BULLETIN OF THE POLISH ACADEMY OF SCIENCES
TECHNICAL SCIENCES, Vol. 71(1), 2023, Article number: e144589
DOI: 10.24425/bpasts.2023.144589

EDITORIAL

SPECIAL SECTION

Lightweight structures in civil engineering – contemporary problems

Jacek SZAFRAN[1], **Alphose ZINGONI**[2], **Maria Pia REPETTO**[3], and **Marcin KAMIŃSKI**[1]

[1] Lodz University of Technology, Al. Politechniki 6, 90-924 Łódź, Poland
[2] University of Cape Town, Department of Civil Engineering, Rondebosch 7701, South Africa
[3] University of Genoa, Department of Civil, Chemical and Environmental Engineering, Via Montallegro 1, 16145 Genoa, Italy

Lightweight structures are civil engineering objects which distinguish themselves from similar structures erected up till now by a relatively small amount of construction material and extremely high design parameters such as large spans of roofs or bridges without middle supports, the considerable height of buildings, towers or masts, and extremely large useful surface or free volume of buildings, tanks, or reservoirs. Typical examples of structures fitting this definition include spatial lattice structures, plate and shell structures, domes and membranes, high-rise buildings, towers, reservoirs, bridges, and thin-walled, tension, cable and pneumatic structures.

It could be argued that methods and measures designed to develop lightweight structures will always be widely required in the construction industry. Several issues drive these developments forward. The first one is the economy and general costs related to the erection of a building structure. Given that costs are primarily determined by the weight of the structure and the amount of building material, the optimization of the use of materials will never cease to be the subject of research and implementation activities. One example is steel structures whose weight is the main quantity subject to optimization. Similar considerations are also given to structures made of concrete, reinforced concrete, or wood. In addition to this main topic, there are ongoing efforts to improve the construction processes that are particularly important as far as lightweight structures are concerned. Other engineering and scientific studies aim at finding new materials that are highly robust and meet certain performance requirements at the same time.

The second driver for developments in lightweight structures relates to their durability and long-term usability. Design or material solutions are not considered successful if they make it possible to erect a lightweight structure, but its functional properties quickly deteriorate. A large number of well-documented solutions failed to satisfy the durability requirement in the period expected from engineering structures (50 years) due to issues such as inadequate resistance to corrosion, excess vibrations, and fatigue.

The third subject widely addressed in engineering studies concerns the reinforcement of existing structures meaning an upgrade activity designed to effectively improve their durability or load-carrying capacity of their structural elements. When such measures are implemented, considerable emphasis is given to providing solutions that are both correct in terms of technology on the one hand and inexpensive on the other. A rather common opinion is that it is often more difficult to design and implement a reinforcement for an existing structure than to construct a new one. This results from several factors such as limited access to all elements, inability to do welding work, or inadequately developed approaches to calculation-based analyses that should produce a valid estimation of load-carrying capacities of reinforced elements. Another quite simple consideration should also be taken into account: structures meeting the requirements imposed on lightweight structures are generally subject to considerable effort, so any attempt to increase the load exerted on such a structure necessitates its reinforcement. A contemporary example of such a measure is the installation of photovoltaic panels on roofs of lightweight steel hall structures.

This Special Section of the "Bulletin of the Polish Academy of Sciences: Technical Sciences" is devoted to different aspects of lightweight structures in civil engineering. Notably, papers in this section do not address only the application of widely used materials in "lightweight structures", such as steel. Papers included dealing with the condition survey of existing structures, determining complex types of actions, the use of probabilistic estimation in soil mechanics, and more. This Special Section will contain selected extended versions of papers that were presented at the International Conference of Lightweight Structures on Civil Engineering in 2021. The LSCE 2021 conference

Manuscript submitted 2023-01-26, initially accepted for publication 2023-02-13, published in February 2023.

held in Łódź on 2 and 3 December was a tribute to honor the achievements and work of Professor Jan B. Obrębski. The Conference is a part of research activities of the Polish Chapters of the International Association for Shell and Spatial Structures.

