



THE STRUCTURAL SYSTEM'S INFLUENCE ON THE ARCHITECTURAL FEATURES OF THE BUILDINGS

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Abstract. *The function of structural systems in buildings is to resist loads acting on structures and provide a skeleton in the building which encloses and subdivides space to provide a protected environment for the users. Therefore, the structural system gives strength and stability to the building. Besides these strengthening characteristics, observed from a structural point of view, the structural systems also influence the architectural features of buildings, such as the room's organization and size, the pattern of movement, the arrangement of furniture and other interior elements, the functionality, the total interior, and exterior design, the choice of structural and non-structural materials for walls, floors, ceilings, envelopes, doors, windows, façade, etc. In this study, the structural system influence on architectural features of buildings will be analyzed through a detailed examination of a case study – project of a hotel building, located near the border between Kosovo and Macedonia.*

Keywords: *structural system, architectural features, case study, hotel building.*

1. STRUCTURAL SYSTEMS IN BUILDINGS

The structural system can be defined as a group of inter-related or inter-dependent elements which form a complex connected structure, designed and built to resist different loads. The elements of the structural system can be illustrated as the bones of the human body. If the bones are weak, not aligned properly, and integrated into the human body, then the human body would not be able to work or perform well. Similarly, if the structural system elements are not properly integrated, then the structure would not be able to receive and transfer loads [1].

Nowadays, the input of new and modern structural systems into the construction industry has created a competitive environment. Choosing the most suitable structural system has become increasingly difficult. Some structural systems have priority over others due to their unique features, as well as the special requirements of various construction projects. In this process, many project features should be taken into consideration and detailed analysis should be done. Contemporary constructions, sustainable development, biophilic design, improvement in the quality of life, better comfort, and housing enhancement indices, require a transition from traditional construction methods to new technologies [2].

Furthermore, a building structure's ecological impact due to the embodied carbon in the chosen materials has become an increasingly prominent factor in the selection of building structural systems [6]. From an architectural point of view, the elements of the structure play an important role, not just in the load-bearing capacity of the building, giving it the needed strength and stability, but also in the internal organization, patterns of movement, the shape of the building, the type of façade, the materials, the function, the aesthetics, etc.

Some of the structural systems that are commonly used in high-rise buildings are wood frame as a lightweight structural system, reinforced concrete frame or massive structural system, and steel frame structural systems. In addition, there are some newly engineered products that are slowly finding their way in the construction sector, due to their positive characteristics. There are proposed procedures and guidelines for the selection of optimum structural systems and materials in two stages. Stage one is based on a list of criteria, including architectural considerations. Stage two evaluates selected systems and materials for optimum performance of criteria considered critical for a given project. However, the selection of structural system and material is often done according to personal experience or perception without being evaluated as it should be for optimum performance [1].

1.1 The Importance of the Structural Systems in Architecture

Vitruvius believed that an architect should focus on three central themes when preparing a design for a building: firmitas (strength), utilitas (functionality), and venustas (beauty) [5]. All three of them are as equally important and inter-correlated.

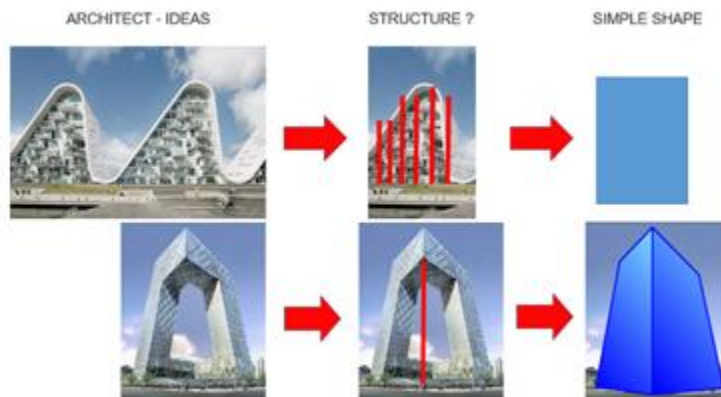


Figure 1. The importance of the structural system in determining the shape and aesthetics of a building

The functionality is usually the most important and primary theme and it is based upon the needs of the users, the organization of spaces, and patterns of movement, while the shape of the building should be in accordance with it. On the other hand, the strength of the building is obtained by its structural system and should be aligned with the shape. In the end, all these aspects are giving the building aesthetics, whether it is exterior or interior. The architect must have a good knowledge of the structural systems because having only an idea for the shape is not enough (Figure 1).

