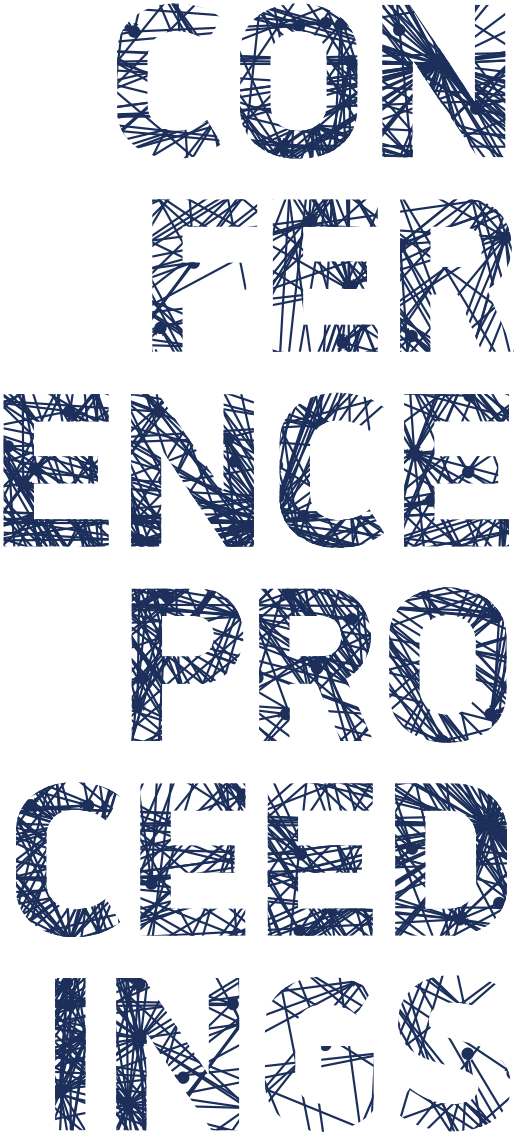

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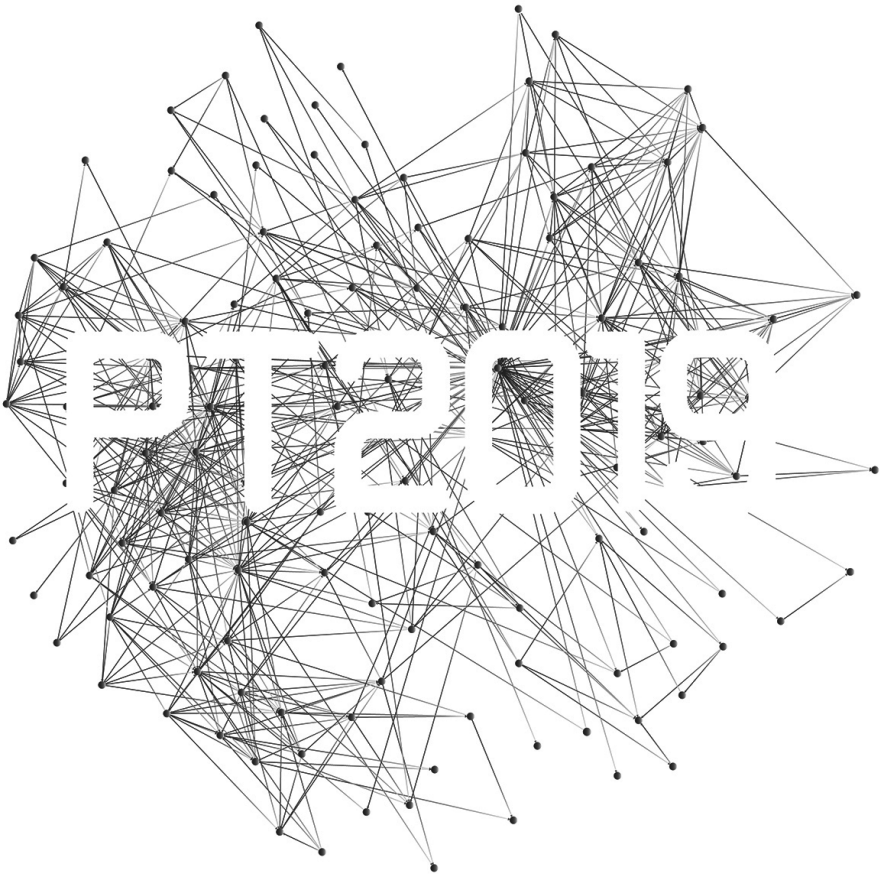

