapse, the possibility of staged calculation is provided. At the initial stage, the stress-strain state of structures under normal operation conditions is determined. At the next stages, the stress-strain state of the structures that occurs during local destruction was determined, provided that the deformations of the structures that occurred as a result of normal operation were taken into account [2].

References

[1] EN 1990. Basis of Structural Design –Brussels: Eurocode European Committee for Standardization. – 2002. – 89 p.

[2] ISO 2394:1998. General principles on reliability of structures. – International Organization for Standartization. ISO, Geneva, Switzerland. –1998.

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SENSITIVITY MODELING OF SELECTED ROAD TRANSPORT NOISE PARAMETERS

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Abstract

The metrology of environmental noise pollution and interpretation of the obtained results are carried out in the decibel state space. These analyses are related to the Weber-Fechner law, which determines humans' perception of acoustic pressure disturbances. The equivalent sound level is the most commonly used parameter to describe these disturbances. Environmental noise analyses are concentrated in the ranges from 80 dB to 130 dB, considered harmful, and from 45 dB to 80 dB, considered burdensome. Increasingly, in environmental analyses, attention is paid to the range of sound pressure levels from 8 dB to 45 dB, which is associated with the analysis of acoustic comfort. An essential element of the decibel scale analysis are also values from 0 dB to 10 dB, which can be associated with the interpretations of the results: the uncertainty of environmental noise measurements, the effectiveness of improving the acoustic climate, or exceedances of permissible noise levels occurring in the environment, which are most often determined by the Euclidean difference of the noise levels considered.

The question that arises is the interpretation of measurement results in the given ranges of the decibel scale. The authors seek answers to such a question in the analysis of the proposed model of the sensitivity coefficient of the equivalent sound level expressed in the decibel scale, which refers to the logarithm value of the relative energy of acoustic disturbances to the relative energy of acoustic pressure disturbances. The paper analyzed the problem of whether the representation of acoustic disturbances in the decibel scale has a constant value in the entire range of analyzed noise levels.

The results of the simulations showed that for noise levels greater than 30 dB, it can be assumed that the value of the sensitivity coefficient of the equivalent sound level does not change and has a constant and linear course. However, this coefficient does not have this property in the range from 0 dB to 30 dB. In this range of analysis in the decibel scale, the representation of changes in input-to-output quantities of the measurement path occurs nonlinearly.

References

[1] Graziuso, G., Francavilla, A. B., Mancini, S., & Guarnaccia, C. (2022). Application of the Harmonica Index for noise assessment in different spatial contexts. In Journal of Physics: Conference Series (Vol. 2162, No. 1, p. 012006). IOP Publishing, http://dx.doi.org/10.1088/1742-6596/2162/1/012006

[2] Khan, D., & Burdzik, R. (2023). Measurement and analysis of transport noise and vibration: A review of techniques, case studies, and future directions. Measurement, 113354, https://doi.org/10.1016/j.measurement.2023.113354

[3] Małecki P., Lipecki T., Czopek D., Piechowicz J., Wiciak J.; Acoustics of icelandic lava caves, Applied Acoustics, Vol. 197, 2022.

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SOLVING PROBLEMS OF EXTENDED THERMO-ELASTICITY BY MEANS OF R-FUNCTIONS

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Abstract

The given research suggests the method of solving problems of extended thermo-elasticity for isotropic and complete dimensions [1].

Oscillations of these bodies are shown in the LAME-form equations with boundary and initial conditions. The research formulates boundary and initial extended conditions of heat exchange of the second and third kinds, boundary conditions of the first and mixed problem.

Four problems of extended thermo-elasticity with different boundary and initial conditions are presented here. Combinations of these conditions allow to solve a wide of applied problems.

To solve the formulated initial and boundary problems the researchers applied time discrimination by means of substitution of the unknown movements, temperatures and tension data and their derivates by their discrete equivalents. When using the ROTE-method the researchers reduce every extended thermo-elastic problem to consistency of stationary boundary problems. At the same time, the right parts of heat conductivity and movement equations contain solving on the previous time layers. In this way the researchers reach the consistency of stationary boundary problems.

The problems solutions is noted in the form of structural formulas correctly consider boundary conditions and the body's form regardless from the choice of indeterminate component. Composing of structural formulas is done due to due to the left parts of the equations of the field boundaries or their branches with boundary conditions of the same type. Such equations are put down by means of R-functions, more exactly R- operations, which possess the same properties as functions of algebra in logic [2,3].

Under conditions of numerous realizations of solving structures, functions of indeterminate components are resented as developments by the elements of classical polynomials and splines..

References

[1] Bodnar Yu, Syniekop M., Podhorecki A. Consideration of heat transfer speed while measuring two-dimensional thermal stresses by means of the method of R-functions. AIP Conference Proceedings 2077, 020007(2019). https://doi.org/10.1063/1.5091868.

[2] Rvahev r.l. Theory of R-funtions and its some aliations. Kyiv. Naukova dumka, 1982. 552 h.

[3] Rvachev, V. L. Method of R-functions in boundary-value problems. Soviet Applied Mechanics, 11(4), 345–354. doi:10.1007/bf00882900

APPLIED MECHANICS 12/2024

OPTIMIZING HEAT ENERGY CONSUMPTION OF THE PEAT DRYING PROCESS IN STEAM TUBE DRYER

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Abstract

The damage of many facilities for the generation of centralized heat supply as a result of Russia's military aggression requires the expansion of the use of small and medium power boilers. The search for alternative types of fuel that could supplement the traditional ones (coal, gas). One of these types is peat briquettes. The most energy-intensive process in the production of peat briquettes is the process of peat drying. The most energy-consuming complex in the production of peat briquettes is the energy technological complex of peat drying process. Determining the optimal operation regimes of dryers is not possible without the formation of an adequate factor field, describing the character of the drying process [1].

The Group of adaptive model evolution (GAME) method was chosen to build mathematical model of peat drying process. In order to minimize energy consumption in the drying process, it was proposed to determine the required amount of heat (kJ) for peat drying, certain physical and mechanical properties of peat, and the productivity of the dryer, which allow obtaining dried peat with the necessary quality characteristics and determine the minimum acceptable costs thermal energy for certain modes of operation of the dryer. The adequacy of mathematical model for each target function of the energy technological drying process was analyzed and chosen by refined coefficient of determination, Schwartz criterion, and minimum shift criterion. Also, a procedure for monitoring heat energy consumption of peat drying process was developed. It includes control of heat consumption for 1-hour, specific heat consumption for evaporating 1 kg of moisture from peat and determining the required level of heat energy supply for the peat drying process. The specific heat consumption per 1 kg of moisture, which is removed from the material, in a real dryer is [3]:

$$q = q_1 + q_2 + q_3 + q_4 + q_5, \quad (1)$$

where q_1 is the specific heat consumption for the evaporation of moisture from the material, kJ/kg of vapor. moisture; q_2 – specific heat consumption for heating the dryer, kJ/kg of vapor. moisture; q_3 – specific heat consumption for heating the drying agent, kJ/kg of vapor. moisture; q_4 – specific heat consumption for heating transport devices, kJ/kg of vapor. moisture; q_5 – specific heat consumption to cover losses in the environment, kJ/kg of vapor. moisture

This will make it possible to control the consumption of thermal energy within the necessary limits and to choose the necessary levels of heat consumption for during peat with different characteristics. Operating and control of peat drying process according to the developed model made it possible to reduce the electric capacity of the dryer by more than 0.3 kWh/ton of drying peat, and the heat capacity by 25 kJ/ ton of drying peat.

References

[1] Bosak, A., Matushkin, D., Dubovyk, V., Homon, S., Kulakovskyi, L. *Determination of the concepts of building a solar power forecasting model*. Scientific Horizons 24(10), 9-16, 2021.
[2] Gneushev, V. O. *Peat briquetting*. Monograph. Rivne, 167, 2012.

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EXPERIMENTAL AND THEORETICAL RESEARCH OF CRACK RESISTANCE IN BEAM STRUCTURES REINFORCED WITH MIXED REINFORCEMENT

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Abstract

Concrete, rod smooth and corrugated reinforcement, sheet smooth and corrugated steel were used abundantly for making reinforced concrete beam structures with external reinforcement.

However, the researchers did not include rather interesting, in our opinion, type of sheet reinforcement – steel cut and stretched sheet. Due to the original geometric shape of the side surface and good strength characteristics, steel cut and stretched sheet can also be used as working external reinforcement in reinforced concrete structures

It is proposed to conduct experimental studies in order to analyze the moment of crack formation and their development in such structures under load for researching the possibility of applying steel cut and stretched sheet as external longitudinal working reinforcement in reinforced concrete structures [1].

The article presents the results of an experimental and theoretical research of the crack resistance of beam structures in the form of cut and stretched sheet and rod reinforcement.

Considering our research, we have made four experimental beam samples, two of which are analog beams: B-II-1, B-II-1* and B-II-2, B-II-2*. The only difference of the was about the placement of the working reinforcement. In B-II-1, B-II-1*, the working reinforcement was concrete in the protective layer, and in B-II-2, B-II-2* without a protective layer, but the cut and stretched sheet was not exposed, moreover, due to its geometric shape, the concrete mixture completely covered the sheet during making the test samples.

Experimental studies have shown that the moment of crack formation in B-II-2 and B-II-2* series beam structures is 1.13-1.39 times higher than in B-II-1 and B-II-1* beam structures. But in construction practice, it is possible to recommend the use of beam structures reinforced with a steel cut-and-stretched sheets, which is located both without a protective layer of concrete and with it [2].

References

[1] Dobrianskyi I., Burchenya S., Shmyh R. Crack Resistance of Steel Concrete Beams reinforced with a Cut-and-Stretched Sheet. *Building Structures*: a collection of scientific works. K.: State Enterprise "State Research Institute of Building Structures", 2013. Issue 78, Book 1. P. 458-464.

[2] Burchenya S., Famulyak Y., Sobczak-Piastka J. Modelling of Work of Cut and Stretchy Sheet in Span Beam Structures with the Mixed Reinforcement». *IOP Conference Series: Earth and Environmental Science*, 2019, 362(1): 012114 https://doi.org/10.1088/1755-1315/362/1/012114

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3D PRINTING OF A SEMI-CIRCULAR UNREINFORCED ARCH USING A BUILDING PRINTER

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Abstract

The research aims to design the structure of an unreinforced semicircular arch and develop a technology for its manufacturing on a construction 3D printer. Based on the developed technological recommendations, perform 3D printing of unreinforced arches in manufacturing conditions.

Previous research has been conducted using 3D printing [1, 2].

To achieve this objective, a manufacturing technology was developed, which includes designing structures and modeling an unreinforced arch in a specialized software package; manufacturing structural frames for supporting zones; determining the movement path of the printer nozzle; applying mortar layers; arranging structural reinforcements in support zones; arranging embedded steel tube details in each of the two supports. 28 days after the printing is completed for mortar hardening, the finished arch structures are transported to the laboratory for further research.

The dimensions of the designed arch with the nozzle movement path of the 3D printer are shown in (Fig. 1).

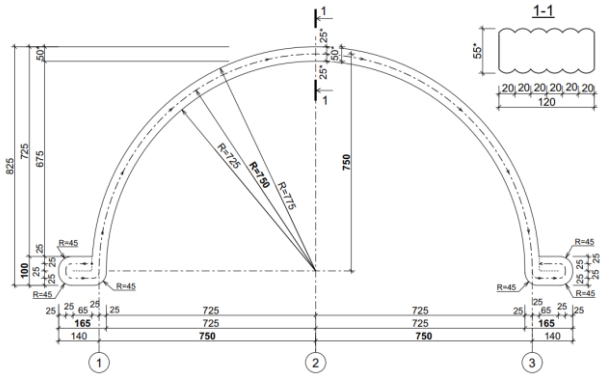

Figure 1. Scheme of the printer nozzle movement path

The developed technological recommendations for printing unreinforced arches using a construction 3D printer ensured the production of arched structures that can be used for scientific research and in real construction.

References

[3] Demchyna, B., Vozniuk, L., Surmai, M., Havryliak, S., Famulyak, Y.: Experimental study of the dome model made using a 3D printer from PLA plastic, AIP Confer-ence Proceedings 2949(1), 2023.

[4] Demchyna, B., Vozniuk, L., Surmai, M.: Testing of the Ribbed Dome Which is Manu-factured by 3D Printing, Proceedings of CEE 2023, 438, 2024.

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LOAD-BEARING CAPACITY OF BEAMS MANUFACTURED USING 3D PRINTING AND REINFORCED WITH WELDED FRAMES

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Abstract

This article is devoted to the research of the efficiency of using 3D printing technology for the manufacturing of beams reinforced with flat welded frames.

