An interdisciplinary approach to tall buildings teaching in architectural education

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ABSTRACT: In recent years, the world has seen an increase in the number of tall buildings and their height. Tall building design is a complex process and requires an interdisciplinary approach. For this reason, courses are being offered in many universities to introduce future architects to the knowledge of tall building design. One such course is available in the Faculty of Architecture at the Warsaw University of Technology, Poland. The aim of this article is to present the teaching methods for the elective course *Tall Buildings Design*. The premise of the course is to teach students about the construction, structural and technological issues typical to designing tall buildings. The course includes lectures and seminar classes. The main method used in teaching is the case study. This method contributes to developing architectural knowledge and serves to improve the design workshop. It can also effectively activate students' interest and engagement which leads to deepening their knowledge.

INTRODUCTION

The beginning of the 21st century brought a rapid development of tall buildings and new height records. A landmark moment was the crossing of the 500 m mark with the construction of the Taipei 101 skyscraper in Taipei, in 2004 by the architectural firm C.Y Lee & Partners. Since then, a total of eleven tall buildings over 500 m have been erected around the world. Currently, the tallest building is the Burj Khalifa in Dubai, built in 2010 by the architectural form SOM. The tower is 828 m high.

Although the tallest buildings are the focal point of attention because of their height, the development of tall buildings pertains to different scales and heights. For this reason, the Council on Tall Buildings and Urban Habitat (CTBUH) has developed international standards for measuring and defining tall buildings [1]. Importantly, the lower height limit from which a building is defined as tall has not been specified, but criteria for classifying a building as tall have. These criteria include:

- height in relation to the development context, i.e. a building with, for example, 14 storeys will not be considered tall in cities such as New York or London, whereas it will be a definite dominant feature in developments with lower heights, as exemplified by some European cities or in the suburbs of large cities;
- the proportions of the building, there are many buildings that are not characterised by their considerable height, but are distinguished by their considerable slenderness, thus giving the impression of a tall building. The reverse situation may also exist, where buildings are quite tall, but their proportions - e.g. large plan dimensions in relation to height, preclude classification as tall buildings;
- technologies specific to tall buildings, e.g. vertical communication solutions, structural solutions for handling horizontal wind loads, etc [1].

The annual reports published by the CTBUH provide information on the current state of tall building development worldwide. In 2022, there were already 2,070 buildings with a minimum height of 200 m [2]. The intensity of tall buildings development is changing the skyline of many cities located in different regions of the world. The presence of tall buildings can have a place-making effect [3]. The development of tall buildings is becoming a significant urban planning challenge, but it also presents challenges in the design of the buildings themselves. The taller the building, the greater the engineering problems. This applies, for example, to the design of a structural system that carries vertical loads but, above all, counteracts lateral loads from the wind, or effectively counteracts loads in seismic regions.

The challenges posed by the development of tall buildings relate to several issues. At present, one of the most relevant issues revolve around the issue of sustainability [4]. The importance of this problem is evidenced by figures published in a United Nations report, which predicts that 68% of the global population will live in urban areas by 2050 [5]. It is to

be presumed that megacities will develop, and the ideas of vertical cities will not just be a utopian vision, but will become a real design challenge as a result of high-density development.

For these reasons, the article addresses the issue of educating future architects in the design of tall buildings, and presents an analysis of the teaching methods and subject coverage. The design process for tall buildings is complex and requires an interdisciplinary approach. Hence, the teaching process for the design of tall buildings has to address issues from a variety of disciplines. In addition to the architectural aspects, the key design issues revolve around material and spatial solutions for the structure, façade, vertical communication, and more. As mentioned above, sustainability issues are also pertinent in the design of contemporary tall buildings.

METHODS OF TEACHING TALL BUILDINGS IN ARCHITECTURE FACULTIES

The intensive growth of urban development around the world also translates into educational offerings aimed at future architects and engineers. In selected architecture degree programmes, subjects are offered to introduce and familiarise students with the most important aspects of tall building design. This is most often the case with Master's degree programmes. Teaching is carried out through various didactic forms/formats, the most common being lectures, seminars and projects conducted in project studies.

Master's programmes offer subjects with specific learning objectives. The main aim may be to teach the design context associated with tall buildings or to teach the skills needed for tall buildings design. The subject of tall buildings in the design context enables students to gain knowledge of the latest technical, technological and structural solutions. A tall building can also be an interdisciplinary or multidisciplinary project theme [6]. In that case, it is led not only by architects, but also by representatives of other disciplines. The project work involves specialists in structural design, energy efficiency, façade design, installation, smart buildings, and others. The complexity of the problems in the design of tall buildings, creates opportunities to tackle a project that requires collaboration and coordination.