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PLACES AND TECHNOLOGIES 2019

KEEPING UP WITH TECHNOLOGIES TO TURN BUILT HERITAGE INTO THE PLACES OF FUTURE GENERATIONS

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TEXTILE MEMBRANE STRUCTURES IN REFURBISHMENT OF BUILT HERITAGE

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ABSTRACT

The aim of the research is to investigate the current developments in the use of textile membranes in architecture. More precicely this research is focused on usage of textile membrane structures in refurbishment of built heritage.
The main goal of the application of this type of structures is reafirmation of built heritage. The idea is based on using this space for open air theaters and music events.
This research looks into options to find solutions which enable afirmation of historical places and their new further usage by aplicating textile membrane structures. This will be done through the following objectives: 1. defining textile membrane structures and other terms and concepts important for understanding the research, 2. a historical overview of the beginning of the use of membrane structures in refurbishment of built heritage, 3. defining set of requirements that these structures in refurbishment of built heritage have to carry out, 4. case studies, 5. systematization of applied materials, 6. systematization of textile membrane structures.
This would be 3-part research: 1. research of textile membrane structures and it's application, resulting with tipology of textile structures, 2. research of principles of built heritage protection and presentation, resulting with set of requirements that textile membrane structure should carry out, 3. case studies. This research is completed with examples of application of this structures in Serbia in the context of built heritage protection and presentation.

Keywords: textile membrane structures, built heritage, protection, presentation, reafirmation

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INTRODUCTION

The protective membrane structures are increasingly being used in projects for refurbishment of built heritage as they meet a wide range of criteria relating to simple installation, dismantling, transportation, maintenance, adaptation to tourist visits and more. These structures, in addition to the above mentioned criteria, must also meet the requirements for preserving the authenticity of the built heritage and its presentation. Protective membrane structures should offer the possibility of changing their initial shape, without neglecting the possibility of upgrading the structures or enlarging the area under them. It is extremely important that the installation of these structures does not require the use of cranes or heavy machinery because of the possibile damage to the historical monuments.

Protective structures have a primary role in the projects for the refurbishment of built heritage. They ensure safety of the further deterioration of the remains of objects of importance. Jelena Ivanović- Šekularac, Jasna Čikić Tovarović and Nenad Šekularac divide protective structures into: 1) permanent (Fig. 1) and 2) temporary (Fig. 2).

Figure 1: Permanent protective steel structure over the site in Lepenski Vir.

Figure 2: Temporary protective wooden structure over Medijana.

Temporary protective structures are a special type of structures which is independent of the existing structure: static stability of the existing structure is not put at risk. Implementation of this type of protective structures allows smooth reconstruction and restoration works. All construction works, procedures and materials that are used for protective structures must provide stability and cover the facility or its specific parts, they must be reversible as well. It is a method that provides the return of the facility to its original state without any damage (Ivanović-Šekularac et al, 2017:31).

Shells are thin-walled supporting structures with spatial load transfer. They are structures of a single or double curvature in which one dimension - the thickness is small in relation to the other two dimensions and the radius of the curve (Nestorović, 2000:73). The perfectly flexible shell is called the membrane (Hajdin, 1984:9). Thus, hereinafter the term membrane will refer to the state of stress in the structures, and not to the applied material.
Membrane structures belong to a group of lightweight structures, and they will be hereinafter referred to as lightweight structures. Any structure, whose shape structure, regardless of the type of material used, is determined through the process of optimizing the elements for the effective carrying of the relevant load, can be called lightweight structure. Lightweight does not indicate a quantitative value of the structure, but the qualitative one: it does not indicate the bulk density but the subjective feeling of the structure in the space.
Having reviewed literature, and in accordance with the theme of work, protective membrane structures will refer to primary structures with a fabric cover, which cover archaeological sites and other forms of built heritage, in order to protect and present them.

The primary structure is most often materialized in the form of (Ivanović-Šekularac et al, 2017:31):

- steel structures (Fig. 3),
- wooden structures (Fig. 4),
- tent structures (Fig. 5).



Figure 3: Primary steel structure of the protective membrane structure in the courtyard of the castle Kufstein.

Figure 4: Primary wooden structure of the protective membrane structure in Medijana.

Figure 5: Tent structure of the protective membrane structure over the churchyard in Bad Hersfeld.

