Structure vs. Ergonomics in Contemporary Hotel Design

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Abstract. The structural system is not only a carrier of architectural form, but also an important factor in the process of formulating the spatial-functional plan of facilities. Its impact goes far beyond the basic function of ensuring safety of the building. Proper coordination of architectural solutions and structural system allows zone optimization, influences layout arrangement and interiors span and therefore has a strong impact on ergonomics of room solution. Moreover, it allows combining (correct mutual positioning) of the various zones in the building, deployment of special and additional functions (e.g. swimming pools, conference centers, parking lots, etc.). Such interaction is also crucial for matching the hotel facilities to the surrounding environment. Presented article is a summary of research on architecture to structure relation, in pursuit of optimal solutions for maximizing safety and comfort of use in contemporary hotels. The needs of people with impaired physical of psychical conditions were also taken into account.

Keywords: Contemporary hotel design · Structural system · Interdisciplinary co-creation

1 Introduction

In the fully integrated design process architecture and structure are elaborated simultaneously in a close cooperation of branches. Such approach is dictated by direct relation between form and its' support. If these two are properly solved, than whole investment can be optimized as far as: costs, ecology, user and fire safety are taken into account. When incorrectly placed: structure span, load barring and support elements, can ruin functionality and elasticity of large scale spaces (like: swimming pools, SPA areas, conference halls, ball rooms, sport facilities), room dimensions or may become hazard for people suffering from different kinds of chronical or temporary psychophysical disabilities. On the other hand optimal solutions allow strengthening architectural expression, harmonious fitting of building into surrounding and most of all provide long-lasting security of whole investment. In light of these arguments this article was dedicated to present a short description of study process and conclusions on search for optimal and ergonomic relation between architecture and structure in contemporary European hotels.

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2 Aspect of Time in the Design

Consideration of architecture and structure mutual relation must be always carried out in four dimensions – three spatial dimensions and time. This is the problem of transience of architecture.

The buildings are aging in several aspects: technical, functional and aesthetic. According to [11] average period of “life of the building” is approx. one hundred years, of course, with deviations in either direction. After this period, each object – except perhaps for monumental buildings – exhausts its usefulness, in at least one of the aforementioned aspects. Then, the decision as to its further fate is necessary. There are only two possibilities: modernization or demolition. This dilemma arises in the categorical form at the end of the “life of the building”, but in fact the whole period is a process of formation spread out over years (preparation of investment, design and realization), because of constant need to adapt facility to changing conditions of use. However, these transformations may have minor intensity. “End of life” states the moment when possibilities of the continuing modernization exhausted and there must be decision taken on radical changes [10]. The more building is susceptible to continues upgrading, the more moment discussed can be postponed. In this context, it is essential that initially adopted solutions are as flexible as possible, allowing transformation of the building to the maximum extent.

In presented study firstly three dimensions were simplified and expressed in layouts and sections, which is fully sufficient for engineer considerations and interpretations. For aspect of time, structure duration was estimated and given in the discussion part of paper.

Research was carried out on a theoretical background (literature survey) and in a practical aspect (case study on site and in text sources). There have been around 30 examples analyzed, selected in to order obtain most diversified architecture-structure relations. Studies are based on European examples, taking into account, that each culture (European, Asian, American, African, etc.) has different customs in space arrangement [4] and uses diversified construction methods and materials. Due to need for limiting text content only conclusions from this part were discussed in “typology” paragraph. Further on synthesis was used to form concise typology and extract main cases form A-D for buildings’ layouts and 1–4 for its’ cross-sections. Having main aspects emerge a discussion was executed with use of: critical analysis, cooperative synthesis and synthesis. The same methods were used for conclusions section.

3 Functional Typology of Hotel Buildings

The functional layouts which are applied in the design of hotels appear in great diversity. However, their visual differentiation does not interfere with the finding of common features, allowing building a systematic classification. Based on highly diversified source typologies (created for hotels or buildings of public use) [1, 3, 6–9, 12–14] and taking into account the structural aspects of the building, the following systematics of layouts have been created (Fig. 1):

- central – containing also atrium arrangements – (with structure and service elements in the center of the layout) – case A
- alley – containing multi-alley, bay and angled or organic linear solutions – (with structure and service elements placed along corridors and lateral walls of rooms or external facade) – case B
- eccentric – notion used by [3] – (with unusual layout form, therefore with asymmetrically placed structure and service places) – case C
- hybrid – containing also nested arrangements – (connecting two or more aforementioned systems) – case D
- scattered – a group of independent small buildings (bungalows) (not considered in this study).

