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EDITORIAL

SPECIAL SECTION

# Sustainability, reliability, and durability of civil engineering structures

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Sustainability, reliability, and durability are consistently key concerns in the construction industry. For the sake of development, new materials and structural solutions are constantly being invented. Modern approaches to structural design involve optimization techniques, which allow for the efficient use of the construction material. On the other hand, unconventional materials or cross-sectional shapes are increasingly used nowadays, either for structural members or in joints. This issue demands a thorough analysis of the mechanical behaviour of novel solutions, identification of their parameters, and development of their mathematical representations. Laboratory, computational, and analytical work is conducted for this purpose, both in deterministic and stochastic approaches. However, in the end, what matters for an ordinary occupant of a given structure is the safety and comfort of use. Thus, certain methodologies are being developed to assess these issues and draw conclusions for future structures. These critical issues are covered in the selected topics of the Bulletin of the Polish Academy of Science Technical Sciences. The Bulletin previously offered special sections fully or partially thematically referring to civil engineering, such as "Civil Engineering – Ongoing Technical Research. Part I" Bull. Pol. Acad. Sci. Tech. Sci. vol. 64, no. 4, 2016, "Civil Engineering – Ongoing Technical Research. Part II" Bull. Pol. Acad. Sci. Tech. Sci. vol. 65, no. 6, 2017, "Recent advances in structural control and health monitoring", Bull. Pol. Acad. Sci. Tech. Sci. vol. 71, no. 3, 2023, see e.g. [1, 2] or "Lightweight structures in civil engineering – contemporary problems", Bull. Pol. Acad. Sci. Tech. Sci. vol. 71, no. 1, 2023. The significance of advancing knowledge in the field of civil engineering is apparent, with new findings published in key books [3–5] or papers concerning, e.g. diagnosis and reparation of buildings [6], damage detection in structures [7], civil infrastructure resilience and sustainability [8], or reliability ofcivil engineering structures [9].

Considering the Bulletin Readers' interest in civil engineering, the Special Section "Sustainability, reliability, and durability of civil engineering structures" is now presented, with papers that, by studying specific cases, fully embrace all aspects related to the topic, starting from geometry design, determination of load acting on a structure, characteristics of the material for construction purpose, characteristics of structural behaviour under a certain load, identification of structural parameters or model, safety assessment, and finally, comfort of use. Most of the papers included in this Special Section were orally presented during the 29th International Conference "Lightweight Structures in Civil Engineering", held in December 2023 at the Gdansk University of Technology. The Conference was part of the research activities of the Polish Chapter of the International Association for Shell and Spatial Structures. The papers are briefly outlined below.

The problem of structural optimization is discussed by S. Czarnecki and T. Lewiński in "Trusses of the smallest total potential energy". The Authors tackle the problem of topology optimization of trusses subjected simultaneously to static load and to displacements of selected supporting points. The starting point is a formulation of the total potential energy of such systems. The problem of energy minimization is analytically transformed into two mutually dual problems, expressed either in terms of stress or displacements. This is achieved by eliminating all the design variables. The Authors present detailed mathematical reasoning and illustrate the problem by case studies of 2D and 3D trusses subjected to static and/or kinematic load. The Authors focus on the problem of non-uniqueness of the solution, which appears especially when both kinds of loading are simultaneously present, as well as on the problem of the global minimum determining.

Determination of load acting on a structure may be challenging, specifically for structures with curved geometries. Wind load acting on a torus-shaped structure is considered by

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A. Padewska-Jurczak, Z. Buliński, and T. Krysiński in the paper "Determination of wind force acting on an object in the shape of a bent pipe". The Authors focus on the determination of aerodynamic forces that impact a fragment of a torus-shaped structure under high wind velocity. A numerical approach to identify the forces is adopted, coupling the finite volume method with the finite element method to simultaneously solve structural and fluid flow problems. The Authors compared the obtained values of the aerodynamic forces with the results of analytical calculations, which were previously presented. The Authors finally propose explicit formulas for the aerodynamic forces related to wind pressure and geometry of the considered structure.

K. Winkelmann and others describe an approach to identify possible imperfection levels in adhesive-bonded joints "Random field-based simulational identification of potential levels of material imperfections of adhesive-bonded joints". The Authors conducted laboratory uni-axial tensile tests of dogbone adhesive specimens to determine the basic mechanical properties of the material. By observing the scatters of the results and also the non-homogeneity of the material on a micro-scale, the Authors propose a stochastic finite element model of the adhesive, with a random distribution of pores, and validate the model to the uni-axial test results. The evaluated model of the adhesive is subsequently applied in a numerical model of an adhesive-bonded single-lap joint specimen. The model is analyzed for the reliability assessment of such a joint.

