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Co-operation between study programmes within architecture and civil engineering

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ABSTRACT: Dealt with in this article are possible areas of co-operation in teaching between the Faculty of Architecture (FA) and the Faculty of Civil Engineering (FCE) at Slovak University of Technology in Bratislava (STU). Bratislava, Slovakia. The areas of co-operation concern students' seminar assignments. Within the Design Studio, subjects at Bachelor degree level, and Design Studio II at Master's level within the Faculty of Architecture, cover the architectural designs of buildings. Over the past few years, the designs of high-rise buildings studied within the Design Studio at the Faculty of Architecture have been used as the basis for Diploma works and PhD theses at the Faculty of Civil Engineering in the study programme, Structures of Buildings. The intention of teachers managing the design studio projects in both faculties of STU is to model and elaborate the design studio assignments. This enables the students from study programmes Architecture and Structures of Buildings (and possibly other programmes) to reciprocally communicate and enrich each other's work.

INTRODUCTION

Architectural designs of buildings produced in the Design Studio in the Faculty of Architecture at Slovak University of Technology in Bratislava (FA-STU), Bratislava, Slovakia, especially in the higher years of study, are intended for particular surroundings with definite disposition and structure. The designs, especially those made for high-rise buildings, represent unique solutions from the viewpoint of shape and structural system design. It is standard in architecture to produce a preliminary design of the structural system of a high-rise building without dimensioning the structural element's cross-sections. Architectural proposals for two high-rise buildings, which were situated in Bratislava, were supplied as groundwork for Diploma works and PhD theses for students at the Faculty of Civil Engineering (FCE) in STU for the programme Structures of Buildings and Applied Mechanics. The designs of the structural systems for the high-rise buildings were verified and recalculated by students of this programme at FCE as proper design for a given architectural volume and disposition. Using these two works, the authors verified the model of co-operation between the study programmes of the FA and the FCE.

ARCHITECTURAL PROPOSAL FOR A HIGH-RISE BUILDING

The main task for students in the Design Studio at the Faculty of Architecture was to design a high-rise building with the right proportions for the given urban context. High-rise buildings in Bratislava are up to 120 m high. A problem is searching for the right ratio between the height of a high-rise building and its perceived width. The slimness of the building is dependent on the size and the shape of the floor plan and the overall shape of the building. The ratio of the vertical communication core area to the free floor area for functional usage needs to be considered.

The proper structural design of a high-rise building enables the variable usage of the floor plan and a change of function along the height of the building. In both case studies, a combination of vertical communication core and perimeter tube structural system was chosen. The perimeter tube structural system is usually used for high-rise buildings with height above 250 m [1]. The authors selected such a structural system, because of its free dispositional plan not limited by emplacement of columns within the structure. The first case study used slantwise passing columns to create the diagrid tube structure. The second case study used a double tube structure. The inner tube was formed by perpendicular columns at the perimeter of the floor slabs and the outer tube was formed by a rectangular grid of floor slabs, which created the outer exoskeleton connected with slabs in intersection nodes.

CASE STUDY 1: HIGH-RISE BUILDING WITH DIAGRID TUBE STRUCTURE

As part of the teaching in the Structural Module Design Studio in the Faculty of Architecture, high-rise buildings were designed for the locality, Račianska - Kukučínova Street in Bratislava. This locality is close to two existing high-rise buildings - the *Manhattan* apartment house (built 2008) and the military academy hostel (built 1977). These existing high-rise buildings determined that new constructions be in the east corner of the urban area. High-rise buildings in the locality bordered by Račianska - Kukučínova streets was in accordance with urban plans created in students' diploma theses for this locality in previous years. Within the urban study two similar high-rise buildings with different heights were to be situated in this area. The higher (height 165.4 m and 44 floors) of them was designed by students in the Structural Module Design Studio at FA-STU.

Architectural Design

The main task was to design a very slim high-rise building with an efficient ratio between the utility of area in the storeys to the area for vertical communications and technological facilities, which would be in a narrow corner of the lot. The building would be bordered by two streets carrying traffic. Another requirement for the design was to develop a universal floor plan of the high-rise building, where the functional usage of a storey could be changed to apartments, hotel rooms or open office spaces. The structural system with reinforced concrete core and perimeter load bearing tube system is appropriate for this type of high-rise building.