2. CASE STUDY OF A HOTEL BUILDING IN MACEDONIA

The impact of the structural systems on certain architectural features in buildings will be examined through a case study – project of a hotel in Macedonia (Main Project for B5 - Hotel Complexes: Hotel and Business Hall - Casino, with the technical number 11/21-1, from April 2021, main designer Marija Miloshevska Janakieska, Graduated Engineer Architect). The location of the building is in the Municipality of Chucher Sandevo, near the Kosovo-Macedonia border – border crossing Blace (Figure 2).



Figure 2. Location of the Building

Vehicles can enter the site from the access street on the south side of the location, and the movement is through an inner street, which starts with an 8% slope, in order to overcome the height of the terrain, which is quite steep. The design of the inner streets enables vehicles and buses to move through them smoothly and comfortably. The parking lot is within the location and all parking spaces can be reached via an inner street.

The building consists of four levels: underground, ground, first, and second floor. From a functional point of view, all technical and staff rooms, such as storage (including food storage, waste room, cold storage, deep and beverage storage), laundry and ironing facilities, administration rooms (info desk, offices with meeting room, wardrobes, showers and toilets for employees, kitchen and room for employees), hydro room, documentation room, machine room, server room, mechanical and electrical room, are located on the underground level. The ground floor is the biggest floor plan, and this is where all important areas, such as reception, wardrobe for guests, lobby, registration area, gaming area - casino, kitchen, restaurant, hotel facilities (bar, office, doctor's office, toilets, etc.) are placed. In addition, five hotel rooms are positioned on this floor (Figure 3). The first and second floors are reserved only for hotel areas, with five rooms on each of them.

The organization of the premises and the functionality is made in accordance with the architectural, urban, and climate conditions of the location, following the Urban Plan, the existing regulations and norms for this kind of buildings, as well as in agreement with the wishes, directions, proposals, and requirements of the investor.



Figure 3. Ground Floor Plan (Main Project B5 - Hotel Complexes, with technical number 11/21-1, responsible designer Marija Miloshevska Janakieska)

The structural system of the building is mixed and it consists of different types of structural elements and different materials. The canopy structure at the main entrance for guests consists of steel columns connected with steel trusses, positioned in two directions. The hotel premises (marked with blue color in Figures 4 and 5) have reinforced concrete frame structures, with reinforced concrete columns, beams, and slabs. The main hall, which is intended for the casino (gaming area), has a structural system with two different materials: reinforced-concrete columns and primary beams, connected with steel trusses, placed in the opposite direction of the beams. The spans between the columns in this part are approximately 12 meters (Figure 4 and 5).

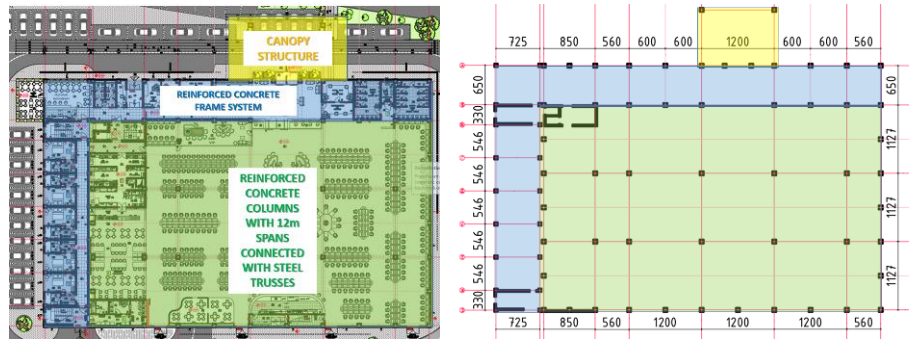


Figure 4. Structural system of the building and module spans represented in ground floor plan