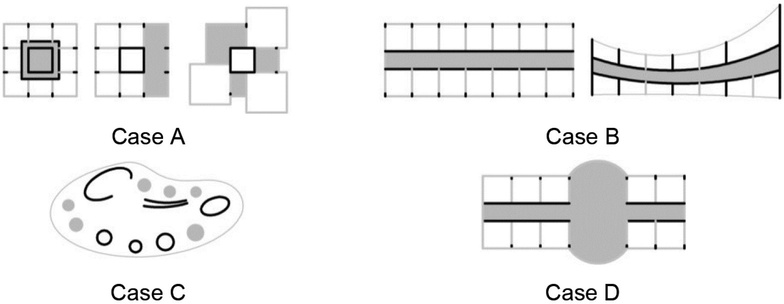


Fig. 1. Typology of layouts with consideration of hotel building's structure

The presented typology significantly generalizes and idealizes the actual schemes, however, thanks to this enables finding common features of objects. In particular, it allows defining concerns that are closely related with residential floor planning, which serves as a base for all most important investment considerations on economy or ergonomic aspects. Arrangement of the structural system is not the least important of them.

4 Review of Feasible Structural Systems

When analyzing the feasibility of various functional variants and different architectural forms of hotel facilities, one should systematize the means that are available to designers. The carrier of architectural content (functional and visual) is a structural system. Its primary function is to transfer all loads that act on the object on the ground and provide it with sufficient rigidity and reliability. However, these basic tasks can be achieved through the use of very different technical solutions. From their selection depends the implementation of architectural assumptions.

It is assumed that the most important criterion for the classification of structural systems is type of elements responsible for providing spatial rigidity of the building. On this basis, Khan and Moore [5] developed the following classification:

- shear systems: shear wall, shear frame, braced frame (longitudinal, crosswise, mixed)

- core systems: central core, split core, end core, atrium core (single, multiple)
- core-frame and core-outrigger systems: shear wall core, rigid/braced frame core
- partial tubular systems: end channel framed tube with interior shear trusses, end channel and middle framed tube
- tubular systems: framed tube, perforated shell tube, deep spandrel tube, single tube, tube-in-tube
- core-tubular systems.

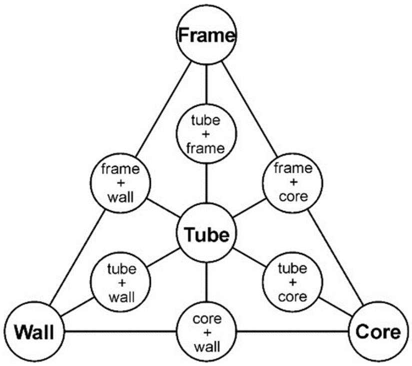


Fig. 2. Classification of structural systems in outline, based on Khan and Moore [5]

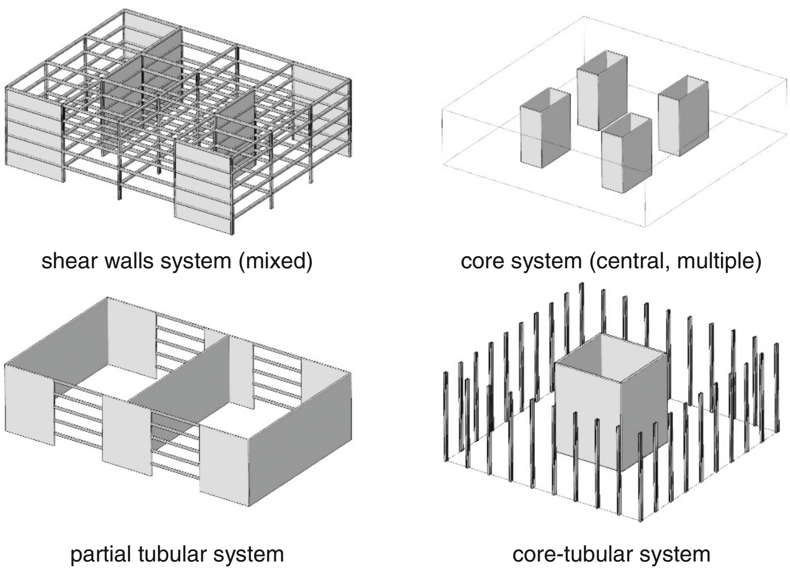


Fig. 3. Schematic diagrams of selected structural systems

This classification considers four main types of elements providing rigidity due to their geometry, while showing how they can be meaningfully combined. The outline of this classification is shown in Fig. 2. These general relationships are implemented in practice by a variety of technical solutions. For example, the core can be realized as set of RC walls or as a braced frame. Similarly, is with shear walls system. This makes the vocabulary at the disposal of designers very rich and allows the implementation of different objectives. This is illustrated by examples of selected structural systems in Fig. 3.

