The Use of Shells in the Design of Recreational Complexes

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Abstract. The article provides a brief description of parametric and mesh shells, their advantages over traditional types of structures when designing recreational complexes are indicated. Examples of the use of rod and mesh shells are also given, and modern design methods by means of generative design and the use of shells for recreational facilities are indicated.

1. Introduction

In the first half of the 20th century, shells were used most often in industrial construction, where it was required to cover spans of more than 30-40 m with minimal metal costs. Shells were rarely used in the construction of residential, recreational and administrative buildings. Subsequently, architects such as Buckminster Fuller, Norman Foster, Frank Gehry, Nicholas Grimshaw and Santiago Calatrava made a great contribution to the implementation of load-bearing mesh shells in world architecture.

In recent decades, thanks to the use of computers for structural analysis, mesh shells have become widespread. In the 21st century, mesh and bar structures became one of the main means of shaping modern buildings.

In this study, parametric (digital) methods for creating shells for recreational complexes using design on the Rhinoceros + Grasshopper platform are featured. The flexibility of this toolkit allows it to be used at different stages of the project, both partially and fully to carry out design tasks, as well as to illuminate the widest range of computer modeling issues.

Using an integrated approach, as part of the article, the author tried to summarize the information that exists in the field of modern architectural design and identified 4 aspects that architects most often take into account in practice. These aspects interact with each other to one degree or another at different stages of the project process. In outline design, these are: Morphological, Economic, Cultural and Social aspects.

The material in this article considers the most significant for the architectural appearance of structures - the morphological aspect.

The huge scale of construction of recreational complexes requires the rapid development and technical improvement of the industrial industry. In the Russian Federation, with its vast spaces and territories, there are considerable difficulties in designing large recreational complexes and their facilities. In various regions of Russia there is constantly a need for the construction and design of modern leisure and tourism facilities.
With the advent of reinforced concrete in the 20th century, capable of taking on new forms, resisting compression, stretching and bending, they began to create building structures - shells.

The development of synthetic materials has allowed the creation of soft shells, pneumatic and tent structures. Soft shells have more opportunities for use in modern recreational complexes. Firstly, such shells can be of any shape. A feature of such shells is the ability to perceive only tensile forces.

The construction of monolithic reinforced concrete shells requires complex wooden and plastic formwork. With the advent of parametric architecture, the curvilinearity of the shells is able to acquire various non-linear, non-standard forms. This is very important for the design and construction of modern leisure and tourism facilities, for overlapping recreational spaces and organizing recreation in the cold season. In the latter case, the shells can be used as temporary recreational structures of a seasonal type. For example, a tennis court closed by a pneumatic shell or a swimming pool at a recreation complex, a dining room, a restaurant, a club, a recreation area.

2. Relevance of the topic

The relevance of parametric methods in the design of shells and the construction of recreational complexes with their use is directly related to the determination of the time frame for the study of this issue. These frames are very blurry, because without predetermined parameters, architecture cannot exist. The actualization of the topic of parameters in the architecture of recreational facilities is being revived in the age of information technology in which we live today. We draw attention to this, partly because in the historical context there is a certain cyclical nature and each subsequent cycle allows us to obtain more and more in-depth knowledge about matter or, if we use computer terminology, everything has an even greater “resolution”.

Parametric design methods are increasingly being introduced into everyday architectural practice. Along with BIM technology, they expand the tools and accuracy of the architectural design. The gap between the various stages of the project process becomes smaller and smaller, the integration component becomes more and more practical, from which it’s practically one step from sketch to production.

Considering the huge need of people for recreation and rehabilitation, there was a need for the design and creation of new types of recreational complexes. A new type of recreational complex is based on parametric design and the use of software at all stages of design in order to create interconnections between the various elements of the project, its form, design, and, as a result, translate new engineering ideas into an integrated structure of effective and effective non-linear recreational facilities.

When designing recreation facilities, it is most important to use parametric shells. There may be several reasons for this:

1. Curves of such buildings using shells correspond to the purpose of these recreational structures, which cannot be created without resorting to parametric modeling of shells (for example, City of Arts in Valencia (architect Santiago Calatrava)) or Yas Marina Hotel, Yas island, Abu Dhabi.

2. With regard to the construction of recreational complexes, parametrism offers interesting solutions. For example, the interconnection of the bearing capacity of the supporting structural elements, depending on the dimensions of the building, the geography of construction, the shape of the building and their location in the structure, allows these elements to change their shape, size and placement. Based on the rational use of resources, racks of frame elements on the second floor can be of smaller cross-section, which will reduce the overall weight of the structure. Of course, these changes are not calculated manually, but are generated by design programs according to the given algorithms. This saves the designer time, as a result, and money. But here the problem arises of the typical dimensions of the materials used, if we are not talking about concrete monolithic structures. Therefore, the practical implementation of the parametric architecture of recreational complexes is closely interconnected with digital production. Here, the main contender for the most rational builder, of course, is 3D printing of objects, and there are a lot of examples of such projects. But 3D printing,
in spite of all its prospects, cannot yet provide a full cycle and is very demanding on materials science, equipment complexity, the size of 3D printers and designers capable of thinking with “3D printing”.