During the experiment, beam deflections were measured using three clock-type indicators with a measurement scale of 0.01 mm. Two indicators were mounted on supports at the upper face of the beam and the one in the centre of the span was connected to the lower face.

Previous research has been conducted using 3D printing [1,2].

The measurements of the relative deformations of the beam concrete were carried out using 12 micro-indicators of the clock type with a measurement scale of 0.001 mm. The indicators were installed on the concrete surface on holders previously glued to the beam. To determine the deformation of the main reinforcement, two microindicators were used, which were attached to holders welded to the reinforcing bars.

According to the production technology, the beam was made horizontally in five layers, and after gaining strength, it was turned 90 degrees to the design position. To account for possible errors, the sensors were duplicated on both sides of the beam.The scheme of the laboratory test bench is shown in (Fig. 1)

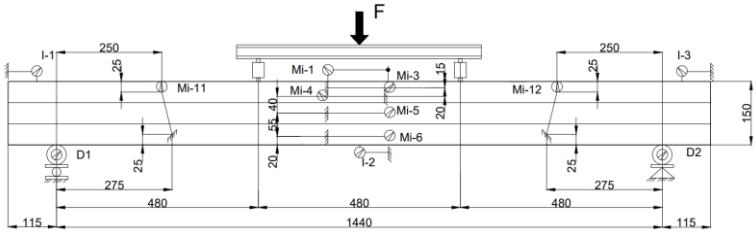

Fig. 1. Scheme of the laboratory test bench. I-1 - I-14 - microindicators; I-1 - I-3 - indicators; D1 - D2 - dynamometers

As a result, the beam was tested and its bearing capacity and deformability were determined. Graphical dependences of the distribution of deformations of concrete and reinforcement depending on the load along the height of the beam section were constructed. Graphical dependencies characterizing the change in deflection under static load were constructed.

References

[1] Demchyna, B., Vozniuk, L., Surmai, M., Havryliak, S., Famulyak, Y.: *Experimental study of the dome model made using a 3D printer from PLA plastic*, AIP Confer-ence Proceedings 2949(1), 2023.

[2] Demchyna, B., Vozniuk, L., Surmai, M.: *Testing of the Ribbed Dome Which is Manu-factured by 3D Printing*, Proceedings of CEE 2023, 438, 2024.

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IMPEDANCE MODELING OF THE PRESSURE SHOCK ABSORBER IN A HYDRAULIC LIFTING SYSTEM

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Abstract

This study focuses on the impedance modeling of a pressure shock absorber (PSA), consisting of a hydropneumatic accumulator (HPA) and a damping element (DE) in the form of a throttle resistor as a damping resistor (DR), to dampen the pressure shock in the hydraulic lifting cylinder used in the front and rear hydraulic lifting system (HLS) of a bricklaying robot (BR). The operation of an industrial BR, which consists of laying bricks of different weights in a large workspace, causes variable dynamic loads that are transmitted to the HLS and generate a pressure shock in the hydraulic lifting cylinders. The shock damping of the pressure using PSA in the HLS ensures that the BR support is stable, robust, and resistant to large variable loads. This affects the precise execution of the BR trajectory during bricklaying. Figure 1 shows both a view of the extendable support leg in the front HLS and a functional drawing of the hydraulic lifting system.

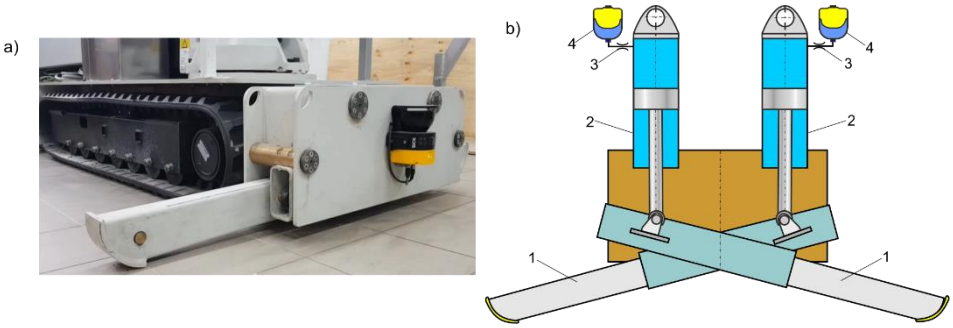

Fig. 1. Hydraulic lifting system of bricklaying robot: a) view of the extendable support leg in the front hydraulic lifting system, b) functional drawing of the hydraulic lifting system: 1 – support legs, 2 – hydraulic lifting cylinders, 3 – damping elements, 4 – hydropneumatic accumulators.

The PSA model is critical for the modeling, simulation, and control of a hydraulic leveling system (HLS). The PSA is modeled by lumped *RLC* elements based on the analogy between hydraulic and electrical circuits, where *R* is the hydraulic resistance, *L* is the hydraulic inductance, and *C* is the hydraulic conductance. The damping of the pressure shock generated in the hydraulic cylinder by HSD can be modeled in the frequency domain using the impedance $Z(j\omega)$, which is determined by the ratio of pressure $p_c(j\omega)$ in the hydraulic lifting cylinder to the flow rate $q_a(j\omega)$ into HPA, with takes into account the complex addition of hydraulic resistance *R* and hydraulic reactance *X*,

$$Z(j\omega) = \frac{p_c(j\omega)}{q_a(j\omega)} = R + jX = R + j(X_L - X_C) \tag{1}$$

where X_L is the hydraulic inductive reactance ($X_L = L\,\omega$), X_C is the hydraulic capacitive reactance, ($X_C = 1/C\,\omega$), ω is the angular frequency.

To evaluate the damping effectiveness of the PSA, the damping performance index *D* in the frequency domain was used. The results of the PSA studies based on impedance modeling and the use of the damping performance index *D* can provide a basis for improving semiactive, adaptive, and predictive damping methods.

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STUDY OF BENDING OF PRISMATIC RODS WITH CROSS SECTIONS OF COMPLEX SHAPES BASED ON CONFORMAL MAPPING

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Abstract

The problem of bending elastic rods with cross-sections of complex shape is considered. To solve the problem, the Muskhelishvili method was used, which is based on the theory of functions of a complex variable and conformal mapping. This method has wide application for the study of plane problems of the theory of elasticity and torsion of rods. For the case when the reflection function is written in the form of a polynomial of arbitrary degree for a wide range of problems, this approach allows obtaining analytical formulas for determining stresses.

The implementation of the Muskhelishvili method in problems of bending prismatic rods is complicated. This is due to the fact that for the bending problem, the solution is written by Cauchy integrals of functions that have a complex form. In this work, the function that conformally maps the section on a circle is obtained as a segment of the Taylor series. After transformations, the solution is written in analytical form, which contains the sum of products of polynomials, which can be of any degree. To implement the described approach, it is necessary to perform multiplication, differentiation and addition of 2-5 polynomials of arbitrary degree. To carry out such operations on polynomials, procedures developed in computer mathematics systems are used. With the use of the developed approach, the study of stresses in rods with cross-sections of a complex shape was performed.

Rods with sections in the form of equilateral polygons with 4, 6, 8, 10, 12 sides are considered. When calculating, Taylor's series held up to 100 members. It is assumed that the force acts perpendicular to the side of the polygon (option 1) or directed to its top (option 2). In both versions, the stresses in the center are the same, and they practically do not differ from the corresponding stresses in a rod with a circular cross-section (the deviation does not exceed 1%). For the second variant, the maximum stresses are reached in the center of the cross-section, and for the first - at the edge of the rod, and for the quadrilateral and hexagonal cross-sections, they increased here by more than 10%.

Consider a cross-section of a circular shape, which has 6 protrusions. The maximum stresses were obtained near the boundary of the body around the beginning of the protrusions. These stresses turned out in 2,25 times higher than the average cross-sectional stresses.

The stress for a section in the form of a sector of a circle was studied.The maximum stresses occurred near the circular boundary of the section. A cross-section of a circular shape with a wavy border is considered. The maximum stresses occur in the central part of the cross-section. At the boundary, the relative stresses were less than 1.

Conclusions. An algorithm for studying the bending of elastic rods has been developed based on the relations of the theory of elasticity. The ratio for stresses is written in the form of Cauchy integrals based on the use of conformal mapping. Integrals are obtained in analytical form with the additional use of software for operations on polynomials developed in computer mathematics packages. The study of the bending of rods with cross-sections of a complex shape was performed, characteristic features in the stress distribution were established.

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METHODOLOGICAL BASES OF STRUCTURAL CALCULATION OF FORTIFICATION PROTECTIVE STRUCTURES

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Abstract

This article presents a methodology for calculating protective structures. The paper also considers the penetration of complex multilayer structures using the example of a three-layer protective coating [1]. The process of ammunition penetration into a protective structure is considered on the basis of energy provisions. In this case, the entire reserve of kinetic energy of the ammunition before impact is transformed into breakdown energy and the work of internal forces of the section of the supporting structure of the protective structure, i.e., the slab

$$W_e = W_{pr} + W_i, \tag{1}$$

The condition for ensuring flexural strength under high-speed impact is given based on a simplified method of calculating deflections allowed by design standards. Finally, the condition for ensuring bending strength under the action of a high-speed impact is as follows

$$mv^2 \le \frac{4M_{ult}}{l} h_{pr} + \frac{1}{3} M_{ult} \frac{1}{r_{ult}} \quad l. \tag{2}$$

The local effect of ammunition is characterized by damage and destruction of the structural material at the point of impact. The general effect is characterized by deformations of structures during their oscillations caused by the impact and explosion of ammunition. For concretes, there is a functional dependence of compressive strength and permeability coefficient

$$k_{pr} = f\left(f_{fck,prism}\right). \tag{3}$$

Acceptance of the relationship in this form allows us to recommend a formula for determining the reduced strength of concrete with reinforcement [2].

$$f_{c,red} = f_{fck,prism} + \varphi \mu_{xy} f_{s,xy}, \tag{4}$$

Reinforcement affects the strength of concrete if the following requirements are met [3]:

1) the cross-sectional areas of the bars per unit length in one and the other direction do not differ by more than 1.5 times;
2) the distance between the rods of the same direction is not more than 150 mm and not more than 1/3 of the smaller side of the cross-section of the element.

References

[1] Filipchuk S., Karavan V., Makarenko R. Study of reinforcement adhesion to concrete under static and dynamic loads. AIP Conference Proceedings. 2023, 2949(1), 020007.
[2] DSTU B V.2.6-204:2015. Calculation and design of reinforced cement structures of buildings and structures. K.: Ministry of Regional Development of Ukraine, 2015. 42 p.
[3] Babich, Y., Filipchuk S., Karavan, V., Sobczak-Piastka, J., Nalepa O. Research of deformative properties of concrete taking into account the descending branch of deformation/ // IOP Conference Series: Materials Science and Engineering, 2020, 960 (3).

APPLIED MECHANICS 12/2024

INFLUENCE OF CORROSIVE ENVIRONMENT ON FATIGUE LIFE OF ADDITIVELY PRODUCED 18NI300 STEEL UNDER CYCLIC LOADING CONDITIONS

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Abstract

Engineering materials are more vulnerable to multiaxial cyclic loading compared to uniaxial loading. This fragility is more pronounced in aggressive environments, where failure is caused by the combined effects of chemical corrosion and cyclic loading. The interaction of these factors accelerates complex failure mechanisms in additively manufactured materials, significantly reducing their structural integrity and fatigue life. Although there has been more attention on corrosion fatigue, no research has investigated the structural integrity of materials under the combined effects of multi-axial loading and aggressive environments. Regardless of its ultra-high strength, toughness, weldability, and ease of manufacturing, poor corrosion resistance of maraging steel and lack of studies under aggressive medium restricts its use in offshore applications and corrosive environments [1]. This study presents the corrosion fatigue behavior of 18Ni300 maraging steel fabricated through selective laser melting. A total of 40 specimens were fabricated using the EOS M280 system, followed by heat treatment at 490°C for 4 hours. Owing to its proven potential to enhance surface integrity and induce beneficial compressive residual stress [2], sandblasting operations have been employed following printing and post-corrosion. The blasted specimens were exposed to a 5 wt% of NaCl aqueous solution at 35°C for 7 days. The selected NaCl solution, temperature, and humidity of the test chamber were followed ASTM B117 standard. The effects of aggressive environment on the structural integrity of 18Ni300 maraging steel were assessed by evaluating weight loss, microhardness, and corrosion fatigue performance. The experimental results showed that samples submerged for 7 days under a corrosive environment exhibited 0.33 % increased weighted mean hardness compared to a reference sample, with a measured mean hardness of 613.61 Kgf/mm^2. Samples exposed for 7 days showed 0.113 gram mean weight loss with 0.02 gram standard deviation compared to non-corroded samples. Fully reversed (R = -1) corrosion fatigue test results under uniaxial, torsional, and combined load revealed that corroded sample groups demonstrated reduced uniaxial and torsional fatigue strength compared to uncorroded ones. Under combined loading condition, the variation in fatigue characteristics was found insignificant with a corroded sample group exhibiting superior fatigue characteristics, which is also confirmed by the corrosion damage result. The current study emphasizes the potential of maraging steel for use in corrosive environments under combined loading without compromising its structural stability.