5 Challenges to Structural System Due to Functional Layout

An important aspect of the choice of structural system is its accommodation to different functional schemes. Hotels are objects in which this problem is particularly evident. The reason for its occurrence is the spatial interweaving of different functions, which requires from the structural system varied parameters for: a span, height, loadings, a dynamic impact, a size of openings, etc. These parameters in a specific way interfere with each other, and their simultaneous fulfillment is often a challenge. This can be illustrated by a simple example of the hotel, where in underground part parking is located, above – a block of conference and restaurant facilities, then the hotel rooms and – at the top – SPA with pool and block of restaurants again. Each of these functions requires a different design grid, spans and imposes different loads. If we combine this with supplementary office function connected with the hotel – what is very common – the situation becomes even more complicated. This is the first group of concerns closely related to hotels' structural systems, which serves as a base for all most important investment considerations on economy or ergonomic aspects.

As outlined in Sect. 3, selection of the structural system optimal to the functional layout used in the particular hotel, is one of the most important issues, which a designer faces. Systematization of variable decision parameters allows their mutual customization. Introduced classification allows creation of a direct link between structure and function at the level of idealized schemes. To each of the cases presented on Fig. 1 can be assigned an appropriate structural system. Exemplary relations are presented below:

- case A – tubular systems, core-tubular systems, core-frame systems
- case B – shear systems
- case C – multiple cores systems, partial tubular systems, tubular systems
- case D – shear systems.

The apparent obviousness of these relationships does not detract from their practical usefulness.

The second group of concerns related to applied structural systems is related to the above-mentioned interweaving of functions with very different requirements to the structural system. The four specific, most likely appearing basic cases can be specified (Fig. 4).

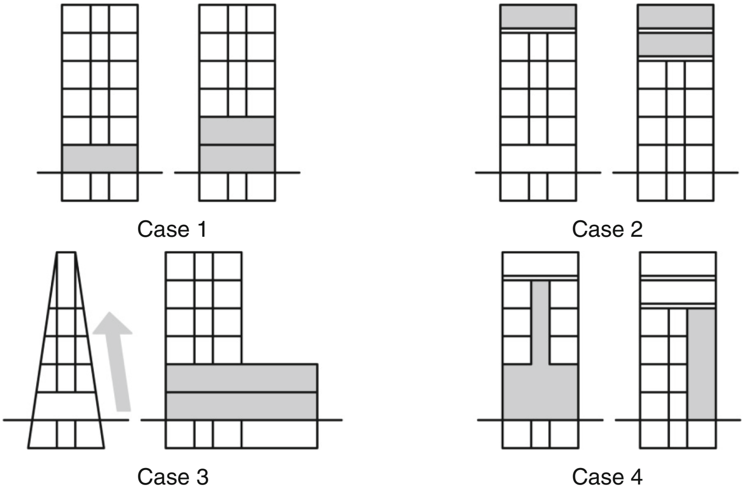


Fig. 4. Typology I. Hazards for support structure: case 1 – large scale rooms below rooms, case 2 – heavy load rooms on upper floors, case 3 – diversified layout on reach floor, case 4 – atrium.

Case 1 occurs when large scale rooms (span reaching up to 20 m and more) are located in the lower part of the building: on an underground floor, a ground floor or a first floor. This causes the separation of the upper storeys' structure from the foundations. This is a very common situation. In absolute majority of cases it is impossible and unreasonable to continue on the upper floors structure retaining the large span, divided functionally by non-structural walls. Thus, the structure of the upper storeys' (which require reduced spans) is somehow suspended over the lower portion and must be supported bypassing it.

As the case 2 is recalled a situation where heavy load rooms are located on the top of the building, i.e. public use spaces: swimming pools, SPA areas, Wellness and gyms (sport machines and equipment, water), as well as maintenance rooms: archives (paper) or storage (spare room furnishing, equipment).

