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Multifunctional urban exoskeleton in the context of eco-architecture

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Abstract. The article is devoted to the concept of urban exoskeleton formation, which is a new type of spatial modeling in architecture, turning historical and natural artifacts of the territory into supporting nodes of environmentally friendly design solutions. The features of the exoskeleton method are revealed in the article on the material of the contest «TIMBER IN THE CITY 3: Urban Habitats Competition», devoted to the problems of ecological rehabilitation of problem urban areas using advanced technologies of wooden construction.

1. Introduction

Urbanization is rapidly developing, and it is necessary to think about how to ensure the environmental safety of cities [1]. Here, eco-design comes to the fore. Wood becomes an attractive building material that meets all his needs. Wood is well suited for a wide range of structural and aesthetic applications, offers economical construction and high performance in terms of strength and energy efficiency. Modern mass timber technologies have greatly expanded the possibilities of using this material. For more than a century, medium - and high-rise buildings around the world have been built primarily of concrete and steel. These two existing materials perform well in various design tasks and will remain important materials in the construction of all buildings in the future. And here the question arises: why do we need an alternative to concrete and steel for medium and high-rise buildings? The answer is simple – climate change. The introduction of timber buildings is a design solution that has a much lower carbon footprint than functionally equivalent concrete and steel systems [2-4].

The demand for ecological construction today is global and affects not only the building materials used, but also the ideology of design. Ecology comes into the city, as services, and urban structures (eco-neighborhoods, eco-farms, eco-villages, etc.). Therefore, the possibility of implementing innovative projects using wood should be associated with the needs of society for the formation of an environmentally healthy urban environment and translated into the design methodology. The ecological health of the urban environment should be understood in this case as a set of favorable physical characteristics of human living conditions, social practices of good neighborliness and preservation of the cultural and historical landscape as a whole. Architecture always balances on the edge between historically developed codes of structures and loads and their variability caused by new technologies and ideas of development. Variability is interpreted as a deviation from the standards defined by established laws. Under these conditions, architecture, as a synthetic discipline, should be open to the emergence of innovations, including interdisciplinary effects that can be used as an active potential of architectural diversity. In this sense, the interpretation of the ideology of the exoskeleton

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as an effective interdisciplinary design method, presented in this article, can contribute to the solution of environmental health problems in urban areas with the use of environmentally friendly materials, such as wood.

2. Materials and methods

Rethinking the exoskeleton as a means of forming urban space was developed by the authors of the article in the framework of the method «the Ufa implosion» [5, 6]. Exoskeleton in the common sense is designed to replenish lost functions, increase the strength of human muscles and expand the amplitude of movements due to the external frame. Implosive exoskeleton is understood as both a support and a protective structure formed outside the urban tissue to enhance its elasticity and muscle tone. The exoskeleton «supports» the city from above, «relying» on the points of contact with the geotectonic framework, which are accepted as historical and natural artifacts-monuments of architecture and natural objects of natural origin (Figure 1).

At the first stage of implosive exoskeleton modeling (support), a model of the original context is created, which «fuses» contextual relationships and terms of reference (a set of areas and functions) into a single structure of the future architectural solution. Historical and natural artifacts at this stage are the structural elements.

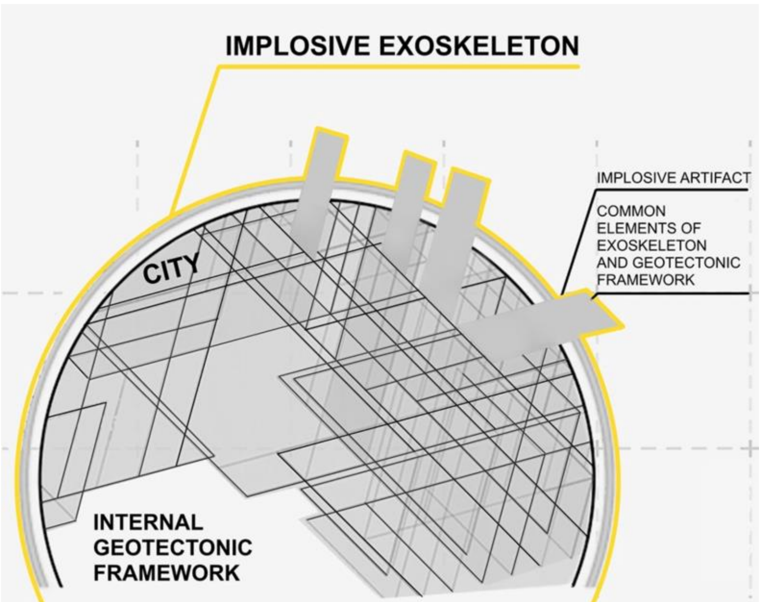

Figure 1. Implosive exoskeleton.