The papers included in this issue of the Bulletin represent the research activities mentioned above.

Paper [1] co-authored by A. Knitter-Piątkowska, O. Kawa, and M. Guminiak is dedicated to structural damage localization. The authors used the wavelet transform method (in discrete form), which makes it possible to extract the desired detailed information from a big set of data representing the global response of a defective structure. The efficiency of the method was tested through a series of numerical examples, where the real flat truss girder is simulated by a parameterized finite element model. Welded joints were introduced in the girder and classic code loads were applied. Static vertical deflections and rotation angles of the steel truss structure were taken into consideration, and structural response signals were also computed at discrete points uniformly distributed along the upper or lower chord. In the authors' opinion, the analyses performed proved that the application of the discrete wavelet transforms to decompose structural response signals is very effective in determining the location of a defect. Evident disturbances of the transformed signals, including high peaks, were expected as an indicator showing that the defect is present in the structure. Another very significant fact is that in the proposed approach there is no need to build an FE model of the real structure. It is sufficient to obtain a structural response signal and analyze it in the proposed way.

Paper [2] co-authored by M. Łasecka-Plura, Z. Pawlak, and M. Żak-Sawiak presents an analysis concerning arch structures that were modeled using curved finite elements. The main aspect here is the finite element modeling of flexible structural joints. The method proposed by the authors makes it possible to take into account not only the influence of shear and axial forces but also the influence of the rotational flexibility of joints. Calculations of the considered arch structures proved that there are certain positions of the elastic joints for which static or dynamic results are almost constant, regardless of the value of the rotational stiffness coefficient of a joint.

Paper [3] by J. Szafran, A. Matusiak, K. Rzeszut, and I. Jankowiak is a report from the experimental activities of the researchers from two independent universities: the Lodz University of Technology and Poznan University of Technology. Results taken during the tests are part of the scientific project called "Polyurea coatings as a possible structural reinforcement system", which explores possible applications of polyurea coatings for improving structural performance (including steel, concrete, wooden, and other structures used in the construction industry). The paper focuses on evaluating the performance of bent reinforced concrete (RC) beams covered with a polyurea coating system. The results cover the bending strength, performance, and cracking patterns of the coated RC beams. In addition, a theoretical model was developed to predict the impact of the polyurea coating on the bending strength of the RC beams. On this basis, the effect of the coating on the bending strength and the performance of the coated beams at the ultimate limit state (ULS) was examined and analyzed. The results showed that the use of the polyurea coating has a positive impact on the cracking state of the RC beams subject to bending with a little effect on their bending strength.

Paper [4] co-authored by A. Padewska-Jurczak, P. Szczepaniak, and R. Walentyński deals with an extremely important aspect of civil engineering, i.e. estimation of the wind load on two lightweight cylinders angled to the direction of the wind. The purpose of the analyses was to determine aerodynamic force coefficients for the airflow around two smooth or rough cylinders positioned at different angles with respect to the direction of wind velocity. Such systems, for instance, may become a part of a tubular water slide. The determined aerodynamic forces of the cylinder systems were compared using two independent research methods: experimental tests carried out in a wind tunnel and computational fluid dynamics simulations. As one of the conclusions, the authors declared that the flow around a pair of smooth cylinders is quite different from that for the rough ones, because during the experiment the first one falls into the critical flow regime, while the second one has supercritical characteristics.