In the architectural design, there was no supposition for using internal columns. The largest span between the core and perimeter tube system is 20 m. The floor plan of the high-rise building has a mutable shape along the height of the building. The shape passes from regular square shape to rhomboidal on the top floor, with two rectangular edges to intensify the impression of visual slimness. Two areas with non-planar surfaces arise on the spatial envelope of the building. The shaping of the support perimeter tube structure could be realised by means of diagrid raster, with slant orientation of load bearing beams. The tube structure with diagrid disposition of support elements appears to be more suitable from the viewpoint of bearing vertical load. The architectural design was elaborated by a model for a universal high-rise building with multipurpose use. The result of the Structural Module Design Studio was the design of the high-rise building, which was visualised in situ (Figure 1), with floor plans (Figures 2 and 3), vertical sections and elevations.

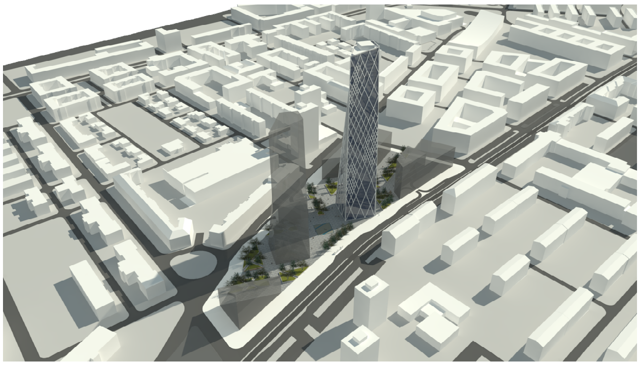


Figure 1: Visualisation.

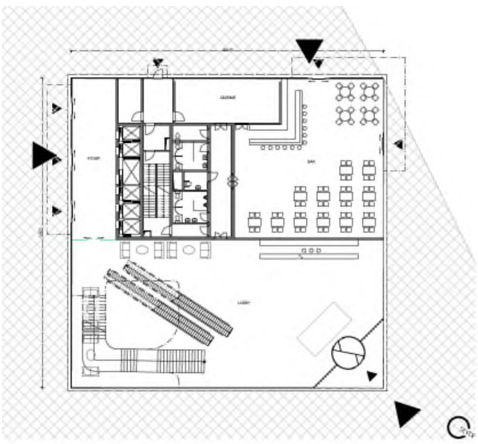


Figure 2: First floor plan.

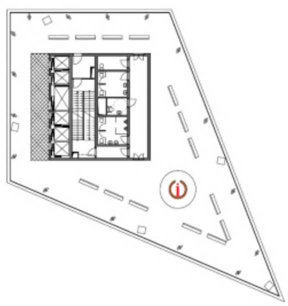


Figure 3: Top floor plan.

Static-dynamic Complex Analyses

In the PhD thesis, *Influence of Reinforcement on High-Rise Buildings*, in the Faculty of Civil Engineering in the study programme Structures of Buildings, one of the researched buildings was the above listed high-rise building [2]. The resultant static solution was achieved in step-by-step phases by the use of several models (Figure 4). The first model was formed of floor slabs and a central core. This model did not satisfy values of limit deformations of high-rise buildings. In a further phase, corner columns were added to the model, then the perimeter tube structure was added with an infrequent division of the diagrid. In following phases, the division of the diagrid structure has been gradually condensed. Only the last model met values of the limit deformations in the horizontal direction for a given load of the required value. The comparison of the tube structure with slantwise beams and the tube structure with vertical columns was the next step of the research (Figure 5). From results of static-dynamic analyses it was determined that the building with vertical orientation of the beams in a tube structure by use of the same cross-section of the beams as in a diagrid tube does not meet the requirements of the European community.

The research will continue with another variant of the static-dynamic analyses, e.g. excision of the corner columns and rounding of the edges of the high-rise building. The authors expect better results for the aerodynamic convection around the building. This building will also be the subject of research in the aerodynamic tunnel in the Road Structures Laboratory at STU.