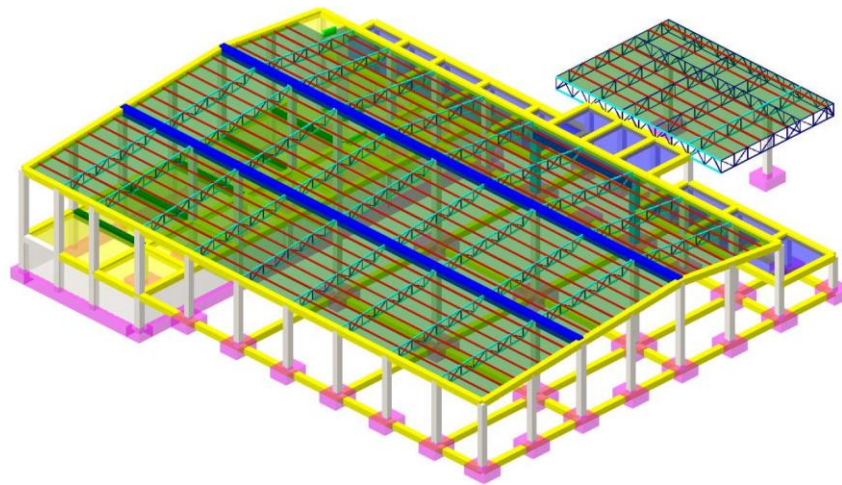


Figure 5. Structural system of the building represented in 3D

The foundations of the building are also mixed, differing only in typology. In choosing the type and material for the foundation, several factors, such as the type of the soil, the purpose of the building, the number of floors, the loads, and the availability of the materials, play a key role. Reinforced concrete is mostly chosen as a material for the foundations, due to its high load-bearing capacity and water and humidity resistance. As for the shape, the foundations can be designed as single foundations, linear foundations, foundational beams for strengthening the single foundations, and foundations slabs.

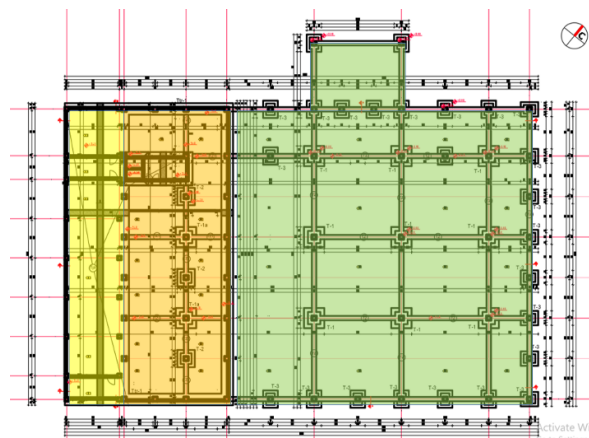




Figure 6. Different types of foundations represented on a Foundation Floor Plan

Due to the complex shape and the mixed structural system, in this building, there are several types of foundations on different parts. The highest part of the building, where the hotel rooms are located, has a slab foundation. The other part of the building, which is not so high, has single foundations, connected with foundational beams (Figure 6).

The building is under construction and the majority of the hotel portion has already been erected (Figure 7).



Figure 7. Photos of the construction site

A few months after the construction began, the investor requested a change in the structural system of the building, only in the casino - gaming area, so that the reinforced concrete columns will be replaced with steel columns, with bigger spans. The changes in the structure caused changes in all other phases and parts of the project and therefore a Project for changes during construction was prepared. This project included all changes in every phase: construction, architecture, electrical installations, mechanical engineering, water supply and sewerage, fire protection, and energy efficiency.

