Domestic and foreign experience of using soft fitting structures in tent equipment

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Abstract. This research is review of purpose like soft enclosing structures made of different types of awning material: structural (construction of awning materials, solid (stretching and rupture) and lighting engineering (light transmission, light reflection). These researches are shown in following: graphs, tables, shorts. The prospect of development this type of construction is reviled on domestics and foreign examples of awning material. Results of studies are presented in the form of graphs and tables on the study of physical and mechanical properties of domestic tent materials and a comparative analysis of domestic and foreign experience in the use of these materials in tent structures.

1 Introduction

"Nothing in Rome, not even a gladiatorial battle, was as surprising as a giant awning stretched over the Colosseum." These words were made in the first century AD by the ancient Roman historian Pliny the Elder. As can be seen, the history of soft enclosing structures and tent structures is not so young. An important milestone in the modern development of such structures was the turn of the 20th-21st centuries. During this period, F. Otto began to create awning and membrane structures, at the same time this direction was developed by the specialists of the Moscow State University of Civil Engineering (National Research University MSUCE) [1]. In this paper we study the physical and mechanical properties of tent materials, examples of domestic and foreign tent structures and draw conclusions about the prospects for their development in Russia.

The popularity of tent structures is determined by their undeniable advantages (ease, mobility), the possibility of giving non-traditional forms and matching modern economic trends [2]. Based on the analysis of history and modern experience, the following areas of application of awning: pneumatic, cable and membrane structures are distinguished: agrarian industry and agriculture, tent shelters for drilling rigs, tents for welding operations, universal and large-span prefabricated awnings, car park, airport and landing canopies platforms, car washes, warehouses for storage of materials and products, hangars for maintenance and storage of machinery and equipment, air hangars, summer café sheds, cinemas theaters, dance floors, entrance groups, arenas for different purposes, scenes collapsible and stationary for cultural events, stage platforms, shadow canopies, and ready-

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made arbors and verandas for kindergarten sites, circus covers (circus tents), sports facilities . On the basis of the constructive feature, the following main types of structures can be distinguished with the use of MO: awning, cable-tent, cable roofing of cable systems, pneumatic structures [3].

2 Methodology

In the process of research, the physico-mechanical characteristics of domestic tent materials were determined, and the domestic experience was analyzed on the example of the most significant projects of tent constructions. Based on the results of studying foreign sources, the main achievements and trends in the development of tent constructions abroad were singled out and examined on specific examples. Based on the results of laboratory and full-scale tests, conclusions were drawn about the main properties of some materials of soft enclosing structures.

2.1 First constructions with application of tent coverings

One of the first buildings in which the awning covers were used in the USSR were circus tents. For example, circus tent in Gorky Park for 1200 seats developed by IISI staff for the Olympics-80. Another outstanding project is a space-barrel dome with a diameter of 43 m. and a height of 12.5 m. with a tent walling suspended from the bottom (TM-B "Volga"), serving as a public centre for multi-purpose use in the international tourist camp "Volga". The next object developed by the staff of the National Research University MSUCE in conjunction with the KSCU, on the instructions of the Government of Tatarstan, was a set of tent structures in the historian-cultural centre of Bulgara near Kazan. Architect is Sladkov Valentin Alexandrovich, chief engineer is Strigin Boris Sergeevich (Figure 1).

Fig. 1. The complex of awning structures in the historian-cultural centre of Bulgara near Kazan.

A great contribution to the study of the physical and mechanical properties of awning materials used as soft enclosing structures in awning structures, which will be discussed below, was made by PhD in Engineering sciences., associate professor of the National Research University MSUCE Strigin B.S., conducted in the international tourist camp "Volga "on the basis of multifunctional public centre. It is a visual proof that the awning structures are the best solution for civil and recreational buildings. In modern society, soft enclosing structures are widely used in the manufacture of hangars, sports facilities, public

catering establishments, as well as for individual design tasks. The important milestone in the development of the Ministry of Defense of Russia was the development of high-strength self-extinguishing tent materials, developed including employees of the Moscow University of Civil Engineering Blinov Y.I. and associate professor Strigin B.S. So, for example, tent material (TM-B), "vinylskozhu" -T. The tests showed high tensile strength (300 kg per 5 cm) and stability of performance (service life -25 years), as well as a variety of colors and shades with different light transmittance factors (see Table 1, Figure 2).

Table 1. Light technical characteristics of fabric-film materials.