References

[1] Yongmei Z., Junjie C., Wenxian T., Weicheng C., Xiaorong W., Fang W., Baoji Y.: *Fatigue and Corrosion Fatigue of 18Ni Maraging Steel*, Archives of Metallurgy and Materials 66, 381–390, 2020.

[2] Bouzakis E., Arvanitidis A., Kazelis F., Maliaris G., and Michailidis N.: *Comparison of Additively Manufactured vs. Conventional Maraging Steel in Corrosion-Fatigue Performance after various surface treatments*, Procedia CIRP 87, 469-473, 2020.

APPLIED MECHANICS 12/2024

DETERMINING THE DEFLECTION DUE TO SHEAR STRESSES TAKING INTO ACCOUNT THE NONLINEARITY OF THE MATERIALS OF REINFORCED WOODEN BEAMS

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Abstract

If we analyze the current state of research on the determination of deflections, there are currently two approaches: 1) the first approach - proposed by Euler-Bernoulli, which takes into account the bending due to the action of the bending moment and neglects the shear; 2) the second approach is described on the example of the Tymoshenko beam [1], which takes into account the shear. Both approaches are used for elastic formulation of the problem, the experience proposed by the above-mentioned authors should be taken into account. Tymoshenko concluded that for beams with a ratio of length to height of the element greater than 6, the relative deformations of the cross section should be neglected, and for beams in which this indicator is less than 6, it should be taken into account. The author also established that the Tymoshenko beam method [1] can take into account the anisotropy of the material, which is positive in determining deflection, especially for wooden elements. However, in literary sources there is a false statement that it is due to the anisotropy of wood that it is necessary to take into account the deflection that occurs from wood shear, and is explained by the ratios of MOE $E_w / G_w = 16..24$.

The modern theory of the Tymoshenko beam does not take into account the non-linearity of the work of materials, as well as the change in the position of the cross-section at the same time from the shear along the fibers and the bending moment, in determining the deflection of wooden beams. Earlier in the articles [2, 3], the method of determining the deflections of wooden beams was given without taking into account the shear stresses of the wood. This article describes the method of taking into account the shear along the fibers in determining the deflection of a wooden reinforced and non-reinforced beams. At the same time, the method takes into account the non-linear deformation of the materials included in the wooden reinforced beams and the change in shear stresses along the length and height of the beams.

References

[1] Timoshenko S. P. Statisticheskie i dinamicheskie problemy teorii uprugosti. — Kiev: Naukova dumka, 1975. — 564 s.

[2] Sobczak-Piąstka J., Gomon S.S., Polishchuk M., Homon S., Gomon P., Karavan V. Deformability of Glued Laminated Beams with Combined Reinforcement. Buildings 2020, 10, 92.

[3] Gomon P., Gomon S., Pavluk A., Homon S., Chapiuk O., Melnyk Yu. (2023). Innovative method for calculating deflections of wooden beams based on the moment-curvature graph. Procedia Structural Integrity 48, Pp. 195-200.

APPLIED MECHANICS 12/2024

ANALYSIS OF THE EXISTING METHOD OF CALCULATING BENDING WOODEN ELEMENTS ACCORDING TO CURRENT DESIGN STANDARDS

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Abstract

Due to its strength, beauty, ease of processing and installation, wood is increasingly used in the construction of various buildings. And the use of glued wood allows you to minimize the impact of natural defects and defects of the material. Most often in construction, wood is used as bending elements. But quality designs require perfect calculation. The calculation of bending elements from solid and glued wood according to the normal cross-section, recommended by the current norms [1, 2], requires the use of the moment of resistance of the cross-section of the element and the calculated values of the bending strength of wood, which are determined on the basis of the laws of operation of an ideally elastic material under load according to the proposals of EN 384 [3] and based on tests regulated by EN 408 [4]. Wood is not such a material. Therefore, the calculation of bending elements made of wood recommended by current standards [1, 2] requires additional analysis.

Numerous experimental studies of the actual stress-strain state of structures under the action of direct transverse and oblique bending of elements made of solid and glued wood [5,6] showed a discrepancy between the obtained experimental data and the data given in [1,2].

On the basis of a detailed analysis [1,2], the main shortcomings of the calculation of bending wooden elements were established.

Ways to improve standard documents [1,2] are proposed, which relate to the calculation of wooden structures working for different types of bending.

References

[1] Eurocode 5, 2004. Design of timber structures. Part 1.1. General rules and rules for buildings, 124.

[2] DBN B.2.6-161, 2017. Constructions of houses and buildings. Wooden constructions. Main provisions. Kyiv: Ukrarchbudinform.

[3] ДСТУ EN 384:2001. Structural wood. Determination of characteristic values of mechanical properties and density.

[4] ДСТУ EN 408:2007. Structural lumber. Structural and glued laminated wood. Determination of some physical and mechanical properties.

[5] Gomon S., Homon S., Pavluk A., Matviiuk O., Sasiuk Z., Puhach Yu., Svyrydiuk O., 2024. Hypotheses and prerequisites for modelling the stress-strain state of wooden element normal cross-section using the deformation calculation method. *Procedia Structural Integrity* 59, 559-565.

[6] Sobczak-Piastka, J., Pavluk, A., Gomon, S.S., Gomon, P., Homon, S., Lynnyk, I. (2023). Changing the position of the neutral line of beams made of glued wood in conditions of oblique bending. *AIP Conference Proceedings* 2928, article number 080007.

APPLIED MECHANICS 12/2024

RELIABILITY OF FUEL PRESSURE TANKS IN TERMS OF STANDARD CRITERIA - AN OPEN DISPUTE

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Abstract

Fuel and gas storage tanks are structures whose design and construction require specific responsibility and accuracy. A possible tank failure brings about huge financial losses due to the negative impact of the released medium on the environment, the loss of stored or processed raw material, breaks in technological process, or the need to rebuild the tank. Each tank failure is a threat to human health and life.

The PED directive [1] makes it necessary to fulfill specified safety standards, however, the directions to select computational methods are general only, and neither a detailed approach nor structural solutions are pointed out. The relevance of the tank design with regard to [1] may be achieved by the application of the EN13445 standard [2] or other codes, e.g. ASME Boiler and Pressure Vessel Code. The standard EN 1990 [3] defines structural safety as its reliability measure, quantified by the reliability index β. The index β is affected by the consequence class (CC) and the correlated reliability classes (RC). In the CC2 and RC2 classes, the minimum β value in the 50-year exploitation period equals $\beta = 3.8$ [3]. This requirement is assumed to be fulfilled while the computations follow the EN1993-1-6 code standard [4], but the reliability index β is not estimated directly. Structural design due to CC3 and RC3 classes makes the designer prove that the minimum reliability index β requirements are fulfilled on the level $\beta = 4.3$. However, the standards do not specify how to process such analysis. The EN1993-1-6 code [4] also allows to assess the reliability index β directly and to compare it with its limit value [3]. These computations are performed rarely.

The work covers the safety assessment of a real working LPG mounded tank. Long-term geodetic measurements of the tank have revealed its non-uniform settlement. To reflect the real structural deflections the FEM computations were conducted, and effective soil parameters were assessed. The analysis proved that the structure does not reach its limit states, so its failure probability equals zero or is hard to determine. On this basis, it can be assumed that the design standards ensure structural safety. However, the designed structure is characterized by the reliability index β far beyond the values prescribed in the standards [5].

To prove this thesis the work conducts a probabilistic analysis of two design parameters: tank sheet thickness and spacing of stiffening ribs. It was detected that considering the scatter of sheet thickness in the computations does not affect the reduction of the structural reliability level. Moreover, the presented analysis pointed out that it is possible to reduce the number of stiffeners, whose construction plays a substantial part in the costs.

It is reasonable to optimize the design process regarding the minimum safety level stated by the standard reliability index β [3]. The work attempts to introduce innovative actions into traditional structural design methods.

References

[1] Pressure directive PED 2014/68/ue.
[2] EN 13445-3 Non-flame-heated pressure tanks Part 3. Design.
[3] EN 1990 Eurocode - Fundamentals of structural design.
[4] EN 1993-6 Eurocode 3 - Design of steel structures part 4-2. Tanks.
[5] Sorn P., Sondej M., Górski J.: *Reliability estimation of underground fuel tank*, Bulletin of the Polish Academy of Sciences. Technical Sciences 71, 2, 2023.

STUDY OF CRACK FORMATION PROCESSES IN REINFORCED CONCRETE ARCHES MADE OF HIGH-STRENGTH RAPIDLY HARDENING CONCRETE UNDER THE ACTION OF STATIC LOW-CYCLE REPEATED LOADS

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Abstract

In the process of planning the experiment, it was envisaged that arched structures would be further used as roofing elements of defense and civil protection structures. When dealing with this type of structure, construction time and structural strength are crucial factors. In order to minimize the time required for the construction of buildings and structures, it is recommended to use high-strength quick-setting concrete as a material. The use of such concretes can significantly reduce the volume of concrete, and thus the self-weight of structures, and reduce the consumption of reinforcing steel in reinforced concrete structures [1, 2].

Arches were tested for static short-term, low-cycle repeated loading until failure. The concentrated load was transmitted from the hydraulic jack to a 600 mm long traverse, which, in turn, transmitted the load to the arch by two concentrated forces at a distance of 300 mm from the axis of symmetry of the arch. The accuracy of the load measurement was 0.05%. After installing the test arches on the press beam and mounting the equipment on it, measures were taken to ensure safety conditions. The final stage of preparation for the tests was to check the operation of the hydraulic system, its tightness, etc.

For the first time, data on the operation of two-hinged reinforced concrete arches made of high-strength rapidly hardening concrete were obtained experimentally, which made it possible to reveal the peculiarities of the stress-strain state of normal sections and the nature of crack development under repeated (low-cycle) short-term static loads, in particular:

1. The bearing capacity of the arches subjected to low-cycle repeated short-term static load of $\eta = 0.16...0.8$ Fu is the same as that of the arches subjected to short-term single static load. With an increase in the class of concrete, the bearing capacity of double-jointed arches increases;

2. As shown by our own experimental studies in comparison with the studies of the authors, the crack resistance of two-hinged arches made of high-strength concrete is higher than that of two-hinged arches made of heavy concrete of ordinary strength (C20/25). The number of cracks that formed and developed in the belt of arches made of high-strength concrete is 50% less than in arches made of ordinary concrete, and the cracking moment is 25% higher.

References

[1] Babych Ye. M., Kochkarov D. V., Filipchuk S. V., Karavan B. V. Konstruktyvni rishennia ta rozrakhunok elementiv zakhysnykh sporud tsyvilnoho zakhystu z zalizobetonnymy arochnymy pokryttiamy / Resursoekonomni materialy, konstruktsii, budivli ta sporudy: zbirnyk naukovykh prats. Rivne: «Volynski oberehy», 2021. Vypusk 39. S. 162–175.

[2] Babych Ye.M. Mitsnist i deformatyvnist vazhkoho betonu pry malotsyklovomu stysnenni / Ye.M. Babych, N.I. Ilchuk / Resursoekonomni materialy, konstruktsii, budivli ta sporudy: Zbirnyk naukovykh prats. Rivne: Vydavnytstvo UDUVHP, 2003. Vypusk 9. s. 116-123.

APPLIED MECHANICS 12/2024

MODELING OF THE COEFFICIENT OF EXCEEDANCE OF THE RECOMMENDED NOISE LEVELS AT THOROUGHFARE USING COMPUTATIONAL INTELLIGENCE

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Abstract

The problem of modeling sound level time series data by using computational intelligence (CI) methods was discussed e.g. in [2]. Examples of CI methods used for this purpose include: fuzzy K-means (FKM), K-nearest neighbor (KNN), singular value decomposition (SVD), and Bayesian principal component analysis (BPCA) as well as regression trees like classification and regression trees (CART) or Cubist. Ensembles of regression tree models like Random Forest are also used [2]. Further optimization of the obtained model can be carried out by particle swarm optimization (PSO), memetic algorithms, ant colony optimization, or genetic algorithms.