3. The objectives of the study are
The objectives of the study is the use of shells in the architecture of recreational complexes. The main part of the study is aimed at a parametric approach in the design of shells. An important task is to identify the shape parameters of recreational objects in order to introduce different shell structures. All these goals must be consistent in this study with such important parameters as comfort and the environment. Shells in the structure of recreational complexes will be considered from the point of view of different functioning and further digital prototyping.

4. The theoretical part
The most commonly used types of shells are:
- Mesh shells - spatial spatial structures, the nodes of which lie on the surface of a single or double curvature; the main material is metal. Also practiced the production of wooden shells
- Sheath-folds - the main material - concrete.
- Shells in the form of rotation hyperboloids
- Shells of positive Gaussian curvature
- Shells in the form of hyperbolic paraboloids
- Membranes, cable-stayed systems - They perceive only tensile forces; the main material is metal, polymeric materials.
- Pneumatic casings - can be pneumo-supporting and pneumoframe. They perceive only tensile efforts; the main material is polymeric materials.

Projects of modern shells are based on the use of modern computer and software to create the relationship between the various parts of the project: its form, design, and, as a result, the embodiment of engineering into an integral structure of expressive and effective buildings of the architecture of recreational complexes.

Modern parametric shells - for the architecture of recreational complexes - is the creation and design of a unique style in which architecture, sculpture and mathematics are interconnected. Digital design must take into account the relationship between the erected building intended for recreation and tourism, the environment and the human factor.

In the design of recreational complexes, the use of parametric shells is aimed at creating certain models that go beyond simple forms and constructive solutions. When creating shells, modern computer tools are used that allow the use of mathematical algorithms. Logical conditions for finding optimal solutions to the problems of creating modern architectural shells in automatic mode. Modern parametric programs expand the possibilities of creating forms and structures of shells.

The advantage of shells is the ability to cover large spans
The specificity of the shells for recreational complexes is that anything can be inside, without touching the shell itself.

Using a shell, you can build something that can generate electricity or condition the building through the natural movement of air.

In the history of modern architecture, the parametric approach is associated with the formation period of nonlinear architecture. In the global context, strategies for introducing new methods into the process of architectural design largely depend on scientific and technological progress and the scientific and philosophical picture of the world in which this topic is considered.

The rapid development of mass production in the 20th century and the exponential growth of the influence of computer technology on production processes at the beginning of the 21st century allowed the formation of a parametric approach.

“Today, rather, we should talk about a computational paradigm that fundamentally affects architecture, design, and art. In architecture, for example, using a computational paradigm helps to derive the concept of an object from very abstract things. The architect conducts a large-scale research
of the territory and creates algorithms that should meet his requirements to the maximum. And the computer counts large amounts of data”.

Characteristic of the parametric approach are such distinguishing features as:

- **Iteration** - the possibility of repeating actions. This term was introduced into disciplinary circulation by the philosopher J. Derrida.
- **Clarification** - with each new iteration or at each subsequent stage of work, the project parameters are refined.
- **Variability** is an integral part of modern architectural design and computer tools. Creating many options and choosing the most suitable is one of the main approaches in modern design.
- **Manageability** - Changing and adjusting parameters at any design stage reduces the number of errors and makes the final result more expected.

5. **The practical significance**

As mentioned earlier, this electronic article presents a parametric approach from the point of view of the morphological aspect in architecture. With some generalization in this aspect, there are 5 principal areas of parametric design:

- Form parameters
- Shell structure parameters
- Environmental / comfort parameters
- Digital Prototyping
- Interactive environment

If we talk about the general process of architectural design, then all 5 parameters interact and intersect and should always be considered in conjunction. Depending on the complexity and scale of design tasks in modern architectural practice, separation of tasks can still occur.

Another distinguishing feature, manifested in architectural design and related to parameters, is the “generative” component.

A generative approach in architecture is a design process in which an architectural object is created in the form of a system that has a certain degree of autonomy.

If we compare the generative approach with the more traditional “instrumental” approach, then unlike the second, the first works with self-organizing systems and their components, while the second completely depends on the plan and the order given by the person.