Case 3 is connected to floor layout design, thus building with nonstandard, "fancy" forms, like: containing parts which are quite different in height (e.g. divided into plaza and tower), with varied layout on each floor, with narrowing or widening cross-section towards top, etc.

Case 4 includes buildings with atrium, which are quite popular in overall hotel design, especially in tall buildings. The latter pose additional challenges for the structure, however their structural systems are included in the above presented classification and will not be discussed separately here.

Additionally, one can distinguish case 5, which is not represented in Fig. 4. This is a situation in which in the building is located underground parking, which structural grid design is different (not necessarily of a greater span) than the structural grid of the storeys' located above. This very common situation may also occur in all four of the aforementioned cases, imposing additional limitations as to the range of solutions available.

All of the challenges described above that arise during design of hotels are a regular part of the project work. Integration of structural system with functional layout and architectural form is a prerequisite for the successful creation of the object. However, in the case of hotels, as well as other public utility buildings, there are additional challenges that could substantially affect the final solution. They concern the adaptation of the object to meet the needs of people with disabilities.

6 Meta-Level of Challenges to Structural System – Hazards for People with Disabilities

All public utility buildings should be tailored to persons with disabilities. These people require creation of a specific environment in which they can feel safe and function in spite of limitations. When creating such an environment it is essential to eliminate all obstacles, barriers and sources of interference that – irrelevant to people without disabilities – can be very tedious and even dangerous for people with limited fitness.

Incompatibility of structural system and functional-aesthetic solutions can be a major source of problems in the use of the building. The following hazard areas can be distinguished:

- limitations on the freedom of forming the functional layout
- limitations within communication zones
- adverse properties of elements of the structural system regarding serviceability limit state
- imposition of disturbances in the perception of space.

The first group of hazards can be easily identified. Limitations on shaping the functional layout may arise from the fact that the modular grid of structural system has a different size than the grid resulting from functional layout. Such incompatibility is often the result of the above-mentioned interweaving of the functional zones in the building. In certain arrangements of the structural system may appear also constraints associated with the emergence of large structural elements which separate zones on their both sides (e.g. shear walls). Also, in a situation when a zone is not physically divided into two separate parts, it is possible occurrence of individual structural components (e.g. columns) limiting functional development of the space or enforcing its division. Additionally, such structural components can be positioned improperly relative to the curtain walls, thereby restricting access to them. It happens that in the building occur structural components of floors which are of significant physical height, reducing the usable height of the interior and possibly limiting lighting the space with natural light.

The above-mentioned hazards are even more serious if appear within the communication zones. Incorrectly placed and designed: pillars or load bearing walls – inclined, blocking main communication routes, untypically or unexpectedly located, as well as narrowings between structural elements, lowered beams or lintels may create serious threats for people with impeded: sight, hearing, walking and psychological abilities. Among them should be mentioned a risk of: collision, impact, stumbling, confusion and complete blockage of a passage, should be mentioned [2]. What is even more improper, structure may cause insufficient space for maneuvering i.e. on a wheelchair or with use of canes, balconies or electric charts, disable access to furniture or equipment and at times limit necessary "kinesthetic space".

However the main task of the structural system is carrying the loads and providing rigidity of the building, its usefulness also depends on other features, commonly referred to as the "serviceability limit state". Insufficient load capacity components, which results in excessive deflection may restrict placement in certain areas of function that cause the occurrence of significant loads. This may in further consequence lead to excessive vibration of the structure. Both of these phenomena are very unfavorable from the point of view of people with disabilities, because they can hinder their movement and cause confusion.

Issue is related to another area of hazards concerning disturbances in the perception of space. This involves not only a decrease in comfort but also even harmful phenomena like material born sounds and vibration transition to the residential areas. Further on elaborated phenomena can cause disorientation through misleading echolocation. Of course, it should be emphasized that the insufficient rigidity of the structure is not the only possible source of undesirable vibrations in the building. Another important source of it may be installation and fittings: elevators, HVAC and similar which can induce and distribute waves. These causes can be quite effectively eliminated by proper insulation and localization of expansion joints. Vibration may also come from outside of the building, i.e. from infrastructural sources (roads, railways, metro, traffic) and propagate through the foundations in the entire object. By careful design of foundations, a lot of vibrations may be avoided. This case, however, is complex and calls for actions, which description is beyond the scope of this paper.