In the educational offer of Delft University of Technology, Netherlands, tall building teaching is provided through project-based subjects. One of these is the MSc 2 Studio *High-Rise Culture* [7] which is concerned with living in high-rise buildings. According to the programme's authors, the erection of tall buildings is nowadays unavoidable and their presence, therefore, needs to be carefully examined in terms of problems, challenges and opportunities. The studio is developing designs located in existing buildings, with the aim of developing open, mixed-use, high-rise buildings. The designs developed as part of the study are intended to be accessible, multifunctional and integrated into the urban fabric.

An interesting teaching proposal from Delft University of Technology in relation to tall buildings is the MEGA project [8], focusing on collaboration and the multidisciplinary redesign of a large structure or tall building. The project is prepared in teams of five to seven students. The scope of the study includes architectural design, climate issues, design calculations, façade design, structural design and building management. Particular attention is paid to the topics of circular use of materials (for example, reuse of materials, demolition planning, adaptation design, use of bio-based materials) and climate resilience (design that takes into account conditions resulting from a changing climate or climate disasters).

Recent years have spearheaded a more advanced offering of teaching the subjects related to tall buildings at the postgraduate level. The programme of these studies offers a comprehensive range of learning enriched by an internship in architectural and engineering offices. Postgraduate courses dedicated to tall buildings are offered by the College of Architecture at Illinois Institute of Technology, Chicago, USA and Iuav University of Venice, Italy.

The first multi-disciplinary post-graduate degree programme focused on skyscrapers and their role of urban density in future cities was created to meet the demand for advanced education in tall buildings. The Master of Tall Buildings and Vertical Urbanism (M.TBVU) course [9] is offered by the Institute's College of Architecture, in collaboration with the CTBUH, and the SOM architectural firm (previously known as Skidmore, Owings & Merrill LLP). The study lasts three semesters and focuses on design and research. Teaching is provided in the form of project studies, research methodology classes and seminars that address the cultural, historical, design and construction context of tall buildings. Research topics dealt with by students include massive timber construction, structural systems, vegetation integration, aerial bridges or new financial models, among others.

Another advanced tall buildings programme is offered by Iuav University of Venice. The programme's assumption is that students …*will acquire the mindset and skills needed to work in large architectural/engineering practices and deal with the various aspects of the design of complex buildings such as tall buildings* [10]. The study programme comprises four modules: Module 1 - Tall Building Basics, Module 2 - Tall Building Advanced, Module 3 - Tall Building Studio, Module 4 - Tall Building Practice. Teaching is provided in the form of lectures, seminars and design studies. Workshops are also planned as part of the tall building design.

TALL BUILDINGS IN THE TEACHING PROCESS IN THE FACULTY OF ARCHITECTURE AT THE WARSAW UNIVERSITY OF TECHNOLOGY, POLAND

The teaching of tall buildings in the Faculty of Architecture at the Warsaw University of Technology, Poland, has a long tradition and is linked to the teaching of technical subjects through Professor Stefan Bryła. Professor Bryła

was a lecturer and an outstanding structural engineer, one of the pioneers of welded structures. He designed the steel frame structure of the Prudential Tower in Warsaw, Poland. It was the tallest building in Warsaw and the second tallest in Europe before the Second World War [11].

The contemporary theme of tall buildings in architectural education was developed by Professor Adam Zbigniew Pawłowski. Professor Pawłowski introduced elements of teaching about tall buildings in the form of a seminar aimed at introducing architecture students to the basic interdisciplinary aspects of contemporary tall building design, the interdependence between the form, function and height of a tall building and its structural system [12].

The *Tall Buildings Design* seminar continues to be the primary form of education on aspects of the design, construction and use of tall buildings, aimed at students of the Faculty of Architecture at the Warsaw University of Technology. The course includes lectures and seminar classes covering technical, technological and structural solutions representative of contemporary tall buildings. The lectures are designed to provide an introduction to the issues involved in the design of tall buildings. The aim of these classes is to systematise, but also to deepen the knowledge necessary for the seminar part of the course. This is particularly relevant for building, construction and technology issues. The lectures prepare students for the seminar part of the course, which consists of the development, presentation and discussion of topics selected by the students, taking into account the issues listed in Table 1.