2.1. The Influence of the Changes of the Structural System on the Architectural Features of the Building

It is constantly debated which material to choose for the construction of a building. The debate intensifies, especially when it comes to steel or reinforced concrete. Each has its benefits. While concrete may make use of readily-available materials and aggregates, structural steel has an edge due to its high tensile strength, weld ability, and toughness [7]. Due to the lightness, high strength, and stiffness per weight, the steel allows bigger spans between the columns, compared to the reinforced concrete, which can be observed in the two projects (Figure 8). In addition, the dimensions of the steel columns are smaller. This resulted in a different organization of the floor plan, especially in the interior design and the internal layout of the slot machines in the casino area. The organization of the structural system has an important role in designing and positioning of the rooms and the furniture. The walls and other partitions are usually aligned with the structural elements, especially with the columns and the beams. In this case, a completely different arrangement of the furniture was designed, so it will adjust to the new position of the columns.

The number of steel columns and their dimensions are smaller compared to the concrete ones and therefore the net area of the casino is bigger with the steel structure. In the first project, with reinforced concrete columns, the net area

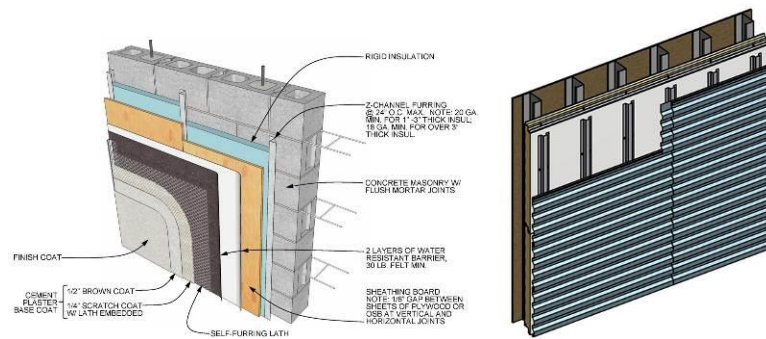


Figure 10. Comparison of different types of wall details: old structural system with masonry block walls on the left and new structural system with sandwich walls on the right

3. CONCLUSION

The structural system is a very important and irreplaceable part of the building and therefore should be designed with special care, taking into consideration all aspects, such as the strength, stability, functionality, organization, finances, needs, ideas, ecological impact, building shape, and materials. In this study, the influence of the structural systems on certain architectural features was examined through a case study – project of a hotel in Macedonia.

For this building, two separate projects with differences in the structure were prepared, which made it suitable for analysis. The results of this study showed that the type of structural system, together with the structural elements and materials have a very big impact on the architectural features of the building. The replacement of reinforced concrete columns with steel caused changes in the organization of the interior space, different arrangement of the furniture, changed patterns of movement, and increased in the net area of the inside space for 0.34%. The interior space became visually larger, with fewer visual interruptions and a clear perspective view, which improved the space quality and comfort.

In addition, the steel structures are very light compared to concrete ones and the steel members can be easily replaced, changed, assembled, or disassembled. The erection and installation are faster and easier and the formwork, which is crucial for the reinforced concrete, in this case, is unneeded. Due to the light weight, steel elements are very easy to transport.

The changes of the structural systems are changing the choice of materials for different architectural elements, especially in the facade and interior walls. This resulted in a light construction in combination with light walls which will enable a better response of the whole building to seismic forces under the action of an earthquake.

In cases where the structure is exposed, whether in the exterior or interior, its impact on the building shape will be noticeable. There are architectural examples where the impressionability of the external appearance arises from the structural system of the building.

Finally, the results of this study emphasize the importance of the structural system in buildings from an architectural point of view, and therefore engineers should pay attention in the process of selecting and designing the structure. Additionally, the knowledge of the engineers who are involved in the designing part must be expanded through demonstration projects, workshops, lectures, and collaboration among representatives of different sectors, in order to achieve a better understanding of the potential of the structure.



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