Paper [5] by J. Bęc, E. Błazik-Borowa, and J. Szer studies dynamic aspects of scaffolding structures. Without any doubt, we can consider these special structures as lightweight ones. Moreover, one of the characteristics of scaffolds is that they are used many times during their lifetime. A scaffolding structure of medium size is analyzed in this paper. The structure FEM model was loaded with a single harmonic excitation force with various frequencies ranging from 1 Hz to 12 Hz and applied at several selected points on the scaffolding façade. The biggest amplitudes of vibrations displacements occurred in the horizontal direction perpendicular to the façade when the sinusoidal force in the same direction was applied. However, these vibrations are limited to the same deck level as the point where the excitation force was applied. The most propagated vibrations are the ones produced with the horizontal force along the façade, and the component of displacements in the same direction is also visible at large areas of the scaffolding façade.

Probabilistic estimation of the impact of diverse soil conditions on tank deformation is the main subject of paper [6] prepared by J. Górski and K. Żyliński. The authors performed probabilistic calculations of a vertical-axis, floating-roof cylindrical shell of a tank with a capacity of 50 000 m^3 placed on stratified soil with heterogeneous material parameters. The impact of a random subsoil description was estimated using the point estimation method. The conducted tests show that the structure exhibits slight deformation due to subsoil stiffness degradation. However, the impact of the non-uniform tank settlements on the locking of the guides of a floating roof or failure of the tank equipment can only be fully assessed after a comprehensive analysis of the tank shell deformation.

Paper [7] by M. Solovei, P. Obara, and J. Tomasik presents tensegrity structures. The main goal of the paper is to prove that only tensegrity domes with mechanisms are sensitive to the change of the level of initial prestress. Two tensegrity domes (Geiger and Levy dome) were considered. In addition, a standard single-layer dome was taken into account for comparison. The analysis was carried out in two stages. The analysis demonstrates that for a dome with mechanisms, the adjustment of prestressing forces influences the static properties. It was found that the stiffness depends not only on the geometry and properties of the material but also on the initial pre-stress level and the external load. When there are no mechanisms, structures are insensitive to the initial prestress level. As the main conclusion, the authors underline that tensegrities offer many advantages and are a better alternative to domes without mechanisms that can only be used as avant-garde architectural designs.

ACKNOWLEDGEMENTS

We would like to express our gratitude to all the authors of the papers included in this Special Section devoted to lightweight structures in civil engineering. Additionally, we would like to thank all reviewers for their efforts and valuable feedback, which significantly improved the quality of the papers. Special thanks are due to the Editors Professor Marian Kaźmierkowski and Professor Bartłomiej Błachowski. Without your help and your friendly approach, it would not be possible to create this Special Section. Finally, we would like to thank Ms. Renata Podraza, Copy Editor, for her professional help and assistance.

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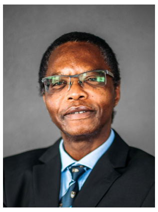
jacek.szafran
p.lodz.pl

Jacek Szafran DSc, PhD, Eng. is currently working at Lodz University of Technology, Faculty of Civil Engineering, Architecture and Environmental Engineering. He has a PhD degree in a range of technical sciences in civil engineering (defended with distinction). His PhD dissertation was entitled "Stochastic analysis and reliability of steel telecommunication towers structures". He received his habilitation degree for a series of monographs under the common title "Experimental and computer reliability analysis of the steel truss towers". He authored over 70 scientific publications in peer-reviewed international journals, proceedings of major international conferences, and book chapters. His research activities concern mechanics and design aspects of steel structures, reliability analysis of engineering structures, and research and development of telecommunication structures. He has also engineered and designed over 700 different telecommunication structures located in Poland.