Table 1: Main topics and format of classes.

Main topics	Format of classes
Development of tall buildings: • Historical perspective; • Generations of tall buildings in the historical perspective; • Technological, structural and material breakthroughs.	Lecture
Architectural aspects of tall building design: • Architectural and structural search for a tall building form; • Building function and its impact on spatial solutions; • Vertical communication and its arrangement in the building plan.	Seminar
Engineering aspects of tall building design: • Structural systems; • Contemporary structural materials and their properties in tall building design; • Wind engineering; • Seismic aspects in the design of tall buildings.	Lecture Seminar
Façades and roofs: • Material solutions for tall building façades; • Curtain walls; • Double façades; • Natural ventilation and circulation in tall buildings; • Roof solutions.	Lecture Seminar
Sustainability in tall building design: • Energy efficiency; • Renewable energy sources; • Aspects of greenery in the design of tall buildings; • Green building certification.	Seminar

Seminar topics focus on the location and function of tall buildings, e.g. *Residential tall buildings in Europe, Tall office buildings in London, Tallest residential buildings in the world, The tallest buildings in the Far East, Tall buildings in New York*. Themes formulated in this way narrow the scope of the search for reference objects. However, this is beneficial as students focus on a specific group of buildings.

The primary method used in teaching tall buildings during the seminar is the case study. This method is commonly known as the research method. It can also be an effective teaching method at the university level. Richard Foqué, in his book *Building Knowledge in Architecture*, argues that the case study is the most appropriate research technique in architecture, especially in improving design craftsmanship, as well as in building knowledge in architecture [13]. This confirms the validity of the use of the case study method, which draws on experience gained in design and implementation practice.

When developing seminar topics, students make an initial survey of tall buildings that meet certain criteria, e.g. considering the function of the building, location, height. It is also a stage to become familiar with the context of tall building design. Students then select four buildings by intuition and proceed to analyse them in detail. According to Francis, using the case study method, three levels of analysis are possible [14]. The first level is the design summary. The second stage includes a full case study. The third stage is a more in-depth case study with contextual or specialised, industry-specific material. With regard to this breakdown, a summary for selected tall buildings is shown in Figure 1

and Table 2. The table contains information that refers to data such as: project name, location - city, architects, structural engineers, construction completed year, height of tall buildings, number of stories, gross floor area (GFA), function, architectural design form inspiration, building form, structural system, façade solution and type of certificate.

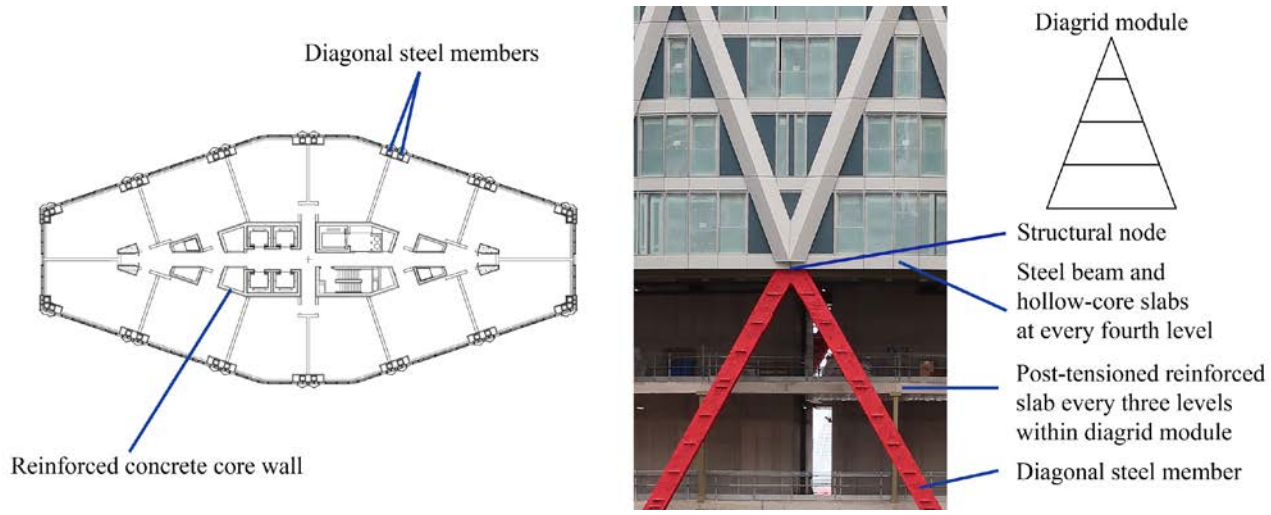
a) b) c) d)

Figure 1: a) Newfoundland Tower in London; b) South Quay Plaza in London; c) One Park Drive in London; and d) One Nine Elms in London (photographs by A. Jóźwik).