BEGINNING OF MEMBRANE STRUCTURES APPLICATION IN PROJECTS OF BUILT HERITAGE REFURBISHMENT

By analyzing the examples of the protective membrane structures application in the projects for the refurbishment of the built heritage, the systematization of the same can be done based on the changes of the initial sthape of the structure, as follows:

- fixed structure (the primary structure does not change the position)(Fig. 6),
- mobile structure (the primary construction is movable, which allows a different degree of openness and exposure of the built heritage that it covers) (Fig. 7),
- convertible structure (the primary construction does not change the position, but the wrapper can open and close) (Fig. 8).



Figure 6: Fixed protective membrane structure, arena Nimes, France.

Figure 7: Mobile protective membrane structure, Jaen, Španija.

Figure 8: Convertible protective membrane structure, summer stage in Luxembourg.

Studies of built heritage refurbishment, which require strict compliance with established principles, have a direct interest in the development of membrane structures: based on the analyzed examples of the application of the protective membrane structures, their dominant application in the projects for the refurbishment of the built heritage can be confirmed.

In addition to testing the characteristics of textiles, when designing a protective membrane structure in the projects for refurbishment of built heritage, it is necessary to examine a suitable methodological approach so that the structure could respond to the specific context and to establish a close connection with the existing facilities. According to Alessandra Zanelli, the key

criteria that the protective membrane structure has to satisfy in the projects of built heritage refurbishment are:

- high degree of flexibility
- simple installation and dismantling
- possibility of reusing after dismantling

In accordance with the protection principles for the refurbishment of built heritage prescribed by Ikomos (ICOMOS), and which relate to the preservation of authenticity, precisely defined by the Nara Document (1994), Alessandra Zanelli and Josep Llorens set out the following criteria which the new structure must satisfy (Llorens, Zanelli , 2016:20):

- preserve the historic character of the building,
- be non-invasive and compatible with the existing building,
- be different from the historic structure.

According to Monica Macieira, the protective membrane structure can be part of the refurbishment of built heritage as an element (Macieira et al, 2017: 7):

- protection from the sun,
- for the integration of heat,
- protection from ice,
- heating system,
- cooling system,
- for the production of electricity,
- for ventilation,
- information transfer (media-facade),
- for water protection,
- for acoustic absorption,
- structural armatures,
- earthquake protection (non-structural element).

According to Christian Schittich, Carlo Scarpa is considered to be the pioneer of the creative refurbishment of built heritage whose main principle was a contrasting material- making a clear distinction between the existing and the newly designed through the use of contrast materials (Fig. 9).

Figure 9: Application of contrasting materials to the refurbishment of the castle in Verona (Castelvecchio).

Alessandra Zanelli states a resurbishment project for the of the Križanke Outdoor Theater (Križanke Summer Theater) in Ljubljana in 1964 as the first example of the application of textile membrane structures in the refurbishment of the built heritage.

The theater within the ruined University Romanesque Church in Bad Hersfeld (Stiftsruine Bad Hersfeld), the remains of which are considered to be the largest in the world, and which was built in 1038, was covered by a textile membrane structure in 1968 with the aim to reduce the impact of daily and seasonal climate change on the possibility of using the summer stage. The author of the project was Frei Otto. The structure consists of a central pillar 32m high, textile cover and tension cords. The structure can be opened / closed as needed in a few minutes (Figure 10).

Figure 10: Opening / closing the textile membrane structure above the church yard in Bad Hersfeld.

PROPERTIES AND SYSTEMATIZATION OF APPLIED MATERIALS IN PROTECTIVE MEMBRANE STRUCTURES

By the beginning of the 20th century, various materials were used in tent structures. Starting with primitive tents made of animal skin, through concrete membranes, in the first half of the 20th century we come to social and technological progress, which resulted in the invention of new textiles. The intensive use of textiles in membrane structures began after World War II. Until then, conventional objects differed on the basis of the material used. Unlike conventional objects, the membrane structures are distinguished by the immutability of the structural system in relation to the applied covering material. The membrane structures are mostly double-curved and the applied material, according to Rogier Houtman, must meet the following conditions (Houtman, 2015:101-103):

- it must be able to transmit only tensile stress,
- it must be able to allow deformation.

Woven material or foil is usually used for membrane structures. Any material whose thickness is negligible in relation to the surface is considered to be foil. Modern architecture has recognized the potential in the application of foils in such structures. This explains why membrane structures are often referred to as textile structures (Houtman, 2015:101).

