Model of Building Envelope Towards Energy Efficiency and Adaptability as the Architectural Approach

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Abstract: In this article we will look beyond the definition of "building envelope" as taken from the dictionary, we will try to consider this concept not only as a set of elements – bricks, glasses, compounds, materials, sized and executed after hundreds of calculations, not only as "Clothing" but as a critical review of the shaping factor. A model of building envelope can be used to analyse the basic parameters as energy efficiency and adaptability. How to design sustainable building envelopes and enhance the overall building energy performance through aesthetics and structural principles is a major aspect of the contemporary architectural design process. The building envelope could not be analysed only as a unique component but an integral element of while system with considerable importance regarding the building's appearance. It should provide additional functions such as loadbearing capacity, active or passive microclimate control and individual aesthetic expression.

1 INTRODUCTION

Observation needed for architectural form that expressed by building envelopes. If we put ourselves in the role of the tourist visiting a city for the first time, we will look at various historical landmarks and modern buildings, analysing them from the point of view of immediate perception, of observation. Architectural forms will alternate in front of us, and we can perceive them only as a result of their building envelopes, glancing at their surfaces. If we enter the building, if we participate in the activities inside, we will be able to realize how much the created spaces are convenient to use, and if we have basic structural knowledge, we will even be able to guess their materials. All these observations and reflections can lead us to different conclusions – the building is beautiful (ugly), the building is functional (it is uncomfortable), the building looks stable (I better get out of here quickly). Some of the conclusions are common and a consequence of indisputable evidence, while others are quite subjective and the result of a different aesthetic views (Ivanova, 2021).

If we analyse the architectural shape from the point of view of its building envelope, only the visible part of the building can be observed. Characteristics such as size, volume, geometry, proportions, openings, colours, reflections. The main categories are qualitative. If we look at a wall, for example, we cannot determine its capacity of load-bearing strength, nor is it really part of the main structure. We cannot define the properties of the real material, its general behaviour under loading. We also need to know, at least in general terms, how the loads are transferred to the foundations. Our building knowledge and the laws of mechanics can help us understand this. Therefore, we can assume whether this wall can be load-bearing or not, based on this type of analysis.

On the other hand, the same wall serves to close or partition the architectural space and thus it has a practical purpose, different from the role of a structural element. This function also affects some of the wall properties such as thickness, shape, and openings. Even if architectural elements have a load-bearing function, their shape must also be interpreted with a view to their spatial use as elements having both a structural and a spatial function. The final shape of the elements can also be influenced by the specifics of the technological implementation (Ivanova, 2021).

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Figure 1: Union Trust Building, arch Louis Sullivan, 1893.

2 FORM FOLLOWS ENERGY

The relation between energy and the shape of the building envelope implies decades and sometimes centuries of connected energy and material flows (Cody, 2017). It is based on an interdisciplinary review, explaining complex relationships and energy performing strategies, and it is advisory to be used as a powerful tool to maximize the energy results of our built environment, without forgetting the need for new aesthetic qualities and entirely new forms in architecture and urban design.

Regardless of the climatic zone in which it is located, the building envelope always needs to perform an insulating function to the environment (Deplazes, 2018). Thermal insulation, waterproofing, wind protection and sunshine protection. Instead of working towards more and more effective insulation against the natural conditions, why not try to use the environment to our advantage, using the energy parameters to improve the architectural qualities of the environment through its shape. For a skyscraper, for example, it is especially important to adjust the shape in order to reduce the large wind loads. How the architectural shape will affect the surrounding buildings and the people on the street is studied by using detailed three-dimensional models and computer simulations in wind tunnels even before its construction. This is how we will be able to model and optimise the final effect.

3 DUALISTIC ANALYSIS

A major trend in building envelopes is their increasing complexity. As the possibilities are constantly increasing and expanding, and the implementation of new technical solutions is becoming indicator of the most modern "smart" facades. Their main goal is to increase the comfort level of the users. But the question arises – are they practical? Thus, some new technologies are revised or even are abandoned. Today, based on our new knowledge about the problems of double facades, we can better assess their convenience.