Table 2: Example table with information about the analysed tall buildings under the case study method.

Name of the building	Newfoundland Tower (Figure 1a)	South Quay Plaza (Figure 1b)	One Park Drive (Figure 1c)	One Nine Elms (Figure 1d)
City	London	London	London	London
Borough	Tower Hamlets	Tower Hamlets	Tower Hamlets	Wandsworth
Architects	Horden Cherry Lee Architects	Foster + Partners	Herzog & de Meuron	Kohn Pedersen Fox Associates
Structural engineer	WSP	WSP	AKT II	AKT II
Construction year	2020	2020	2021	2023
Height	219.7 m	214.5 m	204.9 m	199.4 m
Number of storeys	59	68	58	57
GFA	66,982 m²	129,525 m² multi-tower complex	54,656 m²	106,300 m² multi-tower complex
Function	Residential	Residential	Residential	Residential
Architectural design form inspiration	Diamond pattern	Massing strategies	Honeycomb structure	Massing strategies
Building form	Octagonal prism form	Setback form	Cylindrical form	Setback form
Structural material	Concrete-steel composite	Reinforced concrete	Reinforced concrete	Reinforced concrete
Structural system	Steel diagrid structure with a reinforced concrete core	Frame structure	Outrigger braced wall-frame structure	Outrigger braced frame structure
Façade solution	Curtain wall, insulated glazing units with a low-E coating, stainless-steel	Curtain wall, triple glazed units with a high-performance solar coating	Curtain wall, rear-ventilated curtain wall terracotta cladding and elements made of glass and aluminum	Curtain wall, glazed units with white painted metal cladding elements
Green building certification	BREEAM Excellent	-	CfSH Level 4, BREEAM Excellent	-

The next stage in the development of the seminar topic is a detailed analysis of selected design issues discussed in an interdisciplinary context. Among other issues, the design of tall building structure is addressed. In this respect, the classifications of structural systems previously presented in lectures and described in publications [12][15][16] are used. For teaching purposes, plan drawings with marked structural elements and drawings showing the spatial arrangement of the structural elements are particularly useful (Figure 2).



a) b)

Figure 2: a) Newfoundland Tower in London, floor plan (figure by I. Cała); b) Newfoundland Tower in London, diagrid structure (photograph and figure by A. Jóźwik).

The structure of tall buildings not only carries vertical loads, but must effectively counteract lateral forces arising from wind loads. Hence, wind engineering plays an important role in the design of tall buildings, both structurally and in designing the form of the building. In the case of skyscrapers, their form is not just the result of architectural inspiration, but the result of interdisciplinary modelling [17-19].

Similarly, when it comes to tall building façade design, the interplay between building form and structure is noticeable, as is the direct influence of wind engineering and aerodynamic studies. On the other hand, solutions that have a positive impact on shaping the quality of the indoor environment are increasingly being sought. There is also a growing design paradigm pertaining to the decarbonisation of construction processes.

The use of the case study method teaches independent analytical and synthetic thinking, it prompts the search for cause-effect relationships, proposing and recommending problem solutions. In the development stage of the seminar topic, the method refers to several buildings, thus allowing the similarities and differences between the tall buildings analysed to be identified. Consequently, the analyses carried out lead to conclusions. More broadly, the case study method teaches hypothesis-building and can form the basis of theory, which is an advantage of the applied method [20].

The case study method enables the development of many valuable practical skills and the active participation of students in the teaching process. According to C. Roland Christensen, the leading authority on the case study method, student engagement can take place at three distinct levels. At the first level …*students explore a problem by sorting out relevant facts, developing logical conclusions, and presenting them to fellow students and the instructor* [21].

At this stage, the attitude of the student as commentator-observer is adopted. At the second level, greater involvement is indicated, which can be seen in the argumentation of specific solutions. The third level requires in-depth knowledge and context, so that the topic presented is not an abstract idea, but enables the student to take a stand - what they would do, how they would solve the problem in a real-life situation. The level of student engagement is highlighted in the final stage of the course when the seminar topic is presented and discussed in class.