No.	The graphics on Figure 2	Name of TM, GOST, TU, manufacturer, condition, color	Structural schemes of TM	Light technical characteristics, %					
				FSHM-56M				HITACHI	
				τ	ρ	α	β	τ	ρ
1	5	"Teza-C", TU-17-21-231-78 IvVNIPIK, Ivanovo, new, white-washed color		30	52	18	0,57 (d*)	25	52
2	16	"Thesa", TU-17-21-231-78, IvVNIPIK, Ivanovo, a new, yellow color		2	43	55	0,49 (d)	-	50
3	16c	"Thesa", TU-21-231-78, IvVNIIPK, Ivanovo, aging 2g, yellow color		2	39	59	0,52 (d)	-	33
4	75	"Volga-1", experimental, new, green-green color		6	48	46	0,60 (d)	-	46
5	76	"Volga-1", experimental, aging 2d, t-brown color		1	15	84	0,47 (d)	-	17
6	29	"Volga-3", Art. 1146, rd RTI, Yaroslavl, new, gray color		03	28	72	0,41 (d)	-	22
7	21	PVC mark "T", EPKTB "Stroyplastik", Kiev, (experimental), new, transparent, aluminized color		49	40	11	265	52	32
8	22	PVC mark "T", EPKTB "Stroyplastik", Kiev, new, milky white color		37	60	3	168	17	58
9	24	Viniplan, A / O TURO, Kuopio, Finland, new, yellow color		7	67	26	0,94 (d)	-	60
10	20	Canvas tarpaulin, Art. 11124		-	17	-	0,50	-	15

Fig. 2. The graphs of spectral characteristics of TM: a) - reflections (ρ); b) is the transmission (τ). * - reflection of the inside of the TM. 5 - "Theza-S"; 21 - PVC mark "T" (for external fencing); 22 - PVC mark "T" (for internal fencing); 24 - "Viniplan", see Table 1.

2.2 Investigation of physical and mechanical properties of tent materials

Mechanical properties of awning materials are the main ones. determine the existence of tent structures in general. Mechanical properties include the tensile strength of the material, the deformation characteristics of the material, etc. The tensile state of materials under tension is the basis for mechanical calculations of strength and deformation of tent structures, the basis of geometric calculations of the shape and cut of soft shells. The load-strain relationship for different types of awning materials has its own peculiarities. The chemical basis of the material is its design; the interaction of the material components influences this dependence [15].

According to the nature of the macrostructure of the material, TM-B is a reinforcement base with a polymer coating.

The structure of the reinforcing base should not be considered as an idealized interlacing of warp and weft yarns, but the actual one obtained after technological effects, with the application of a protective polymer coating and its vulcanization. When applying polymer mass in the direction of the base, much greater force is applied than on the weft, as a result of which the warp threads are straightened, and the weft threads are bent. Figure 3 shows a micrograph of a section of awning material on lavsan base with a PVC coating.

Fig. 3. The microphotograph of section of the tent material: coating-polyvinyl chloride, reinforcing base-lavsan, 1-core threads; 2-weft yarns.

It can be seen, that the warp threads are straight, the curvature of the weft yarn is significant. The latter, in turn, leads to an uneven deposition of the polymer coating on the surface of the tissue. Strength and deformation characteristics of the awning material in the direction of the warp and weft are different. Figure 4 shows a diagram of uniaxial stretching of TM-B material in the direction of the base, weft, and in the diagonal direction.

Fig. 4. The diagram of uniaxial stretching of materials TM-B, 1 - in the direction of the base; 2 - in the direction of the duck; 3 - in the diagonal direction.

The results of determining the physico-mechanical characteristics of the material TM-B are given in Table 2. The physical and mechanical characteristics of the material are determined on the German explosive machine ZMGi - 250 kr.

Table 2. The physical-mechanical awning material TM-B.

Materials	Strength *, N / cm			Relative extension*, %		
	Along roll (base)	Across the roll	Diagonally roll	Along roll (base)	Across the roll	Diagonally roll
TM-B red color	533	549	94	24	32,3	63,1
TM-B yellow color	526	504	80	28,8	33,7	50,5

* Strength and elongation of materials were obtained by testing 30 samples.

The statistical characteristics of the physical and mechanical properties of the TM-B tent material are given in Table 3.

Table 3. The static characteristics of physical and mechanical properties of awning material TM-B.

Material	Strength			Relative extension		
	The average value, N / cm	The average square deviation, N / cm	The coefficient of variation, %	The average value, N / cm	The average square deviation, N / cm	The coefficient of variation, %
TM-B, red color	533	13	2,43	24	0,94	3,91
	549	14,3	2,6	32,3	0,825	2,6
	94	52,8	56	63,1	6,77	10,7
TM-B, yellow color	526	26,6	5,05	28,8	0,91	3,1
	504	21,3	4,2	33,7	1,75	5,2
	80	21,3	26	50,5	2,05	4,05

* Note: in the numerator-value on the basis, in the denominator by duck
For tent materials, tests are carried out in the direction of the base and weft, they basically sweep along the axes of symmetry.

As can be seen from the test results, the properties of materials in different directions are different. The flow direction of the material is more deformable than the base. Strength characteristics of the material in the direction of the base and weft differ slightly. The materials of TM-B are of red color in comparison with the TM-B mate of yellow color more homogeneous, less deformed and has higher strength in the duck direction. The strength of the material decreases sharply and the deformation in the direction of the diagonal increases. The strength in the direction of the diagonal decreases almost 7 times, and the deformability increases by a factor of 2.

A comparison of the physical-mechanical characteristics of material TM-B and other tent materials is given in Table 4.

Table 4. The static characteristics of physical and mechanical properties of various tent materials.