There are currently two main types of structure systems in which textiles are involved: pneumatic systems (Figure 11) and membrane systems (Figure 12).

Figure 11: Pneumatic structure of the arena in Tokyo (Tokyo Dome)

Figure 12: The membrane roof structure of the Bullring Arena (Zaragoza, Spain)

Pneumatic systems are structural systems in which the principles of mechanical engineering are used: positive internal air pressure is used to stabilize the membrane (Nestorović, 2000: 239). Membrane systems use cables, steel or other frames as a primary structure, through which textiles are tensioned. Both systems are lightweight, and are characterized by the rationalization of the structure that can bridge the large ranges.

PROPERTIES AND SYSTEMATIZATION OF TEXTILE MEMBRANE STRUCTURES

The criteria that the textile must meet differ in the pneumatic and membrane structures. In order to focus on the theme of work, in this chapter, we will discuss only the criteria that textiles must satisfy in membrane structures.
Having reviewed practical examples, depending on the position / location of performance, the protective membrane structure are divided into:

- external (exterior),
- internal (interior).

A group of authors gathered around Alessandra Zanelli distinguishes the following characteristics of temporary external protective textile membrane structures (Zanelli et al, 2013:2-3):

- a high degree of flexibility,
- adaptability to geometry of space,
- ease of construction,
- simple construction and dismantling,
- easy transport,
- easy maintenance,
- possibility of reuse.

However, depending on the type of applied textile, the performance of these systems can be improved in relation to the specific requirements of the environment in which the system is placed. Many authors set criteria which textile in external protective membrane structures must satisfy:

- mechanical requirements (tensile strength, elasticity),
- watertightness (resistance to atmospheric precipitation),
- vapor permeability (in order to avoid condensation),
- ventilation,
- translucency (in order to illuminate the space under the structure naturally),
- reflectivity,
- self-cleaning (which means that dirt, chemical particles, dust are washed with water),
- fire resistance.

Systematization of protective textile membrane structures based on the type of applied covering material

Today, awareness of the importance of applying technologies and materials that meet the principles of environmental conservation and ecology is significantly increased. Textile membranes and foils offer efficient solutions that satisfy aesthetic parameters, not only because of their lightness, mechanical and chemical properties, but also because of their adaptability to changing environmental parameters and functional flexibility (Macieira et al, 2017:3). Technological progress has resulted in innovations in the field of material development. We distinguish two types of textiles in protective membrane structures:

- untreated textiles,
- treated textiles.

Untreated textiles have a high degree of watertightness, and low resistance to UV radiation, bacteria and fungi, and for this reason it is rarely applied in protective membrane structures. The twentieth century brought innovations in the field of materials laminating, and the aforementioned problems were overcome by coating the fabric with polymer material for protection, improving its performance and lifetime. According to the representation in membrane structures, there are three types of textiles (Drew, 2008: 32):

- polyester with a PVC coating,
- fiberglass coated with PTFE,
- fiberglass silicone coating.

Polyester coated with PVC is the cheapest and easiest to manipulate as compared to the other two materials, but it also has the shortest lifespan. According to Philip Drew fiberglass coated with PTFE and polyester fabrics coated with PVC have a 90% share in materials used in membrane systems. The basic structure of these three materials is: the first (bottom) layer is a basic fabric, usually made of polyester or fiberglass.

Today, a large number of companies are engaged in improving the textiles performance, which resulted in textiles of different durability, specific weight, resistance to chemicals, paints, and more. By analyzing the practical examples, the dominant application of polyester with a PVC coating has been established.

CONCLUSION

The aim of this study is to perceive the possibilities of using textile membrane structures in the projects for refurbishment of built heritage. Having analysed the practical examples and reviewed the literature, the systematization of applied materials, both structures and coverings, is carried out, and the parameters that such a structure should satisfy in the refurbishment of built heritage are defined.

The general conclusion of the research would be that textiles have inherent qualities and performance that extend the range of applications of textile membrane structures in the construction and reconstruction of buildings, such as: resistance, flexibility, adaptability, low specific weight, easy transport and installation, resistance to adverse weather conditions, reduced economic and environmental impact, reversibility.

By analyzing the relevant examples and reviewing the literature, it can be concluded that the wooden primary structure is applied in the design and construction of protective textile membrane structures, but the application of the steel primary structure is more frequent. By analyzing the relevant examples, the dominant application of fiberglass coated with PTFE is noticed.

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