All above mentioned methods require measurement data to build a model. In this paper, data initially consisted of sound level values recorded in a noise monitoring station, situated at one of the thoroughfares in Kielce, Poland, consisting of class-1 sound level meter, a road radar, and weather station. Measurements at the station were made continuously and the RMS (root mean square) of the A-weighted sound level was saved in the buffer in 1 second intervals with a resolution of 0.1 dB. Using this data, the A-weighted equivalent sound level $L_{A,eq}$, expressed in dB(A) was calculated for 1-hour intervals and for the three 24-hour subintervals: day (6–18), evening (18–22), and night (22–6).

However, the authors of [1] noticed that quite significant change in traffic conditions, e.g. reduction of average speed by 10 km/h, resulted in relatively small decrease of sound level $L_{A,eq}$, from 68 to 67 dB(A) in this case. Therefore, a new measure of noise annoyance, namely the coefficient of exceedance of the recommended noise level, k_i, was introduced by the authors of [1]:

$$k_i = \frac{10^{0.1L_i}}{10^{0.1L_{ref}}} = 10^{0.1(L_i - L_{ref})} \tag{1}$$

where L_i and L_{ref} denote the measured equivalent sound level and the recommended reference noise level, respectively. According to WHO, L_{ref} should not exceed 53 dB during the day, and 45 dB at night.

The measurement data, initially recorded as $L_{A,eq}$ values, were transformed into k_i values according to eq. (1) and used as the training data for the Random Forest method. The obtained models showed quite good accuracy of the predicted k_i values. For example, one of the elaborated models, valid for nights from Monday to Friday showed mean absolute error of 14.3 and root mean squared error of 19.4, despite the large variability of k_i values in the training set, which range from 33.0 to 185.8.

References

[1] Batko W., Radziszewski L., Bąkowski A.: *A Scalar Measure of Acoustic Hazard Assessment*, Archives of Acoustics 49(3), 299-306, 2024.

[2] Kekez M.: *Model-based imputation of sound level data at thoroughfare using computational intelligence*, Open Engineering 11(1), 519-527, 2021.

APPLIED MECHANICS 12/2024

EVALUATION OF MECHANICAL PROPERTIES OF CUZN40 AND CUZN42 ALLOYS FOR ELECTRICAL CONTACTS: IMPACT OF MATERIAL STIFFNESS ON PERFORMANCE AND RELIABILITY

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Abstract

Electrical contacts are used in many devices. The materials used for their production must have specific properties and characteristics. Therefore, high-quality materials for contacts must meet all requirements and standards. In the automation industry, particular attention is paid to the quality of materials from which contacts are made. Due to regulations such as the RoHS and REACH directives, the use of lead has been banned in many areas. Recent environmental, health, and safety regulations restrict the use of hazardous substances in critical manufacturing sectors and consumer products.

This study presents the results of a comprehensive analysis, which was conducted to evaluate the mechanical properties and durability of two brass alloys, CuZn40 and CuZn42, newly used in electrical contacts. A total of 100 specimens were prepared, consisting of 50 samples from each material, with two different contact cross-sections of 0.5mm² and 0.75mm². The primary objective was to assess the performance of these materials under mechanical stress and repeated usage conditions.

The prepared samples underwent a series of mechanical tests, focusing on two key areas: tensile strength and endurance. The tensile strength tests were conducted to determine the force required to break the contact crimp connection with a conductor, providing valuable data on the mechanical robustness of the materials. In addition to the tensile strength evaluation, the samples were subjected to a 100-cycle connection and disconnection test to simulate real-life usage conditions where electrical contacts are frequently connected and disconnected. This endurance test aimed to measure the wear resistance and long-term reliability of the materials in practical applications.

The results from both the tensile strength and the 100-cycle connection tests were analyzed to determine the suitability of CuZn40 and CuZn42 for use in electrical contacts, with a particular focus on the influence of the base material performance [1]. This study provides insights into how different brass alloys impact the mechanical integrity and durability of electrical contacts, contributing to the selection of optimal materials for applications in which long-term reliability is critical. The increase in tensile strength of CuZn40 by 10N resulted in greater material stiffness, which directly impacted the forces required for both insertion and extraction of the contact [2]. This increased stiffness is a negative factor, as it can lead to higher mechanical and electrical resistance during use, potentially disqualifying the contact for certain applications where ease of connection is critical.

References

[1] Zhai, C. *Interfacial electro-mechanical behaviour at rough surfaces* // Extreme Mechanics Letters : journal. Vol 9 (2016) 422—429.

[2] Kogut L., Etsion I., *Electrical Conductivity and Friction Force Estimation in Compliant Electrical Connectors,* Tribology Transactions, Vol.43 (2008), 816 – 822.

APPLIED MECHANICS 12/2024

REINFORCEMENT OF DAMAGED BRICK PILLARS AND ASSESSMENT OF THEIR RELIABILITY

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Abstract

Brick constructions are prone to cracks of all sorts, but it does not have to make their service life shorter. A brick structure can be strengthened. The most effecacious and widespread method for that is hooping. Reinforced by hoops, pillars and piers with cracks restore their bearing capacity entirely. Hoops can be of different kinds: made of steel or reinforced concrete, reinforced with mortars, consisting of composite materials such as carbon fiber canvases, tapes, meshes, bricks and reinforced bricks.

For partially restoring the bearing capacity of brick pillars affected by major cracks, we propose their strengthening with a reinforced concrete hoop. The reinforcement consists of expanded steel sheet, the concrete is placed by guniting. The paper discloses in full the sequence of process steps leading to masonry reinforcement. It is shown that the bearing capacity of such a composite structure is 1,4 times higher than the one of the original brick structure; its cracking load is 1, 07 times higher. With this kind of strengthening the reinforced concrete alone bears the load; the brick core functions only as a filling, although the load is transmitted through the core.

The paper also includes a reliability assessment for a damaged and a reinforced brick pillar.

APPLIED MECHANICS 12/2024

IMPROPER FORMATION OF BUTTONS IN HISTORICAL STRUCTURES – CASE ANALYSIS

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Abstract

A buttress, as an architectural element, is defined as a vertical structural component of a building that extends perpendicularly from the wall in the form of a short pillar. Viewed from the side, it widens towards the bottom in a stepped or sloping manner. The purpose of a buttress is to reinforce the wall by stiffening it and transferring horizontal forces [1]. For many years, architects have sought various forms for the buttress (often referred to as a "skarpa" or "szkarpa" in Polish) [2]. However, its presence has always subconsciously been associated with the solidity, safety, and stability of the structure.

However, there are instances when, due to a lack of understanding of the building's structural behaviour, negligence, improper ground substrate, or structural ignorance, buttresses begin to malfunction. They can even lead to damage to buildings. The following article is an analysis of two such cases where the safety of structures was threatened due to the malfunction of a building buttress.

The first of these cases involves the monastery church in Szczyrzyc. A secondary buttress added to the apse of the presbytery (Fig 1a) caused cracking of the church's walls and vaults. Studies have shown that the buttress is founded on unstable organic soils, much shallower than the walls of the apse. The connection of the masonry structure led to a situation where the buttress was not a reinforcement but rather an eccentrically suspended load.

a) b)

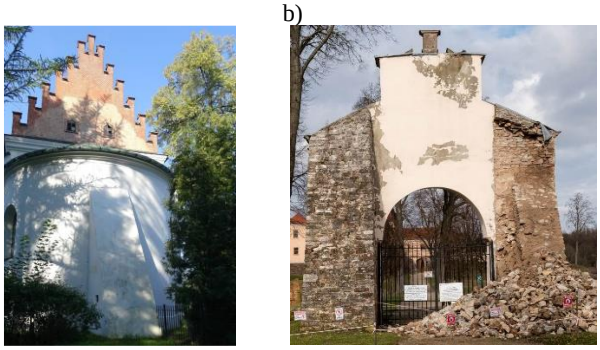

Fig 1. The apse of the church in Szczyrzyc (a) and the Triumphal Gate in Podzamcze Chęcińskie (b)

The second case involves the Triumphal Gate on the grounds of the manor-park complex in Podzamcze Chęcińskie (Fig 1b). The construction of the buttress using stone material without adequate filling with mortar led to water penetration, loosening of the material, and eventually collapse. The debris posed a significant threat to the stability of the gate's structure.

In both cases, eliminating the defective buttress design and replacing it with another technical solution allowed the historic structure to function properly without compromising its value.

References

[1] *Encyklopedia PWN* - Archiwum Ilustracji WN PWN SA © Wydawnictwo Naukowe PWN.
[2] Borusiewicz W.: *Konserwacja zabytków budownictwa murowego*, Arkady, Warszawa 1985.

APPLIED MECHANICS 12/2024

TOPOLOGICAL OPTIMISATION AND CONSTRUCTION OF THE CAR RIM

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Abstract

The object of the analysis was a car rim. It was assumed that only the rim disc was to be optimised. The rim was left unchanged because of the need to work with typical tyres. The main dimensions of the car rim to be optimised are shown in Figure 1. It was assumed that the AlSi7Mg0.3 aluminium alloy rim could have 4, 5 or 6 spokes and that its final mass should be less than 9.0 kg.

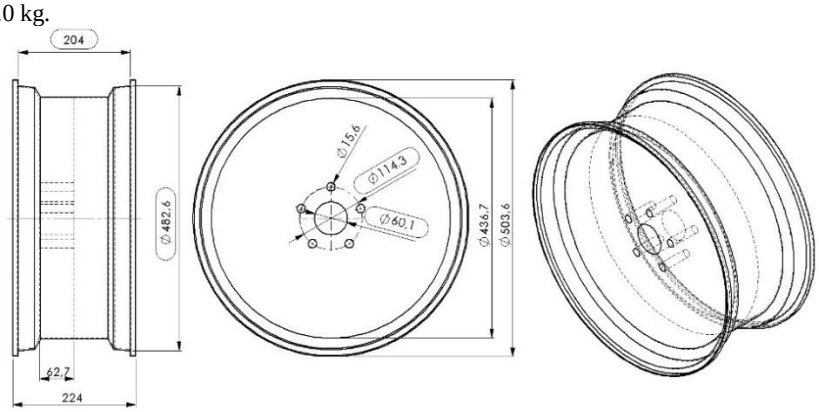

Fig.1. Geometric shape of the optimised rim.

Due to the fact that the whole volume of the model was not the optimisation area, the geometric model was divided into 2 solid objects - the rim and the rim disc. On the contact surface of both objects, the sharing of the nodes was forced. For the wheel meshing 20mm tetra elements were used and for the disc 12mm. The resulting preliminary model consisted of 95 176 nodes and 59 688 elements. Two cases of loads due to rim operation were considered. The first was the vehicle mass and the extreme force caused by hitting an obstacle. The second was the vehicle mass acting on the rim during cornering. In both load cases, a fixed type of constrain was used on half of the tyre contact surface.

The analyses were carried out using sets of strength constraints, design constraints defining the number of arms and technological constraints assuming a maximum arm cross section width of 30 mm to 65 mm. The analyses were based on an 80% weight reduction compared to the original rim with an oversized rim disc. Topological optimisation was performed using the *Density Based* method. This method was chosen because the other methods did not achieve convergence of the calculations or, once convergence was achieved, the continuity of the material volume continuum was broken. For the 4-spoke rim, after 32 iterations, a facet-based model with a mass of 4.53 kg was obtained. For the 5-spoke rim, after 54 iterations, a facet-based model with a mass of 4.71 kg was obtained. For the 6-spoke rim, after 33 iterations, a facet-based model with a mass of 4.57 kg was obtained. On the basis of the facet-based models obtained, the geometric shapes of the rims were proposed. The lowest weight of 8.72 kg was characteristic of the 6-spoke rim.

APPLIED MECHANICS 12/2024

EXPERIMENTAL STUDY ON THE MECHANICAL PROPERTIES OF SCREWS

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Abstract

In this article, experimental results of mechanical properties of screws are presented. Screws are essential fasteners, that play a crucial role in many machines. Screws can be seen in vehicles, machine tools, smartphones and large buildings. Screws usually hold machine parts together, and can be loaded by tensile force, thus this case is studied. Ultimate tensile load was tested for one hundred M6 screws bought in a store (Fig. 1.). Declared class of the screws was 5.8. Mechanical properties of screws are defined in ISO 898-1 [1], which provides an opportunity to compare obtained results with requirements set out in the standard. The minimum ultimate tensile load equals 10400N for screws M6 5.8. whereas for class 4.6 is 8040N. This leads to conclusion, that the real class of the tested screws is 4.6. Twelve screws meet the requirements 5.8 class, probably they were from another manufacturer. Moreover statistical analysis leads to conclusion, that the ultimate tensile loads are not normally distributed. In addition to the ultimate tensile loads, the tensile strength, the hardness and chemical composition of the samples were also tested. Obtained results clerically show, that screws should be tested independently both by manufacturer and seller.

