SUMMARY OF GRADUASION PROJECT

Project name:

"Structural design of the steel structure of multi-storey building in Sofia“

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Architecture:

The architecture of the building for this project to be made was borrowed from a multi-storey building, built in Taipei, Taiwan in 2004. It is designed for commercial, entertainment and administrative purposes. It consists of a high building with 37 over ground floors, reaching *160,6m* in height, and a lower part of the building with 7 over ground floors, reaching the elevation *+45,20m*.

There are 7 underground levels for commercial areas and parking lots. The upper part is served by 8 passenger and 2 service elevators to the 20th floor, where 4 of the elevators provided for passengers are interrupted. In the lower part of the building, intended for a commercial area, the vertical communications are carried out by means of 10 elevators, both for visitors and service. Escalators and several stairwells are provided.

At the top of the building at elevation of *+143,90m* is placed an outdoor pool measuring *7,50m x 20,00m.* The pool is placed in the center of an architectural structure with several storeys, giving an iconic look to the building.

The thesis has been developed for the territory of Sofia, Mladost district. The overall architectural appearance and the number of storeys above the elevation of *+0,20m* are preserved. The underground levels are reduced to 3, reaching an elevation of *-13,40m*, in order to simplify the foundation and strengthen the excavation.

Structural system:

Floor slabs in the building are composite. Composite slabs are constructed from reinforced concrete slab on top of profiled steel decking, which works as a remaining formwork and reduces the amount of lower reinforcement required in the field. Such combined slabs are a good solution from a constructive, technological and economic point of view, as they reduce the thickness of the concrete in the slab, its own weight, as well as the construction time. Special profiled steel decking is used, providing mechanical interaction with the concrete.

The floor slab is calculated as a composite slab. Two stages of work are considered. In the first stage - the concrete placing stage - the profiled steel decking is used as a remaining formwork and works independently, requiring to withstand the load of fresh concrete mix and construction loads. During the second stage of work (operational) a composite slab - steel decking and concrete work together - the concrete has reached the design strength. At this stage, all operational impacts are applied - dead and live loads.

A down stand beam is connected to a composite slab by the use of through-deck welded shear studs. They resist the longitudinal shear (sliding forces) and prevents longitudinal splitting. In vertical direction the shear studs should resist the separation forces, which are trying to separate the composite slab from the steel section

The vertical loads from the floor structures are transported to the base by powerful columns with a composite cross section. Due to the high axial forces and bending moments from horizontal impacts (wind and earthquake), the columns are designed with high-strength steel Histar S460JR. This type of steel is suitable for heavily loaded columns in buildings, located in seismic active areas, because it guarantees dissipative behavior.

The resistance of the horizontal load caused by wind and earthquake is provided by a dual MRF-EBF system, as in both directions moment resisting frames and eccentrically braced frame are provided. The energy is dissipated both from the plastic hinges, formed at the ends of the beams of the MRF, and from the plasticization in the link element, part of the EBF.

The system of moment resisting frames (MRF) consists of rigidly connected beams and columns, forming a space frame that acts as a support system. The eccentrically braced frames are capable of resisting most of the design forces. This type of dual structure system combines the advantages of the two main systems. The structure has a high static uncertainty, very good global ductility and takes advantage of the frame system to distribute the shear force, generated by wind and earthquake, at multiple support points.

The moment resisting frames resist the seismic forces by yielding in the ends of the beam and formation of plastic hinges, which is how seismic energy is dissipated and ductile behavior of the structure is provided. This is possible with the proper design of sections and connections.

The brace systems for resisting the horizontal loads are realized through Eccentrically braced frames (EBF). They consist of columns, beams and braces and also of an active link element.

The design seeks assuring the development of a collapse mechanism of global type by relying on yielding at the active link element to dissipate seismic energy. Depending on the design, the link element yields by shear, bending or both. This project is considering a solution with EBF with replaceable short shear links. According to studies, short shear links have better dissipative behavior than longer links, which dissipate energy by yielding in bending.

Replaceable seismic link elements are a very good solution in seismically active areas, because after seismic impact they can be replaced with new uncompromised elements. This type of connection is proven to be effective and cost efficient, because it prevents the complete reconstruction of the structural elements and leads to much lower costs for the restoration of buildings after seismic impact. Link elements are easy to replace as they can be connected by bolted end plates, which also reduces installation time.

The structure is designed to dissipate energy in the beams and link elements, which means that joints must be designed for increased load-bearing capacity, according to EN 1998-1. Joints are designed as non-dissipative and their elastic behavior is ensured.

There are different type of joint connections designed – bolted flange connection between link element and beam of the EBF, flange connection between column and beam, splice connections of the beams and braces, secondary beam to primary beam category A connection and others.

For the approximate examination of the behavior of the structure in the plastic stage it is designed in the basis of a nonlinear analysis or Pushover-analysis, which aims to predict the sequence of formation of plastic hinges and redistribution of forces between the MRF and EBF-systems.

3D Analysis of the structure:

Due to the complexity of the structural system, the unclarity regarding the distribution of forces, as well as the lack of regularity in plan and height, a 3D model has been prepared, which gives a clearer idea of the behavior of the structure.

The analysis model of the structure is made with the ETABS program. It consists entirely of frame - elements interconnected rigidly. Exceptionally the secondary beams, which are connected to the primary beams. The structure is fixed at Base3 level. The floor structures are modeled as rigid diaphragms on each floor level.

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Elements form two frames of the structure, parallel to different direction axes are designed. For the design of those elements are used only the results from the linear modal analysis.

Foundation:

The foundation construction of the building is a foundation slab with variable thickness and pouring concrete piles, placed under the multi-storey part of the building (the part of the building reaching an elevation of *+160,6 m*)

Piles are placed under each column of the multi-storey building and between the columns as well to observe the minimum required distances, ensuring the independent behavior of each pile. The total number of piles is 85 and they are united by a foundation slab with a thickness of *3m.* In the area of the low building the foundation slab changes its thickness to *1m.*

A solution of the building with 3 underground levels and basement walls is considered. The basement walls together with the foundation slab act as a rigid box-like structure and distribute the horizontal earthquake forces, which are completely balanced by the ground pressure at rest and the friction forces in the foundation slab. As a result the piles take only axial forces from the vertical loads and insignificant bending moments from the bending of the foundation slab.

Construction technology

In the current graduation project is considered a technology for installation of the structure and an exemplary technology for concrete work above elevation +0.00.

For the installation of structural elements are provided tower cranes. For the implementation of the structure up to elevation +45.20 m there are three tower cranes provided, one of which is located on the outside of the multi-storey building (*160,6 m*), and the other two are to serve the parts of the building, reaching elevation *+45,20 m*. After reaching this elevation, the two tower cranes are disassembled and only one tower crane remains, serving the growing structure up to *160,6 m*. It has a horizontal boom, high load capacity and increases itself in height. Supports are necessary among the service floors, due to the increasing high of the tower crane.

The concreting is realized with two stationary concrete pumps with distribution booms. Their delivery rate is selected on the basis of the required hourly inflow of concrete for monolithic execution of floor slabs. One concrete pump serves the multi-storey building and the other - the lower structure. The concrete reaches the required elevation by means of a special construction, reinforced at the levels of the completed composite floor structures.