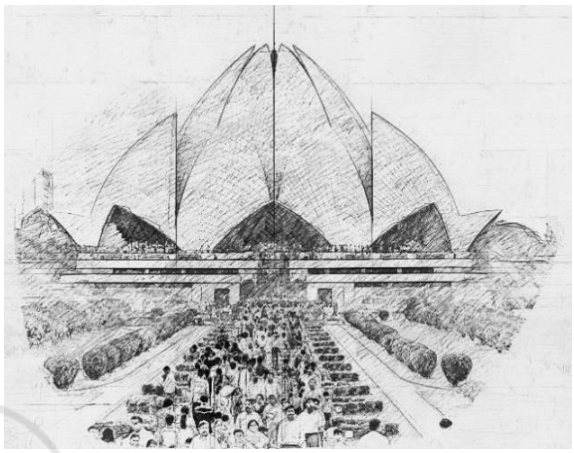

Figure 2: Lotus Temple, Bahá'í House of Worship.

Figure 3: Frei Otto's Munich Olympic Stadium.

Dualistic analysis implies the consideration of the building envelope in depth, dividing it into its possible components. On the basis of such analysis, the characteristics can be better evaluated, and it would be possible to make an informed decision about what type of building envelope to apply:

- Matter with self-retaining form under the action of external forces (self-defining). It performs both a carrying and enclosing functions;
- Matter that cannot retain its form under the action of external forces and needs other matter to "carry" it. Primary structural elements perform only the load-bearing functions, and other "non-structural"

secondary elements - the enclosing functions.

Examples of the two types – self-retaining and non-self-retaining envelopes.

3.1 Basic Principles for Creating a Model of Building Envelope

The objectives are based on four main ideas:

- Breaking with the idea of a building envelope as a technical-utilitarian artifact.
- Determining the leading role of structural characteristics, materials and construction methods as a basic formative principle, rather than creating a monumental expression of a constructive paradigm.
- Creating of architectonic mega-sculptures, not just enclosing facilities.
- Transformation of building envelope from a utilitarian element of the cityscape into an urban symbol.

A purposeful and adequate choice of a type of structural system can be made by hierarchical arrangement of the leading characteristics. The following steps can be defined as specific phases: (1) First Step; (2) Second Step; and (3) Third Step.

3.1.1 First Step

On the basis of an analysis of the characteristics and requirements of the building in terms of:

- Indicative area
- Function
- Location
- Local construction practice
- Architectural concept

3.1.2 Second Step

Decisions must be made regarding the placement of the structural elements that will define the space and the appropriate material for the main purpose.

- Span distance
- Proportions
- Overall height of the building

3.1.3 Third Step

The implementation of specific elements and the calculation of their size and shape - eg. steel sections - round, 2T hollow, etc. there are:

- Sizing based loads
- Types of elements
- Types of connections
- Visibility/hidden elements

4 GEOMETRICAL REDISPOSITION

4.1 Building Envelope, Placed in Front of the Main Structural Plane

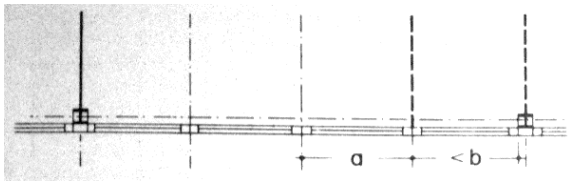

Figure 4: Examples of envelopes, placed in front of the plane – large scale of the main structure span.

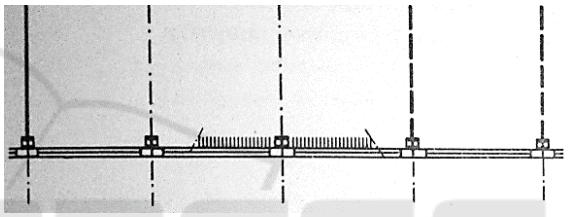

Figure 5: Examples of envelopes, placed in front of the plane – small scale of the main structure span.

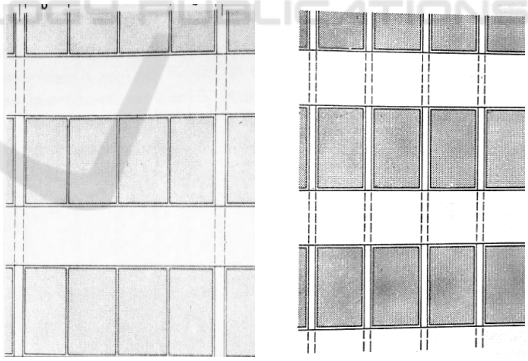

Figure 6: Examples of envelopes, placed in front of the plane – small and large scale – façade views.