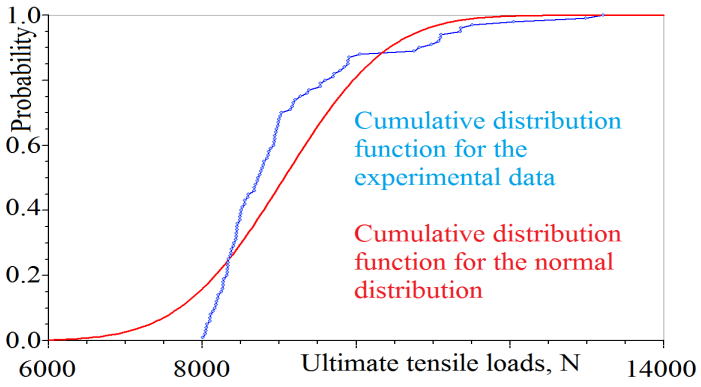

Fig.1. Cumulative distribution function obtained for the experimental data compared against the normal distribution

References

- ISO 898-1 Mechanical properties of fasteners made of carbon steel and alloy steel

APPLIED MECHANICS 12/2024

REMOVAL OF A MONOLITHIC REINFORCED CONCRETE FLOOR SLAB DAMAGED BY THROUGH CRACKS FROM AN EMERGENCY STATE

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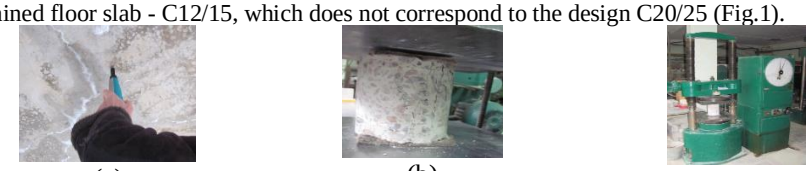
Abstract

The issue of durability and reliability of monolithic reinforced concrete structures is always relevant. Timely technical inspections of structural elements of the building, detection of defects and elimination of the cause of their occurrence make it possible to restore the load-bearing capacity by carrying out repairs and increase the durability of the building [1, 2]. The article highlights the results of the visual-instrumental inspection of the ceiling above the eleventh floor of the unfinished residential building on the street. Chemists in Ivano-Frankivsk. Conducting a visual-instrumental inspection of the floor slab above the eleventh floor is associated with the need to determine the causes of cracks on the entire surface of the slab in the upper and lower zones and establish the technical condition and provide proposals for further operation of the floor slab. At the time of the inspection, the building had eleven floors. It is planned to build three more floors and a technical one. Destructive and non-destructive methods determined the average grade of concrete of the examined floor slab - C12/15, which does not correspond to the design C20/25 (Fig.1).



(a) (b) (c)

Fig.1. Determination of the compressive strength of concrete of a monolithic reinforced concrete slab: (a) by a non-destructive method; (b) destructive method; (c) stage of initial load of the sample.

Field studies and control calculations of the load-bearing capacity showed that in the compressed zone of the floor slab, all excessive cracks are shrinkable. Since the compressed zone of concrete is excluded from the work, the additional load on the slab will cause its destruction. To ensure further safe operation and perception of forces in the compressed zone of concrete, it is proposed to increase the working height of the slab, to perform reinforcement of the reinforcement element with main reinforcement in two directions. Schemes of reinforcement and instructions for the order of execution of work when reinforcing the floor slab are proposed.

References

[1] Kramarchuk A., Ilnytskyy B., Lytvyniak O., Famulyak Y.: *Strengthening prefabricated reinforced concrete roof beams that are damaged by corrosion of concrete and reinforcement*. In.: Reliability and Durability of Railway Transport Engineering Structures and Buildings, IOP Conference Series: Materials Science and Engineering 708, 012060, 2019. DOI: 10.1088/1757-899X/708/1/012060.

[2] Vybranets, Y., Vikhot, S. & Burchenya, S.:. *Field Tests and Analysis of Flat Monolithic Reinforced Concrete Slabs.* Lecture Notes in Civil Engineering, 438, 484–497, 2024. https://doi10.1007/978-3-031-44955-0_49.

APPLIED MECHANICS 12/2024

INVESTIGATION OF PLASTIC DEFORMATION MULTI-CYCLE LOADING IN POLYURETHANE FOAM

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Abstract

The problem of the effect of multi-cycle loading causing plastic deformation is particularly relevant for hyper-elastic and soft structurally heterogeneous materials. This is because the mechanical properties of these materials change in the presence of plastic deformation. In contrast to fragile porous and foamed materials, where the presence of plastic deformation leads to the appearance of cracks and does not allow further loading, in soft materials only a change in the microstructure of the material occurs along with a change in its mechanical properties. At the same time, further use of such materials is possible. Therefore, the influence of changes in the mechanical properties of structurally heterogeneous foam materials on their mechanical behaviour under the action of a load causing plastic deformations is relevant. To solve this problem, the method of analytical-numerical modelling of the mechanical behaviour of structurally heterogeneous materials under the action of a dynamic non-stationary load was used in the paper [1]. The approach proposed in [1] is developed based on the Coosserat continuum model, which allows taking into account the influence of rotational-shear deformations of microparticles of the medium and reduces the solution of the non-stationary problem to a system of integral equations in the frequency domain. In addition, to study the effect of changing the mechanical behaviour of foam materials, a series of two-component polyurethane foams with different blowing agent to polyurethane ratios were prepared. For test specimens of these foams, the influence of the load causing the presence of plastic deformations on the change of their mechanical behaviour under compression was experimentally investigated using a method similar to [2].

At the same time, using the method of simulation analysis [3] and the analysis of microstructural sections of elements of foam samples, the values of microstructural properties of polyurethane foams at different stages of loading were determined. These characteristics were used for the numerical modelling of the propagation of elastic momentum in structurally heterogeneous materials under the action of loads causing plastic deformations. The numerical results allow us to evaluate the change in the mechanical behaviour of polyurethane foams and their vibration-absorbing properties under the action of loads that cause plastic deformations.

References

[1] Mikulich, O., Shvabyuk, V., Pasternak, I., Andriichuk, O.: *Modification of boundary integral equation method for investigation of dynamic stresses for couple stress elasticity*, Mechanics Research Communications 91, 107–111, 2018

[2] Mikulich, O., Hulay, O., Furs, T., Shemet, V.: *Strength and mechanical characteristics of modified polyurethane foams*, Procedia Structural Integrity 59, 460–465, 2024.

[3] Mikulich, O., Komenda, N., Guda, O., Kradinova, T.: *Simulation analysis of the influence of changing mechanical characteristics of polyurethane foams*, Procedia Structural Integrity 59, 466–470, 2024.

APPLIED MECHANICS 12/2024

THE IMPACT OF VARIABLE LOADING ON THE STRENGTH OF WOOD BONDED JOINTS

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Abstract

Wood, due to its advantages, is increasingly being used as a construction material. In recent years, there has been rapid development in adhesive wood joint elements. Ongoing research aims to optimize bonded joints and enhance the strength of designed wooden structures. A review of the literature indicates that studies on wood bonded joints primarily focus on determining static tensile, shear, and bending strength, as well as the influence of various factors on strength. These factors include, for example, the type of adhesive, the effects of high temperature, or humidity [1].

Although most adhesive-bonded structures, including wooden ones, are subjected to variable loads during use, the number of studies dedicated to such research is significantly lower. This may be due to the fact that industry and national standards most often specify quantitative criteria regarding the mechanical properties of bonded joints determined under monotonic loads.

The scope of this work involved conducting experimental studies under monotonic and variable load conditions. Figure 1 schematically shows the adopted methodology and test conditions. The samples for testing were made from beech and pine wood, and they were prepared in accordance with relevant standards.

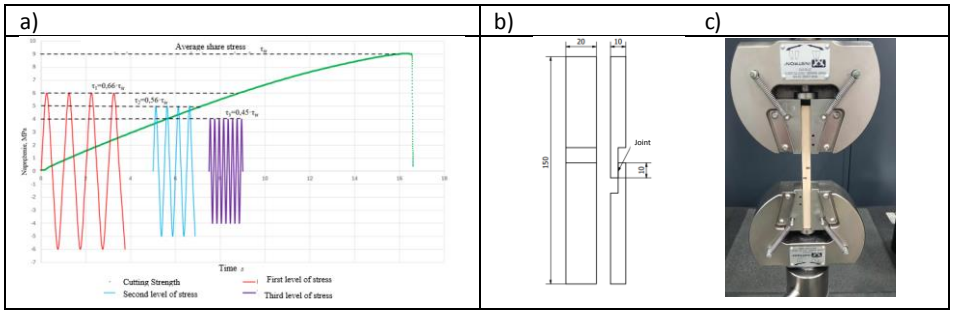

Fig.1. Test conditions: research program, samples, testing apparatus

Based on the analysis of the test results, a significant impact of variable loading on the strength of the bonded joint was observed. At the level of variable load corresponding to half the immediate strength of the joint, the durability of the connection did not exceed several hundred load cycles. The analysis of fractures obtained after the tests indicates that the failure of the bonded joint primarily occurred within the joined materials. The obtained test results confirm the validity of including fatigue tests, in addition to monotonic tests, when quantitatively assessing the quality of bonded joints.

References

[1] J. Vanerek, R. Balkova, M. Smak, A. Betak i Z. Vejpustek.: The effect of long and short term elevated temperatures on the behaviour of lap glued joints of load-bearing spruce elements, International Journal of Adhesion & Adhesives 129 (2024) 103575, pp.1-10.

APPLIED MECHANICS 12/2024

FATIGUE EVALUATION OF THE DEGRADATION OF A CAST STEEL STRUCTURE DUE TO FIRE

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Abstract

The primary factor influencing the strength parameters of steel after a fire is the course and intensity of the heating and cooling processes of the material [1]. The measure of this intensity is usually the time and speed of temperature changes. For example, hot-rolled steel heated for 3 hours at 600°C and then cooled to room temperature essentially retains its original mechanical properties. However, a 3-hour heating of the same steel at 700°C followed by cooling can result in a reduction of strength parameters by up to 15% [2].

Structural elements, which have obtained their nominal parameters through processes such as rolling, drawing, or forging, are particularly susceptible to a deterioration of mechanical properties due to events like a fire. The work-hardening effect achieved during these processes diminishes rapidly as the temperature increases. This issue becomes significantly more complex when the elements exposed to fire are made of puddled or cast steels. Puddled steels and early cast steels are materials whose current properties may differ significantly from their original ones due to the natural aging process of the material.

The most commonly used tests to assess the suitability of structures subjected to high-temperature exposure for further operation are tensile tests, hardness tests, and impact tests [3]. Fatigue tests are rarely used to assess the degree of degradation of mechanical properties. For this reason, this paper attempts to assess the validity of fatigue tests as additional tests that allow for identifying the state of the material after a fire and at the same time qualifying it for further use. Samples for the tests were taken from a hall structure built in the 19th century using welded steel, which was destroyed after more than 130 years due to a fire. The paper presents the results of basic tests recommended for assessing the degree of degradation of steel properties after a fire, i.e. static tensile tests, impact strength, hardness and additional fatigue tests. The tests were carried out for two material states, i.e. after a fire and in a state in which no temperature impact on the structure was observed.

The obtained test results indicate that, as a result of the fire, there is a reduction in the basic mechanical parameters and a change in the microstructure of the tested steel. Based on the conducted tests, it can be concluded that fatigue tests can expand the range of control studies for materials subjected to high-temperature exposure. When combined with static tests, they allow for a more comprehensive assessment of the cyclic properties of materials exposed to high temperatures.

References

[1] Setién J., González J. J., Alvarez J. A., Polanco J. A.: *Evolution on mechanical behaviour in a structural steel subjected to high temperatures*, Engineering Failure Analysis 9, (2002) 191–200.

[2] Maślak M.: *Badania stali konstrukcyjnej po pożarze w kontekście oceny możliwości jej dalszego użytkowania w elementach nośnych ustrojów budowlanych*, Przegląd Budowlany 6/2012.

[3] Lesiuk G., Rabiega J.: *Badania wytrzymałościowe XIX-wiecznych elementów konstrukcyjnych wykonanych ze stali zgrzewnych*, Logistyka 6/2011.