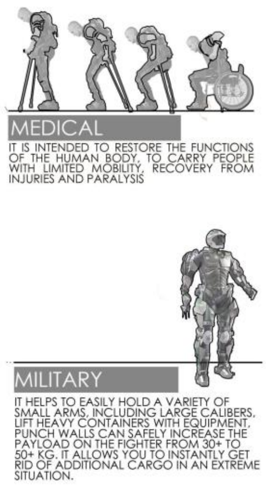

Figure 2. Medical and military types of exoskeleton

In the second stage of implosive exoskeleton modeling (support), historical and natural artifacts are isolated and developed as support nodes of the exoskeleton. Depending on the contextual characteristics of the identified artifacts is assigned to a specific function of the exoskeleton, such as medical or military. The medical type works to maintain a stable ecological «health» of the urban environment. The military type is designed to prevent extreme situations (Figure 2).

Further, the selected function of the exoskeleton becomes the basis for the use of problem-oriented world experience of design research in the field of environmental service. Thus, the created proto-structure of the future design solution is complemented by the characteristics of supporting living conditions and is included in the current trends in the development of advanced construction technologies and materials. On their basis, the exoskeleton of the design strategy is formed, which is then «embodied» by real building structures of the architectural solution.

Figure 3. Initial situation.

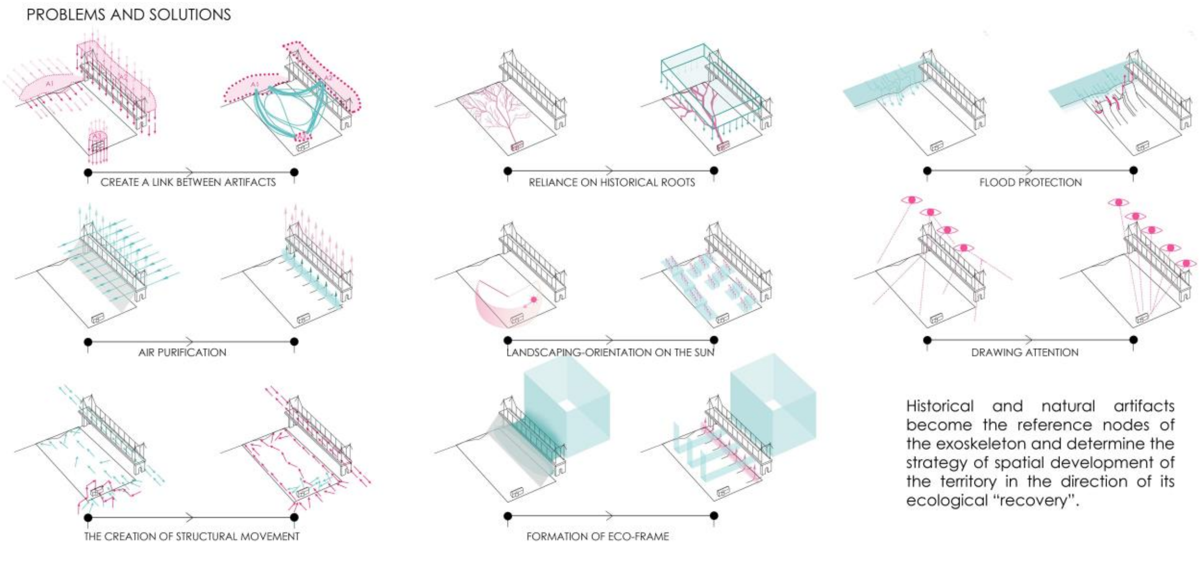

Figure 4. Study of the embeddedness of the territory in the environment.

3. Results

The ideal experimental platform for the development of the urban exoskeleton concept was the competition task «TIMBER IN THE CITY 3: Urban Habitats Competition» [7]. As part of the competition, participants were tasked with transforming a vacant former industrial estate on the East river in Queens, New York. It was necessary to create the project of ecological quarter, using progressive experience of wooden construction. The eco-district was to include affordable housing, a large community Wellness center, an early childhood education center, and a landscaped waterfront. The authors of the article proposed a conceptual model of ECO-lab, which is the embodiment of the algorithm of integration of the world experience of ecological construction and architecture into the existing project context (Figure 3).

