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OPTIMAL TECHNOLOGIES OF AWNING STRUCTURES TAKING INTO ACCOUNT VARIOUS CHARACTERISTICS OF THE PARAMETERS

The work deals with the issue of computer modeling and some physical properties of modeled objects. Issues related to membrane awning structures, which are relevant nowadays, are also considered. Geometric modeling is considered as a direction of mathematical modeling, which includes the description of geometric images and the execution of certain operations on them in two-dimensional, three-dimensional or multidimensional space. The requirements for design tools and solving the problem of finding the optimal cutting of structural materials for the production of technical objects are analyzed. The characteristics of awning structures, the possibilities of forming, the use of various materials and the combined options of combining the awning with other materials are considered. The use of awning structures makes it possible to create not only small architectural forms, quickly assembled mobile structures that are easily transformed according to the change of functional purpose, but also to form new types of objects. Modern technologies combine the advantages of industrial construction methods with the individualization of the form, opening the way to the use of awning structures. Membrane coverings, as one of the modern trends in presenting a new form of roofing, create new spatial characteristics of architectural objects. Therefore, in order to solve the theoretical problems of calculating a high-quality awning structure, it is necessary to use special methods based on the use of the equilibrium state of membranes. Providing a wide variety of forms, this type of coating has wide prospects for use on a par with other architectural and structural systems. Ukraine has potential opportunities for the use of awning structures in the design of original objects. An informational model of commensuration of architectural form elements established on the basis of informational modularity of ratios of dimensional structure elements is proposed. The practical value of the method lies in the possibility of direct design of the awning surface, in contrast to other known methods, which proceed from rigid boundary conditions.

Key words: computer modeling; tent construction; surface; spatial membranes.

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ОПТИМАЛЬНІ ТЕХНОЛОГІЇ ТЕНТОВИХ КОНСТРУКЦІЙ З УРАХУВАННЯМ РІЗНИХ ХАРАКТЕРИСТИК ПАРАМЕТРІВ

У роботі розглянуто питання комп'ютерного моделювання та деякі фізичні властивості модельованих об'єктів. Також розглядаються питання, пов’язані з мембранними тентовими конструкціями, які є актуальними в наш час. Геометричне моделювання розглядається як напрямок математичного моделювання, що включає опис геометричних образів і виконання над ними певних операцій у двовимірному, тривимірному або багатовимірному просторі. Проаналізовано вимоги до засобів проектування та вирішення задачі пошуку оптимального розкрою конструкційних матеріалів для виготовлення технічних об’єктів. Розглянуто характеристики тентових споруд, можливості формоутворення, застосування різноманітних матеріалів та комбінованих варіантів поєднання тенту з іншими матеріалами. Застосування тентових конструкцій дає можливість створювати не лише малі архітектурні форми, швидкозбірні мобільні споруди, які легко трансформуються відповідно до зміни функціонального призначення, а й формувати нові типи об’єктів. Сучасні технології поєднують переваги індустріальних методів будівництва з індивідуалізацією форми, відкриваючи шлях до використання тентових конструкцій. Мембранні покриття, як один із сучасних напрямків представлення нової форми покрівлі, створюють нові просторові характеристики архітектурних об’єктів. Тому, щоб вирішити теоретичні задачі розрахунку якісної тентової конструкції необхідне застосування спеціальних методів, що основані на використанні рівноважного стану мембран. Забезпечуючи широке розмаїття форм, цей вид покриття має широкі перспективи використання на рівні з іншими архітектурно-конструктивними системами. Україна має потенційні можливості застосування тентових структур при проектуванні оригінальних об’єктів. Запропоновано інформаційну модель співрозмірності елементів архітектурної форми, що встановлюються на підставі інформаційної модульності співвідношень елементів розмірної структури. Практична цінність методу полягає в можливості прямого проектування поверхні тенту на відміну від інших відомих методів, які виходять з жорстких граничних умов.

Ключові слова: комп’ютерне моделювання; тентова конструкція; поверхня; просторові мембрани.

