# On the Applications of Michell's Theory in Design of Buildings, Bridges and other Engineering Structures

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## Abstract

The theory of Michell's structures reveals how to optimally transmit the given external load to a given support or how to optimally transmit the given system of self-equilibrated loads. In Michell's structures bending is totally eliminated, while single members are fully stressed by tensile and compressive forces. As a result, the structure is perfectly suited to applied loading and has minimal possible weight. Since this remarkable idea has been proposed by A.G.M. Michell in 1904 [1] many specific analytical and numerical solutions corresponding to various loads and boundary conditions have been derived [2]. These solutions did not remain only the theoretical concepts but stimulated development of various numerical methods of topology optimization widely applied in engineering practice. On the other hand, they have directly inspired civil and mechanical engineers and influenced the design of high-rise building, large-scale roofs, long-span bridges as well as crashworthy structures for automotive and railway industry.

The objective of this contribution is to present and critically analyze potential practical applications of Michell's theory in civil and mechanical engineering. The first part of the talk will describe concepts of Michell-inspired "wingy" and "bulbous" skyscrapers proposed by Polish architects as well as selected optimally shaped high-rise buildings constructed by architectural office Skidmore, Owings and Merill. The analysis of two extraordinary large-scale coverings of public buildings which combine the elements of tensegrity and theory of Michell's structures will be used to present the optimal interplay of compressive and tensile forces in structural design. Moreover, similarities between theoretical layouts of Michell's structures created over multiple spans [3] and selected designs of cable-stayed, arch and deployable bridges will be illustrated. The second part of the speech will unveil the correspondence between Michell's theory and design of crashworthy structures for automotive and railway industry, which have to combine the requirements of large stiffness and energy dissipation. The examples will cover application of ground structure method for design of protective barriers, design of car body with internal reinforcement shaped in accordance with Michell's layouts and crashworthy design of cars for high speed trains. The talk will be accomplished by presentation of original prospective applications of Michell's structures proposed by the authors.

## References

[1] A.G.M. Michell, "The limits of economy of material in frame structures", *Philosophical Magazine*, vol. 8, no. 47, pp. 589–597.

[2] T. Lewiński, T. Sokół, C. Graczykowski, *Michell Structures*, Springer, 2019, ISBN 978-3-319-95179-9.

[3] A.V. Pichugin, A. Tyas, M. Gilbert, L. He, "Optimum structure for a uniform load over multiple spans", *Structural and Multidisciplinary Optimization*, vol. 52, pp. 1041–1050.