APPLIED MECHANICS 12/2024

POST-FAILURE BEHAVIOR OF STRUCTURAL MULTI-LAYERED GLASS

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Abstract

A Eurocode for the design of glass load-bearing structures is currently under development. In this regard, the European standards organisation CEN has prepared the Technical Specification CEN/TS 19100. The first three parts were published in 2021 [1-3], and the fourth part in 2024 [4].

According to CEN/TS 19100-1 [1], in addition to the traditional Ultimate Limit State (ULS) and Serviceability Limit State (SLS), a Fracture Limit State (FLS) and Post Fracture Limit State (PFLS) have been introduced for glass structures. The ULS and SLS given in EN 1990 [5] include limit states of unfractured (intact) glass components. The design rules in ULS and SLS are presented in Parts 1-4 of CEN/TS 19100 [1-4]. The Fracture Limit State (FLS) evaluates safety during fracture, while the Post-Fracture Limit State (PFLS) evaluates safety after failure. FLS and PFLS are classified as emergency design situations according to EN 1990 [5]. The design rules for FLS and PFLS are given in [2-4]. In addition to the classification into Consequences Classes (CCs), glass components are assigned to Limit State Scenarios (LSS), which describe groups of limit states (Table 1).

TABLE 1. Limit State Scenarios (LSS) depending on limit or fracture state [1]

	Limit State Scenario (LSS)			
	LSS-0	LSS-1	LSS-2	LSS-3
Design for the unfractured glass state	SLS ULS	SLS ULS	SLS ULS	SLS ULS
Design for the glass fracture state (safe glass fracture)		FLS		FLS
Design for the post-fractured state (residual load capacity)			PFLS	PFLS

The fracture behaviour of plates consisting of layers of different types of glass is considered. The aspects of the concept of four limit states in relation to the sequence of glass layer fracture in multi-layered glass plates with different cross-sections are presented.

References

[1] CEN/TS 19100-1:2021. *Design of glass structures - Part 1: Basis of design and materials*. European Committee for Standardization (CEN), Brussels. 2021.

[2] CEN/TS 19100-2:2021. *Design of glass structures - Part 2: Design of out-of-plane loaded glass components*. European Committee for Standardization (CEN), Brussels. 2021.

[3] CEN/TS 19100-3:2021. *Design of glass structures - Part 3: Design of in-plane loaded glass components and their mechanical joints*. European Committee for Standardization (CEN), Brussels. 2021.

[4] CEN/TS 19100-4:2024. *Design of glass structures - Part 4: Glass selection relating to the risk of human injury - Guidance for specification*. European Committee for Standardization (CEN), Brussels. 2024.

[5] EN 1990:2023. *Eurocode: Basis of structural design*. European Committee for Standardization (CEN), Brussels. 2023.

APPLIED MECHANICS 12/2024

FINITE ELEMENT ANALYSIS OF STRESS-STRAIN STATE OF LAMINATED GLASS PLATE

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Abstract

A numerical model based on the Finite Element Method (FEM) of a laminated glass plate consisting of 3 layers of annealed glass, each 10 mm thick, laminated with a 2-layer film is presented. The calculation was performed using the RFEM program (Dlubal Software). The particularities of laminated glass simulation are presented. The geometry of the plate was described by a surface. For this purpose, the material and thickness parameters that determine the surface stiffness were predefined. The surface type was selected as 'glass', and the surface was defined with dimensions of 0.5 m x 0.5 m. During the FE mesh generation, 2D elements were created on the surfaces. The load was set as a force uniformly distributed over the square area in the centre of the surface, similar to the experiments.

A specialised RF-GLASS add-on module was used to design the corresponding cross-section of the plate with the specified layer thicknesses and their physical and mechanical properties. The physical and mechanical properties of the glass were taken from EN 572-1 [1] and the Bridgestone EVASAFE polymer film was taken from the DIBt technical approval [2]. The appropriate settings were then selected for a given section. A 2D calculation option was selected for the linear analysis, during which an equivalent cross-section was created and the plate was calculated in accordance with Mindlin plate bending theory. The geometric model was meshed into elements with a length of 50 mm. The plate was supported at the four corners corresponded to the nodal supports of the "hinge" type.

The calculation model of the laminated glass plate is shown in Fig. 1.

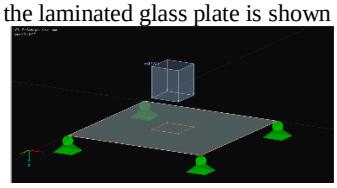

Fig.1. FEM calculation model of a plate

The results of the calculation were used to obtain the values of stresses and displacements in all layers of glass for different stages of loading. The theoretical and experimental results were compared.

References

[1] EN 572-1:2012+A1:2016. *Glass in building - Basic soda lime silicate glass products - Part 1: Definitions and general physical and mechanical properties.* European Committee for Standardization (CEN), Brussels, 2016.

[2] DIBt: Allgemeine bauaufsichtliche Zulassung Nr. Z-70.3-197: *Verbund-Sicherheitsglas mit einer Verbundfolie der Produktfamilie EVASAFE mit Ansatz eines Schubverbundes*, Deutsches Institut fur Bautechnik (DIBt), 2014.

APPLIED MECHANICS 12/2024

SIMSCAPE ENVIRONMENT IN OBJECT MOTION MODELING ON OBLIQUE CHUTE WITH GUIDES

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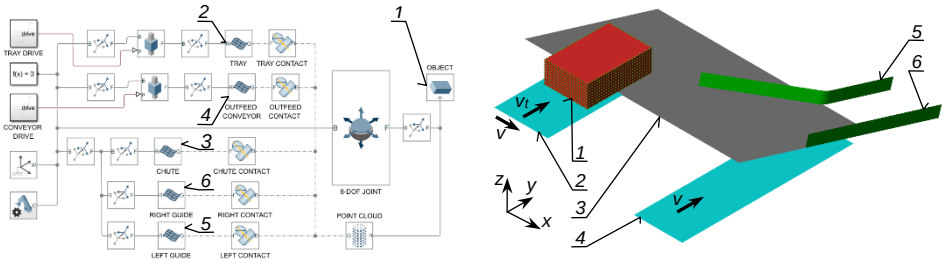
Abstract

The technical solution used to automate the labour-intensive processes of picking courier parcels or handling baggage at airports [1] are cross-belt sorting systems. Achieving high efficiency of this system requires the use of equally efficient and precise feeding and outfeed devices. In addition to high efficiency, the aim is also to obtain the greatest possible number of directions of redirecting objects to outfeed lines, built in the smallest possible space. In order to determine the required configuration of outfeed lines space (Fig. 1), it is necessary to develop a dynamic model of the moving objects' process on a chute with guides, which, after experimental verification, will allow for selecting the optimal parameters of this process.



(a) (b)

Fig. 1. Simscape model: a) flowchart, b) Mechanics Explorer environment for 3D motion animation; 1 – object, 2 – tray cross belt, 3 – chute, 4 – outfeed conveyor, 5 – left guide, 6 – right guide, v – velocity of trays in the track, along the chute, v_t – tray cross belt velocity, v_c – outfeed conveyor velocity.

The aim of the research is to develop a model of the moving cuboid objects' process on an inclined plane with guides, using Simscape, which is an extension of Matlab Simulink 2024. In this study, the key role is played by the descriptions of two physical phenomena, i.e. inelastic collision of bodies and dry friction, which are presented in the paper. The simulation results of the proposed model were verified during experimental studies.

References

[1] Piatkowski T., Wolski M., Model of positioning objects by the system of oblique friction force fields on horizontal and vertically offset planes, Mechanism and Machine Theory 156, 2021.

APPLIED MECHANICS 12/2024

INFLUENCE OF THE FORM AND WIDTH OF CROSS PASS ON THE AUDIENCE SURFACE FORM OF PUBLIC BUILDINGS

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Abstract

In auditoriums visibility is calculated mainly on the basis of two-dimensional model of visibility when calculation is conducted in a longitudinal section of the hall. In this case use the concept "focal point" which visibility provides free visibility of a subject to observation in general. We can see the same idea in the literature on architectural acoustics. All places in a row (and monocular eyes of the audience of this row) are located at one height and each row is presented by one place. Such approach is correct if rows in the plan are straight lines parallel among themselves which are parallel to the focal line (for example, the lower edge of a flat screen) or the focal line and rows in the plan are concentric circles [1].

But in design practice, other forms of both the focal and rows in plan are often encountered [2]. In that case, free visibility should be calculated using three-dimensional model of visibility [3]. At the same time each place in the hall (and, respectively, a monocular eye of the viewer) will have a different height and the floor of each row will be not horizontal.

In auditoriums often arrange cross passes which separate groups of rows of a different form in plan. At the same time width of pass changes, as a rule, increasing as approaching longitudinal passes or exits from the hall. Influence of width and the location of cross pass on height of raising of rows when calculating for two-dimensional model of visibility is analysed in the publication.

If visibility calculates on three-dimensional model, then the form and width of pass influence a row form located behind cross pass. And as the form of a curve of monocular eyes of the audience of the specified row is used further for calculation of z-coordinates of monocular eyes of the audience of the subsequent row, it, thus, influences a form of all surface of the audience.

It is possible to draw a conclusion that the form of curve dependence of heights of eyes of the audience of the row placed behind pass significantly depends on a form of this row in the plan, and the maximum height of eyes of the audience – on whether width of cross pass changes. The significant change in width of cross pass (expansion to edges of a row) leads to significant increase in the maximum height of eyes of the audience, the following with pass of a row, and height difference between the maximum and minimum values of heights of eyes of the audience within a row.

Therefore, it is better not to increase needlessly pass width and if in it there is a need, then it is necessary to set such form of the row following cross pass that it approached a form of the row placed before pass. For example, if the row placed before pass is a circle, then the row placed behind pass can be not concentric circle but close in a form to concentric.

References

[1] Pugachov, E.V., Zdanevych, V.A., Kundrat, T.M. and Litnitskyi, S.I. *Visual perception, visibility and evaluation of obscuration in buildings and structures for spectators: monograph.* Volyn amulets, Rivne, 2023, 348 p.

[2] Kokoch, M.V. and Pugachov, E.V. *Geometric classification of rows for viewers.* Technical aesthetics and design, 8, 2010, 164-168.

APPLIED MECHANICS 12/2024

INVESTIGATION OF STREAM STRAIGHTENERS IN A STRAIGHT CHANNEL

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Abstract

The stream straighteners are the devices used for the reduction of the vortices in the flow. They are most often designed as a group of small channels with a circular or rectangular cross-section area, and they are placed in a duct after the pump or before the sensors. The stream straighteners are used in many applications due to the turbulent decrease or the hydraulic entrance length reduction [1–3]. The place of the stream straightener should increase the repeatability and accuracy of measurements. Although straighteners are widely recognized and used in technology and science, their operation and efficiency are still not enough described.

The paper investigates the influence of a stream honeycomb straightener (Fig. 1) placed one meter behind the axial fan on the flow turbulence and velocity profile. The tests were carried out for Reynolds number equal to $Re = 10000 - 45000$. The straighteners with hydraulic diameter $d = 5, 10, 20$ mm, and length $l = 5, 10, 20, 40$ mm were used. The velocity was measured one meter behind straighteners and compared to the measurement carried out without the straightener installed. The velocity profile on the channel output was measured with the MiniCTA 55T30 hot-wire anemometer with a single wire probe 55P16 and NI9215 data acquisition device. The Reynolds number was calculated based on the Anemometer LCA501-AC.

The evaluation of the straighteners' performance was based on the measurement of the velocity turbulence profile. The presented measurements are preliminary for further numerical and experimental studies of the flow straighteners.

Fig.1. Stream honeycomb straighteners used in the experiment

References

[1] Alizadeh, L.; Fernandes, J. *Turbulent Flow Structure in a Confluence: Influence of Tributaries Width and Discharge Ratios*. Water 2021, 13, 465.
[2] Peszynski, K.; Tesař, V.; Kuliś, E. *Evaluation of linear losses in ventilation ducts with a rounded rectangle cross-section*. MATEC Web Conf. 2019, 302, 01021.
[3] Gao, R.; Liu, K.; Li, A.; Fang, Z.; Yang, Z.; Cong, B. *Study of the shape optimization of a tee guide vane in a ventilation and air-conditioning duct*. Build. Environ. 2018, 132, 345–356.

MOVEMENT OF MATERIAL IN A CHUTE WITH COMBINED FRICTION

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Abstract

Vibrating machines are widely used in various branches of industry and agriculture, both for transporting artificial and loose materials, and for performing various technological processes. Such devices are easily hermetically sealed and their performance can change due to changes in the amplitude of oscillation, they have low energy consumption and are safe to use [1,2]. In this work, the body moves in the chute, its walls are stationary and have different coefficients of friction, and the bottom of the chute can perform oscillating motion in the horizontal plane according to the harmonic law [3].