CONCLUSIONS

Due to the intensive development of tall buildings worldwide, teaching their design, as well as teaching the interdisciplinary design context is becoming an important issue. Skyscrapers are highly complex buildings, so the introduction of issues relating to tall buildings into the curricula of architecture faculties, on the one hand, is intended to improve design competence on the part of students and, on the other, to acquire the ability to work on complex projects.

The development of tall buildings in cities such as Warsaw, Poland, [11[]12][22] has encouraged student interest in the topic of tall buildings, both in terms of their design skills and the design context, including technical, technological and structural solutions. The availability of newly constructed tall buildings in Warsaw also makes it possible to organise visits to construction sites, where students can observe and confront theoretical knowledge with the realities of constructing tall buildings.

In teaching about tall buildings, an interdisciplinary approach is important, as there is an intersection of different disciplines in their design. For this reason, the case study method works well in teaching, as it offers the chance to consider the seminar topic in more depth. The case study method also allows students to engage in the cognitive process

at a deeper level by investigating the information themselves and looking for relationships that have an impact on the design of tall buildings.

REFERENCES

1. CTBUH Height Criteria for Measuring & Defining Tall Buildings (2024), 10 June 2024, https://www.ctbuh.org/resource/height
2. Year in Review: Tall trends of 2022. *CTBUH J.*, **1**, 44-51, (2023).
3. Al-Kodmany, K., *Understanding Tall Buildings: a Theory of Placemaking*. NY: Routledge (2017).
4. Oldfield, P., *The Sustainable Tall Building: a Design Primer*. Oxon/NY: Routledge (2023).
5. World Cities Report 2022: Envisaging the Future of Cities. Nairobi: United Nations Human Settlements Programme (UN-Habitat) (2022).
6. Van den Beemt, A., MacLeod, M., Van der Veen, J., Van de Ven, A., Van Baalen, S., Klaassen, R. and Boon, M., Interdisciplinary engineering education: a review of vision, teaching, and support. *J. of Engng. Educ*., 109, **1**, 508-555 (2020).
7. Delft University of Technology (2024), Studio High-Rise Culture, 10 June 2024, https://www.tudelft.nl/onderwijs/opleidingen/masters/aubs/msc-architecture-urbanism-and-building-sciences/master-tracks/architecture/programme/studios/architecture-and-dwelling.
8. Delft University of Technology (2024), MEGA project, 10 June 2024, https://www.tudelft.nl/onderwijs/opleidingen/masters/aubs/msc-architecture-urbanism-and-building-sciences/master-tracks/building-technology/programme.
9. Illinois Institute of Technology, College of Architecture (2024), 10 June 2024, https://arch.iit.edu/study/mtbvu
10. Tall building design (2022), 10 June 2024, https://www.tallbuildingdesign.eu/.
11. Kowalczyk, R., Skrzypczak, J. and Oleński, W., Politics, history, and height in Warsaw's skyline. *CTBUH J.*, **3**, 32-37 (2013).
12. Pawłowski, A.Z. and Cała, I., *Budynki Wysokie*. Warsaw: Oficyna Wydawnicza Politechniki Warszawskiej (2013) (in Polish).
13. Foqué, R., *Building Knowledge in Architecture*. Brussels: University Press Antwerp (2010).
14. Francis, M., A case study method for landscape architecture. *Landscape J*., 20, **1**, 15-29 (2001).
15. Ali, M.M. and Kyoung, S.M., Structural developments in tall buildings: current trends and future prospects. *Architectural Science Review*, 50, **3**, 205-223 (2007).
16. Ali, M.M. and Moon, K.S., Advances in structural systems for tall buildings: emerging developments for contemporary urban giants. *Buildings*, 8, **8**, 104 (2018).
17. Celadyn, W., Inspirations and their modelling in architecture. *World Trans. on Engng. and Technol. Educ*., 16, **3**, 263-268 (2018).
18. Ilgın, H.E., Review on supertall building forms. *Civil Engng. and Architecture*, 11, **3**, 1606-1615 (2023).
19. Szolomicki, J. and Golasz-Szolomicka, H., Technological advances and trends in modern high-rise buildings. *Buildings*, 9, **9**, 193 (2019).
20. Yin, R.K., *Case Study Research: Design and Methods*. Thousand Oaks: SAGE (2014).
21. Teaching with case studies. *Speaking of Teaching, Stanford University Newsletter on Teaching*, 5, **2**, 1-3 (1994).
22. Goncikowski, M., The skyscraper as a component of public space - the case of Warsaw. *Land*, 11, **4**, 491 (2022).