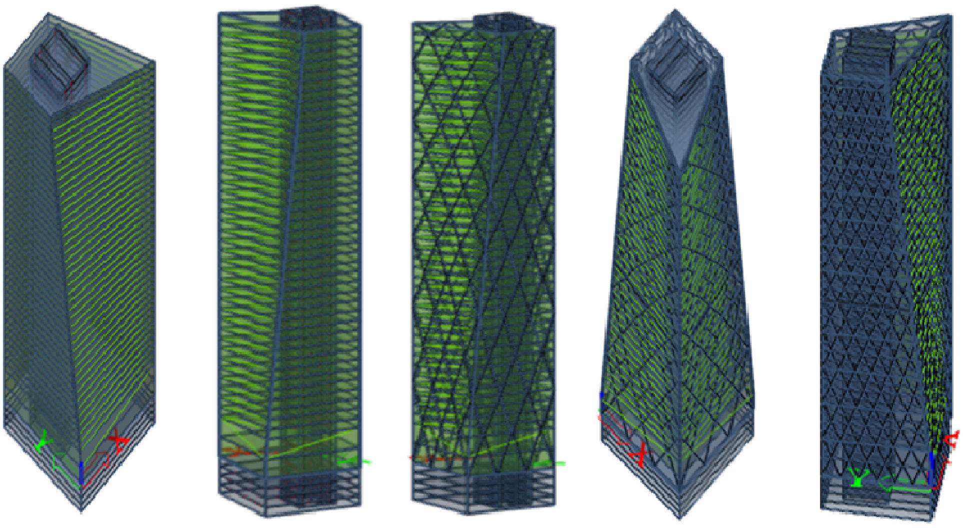


Figure 4: Static models.

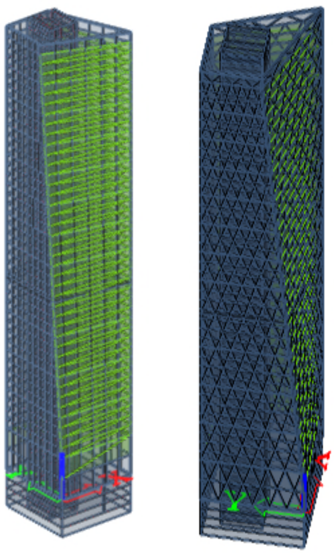


Figure 5: Comparison of static model with vertical columns and static model with slantwise beams.

CASE STUDY 2: HIGH-RISE BUILDING WITH VERTICAL ORIENTATION OF BEAMS IN TUBE STRUCTURE

The second high-rise building was designed within the Diploma Project Design Studio, with the topic of urban and architectural revitalisation of the area bordered by Trnavska and Bajkalska Streets in Bratislava. This locality became successively a part of the broader centre, and that is why the subsequent production and instore facilities added were incompatible in this territory [3].

Accessibility to and from the centre, interconnection with the city transport network and a wide spectrum of functions, especially the neighbouring position to national sports stadiums, create a great potential for the locality. The plan for the revitalisation of the territory was developed within the pre-diploma project in the study programme, Architecture at FA-STU. The diploma task was to design a high-rise hotel building in the exposed corner position of Bajkalska and Trnavska Streets.

Architectural Design

The architectural design of the hotel building with its scale, volume and functional solutions respond to the existing and projected constructions in this locality. These include an apartment complex *Tri veže*, a renovated ice hockey stadium and a new football stadium under construction. The hotel was designed to meet the criteria required for a 5-star hotel with conditions suitable for the accommodation of sportspeople. The hotel facilities, such as cafeteria, restaurant and congress halls are positioned on the first aboveground floors; these also serve the broader public (Figures 7 and Figure 8). The height of the hotel is 80 m and is subordinated to the heights of existing buildings in this locality. The number of aboveground floors is 20 and there are 3 underground floors. The main mass has a prism shape with a perimeter doubled tube exoskeleton structure (Figure 6). The raster (4.2 m) of the tube structure in the vertical direction is at the level of the third floor reduced by diagonal bearing elements to the module with doubled span (8.4 m) in the first aboveground floors [4].

Figure 6: Visualisation.

Figure 7: First floor plan.