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Formulation of the problem

Analysis of the latest research and publications by domestic and foreign scientists showed that technical means are becoming more complicated, and construction materials remain standard. This leads to new requirements for design tools, which must solve the task of finding the optimal cutting of structural materials for the production of technical objects [1]. However, despite the availability of a large number of scientific works on this problem, from the point of view of graphic training of future engineers and technicians, this category is insufficiently studied.

Geometric modeling is considered as a direction of mathematical modeling, which includes the description of geometric images and the execution of certain operations on them in two-dimensional, three-dimensional or multidimensional space [2]. The theoretical basis of geometric modeling is differential and analytical geometry, topology and sections of computational mathematics. Geometric modeling studies methods of constructing curved lines, surfaces and bodies, methods of performing various operations on them, and methods of controlling numerical models [3,4].

Recently, light, cost-effective awning structures have become more and more popular. They belong to the class of soft shells. Such constructive systems are spatial membranes with zero bending stiffness, which consist of complex surfaces of double curvature. These coatings can resist only in tension. Therefore, their perspective is obvious due to the presence of a whole set of positive properties in them, which favorably distinguishes awning structures from traditional ones, such as metal, reinforced concrete, etc. Such properties include: mobility, multi-functionality, lightness, a short period of construction (erection) and dismantling, as well as an expressive, attractive and modern appearance. For choosing design solutions, an important factor is the service life of awning structures, as well as its cost. The term of use depends on the choice of fabric for the shell. The fabric itself has different strength and elasticity in all directions of load application. Therefore, for stressed structures, materials with low creep will be better, because the previous stress can be lost if the fabric is stretched or deformed [5].

The processes of geometric modeling and engineering analysis of similar structures have their own specifics. In contrast to traditional structures under given boundary conditions, the shape of a stretched fabric surface of negative Gaussian curvature is unknown at the very beginning, and can only be calculated using appropriate methods. Another difference is that, due to their specificity, surfaces of double curvature, unlike linear surfaces, are reflected on a flat area only approximately. This complicates the construction of their cutting maps. The awning surface has a number of undesirable properties, such as the presence of "dead" zones, uneven load distribution, stress concentration in individual points, etc.

Thus, the factors that provide a wide variety of positive properties of soft shells are at the same time the reasons that significantly complicate the process of analysis and design of awning structures. Therefore, in order to solve the theoretical problems of calculating a high-quality awning structure, it is necessary to use special methods based on the use of the equilibrium state of membranes.

Main results

The current computer-aided design systems are difficult to imagine without the widespread use of graphical tools. This is due to the fact that geometric models not only visually process objects and processes, which allows the simplest way to achieve the desired results of their optimization, but also serve as the basis for coordinating mathematical and other descriptions of various industrial products.

Some programs, such as KOMPAS and others, include specialized modules for solving specific problems, namely, for building sweeps of technical forms for industry. In our country, the peak of development of tent construction falls on the mid-90s. For a long time, the development of awning structures was held back due to the inconsistency of domestic awning materials with the high requirements for structures of this type, such as light resistance, strength, variety of colors and durability . Now there is a stormy interest in architectural structures made of fabric, which is

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due to the need of modern society for these structures. The service life of structures is an important factor in the choice of solutions, manufacturing features and cost of an architectural fabric structure. The service life is more dependent on the choice of fabric for the shell. The fabric is a non-uniform material in different directions and has different strength and elasticity in all directions of load application. Table 1 summarizes the comparative properties of the materials. When assessing the cost, the cheapest material has the highest value. All of these materials are composites.

Tabl. 1

Fabric type	Strength	Fire resistance	Durability	Cost	Typical use	Term of service	Remark
Composite polyester with PVC coating	5	3	3	4	Temporary, long term	3-15 years	A large selection of products, resistance to UV radiation and fire resistance
Glass fabric with PVC coating	4	4	3	3	From temporary to permanent	5-15 years	Available in limited quantities
Fiberglass with Teflon coating	4	5	5	1	Permanent	25 years or more	The most durable material
Fiberglass fabric with silicone coating	3	5	4	2	From long-term to permanent	20 years	Low strength of seams was found
Multi-layer material based on fiberglass with Teflon coating	3	5	5	1	From long-term to permanent	20 years	Relatively new material

The strength of the material is provided by a mesh fabric base, which is sealed and protected by a coating or film. Plastic, PVC and polyester materials are prone to degradation under the influence of UV radiation, while fiberglass and fiberglass mesh degrade with prolonged contact with moisture.