A mathematical model of the proposed method of vibration transportation was developed for the theoretical study of cargo movement modes. As a result of the numerical integration of the received nonlinear differential equations of motion, the dependences of the average speed of the load on the friction coefficients of the walls and the bottom of the chute, frequency, amplitude and direction of oscillations were obtained. It was found that with an increase in the angle between the direction of transportation and the direction of oscillations, the average speed of the load decreases, and these dependencies are linear in nature.

The average speed of transportation increases when the amplitude of oscillations increases. The main results of theoretical studies have been confirmed experimentally. By changing the oscillation parameters, you can change the average speed of transportation of various loads, depending on the performance of certain technological tasks by this device. The conducted research can be used in the design of vehicles with improved technical and economic characteristics.

References

[1] R.M. Rohatynskyi, L.S. Serilko, Z.K. Sasyuk, D.L. Serilko D.L. / Study of the dynamics of inertial conveyors // All-Ukrainian Scientific and Technical Journal "Vibrations in Engineering and Technologies". – Vinnytsia, 2018. – 2 (89) – P. 41 – 48.

[2] 2. Serilko L. S., Lyashuk O. L., Sasyuk Z. K., Serilko D. L. The research of inertial conveyor transitional chute oscillations influence on its technical and economic indicators / Resource-saving technologies of raw-material base development in mineralmini: multi-authored monograph. – Petrosani, Romania Universitas Publishing, 2020 – p 293-309.

[3] Patent of Ukraine for the utility model "Inertial Conveyor", No. 156803. Bull. No. 32, 2024

APPLIED MECHANICS 12/2024

ENVELOPES OF SHEAR AND NORMAL STRESSES FOR COMPLEX STRESS STATE

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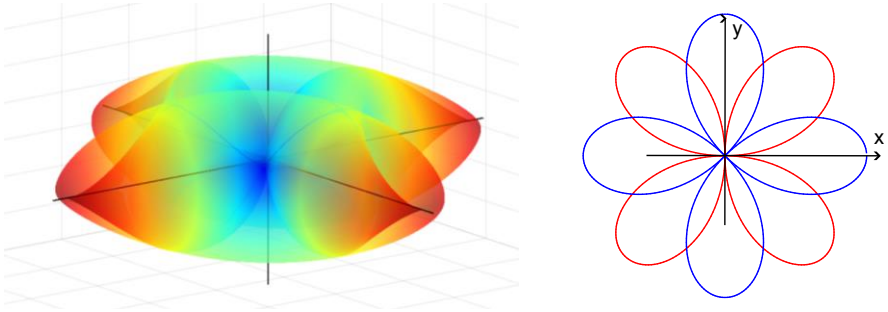
Abstract

Machines and equipment designed today are required to have a certain durability and reliability. To meet these requirements, engineers can make use of the many fatigue models offered in the literature. Based on load data and material properties, these models allow fatigue life prediction. However, depending on the type of model, the required quantities characterizing the load condition, such as e.g. shear stress and normal stress in the critical plane, or the second invariant of the deviatoric stress tensor and the maximum value of the hydrostatic stress, must be calculated based on the time-varying stress or strain components. The calculation of these quantities requires lengthy numerical calculations. For example, for the critical plane or integral models, the number of calculation iterations can, even in the simplest cases, amount to several tens of millions. In several situations, numerical iterations can be replaced by calculations according to analytical relationships. Such relations have been proposed, for example, by Papadopoulos in [1,2]. In the present paper, analytical relations are proposed for the maximum shear and normal stresses in the plane tangent to the surface of a cylindrical specimen loaded in sinusoidally varying tension and torsion with a phase shift of the components:

$$\tau_\alpha = \sqrt{\left(-\sigma_{x(a)}/2 \cdot sin(2\alpha) + \tau_{xy(a)} \cdot cos(2\alpha) \cdot cos(\varphi)\right)^2 + \left(\tau_{xy(a)} \cdot cos(2\alpha) \cdot sin(\varphi)\right)^2} \quad (1)$$

$$\sigma_\alpha = \sqrt{\left(\sigma_{x(a)} \cdot cos(\alpha)^2 + \tau_{xy(a)}\, cos(\varphi) \cdot sin(2\alpha)\right)^2 + \left(\tau_{xy(a)} \cdot sin(\varphi) \cdot sin(2\alpha)\right)^2} \quad (2)$$

where: $\sigma_{x(a)}, \tau_{xy(a)}$ – the amplitudes of the normal and shear stresses, φ – the phase shift angle, α – the position of the plane on which the stresses are considered. Fig. 1 presents the diagrams of the stress envelopes.



a) b)

Fig.1. Distribution of shear stresses calculated numerically (a), shear and normal stresses in plane tangent to the surface of a cylindrical specimen calculated analytically (b)

References

[1] Papadopoulos I V., Davoli P, Gorla C, Filippini M, Bernasconi A. A comparative study of multiaxial high-cycle fatigue criteria for metals. Int J Fatigue 1997;19:219–35. https://doi.org/10.1016/S0142-1123(96)00064-3.

[2] Papadopoulos I. Long life fatigue under multiaxial loading. Int J Fatigue 2001;23:839–49. https://doi.org/10.1016/S0142-1123(01)00059-7.

APPLIED MECHANICS 12/2024

MODELING OF THIN ISOTROPIC POLYGONAL PLATES USING MACROELEMENT METHOD

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Abstract

The article presents an analytical-numerical macroelement method for modeling and solving thin, isotropic plates with a various boundary conditions. The developed method consists of mathematical, computational and geometric models. It was implemented in a computer program to solve the boundary problem of plate structures under continuous load.

The previous authors' articles analyzed symmetrical plates [1], rectangular plates with various boundary conditions [2] and some special cases of non-rectangular plates. The aim of the work is to develop an universal and easy-to-use method for solving plate structures of any shape. In this article, we limit our considerations to convex polygons.

Results for triangular, skewed, trapezoidal and hexagonal plates are presented as examples of solutions. The figure below shows the calculation results on randomly generated nodes.

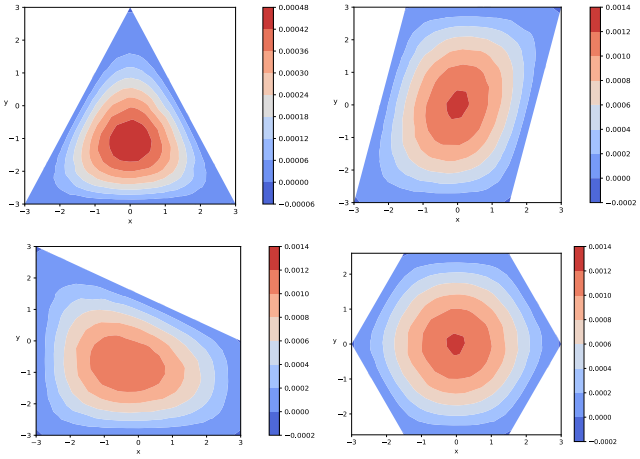

Fig.1. The deflection of a simply supported plate: triangular, skewed, trapezoidal and hexagonal

Based on their analysis, the advantages and limitations of the method are presented. Directions for further development of the method were also indicated.

References

[1] Delyavskyy M., Rosiński K.: *The New Approach to Analysis of Thin Isotropic Symmetrical Plates*, Applied Sciences. 2020; 10(17):5931. https://doi.org/10.3390/app10175931

[2] Delyavskyy M., Sobczak-Piąstka J., Rosiński K., Buchaniec D. and Famulyak Y.: *Solution of thin rectangular plates with various boundary conditions*, AIP Conference Proceedings 2949, 020023 (2023). https://doi.org/10.1063/5.0165300

APPLIED MECHANICS 12/2024

EXAMPLES OF NUMERICAL MODELLING OF COUPLED THERMODIFFUSION PROBLEMS

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Abstract

In this paper the space-time finite element method is used to solve the problem of coupled thermodiffusion in solids. This method can be considered as an extension of the finite element method in the time domain. By considering the time variable in the same way as the spatial variables, a one-step discretization of space-time is performed, which directly reduces the initial-boundary problem to a system of algebraic equations. A deformable solid body is analyzed which is subjected to external loads, heat sources and mass sources. The characterized initial-boundary problem of coupled thermodiffusion is described by a system of partial differential equations and then by virtual time-work equations. The results of selected numerical analyses illustrating the theoretical considerations are presented. In particular, the change of displacements, temperature field and concentration field of the diffusing substance over time due to the action of a time-varying load and a time-varying heat source is discussed. The analyses presented in this article are an extension of the considerations contained in the works [1, 2] and constitute the basis for solving practical problems, and above all, they constitute a very good introduction to nonlinear issues.

References

[1] Sosnowska M.: *Modelowanie termodyfuzji sprzężonej metodą elementów czasoprzestrzennych*, Wydawnictwa PBŚ, Bydgoszcz 2023.

[2] Sosnowska M., Lachowicz M., Podhorecki A..: *Generalization of Hamilton's principle for the problem of coupled thermodiffusion*, Materiały Budowlane 2/2024, 618, 1-4, 2024.

APPLIED MECHANICS 12/2024

MORPING WING WITH VARIABLE CAMBER NEAR TRAILING EDGE

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Abstract

The article discusses calculations for wings with variable chord. In particular, the method of finding the optimal deflection shape is presented and an attempt to estimate the possible reduction of the leaf resistance with such a profile is shown. The paper presents the process of profile optimization using the Optuna framework in which the TPE optimization method was used. The profile analysis was based on the panel method in the xfoil program implemented in CMPLXFOIL [2]. The results of these analyses allow to find the optimal shapes of variable chord aerofoils that minimize aerodynamic drag and maximize lift. The article also compares the basic force coefficients for an example of a wing with classic ailerons and a wing with a variable chord. The calculations of the three-dimensional wing were performed using the VLM method implemented in XFLR5 [3]. The results obtained (Fig.1) indicate a maximum increase in the wing coefficient of Lift-to-Drag Ratio by 50%.

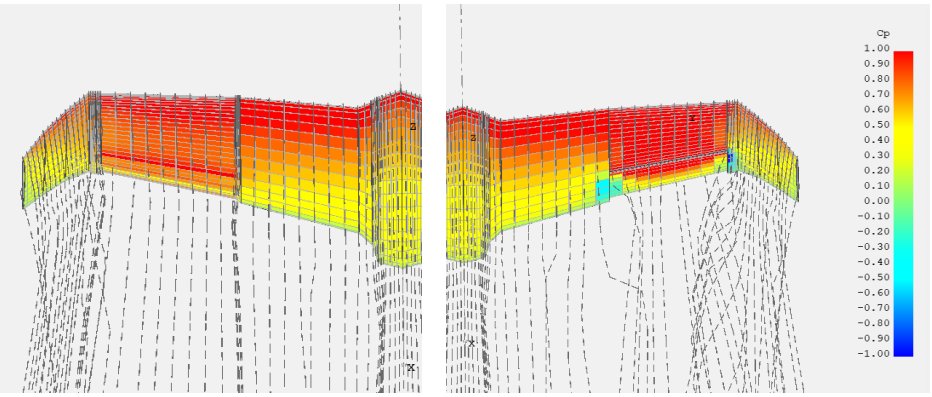

Fig.1. Comparison of flow around morphing camber wing (left) and conventional wing (right)

There can be seen more even distribution of *Cp* and reduction of vortices at the end of aileron. Both of them greatly contributes to reduction of drag coefficient.

References

[1] Akiba T., Sano S., Yanase T., Ohta T. and Koyama M.: *Optuna: A Next-generation Hyperparameter Optimization Framework*. Proc. ACM SIGKDD Int. Conf. Knowl. Discov. Data Min., pp. 2623–2631, Jul. 2019, doi: 10.1145/3292500.3330701.

[2] Drela M.: XFOIL: An Analysis and Design System for Low Reynolds Number Airfoils. Low Reynolds Number Aerodyn. Proc. Conf., Notre Dame, USA, June 5-7, 1989. In: Mueller T.J.: Lecture Notes, No. 54, Berlin, Germany, Springer-Verlag, 1989, pp. 1–12, 1989, doi: 10.1007/978-3-642-84010-4_1.

[3] XFLR5, http://www.xflr5.tech/xflr5.htm (accessed Aug. 30, 2024).