alphose.zingoni
@uct.ac.za

Alphose Zingoni earned an MSc degree (with distinction) and a PhD degree from Imperial College London in 1992 and was a recipient of a prestigious postdoctoral Fellowship of the Royal Commission for the Exhibition of 1851 from 1992 to 1994. He held an appointment as Dean of the Faculty of Engineering at the University of Zimbabwe from 1996 to 1999, before moving to the University of Cape Town in 1999, where he served as Head of the Department of Civil Engineering from 2008 to 2012. His research spans shell structures, vibration analysis, studies of symmetry in structural mechanics, and group-theoretic formulations. He has written numerous scientific papers and four books in these areas and serves on the editorial boards of several international journals. He is the founder, chair and editor of the Structural Engineering, Mechanics and Computation (SEMC) series of international conferences, successfully held in Cape Town every 3 years since 2001. In recognition of his outstanding contributions, three learned societies have elected him a Fellow: the South African Academy of Engineering, the Institution of Structural Engineers (London), and the International Association of Bridge and Structural Engineering (Zürich). He received a B1 rating from the National Research Foundation in 2016, and in the same year, was elected a Fellow of the University of Cape Town in recognition of "original distinguished academic work". In 2019, he won the University of Cape Town Book Award for his book "Shell Structures in Civil and Mechanical Engineering", published in 2018 by the Institution of Civil Engineers (ICE), London.

repetto
@dicca.unige.it

Maria Pia Repetto is a full professor of structural engineering at the Department of Civil, Chemical and Environmental Engineering of the University of Genoa (Italy), where she coordinates the MSc Degree of Architectural Engineering, the PhD Curriculum on Structural and Geotechnical Engineering, Mechanics and Materials and she teaches Steel Construction and Wind Engineering courses. She is a member of the Giovanni Solari Wind Engineering and Structural Dynamics Research Group (GS-WinDyn), working in the multidisciplinary field of interactions between wind and structures (http://www.windyn.org). She is currently leading the ERC-THUNDERR project "Detection, simulation, modelling and loading of thunderstorm outflows to design wind-safer and cost-efficient structures" financed by the European Research Council (ERC). The project involves multidisciplinary research activities in the fields of construction technique and atmospheric physics, with experimental, numerical, and analytical approaches. Maria Pia Repetto is an author of 125 scientific publications mainly addressing wind engineering problems involving the analysis of wind-induced actions, response and fatigue of structures, risk assessment of infrastructures under wind actions, the wind fields modelling in the urban environment, the analysis of thunderstorm wind flow and structural response, and the full-scale monitoring of slender structures. The outstanding achievements and original contributions of her research have been awarded the Junior Award 2011 from the International Association for Wind Engineering (IAWE) and the Raymond C. Reese Research Prize 2014 from the American Society of Civil Engineers (ASCE-SEI).

Marcin.Kaminski
@p.lodz.pl

Prof. Marcin Kamiński is now Head of the Civil Engineering and Transportation discipline at the Lodz University of Technology. He authored two monographs published by Springer-Verlag (2005) and Wiley (2013) and also more than 300 papers in peer-reviewed international journals, proceedings of major international conferences or as book chapters. His research interests concern stochastic mechanics, reliability analysis, computer methods in mechanics including computer algebra, and various aspects of composite materials engineering. He worked under research grants from the Polish Committee of Scientific Research, the Ministry of Science and Higher Education, and the National Science Center in Poland. He is an associate editor of the Mechanics Research Communications journal, an editorial board member of Acta Mechanica, Journal of Composite Sciences, Composite Materials and Engineering, and Advances in Environmental Research and a member of international scientific associations such as IASS and GAMM. He held a postdoctoral position at Rice University (Houston, TX, USA) in the academic year 1999–2000 sponsored by the Foundation for Polish Science and was a visiting researcher and professor in Leibniz-Institut für Polymerforschung, Dresden, Germany (a year in the period 2009-2015) as well as a visiting professor at Politecnico di Milano, Italy (2013). In recognition of his research efforts, he was awarded the John Argyris Award in computational mechanics (ECCOMAS, 2001), the J.T. Oden Faculty Fellowship (UT Austin, TX, USA, 2004), and also the Award of the Polish Association for Computational Mechanics (2020). He co-authored the academic textbook Technical Mechanics (2009, 2013) and was a promoter of 6 doctors and more than 50 engineers at Lodz University of Technology.