The two main methods of attaching the fabric sheath to the anchoring devices are with ceramic cable or with clamps. Some shell designs use both methods of attachment. Inflatables sometimes have cuffs and cables with a panel that covers the fabric and extends beyond the cable. Tensile structures are usually made to order, while anchoring and connecting devices are also made to order. However, basic products such as clamping devices have become more standardized. Some materials of the frame and connecting devices were borrowed from other industries, such as space frames and marine equipment.

When determining the appropriate design aesthetics, the following aspects are taken into account:

1) Tensile structures are flexible, and their elements must be designed for deflection under load;

2) Tensile structures weigh many times less than other buildings, and most of the materials used are translucent;

3) lateral forces in tensile structures play a greater role than in conventional building structures;

4) It should be ensured that the physical decomposition of the force vector (direction angle and magnitude) on each element is accurate.

5) The details, material specifications and reaction forces acting on the connected members of the structure shall be developed in consultation with an engineer or representative of the design firm or manufacturing firm capable of designing such structures.

In recent years, the construction design of fabric structures has been improved due to the widespread use of computer technology. The first stage of the design process using computer modeling is to determine the acceptable geometry of the shell surface. Then a mesh model of the shell is developed. This graphic model is prestressed. The reaction of the shell is analyzed by the interval method or by the method of repetitions. Real loads are checked on the model (wind load, load during

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rain and snowfall), and stresses are calculated for the purpose of choosing the fabric and design of the supports and base.

Applications of fabric structures include short-lived and temporary frame-fabric structures used in agriculture for the construction of greenhouses, greenhouses, and storage facilities. Improved materials have allowed these structures to be used for garbage and waste treatment facilities, tennis courts and swimming pools. More sophisticated structures with complex geometry are used for outdoor concert and sports halls, as well as larger structures such as administrative buildings, medical institutions, shopping malls and airports. Fabric structures do not replace traditional structures, but their unique qualities allow them to perform certain building functions very efficiently. With the use of elastic membranes, the surface of the roof is visually perceived as a finish and part of the architecture at the same time. The shape of the roof in this case is an integral part of the architectural style. That is why the quality of its surface, its ability to self-clean, its immunity to pollution and the influence of environmental factors, as well as the process of wear and tear over time are essential factors when choosing architectural solutions for a particular house or structure.

There is no generally accepted classification of architectural structures made of fabrics, so one of the versions is considered. Of course, in practice there are also various combinations of the proposed classification, as well as the harmonious integration of fabric with other materials (glass, concrete, brick, etc.) in order to create an original image of the building and at the same time reduce its cost (Tabl. 2).

Tabl. 2

In the presence/ absence of a frame	Frame	steel, aluminum, concrete, wood, pneumatic frame, composite
	Cable	a system of supports and tension elements
	Frameless	air-filled
By degree of seasonality	Summer	
	year-round	
By degree of mobility	Stationary	
	Transformed	
	Mobile	
By overall dimensions	large awning structures	hotels, shopping centers, exhibition centers, summer cinemas, playgrounds, air-support structures, hockey rinks, tennis courts, train station and airport terminals, warehouses for storing materials and equipment, hangars
	medium awning structures	pavilions, tents, cafes, canopies
	light awning structures	textile facades, interior elements (stretch ceilings, partitions, furniture)

Conclusions

In global practice, the range of application of architectural structures made of fabrics has significantly expanded, thanks to the increase in the quality of the materials used (both coatings and load-bearing frames). In addition, it becomes possible to solve such urgent problems as alternative energy sources, energy saving and air purification of premises from pollutants. The topic of using architectural structures made of fabrics in Ukraine is not yet sufficiently developed. The trend of slowing down in the development of awning construction should be eliminated, it is necessary to revise the attitude towards similar structures taking into account local conditions, these structures should be introduced into the architecture and design of Ukraine.

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