Regardless of what kind of materials are implemented, there are various generally applicable features and design principles that are valid for building envelopes, and these are described below. A design principle indicates a fundamental solution for a defined construction task in accordance with predetermined functions. Here, rather geometrical “effects” are used, and their interactions linked together in a suitable structure (Knaack et al., 2014).

In both cases of big and small scale of the pattern, the main load-bearing elements of the envelope will be exposed on the façade and the mains structural elements of the buildings will remain hidden. Thus, the distances between the vertical elements will be the only pattern-defining factor.

4.2 Building Envelope, Placed Behind the Main Structural Plane

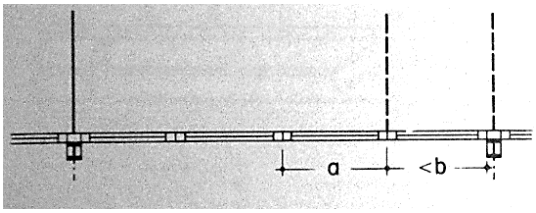

Figure 7: Examples of envelopes, placed behind the structural plane – large scale of the structural pattern.

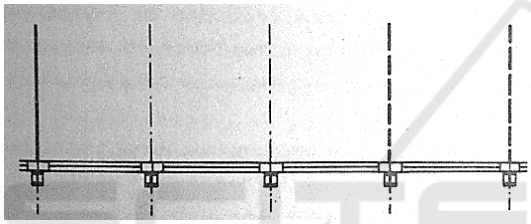

Figure 8: Examples of envelopes, placed behind the structural plane - small scale of the structural pattern.

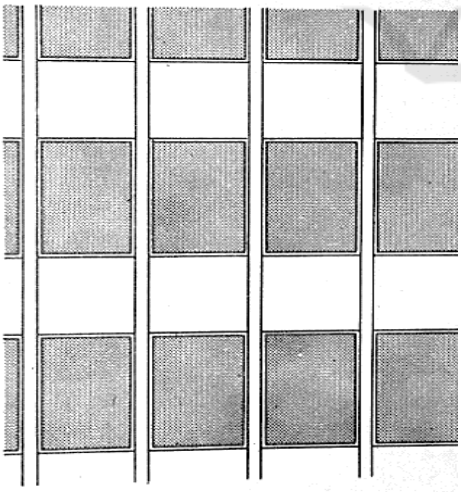

Figure 9: Examples of envelopes, placed behind the structural plane - clear visibility of the structural pattern.

When the envelope is behind, the mains structural elements will be exposed on the façade and they will define the scale and the pattern of the building.

4.3 Building Envelope, Placed in the Main Structural Plane

When the plane of the envelope coincides with the structural plane, the mains structural elements will be exposed on the façade and in the interior equally, but they will create a prerequisite for thermal bridges.

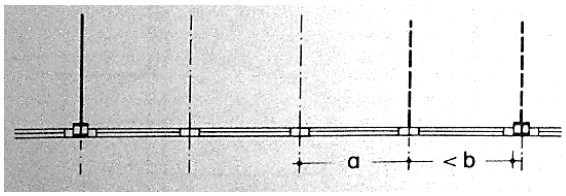

Figure 10: Examples of envelopes, placed in the structural plane – large scale.

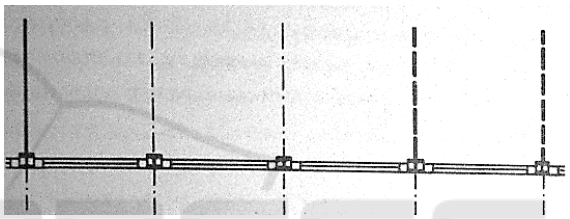

Figure 11: Examples of envelopes, placed in the structural plane – small scale.

5 CONCLUSIONS

All these examples lead us to the conclusion that the primary choice of pattern and the type and place of the building envelope scale and materials is essential in terms of architectural design impact. Facade envelope planning is a particularly important part of the design process. It is a step-by-step process.

The principles of construction and the interrelationship between the building structure and the facade envelope system are fundamental factors. Analysing how facades can adapt to changing parameters is also an important aspect; the selection of atypical and special facade solutions based on local climatic features is a good perspective for possible development of facade technologies. The main objective will be to design, develop and create evaluation methods and parametric simulation models to characterize the performance of innovative building envelopes that are able to capture the multi-parametric characteristics of adaptive facades in specific climate zones.

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