To give an example (Fig. 5a, c) of hotels in Greece and Spain show how distinctly pillars and support walls can limit both vertical and horizontal communication space. This makes it insufficient for people moving on wheelchairs and especially electrical chars and scooters. The later are wider (about 70 cm of width) than typical charts (width around 63 cm), thus require more space that usually recommended in norms. Also people using canes or just having troubles with walking, require additional side area. In other of studied hotels (in Spain) an inclined wall (Fig. 5b), covered by very reflective materials, was used, just by the main entrance. Designers deciding on such solution must be

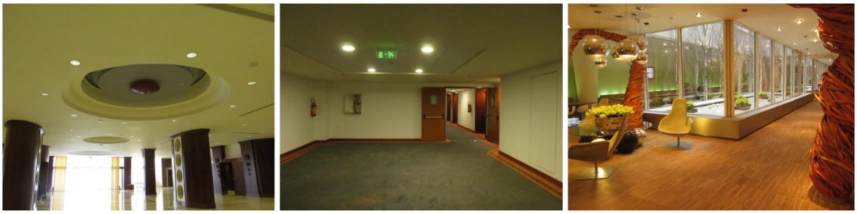
a) b) c)

Fig. 5. Examples of hazards arising from the structural system: (a) pillars and structural walls distinctly limit the vertical communication area (hotel in Greece), (b) inclined wall with reflective materials by main entrance (hotel in Spain), (c) pillars and structural walls distinctly limit the horizontal communication space (hotel in Spain).

aware that uneven angles change echolocation sensation. This method of space orientation is consciously used by people with impaired eye-sight but also is unknowingly used by many human beings to strengthen the information they gather from other senses during movement. Moreover highly reflective, shining and bright material used for building this compartment may be hazardous for all users by creating unexpected reflections, glares and effect of blinding lights during night time (passing car reflectors).

7 The Added Value Which Can Bring Properly Designed Structural System

Common is awareness that well-designed structure can significantly enhance the architectural form, which is the carrier. During case studies it was also confirmed that properly designed structure can optimize space for movement, orientation and visibility. Very good example of such solutions was pillars (Fig. 6a) in one of the hotels in Greece.



a) b) c)

Fig. 6. Examples of structure as a support for the ergonomic architecture: (a) chamfered and well-marked pillars (safety feature) allow orientation in a vast space of a hall (hotel in Greece), (b) even and parallel walls allow fluent movement along them (hotel in Greece) (c) extruded plinth supporting an atrium widow allows safe movement and visibility (hotel in Czech Republic).

In a vast hall space arranged with large, wide columns, chamfered at both sides. Not only their placement help to move and orient in space, but their dark colors at the background of lightly colored materials, clearly stated their presence. Moreover softly arched sides provided safety for people moving on wheelchairs or with impaired vision. In the same hotel (Fig. 6b) another observation was made. Long, parallel walls, additionally marked with elongated carpet boundary patterns, clearly determined walking directions and served as an extra movement support if needed. Similar function was fulfilled by boldly extruded plinth, which was a base for hotel in Czech Republic (Fig. 6c). Additionally this element protected people with sight disabilities form random walking into the glass.

8 Concluding Remarks

In the conducted study there were identified the main areas of the hazards that in the hotel facilities are associated with the applied structural solutions. Methods of solving these problems in turn can qualify for the two groups. The first of these is to obey the technical correctness of applied solutions, the use of appropriate materials and taking into account issues of serviceability. This eliminates problems described in Sect. 6.

Another approach is required to solve problems related to interweaved functional layouts and related changes in a structural system. Rational procedure for solving these problems is to find “common parts” and adapt to them requirements of specific solutions for individual functional zones. It is an approach in which we replace the local optimization by global optimization. The final resulted solution is not ideal in terms of the needs of each zone but allows “optimal” design of the building as a whole.

Despite of method selected it is crucial to integrate work of an architect and structural engineer in order to provide best possible solutions for people with disabilities. Presented number of cases and structure solutions allows designers to adjust particular situations to all diversified variants of functional plan. In this way, they are able to provide users not only with proper safety in a hotel, but even can increase comfort in movement of people with impaired hearing, vision, walking or psychical abilities. Thus, theoretical examples given can be used for practice, as well as carrying out future studies on ergonomic of mutual architecture and structure relations.

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