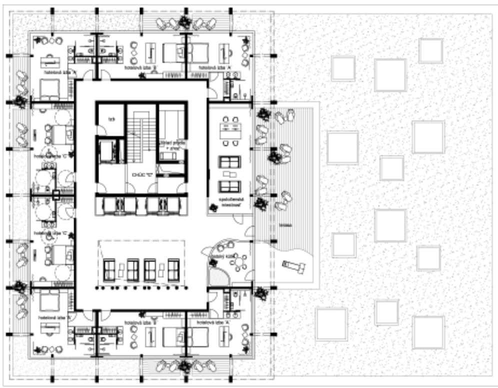
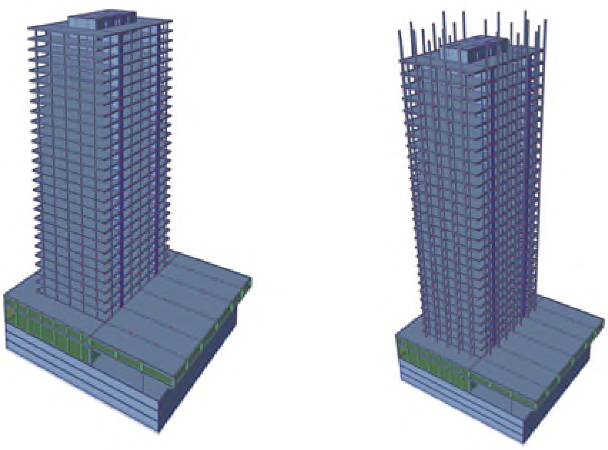


Figure 8: Top floor plan.

Static-dynamic Complex Analyses

In the study programme Building Structures at FCE-STU, the student elaborated the static-dynamic analyses of this high-rise building within the Diploma work, *Static and Dynamic Analysis of the Hotel's High-rise Building* [5]. Two alternatives for the building were elaborated.



a) b)

Figure 9: Models for static-dynamic complex analyses; a) the single tube system - left; and b) tube system with outer exoskeleton - right.

The first alternative is a high-rise building with single tube structure on the perimeter of the floor slabs (Figure 9a). The second alternative is a high-rise building with added exoskeleton to the building, which is set at the envelope of the building (Figure 9b). The result of the research will be the economic and technological analyses and comparison of both structural approaches.

RESULTS OF THE CO-OPERATION

Static modelling may evoke some changes to an architecturally designed building. In the first case, the tube structure was calculated with emplacement of vertical columns in intersectional edges of the planes creating perimeter area of the tube structure along the whole height of the high-rise building. In further modelling of the variants, these columns were removed and the perimeter area of the tube structure designed as a clear diagrid structure [6]. These static *invasions* have an influence on the whole architectural expression of the building's façade.

Feedback and communication showed that students had a heightened awareness of the effects of the static models on architectural designs; students of architecture were able to envisage problematic issues with their works. The use of static models can lead to modifications in architectural designs based on principles of statics.

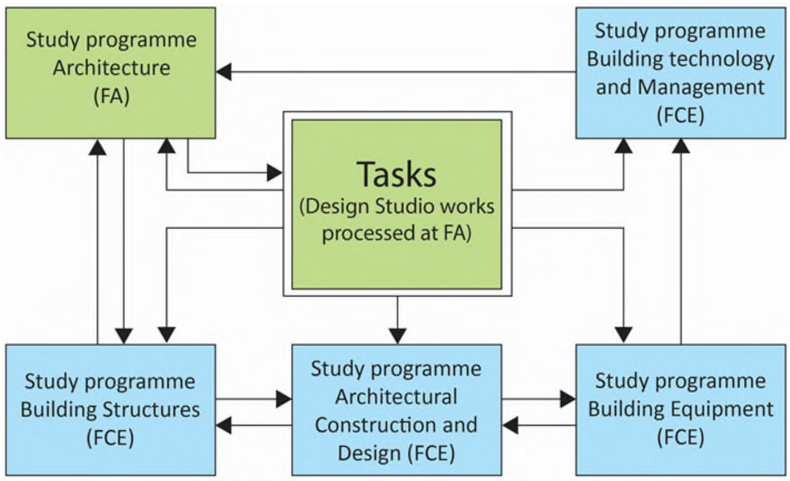


Figure 10: Co-operation between the Faculty of Architecture and the Faculty of Civil Engineering STU.

CONCLUSIONS

Architectural designs by students within the design studios at the Faculty of Architecture may serve as tasks for design studios in study programmes at the Faculty of Civil Engineering in Bratislava (e.g. Building Equipment, Building Technology and Management, Architectural Construction and Design). The co-operative model could lead to communication, as well as the transmission of knowledge and information among students in different study programmes. Communication and sharing of the information leads to a broadening of the cognitive horizons of students in different study programmes. Students should be trained during their study to pursue co-operative endeavours, which is required in civil engineering and architecture.

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