In this study, using both the method of instrumental design and the method of generative design, we consider a scheme consisting of parameters:

1. **The form of the recreational complex**

   The shape of the recreational complex can be subordinated to both the transforming actions of simple geometric shapes and organized by complex algorithms that allow you to respond to the context. This parameter defines the general silhouette of the architectural object, just as it limits and shapes the overall internal space.

2. **Shell structure**

   The parameters of the structure of the shell of the object are repaired by the shaping properties of the general form of the recreational object. The way the shell of the building is “woven” greatly influences the final image of the architectural object. Most often, the structure of the building envelope reacts to the functional purpose inside the building and meets the required comfortable conditions.

   In addition to the aesthetic and utilitarian component, the parameters of the shape of the building and the structure of the shell determine the constructive scheme of the object and very often are in mutual subordination with it.

3. **Functionality**

   One of the main parameters that determine and correct the appearance and structure of the shell. Depending on the effective location of the functions located in the building, the expediency of its existence develops.

4. **Parameters of insolation / radiation**
One of the main factors for most architectural typologies is the orientation of the object in space. How the sun’s rays fall on the shape of an object, its shape, structure, and location of functions largely depend.

5. Interior comfort

Depending on the technological requirements of a particular functional area in the building, as well as the conditions of internal comfort, the shape and structure of the object’s shell react to achieve greater energy efficiency and the feasibility of creating such an object.

When designing objects of recreational architecture, the exact shape, dimensions and structural optimization are necessary. Therefore, the process of computational design is specified. This process is fundamental, and begins with the generation of form and parametric modeling by a team of architects. Then, integrated BIM is introduced for structural calculations.

Since the integration process is used for structural analysis, in order to investigate various loading scenarios and sizes of individual elements, an automated calculation method is developed that allows you to interact between all stages of the project, the construction of the recreational complex and the final structural check of the building.

When designing recreational complexes, mesh shells are most preferred. One of the advantages is the simplicity of their assembly. The designs of mesh shells are erected in a fairly short time and do not require a large number of labor costs during installation and special equipment.

When using mesh shells in the design and construction of recreational complexes, additional supporting structures in the form of various columns, beams, and ceilings are not needed. This is what gives freedom for internal planning and quick changes to this layout. For example, if a recreational complex loses its internal attractiveness over time and ceases to meet modern requirements for recreation and tourism, such a complex can be easily improved.

The mesh frame of the shells shows lower values of compression deformations along the building height for vertical elements.

Recently, mesh shells for recreational complexes are used more often than reinforced concrete thin-walled shells. For example, in two separate hotel buildings in Abu Dhabi (United Arab Emirates) (The Yas Hotel, Asymptote Architectural Bureau, 2009) with a coating of glass and steel, which is a shell, the elements are attached to a non-planar grating, which provides resistance to dynamic effects of wind. The mesh coating of the shell rests on 10 V-shaped columns. V-shaped columns and beams have a cross section in the form of a pipe. The lattice elements are made of rectangular hollow steel.

In addition to various core structures that cover large areas, as in the above hotel in Abu Dhabi, there are core structures in the form of openwork racks. An example is the interior space of a garden in a business school building at the University of Chicago (USA). The building itself consists of several parallelepipeds, but the inner space of the recreational garden is made using a mesh shell. This glass ceiling of the six-story atrium in the center of the complex is supported by four “pseudo-Gothic” supports, inside of which there are pipes through which rain water from the roof will enter the tank under the underground garage for further use.

Architect Massimiliano Fuksas designed an unusual complex in Tbilisi, consisting of two different volumes connected by intersecting pipes. Inside should be a recreation complex consisting of an exhibition hall and a musical theater with 566 seats. Building materials - concrete, glass and steel, so there is a lot of sunlight inside it throughout the day. When designing, diagrid technology was used - lattice overlap made of diagonal cross elements.

6. Conclusions

The use of shells is not a new technology, since their use began many years ago. Initially, mesh shells were used in industrial construction, where large spans were required to be blocked with minimal metal costs. However, now constructions and structures in the form of shells are actively used in the architecture of public, industrial and recreational buildings.
Obviously, the shells in the form of geodesic domes are the simplest and most economical in terms of construction costs, however, the use of other types of mesh shells makes it possible to diversify the appearance of recreational structures.

The given examples of erected steel bar structures show a high level of achievements in construction equipment and science. This article shows only the main areas in which the development of technologies for the use of these shells is going on. There are already many examples of their use, and each year they will appear even more. The architecture of the core shell structures does not stand still. Young architects are offering more and more new abstract core structures. The scope of mesh designs is expanding due to the improvement and widespread introduction of computer technology, new computer-aided design (CAD) systems and programmable machines (CNC). Modern technologies allow you to go beyond the simplest configurations of mesh shells and build not only geodesic domes, but also other mesh forms that give objects an individual memorable appearance.

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