Materials	Strength		Relative extension	
	Avg. val., N / cm	The coefficient of variation, %	Avg. val., N / cm	The coefficient of variation, %
Volga-3	457/390	3,7/6,1	17,2/-	4,1/-
Theza on lavtan	526/466	7/3,6	-	-
Theza on lavtan	542/362	17,7/7,2	-	-
TM-B	533/549	2,4/2,6	24/32,3	3,91/2,6
TM-B	526/504	5,1/4,2	28,8/33,7	3,1/5,2

For comparison, the Volga-3 material was chosen (coating chlorosulfonated polyethylene and butyl rubber, reinforcing base - capron), and promising domestic material. Thesa (coating - polyvinyl chloride, reinforcing base - capron), and promising domestic material. Teza (coating - polyvinyl chloride, reinforcing base - lavsan). In our domestic practice, awning materials on synthetic rubbers have developed a great deal, while overseas PVC-based coatings account for almost half of all types of coatings. PVC-based coatings are characterized by increased weather resistance, they make it possible to obtain soft shells of tent constructions by welding panels with each other, and has rich possibilities for color solutions. The "Teza" material produced by the domestic industry in its properties exceeds other domestic tent materials and is not inferior to the best foreign tent materials. As can be seen from the comparison results, TM-B is not inferior to the best domestic samples in its physico-mechanical properties, and even exceeds the homogeneity of its properties. The

material TM-B is more even in the direction of the warp and weft in comparison with the "Teza" material.

3 Results and discussion

In the course of scientific research the following results were obtained: firstly, the awning constructions have a huge potential for achieving unique expressive forms and solving various architectural problems. Secondly, for the development of this direction it is necessary to use complex constructive systems, the most complicated development of knots and fastenings, constant searches, research and creation of materials for the Defense Ministry of Russia. Also, the lack of domestic experience and innovative developments inhibits the development of this area in Russia. In addition, it should be noted that soft enclosing structures in awning structures create an extensive field for research by young specialists, which creates the potential for scientific and economic growth of this direction of architecture in Russia.

4 Conclusions

At the first stages of the development of tent structures in Russia and abroad, similarities were observed in the materials and types of structures used, but by using more highly technological methods of production and erection, for example, laser cutting, the quality of foreign soft enveloping structures was improved. In modern world practice, structures from the MO, possessing unusual, and often unique forms, covering huge spaces, can no longer be regarded as purely engineering objects. Strong examples of this are the awning structures in Japan [4]. Over time, soft enclosing structures have found application in large-scale objects of national and international importance. So, in 1981 in Jeddah, Saudi Arabia, the airport King Abdul-Aziz was opened, in which innovative constructive solutions were applied. Load-bearing functions perform reinforced concrete pylons 50 m high, between which are tapered conical shells, (PTFE, "Teflon"), 45*45 m. The upper and lower markings of the shell are 45 m and 30 m, respectively. The main functional purpose of the shell is shelter from solar radiation and the creation of an optimal microclimate due to natural aeration created by the temperature drop on the surface of the shell and below it (30 ° C), which significantly reduced operating costs.

References

1. A.S. Makogon G.V. Kulikov, A.I. Kazmina, Actual problems of architecture, construction and energy saving, Simferopol: NAPKS, **24** (2012)
2. Yu. I. Blinov, Construction and architecture, **8** (1985)
3. A.A. Khayrullin, Kama State Engineering and Economics Academy (KPI), **2** (2007)
4. F. Otto, F.K Schleier. Tent and cable-stayed building structures, Moscow: Stroyizdat (1970)
5. V.A. Skopenko, Academic Bulletin UralNIIPproject RAASN, **1** (2010)
6. F. Otto, R. Trostel, Pneumatic building structures. Design and calculation of structures from cables, nets, Moscow: Stroiizdat (1967)
7. G. Rüle, METAL, PLASTICS, CERAMICS, TREE, Moscow: Stroyizdat, **2** (1974)

8. V.V. Ermolov, U.U. Byrd, E. Bubner, Pneumatic building structures, Moscow: Stroyizdat (1983)
9. ZAO Trust-Walter, Texlon System and CPC Walter, On-line: <http://www.rostent.ru>
10. Ivanovoiskozh (Ivanovo), On-line: <http://www.ivanovoiskozh.ru>
11. M.V. Kindinova, G.V. Kulikov, A.I. Kazmina, Actual problems of architecture, construction and energy saving, Simferopol: NAPKS, **24** (2012)
12. Guideline Mehler technologies «Technical guideline to permanent tensile architectures», On-line: <http://www.mehler-texnologies.com>
13. "Textile architecture precontraint 1002S-1202S-1302S-1502S», On-line: <http://www.ferrari.architecture.com>
14. The Serge Ferrari Group «Special issue Sports venues», Serge Ferrari newsletter - flexible composite materials, **7** (2012), On-line: <http://www.sergeferrari.com>
15. V.N. Kupriyanov, Slick-tent materials for building structures.: MHTI name of V. I. Lomonosov (1978)