APPLIED MECHANICS 12/2024

TENSILE TESTS OF UNIDIRECTIONAL GLASS FIBRE COMPOSITE WITH ELASTIC MATRIX

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Abstract

This article focuses on the mechanical strength testing of a flexible composite material under tensile loading in two directions. The aim of the study was to determine in detail how different matrix materials affect the tensile strength properties of the composite under mechanical loading conditions. The tests were conducted in accordance with ISO 1527-5 [1] ensuring consistency and accuracy of the measurements. Three types of matrix materials - EF 80, X60, and Resoltech 1600 - were compared, all in conjunction with HP-U600E fabric. The experimental results allowed for the assessment of the influence of the matrix type on the composite's tensile strength in two directions and its ability to maintain structural integrity under load. Obtained material stiff in direction parallel to fiber, while remaining flexible in perpendicular direction as shown on Fig. 1. From tested resins was selected the most suitable one in considered application. The obtained results are material data required for further development of variable geometry wing structures, where geometric continuity is a key requirement.

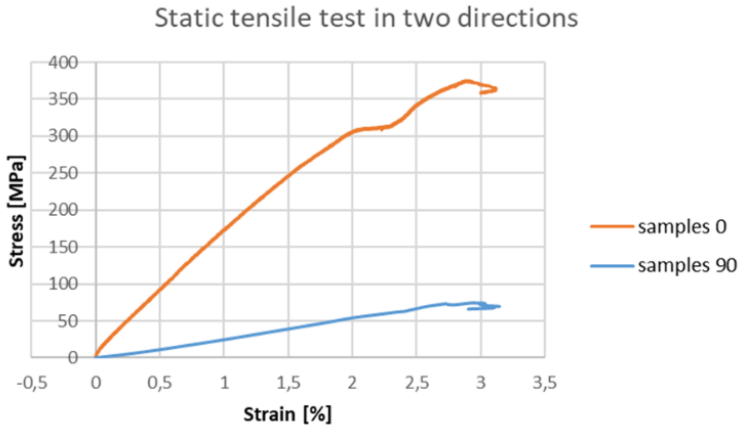

Fig.1. Tensile stress curves of a selected sample made on Resoltech 1600

References

[1] EN ISO 527-5:2021 - *Determination of tensile properties of plastics*, No. 1108, 2021.

APPLIED MECHANICS 12/2024

MULTIFRACTAL APPROACH TO ANALYSE THE SIZE EFFECT OF SELECTIVE LASER MELTED ALSI10MG ALLOY

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Abstract

The fatigue strength of structural materials shows a variable sensitivity to the size effect. This phenomenon results from the inaccuracy of scaling all material properties (e.g. microstructure, defect distribution, surface layer) to a constant level [1]. Considering the size effect during extrapolating results from small laboratory specimens to large objects is critical in assessing the reliability of engineered components.

The size effect in high-cycle fatigue was analysed using a multifractal approach [2]. The assumption of this model is the use of a fractal dimension describing the ligament damage of the material structure. The size effect on fatigue strength decreases with increasing object size. Therefore, a gradually disappearing fractality was used to achieve this non-linear behaviour. The fractal dimension tends to zero as the object size increases. The implementation of the multifractal approach requires the determination of the C_r parameter, as shown below [2]:

$$C_r(D) = C(D)^{\frac{1}{100}} = \left[\frac{y_Q - y_P}{f_m\left(\frac{1}{D}\right)+1} + y_S\frac{1}{D} + y_P\right]^{\frac{1}{2}} \tag{3}$$

where D is the object dimension, C is the constant parameter of the S-N curve and y_Q, y_P, y_S, f_m are the material constants.

Verification of this approach was carried out for the selective laser melted AlSi10Mg alloy. The material is characterised by size effect sensitivity in the range of small variations in specimen size. The cause of this phenomenon is heterogeneity in the microstructure of the material (unmelted powder layers, incomplete fusion between melt pools) as a result of inaccuracies in the additive manufacturing process.

The size effect was analysed for the variable specimen dimension (D) defined by the highly stressed volume [3]. The outputs have been calculated for the constant parameter of the S-N curve (C). The relative errors suggest a good fit between the predicted and experimental results. The fatigue strength can be correctly estimated for a size different from the specimen tested using the multifractal approach. This implies the input of material constants for individual test conditions.

Acknowledgments

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References

[1] Vollertsen F.: *Categories of size effects*, Production Engineering – Research and Development 2, 377-383, 2008.
[2] Carpinteri A., Spagnoli A.: *Size effect in S-N curves: A fractal approach to finite-life fatigue strength*, International Journal of Fatigue 31, 927-933, 2009.
[3] Kuguel R.: *A relation between theoretical stress concentration factor and fatigue notch factor deduced from the concept of highly stressed volume*, Proc ASTM 61, 732-748, 1961.

APPLIED MECHANICS 12/2024

DYNAMICS OF A PROJECTILE FIRED FROM THE KRAB HOWITZER

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Abstract

One of the main problems when studying the movement of a projectile in the air is to determine the functional dependence of the drag force on the projectile's velocity. It is quite problematic to get such dependence analytically. Carrying out experimental studies, there are established a discrete relationship between the values of the Mach number and the drag coefficient for a specific type of projectile. On the basis of these dependencies, the values of the drag force are determined [1], [2], which are used when solving problems of external ballistics.

External ballistics problems are divided into direct and inverse ones. The purpose of the direct problem of external ballistics is to determine the coordinates of the level point of the projectile's trajectory if the value of the aiming angle is known. On the contrary, the aim of the inverse problems is to determine the value of the aiming angle that will ensure that the projectile hits a specific point. For both the inverse and direct problems, it is assumed that the mass and initial velocity of the projectile, air temperature, atmospheric pressure, wind direction and its velocity are known. The authors developed a technique for determining the functional dependence of the drag force on projectile's velocity, air temperature and atmospheric pressure based on the solution of the inverse dynamics problem.

The drag force, the weight of the projectile and the Coriolis force play a decisive influence on the dynamics of the projectile. Conducted experimental studies indicate that there are three different stages in the behavior of the drag force – during the projectile's movement at supersonic, subsonic, and transonic velocities. Therefore, the functional dependence of the drag force of the projectile's movement is determined for each stage in particular. However, a feature of projectile's movement in the final stages with increasing subsonic or supersonic velocities is the effect of an additional force of lateral air pressure. It is initiated by the variable magnitude of the sound velocity vector in the air. As a result of mathematical research, it is established that the force of lateral air pressure is directed perpendicularly to the direction of projectile's velocity. The magnitude of this force depends on the altitude of the projectile, the magnitude and direction of its velocity. The functional dependence of the force of lateral air pressure on these parameters has not been determined, but its value has been determined on the condition that the theoretical flight range of the projectile should be equal to the table value.

A comparison of the kinematic parameters of the projectile's movement determined by the method proposed by the authors with the results given in the shooting tables was made and certain discrepancies were pointed out. The knowledge of the functional dependence of drag force on projectile's velocity allows, using appropriate software, to automate the determination of the elevation angle for each gun, taking into account standard and non-standard firing conditions. It increases the accuracy of hitting a projectile at a given target.

References

[1] Liang K, Huang Z., Zhang J.-m., Defence Technology **13**, 206-211 (2017).
[2] Zygmunt B., Motyl K., Machowski B., Makowski M., Olejniczak E., Rasztabiga T., Bulletin of the Polish Academy of Sciences, Technical Sciences **63**, 229-233 (2015).

APPLIED MECHANICS 12/2024

INFLUENCE OF ACIDIC ENVIRONMENTS ON WOOD DENSITY

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Abstract

Solid wood, like any other material, works in both normal and various aggressive environments, including acidic ones. The fact that the acidic environment affects the density of timber is quite important, and this, in turn, affects the mechanical properties of the wood.

The samples were made in the form of prisms with a cross-section of 30x30x120 mm.

On the basis of experimental studies [1, 2], the density of birch and pine wood at a standard moisture content of 12% and under the influence of different acidic environments (acetic, lactic, and hydrochloric acids) with different periods of sample impregnation, namely: after 1 hour, 3 hours, 7 hours, 1 day, 3 days, 7 days, 14 days, 21 days, 28 days, and 180 days, was determined.

The unimpregnated wood samples at standard moisture content (12%) had a density of 546,8 kg/m^3 for pine and 624,5 kg/m^3 for birch, respectively.

As a result of acetic acid (9%) exposure, the density of pine increased by 55,0% (ρ = 847,4 kg/m^3) and the density of birch by 67,2% (ρ = 1044,3 kg/m^3) after 180 days of impregnation.

After exposure to lactic acid (40%) for 180 days of impregnation, the density of pine wood increased by 42,8% (ρ = 780,9 kg/m^3), and the density of birch timber increased by 79,3% (ρ = 1119,8 kg/m^3).

Due to the influence of hydrochloric acid (15 %), the density of pine timber increased by 66,9 % (ρ = 912,6 kg/m^3) after 180 days of impregnation

However, it should be noted that the density of wood due to impregnation with various acids is constantly increasing, but a significant increase is observed only during the first month of impregnation. Over the next five months, the density of the samples of impregnated pine and birch wood increased only in the range of 1,5% to 7,8%. This is due to the fact that during the first month of impregnation, the wood is almost completely saturated with moisture, and then almost does not absorb it.

Consequently, we have obtained new experimental data on the change in the density of solid pine and birch wood under the influence of an acidic environment (acetic, lactic, and hydrochloric acids). It has been established that the density of solid pine and birch wood increases depending on the period of impregnation with various acidic environments.

References

[1] Homon Sv. Sv., Matviiuk O. V., Savchuk S. M., Vereshko O. V., Kulakovskyi, L. Ya. Vplyv ahresyvnoho seredovyshcha na mitsnisni ta deformivni pokaznyky sutsilnoi derevyny khvoinykh porid. Visnyk NUVHP. Tekhnichni nauky : zb. nauk. prats. - Rivne : NUVHP, 2021. - Vyp. 2(94). - S. 69-80.

[2] Homon Sv.Sv., Savchuk S.M., Vereshko O.V., Kulakovskyi L.Ia. Metodyka eksperymentalnykh doslidzhen sutsilnoi derevyny na stysk uzdovzh volokon pid vplyvom ahresyvnoho seredovyshcha. Resursoekonomni materialy, konstruktsii, budivli ta sporudy. Rivne: NUVHP, 2021. Vyp. 39. S. 57–62.

JUSTIFICATION OF THE PROTECTIVE PROPERTIES OF DUAL PURPOSE CIVIL DEFENSE STRUCTURES

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Abstract

Radiation and chemical protection of people is carried out with the aim of eliminating or maximally weakening the impact on people's health of ionizing radiation and chemically dangerous substances and preserving their work capacity and viability [2, 3].

Radiation and chemical protection measures include:

- organization and implementation of measures to protect people and water sources from radioactive and poisonous substances;
- control of the condition of individual protective equipment and special devices and means;
- organization of radiation and chemical surveillance and intelligence;
- implementation of dosimetry control;
- carrying out measures to eliminate the consequences of infection (pollution).

According to DBN B.2.2-5:2023, dual-purpose protective structures (DPS) are divided into appropriate classes and groups [1].

The protective properties of anti-radiation shelters (ARS) provide for the reduction of exposure to the following predicted dangerous factors:

- the effects of ionizing radiation from radioactive pollution of the area, water and air, by ensuring the normative coefficient of attenuation of radiation exposure (protection coefficient);
- effects of an air shock wave from a side effect of weapons of mass destruction with calculated excessive pressure;
- effects of an air shock wave when using conventional means of destruction;
- side effects of conventional means of injury;
- penetration by fragments of means of conventional damage;
- effects of high temperatures and combustion products during fires.

The requirements for anti-radiation shelters and dual-purpose structures are given in accordance with the requirements of DBN V.2.2-5:2023 [1]. The given example is the calculation of the compliance of fencing structures with the normative protection factor. It is shown that, given the initial data, the protection factor of a dual-purpose protective structure with protective properties of ARS group P-1, which is arranged in separate rooms of the basement floor (parking at the mark -7,500 m), does not provide the necessary protection of people who will be hiding there from dangerous radiation doses. Therefore, it is necessary to carry out other additional engineering measures to ensure the necessary coefficient of attenuation of the radiation effect (collapse of walls along the perimeter, multi-layered external walls, etc.).

References

[1] DBN V.2.2-5:2023. *Protective structures of civil protection.* - K.: Ministry of Development of Communities, Territories and Infrastructure of Ukraine, 2023. - 112 p.

[2] Vasylchenko O., Kvitkovskyi Yu., Myrhorod O., Wheelman O.: *Building structures and their behavior in emergency situations: Training manual*, Kharkiv: KhNADU, 2015. – 488 p.

[3] Zhuravskyi O., Afanasieva L.: *Prospects for the Development of High-rise Construction in Ukraine*, AIP Conference Proceedings. Volume 2949, Issue 1, 020028 (2023). https://doi.org/10.1063/5.0166761. Published Online: 17 August 2023.