At the first stage of implosive exoskeleton modeling, contextual connections and historical and natural artifacts of the territory were revealed (Figure 4). The design area was presented as a model of interaction between four different urban contexts. The first was determined by the proximity of the territory to the abandoned industrial and warehouse area with the surviving historic building of the Terra-Cotta plant, the second - the proximity to a landscaped residential area with a Park, the third provided a link to the East River embankment, the fourth was in close contact with The Queensboro bridge, connecting major urban areas. The model of the future architectural solution «tightened» the selected contexts inside the projected territory, combining them with a multi-level multifunctional public space with a health complex and a children's early education center.

At the second stage of the implosive exoskeleton modeling, three historical and natural artifacts were identified, which became the basis for the integration of various ecosystems and wood as the main building material into the design algorithm. These are The Queensboro Bridge, The Queens Terra-Cotta building, and The East river embankment.

The Queensboro Bridge, located on the border between the «lifeless» project area and the adjacent Queensbridge Park, was a major source of air pollution. In this case, a medical type of exoskeleton was chosen. The proposed project environmental service was associated with air purification by means of landscaping, vertical trusses and bio-curtain device, which was placed on the end facades of residential buildings. Integrated microalgae biozones convert carbon dioxide in the air into oxygen through photosynthesis. Also on the territory of the quarter were placed vertical eco-farms for growing food using hydroponics systems and LED lighting [8].

The Queens Terra-Cotta building was designed in 1892 as the plant's first office. Despite its obvious historical status, it has been repeatedly vandalized. Exoskeleton of the site in this case was also associated with a medical function and aimed at restoring and preserving the history of the site, as well as territorial branding. The environmental service was aimed at transforming the abandoned historic site into a point of attraction, a source of development of the territory and its improvement. In the concept of improvement ECO-lab system of pedestrian traffic descends from the historic building to the waterfront, linking all the buildings of the quarter on the principle of a single «root system».

The East River embankment is both an attractive area and a dangerous area with the possibility of flooding. Therefore, the river is «equipped» with a military type of exoskeleton that allows warning about the danger. Here, as an environmental service comes «the Teaching landscape». «The Teaching landscape» is one of the project approaches of «the Ufa implosion» methodology [9], which involves the formation of directed observation of the environment on the basis of the project model of the observation site. Thus, a syncretic nature of contemplation and thinking is created, which generates a deep «experience» of the territory associated with its geotectonic processes in the citizens. In ECO-lab, recreational spaces rise above the river, the architecture begins to work like a dam, forming multi-level public spaces. The embankment improvement lines become a plastic infographics of possible flooding.

The final stage of the implosive exoskeleton formation is the connection to the development of the architectural solution of the progressive experience of wooden construction. In the ECO-lab model, these are CLT slabs from which the supporting frame of the quarter buildings is created. CLT slabs are safe for humans and are able to maintain comfortable temperature conditions (keep warm in winter, cool in summer), and CLT slabs do not emit harmful substances for the environment. According to the findings of the life cycle study of CLT slabs, the main positive environmental characteristics of the panels include: carbon storage; reduction of greenhouse gas emissions during the production process; overall reduction of environmental impacts compared to non-wood materials.

4. Conclusion

Thus, ECO-lab is the creation of a functioning eco-laboratory that adapts life in the quarter to the environment and forms the ecological consciousness of its inhabitants. This model of the ecological quarter can be a good example of the implosive exoskeleton as a design algorithm in the conditions of demand for ecological and sustainable development of urban areas. Exoskeleton allows maximum integration of the project into the surrounding context with the use of problem-oriented environmental services and advanced building materials. Thus, on the basis of the implosive exoskeleton, a stable and eco-friendly frame of the three-dimensional solution of the block is formed, which is fixed structurally. Wood enters the project at all levels: it is laid in the principle of shaping the «skeleton» of the quarter, works as a design code and participates as the main eco-friendly building material. Relying on historical and natural artifacts as supporting nodes, the formed ecological exoskeleton supports and helps to develop a new urban area (multifunctional complex).

Figure 5. ECO-lab.

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