Mechanical characterization of structures is another topic considered in the Special Section. R. Walentyński, R. Cybulski, and H. Myrcik studied mechanical properties and proposed a numerical model of a double-corrugated steel sheet used for arched buildings or roofs construction in "Introduction to the investigation of reproduction of the real geometry of UBM panels". Such sheets can be manufactured on a building site by a dedicated machine. The lack of a design method for such structures motivated experimental and numerical analysis of double-corrugated steel sheet samples. The exact geometry of each sample was determined by a 3D scanner. Then the samples were subjected to uni-axial compression tests. The tests were numerically repeated for the collected geometries. As far as the panel behaviour under compression is concerned, the Authors note a strong correlation between the experimental and numerical results.

A. Alabedi, P. Hegyi, and M. Krajewski present approaches to identify reliable, but simplified models of some structures, by representing selected structural members or joints by springs. The first team studies encased cold-formed steel structural elements and develops a numerical model, in which encasing material (ultralight concrete) is represented by unidirectional springs in "Assessing the equivalent spring modelling method of CFS elements encased in ultra-lightweight concrete". Such a model shortens the time of calculations, compared to a 3D finite element model containing steel and concrete fractions. Simultaneously, the developed simplified model maintains the accuracy of results concerning the ultimate load of the considered elements, which was assessed based on experimental results. The paper "The influence of brace to chord rotational connection stiffness on the stability of the truss" analyzes a classical steel construction detail, i.e. plane truss working in a 3D structure, in which upper chords of trusses are interlinked by purlins. The Author examines a numerical model of a single truss, and the effect of bracings perpendicular to the truss plane is modelled by translational and rotational springs. The stiffness of the springs is determined through unique mechanical tests on real-scale steel specimens mimicking the upper chord of a truss and a purlin, with a joint constructed as it would be in real construction. Using a bi-axial strength machine, the models were loaded to cause torsion and bending that occur in real construction due to upward wind load. The identified numerical model has practical merit, specifically in out-of-plane buckling analysis of the considered trusses.

In this Special Section, the topic of structural safety is investigated by M. Drozdowska, M. Szafrański, A. Szafrańska, and A. Tomaszewska in the paper "Efficacy of modal curvature damage detection in various pre-damage data assumptions and modal identification techniques", which studies the efficacy of modal curvature method of damage detection in structures when the necessary data (baseline and current mode shapes) are obtained using different methods. The Authors consider three modal identification techniques to determine actual data and four possibilities of baseline mode shape determination. All possible combinations of the methods are analyzed in two examples: laboratory beam with known local damage and real structure – historic masonry tower. The Authors summarize the paper with a practical conclusion concerning the most suitable methods of data possession for the considered damage detection techniques.

Finally, the comfort of the use of building structures is considered by M. Cal and F. Yilmaz. The Authors study specifically the thermal comfort of employees of multi-storey business buildings in "Evaluation of the factors determining thermal comfort and occupational health conditions of employees in multi-storey business buildings in the light of expert experiences". They propose a methodology of the comfort assessment based on a specific survey and assess it in two different geographical regions (Kuwait and Turkey). In the two examples, the Authors underline the importance of including the specific regional needs of occupants of the building.

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**Bettina Brune**, Prof. Dr.-Ing. habil. Since 2024, she has held the Chair of Steel Construction at the Faculty of Architecture and Civil Engineering, Dortmund University of Technology, Germany. Previously, she was an extraordinary professor at this chair since 2017. She is a member of the German DIN standard committee NA 005-08-16, the mirror committee for steel constructions in civil engineering, and a member of the DIN standard committee NA 005-08-37 for steel racking and shelving systems. She is also the convenor of the Technical Working Group TWG7.5 of the European Convention of Structural Steel ECCS, Technical Committee TC 7 "Cold-formed thin-walled sheet steel in building", a member of ECCS TC8 "Structural stability" and TWG 8.3 "Plate structures". She is the project team leader/reference group leader of CEN TC250 SC3.T3/RefGr 3 as part of the EU-Mandate M515/Phase 2 and thus responsible for the revision of EN 1993-1-3 "Design of steel structures – cold-formed members and sheeting". She is a member of CEN TC250 SC3.WG3 and WG5 on behalf of the German national standardization organization. Her scientific interests include thin-walled steel sections and members, instability modes and instability failure of steel structures, plated structures, cold-formed structures, racking and shelving systems as well as joining techniques, high-strength steel, and structural and bridge design. She conducts analytical, numerical, and experimental studies, which often lead to improved design guidelines in accordance with Eurocode 3. Her current research focuses on sustainability, retrofitting of existing steel structures, and re-use of steel components. She has been involved in more than 30 national and international research projects and is the author and co-author of about 80 scientific reports published in journals, monograph chapters, or at conferences. In addition to her scientific work, she is also a practising engineer and prepares expert reports for special engineering projects as a partner of a steel research engineering company in Dortmund.

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