

The external covering is subjected to climatic conditions such as temperature fluctuations, UV radiation, humidity, and wind. Flexible connectors are used to mitigate the adverse effects of these factors, compensating for material deformations.

The use of insulation systems significantly reduces building energy consumption, lowers heating and cooling costs, and increases the comfort of interior spaces. Composite materials employed for insulation are characterized by high strength, longevity, and environmental safety.

Modern technologies and a wide range of materials make it possible to create efficient, economical, and durable insulation systems that meet contemporary energy efficiency standards in construction.

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TENT CONSTRUCTION AS AN INNOVATIVE STEP IN ARCHITECTURE

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The tent form is an architectural typology that spans centuries and borders, serving as a staple across cultures. Early nomads used skins pulled over wooden poles, animal bones, antlers, and tusks to protect themselves from cold and windy conditions. Today, modern architects use basic physics and engineering to design large-scale contemporary buildings. The tent is a complex architectural language – one that straddles the line between the temporary and the permanent, while also functioning as a symbol of modernity and the depth of simplicity. Architects have employed versatile materials and often moved beyond the straightforward teepee structure (commonly used by American Indians) to create inspiring tents. Today, tents are made from glass-reinforced fibers and self-cleaning Teflon coatings, which enhance the fabrics' strength, fire resistance, insulation, and reflective properties. Moreover, these contemporary projects often feature programs that extend beyond conventional tent uses, offering new possibilities for architectural applications.

A membrane structure is a term commonly used to refer to roof constructions that use a membrane supported by steel cables. Their main characteristics are the way they work in tension, their ease of manufacture, their ability to cover large spans, and their flexibility. This structural system requires a

small amount of material due to the use of thin webs that, when stretched with steel cables, create surfaces capable of withstanding the forces imposed on them. A structure with a thin, flexible surface (membrane) that carries loads primarily through tensile stresses. Membrane structures have many merits: they allow the interior space to be unobstructed by pillars and provide a unique way of insulation and air circulation. Additionally, there is a specific idea of installing membrane panels on the exterior of a building for temperature regulation inside.

There are three main tension systems for membrane structures:

1. Membrane Tension Structures are held in place by cables, allowing the tensile stresses to be distributed through their own shape. In structural engineering, a tensile structure is a construction made up of elements carrying only tension, with no compression or bending. The term “tensile” should not be confused with “tensegrity”, which is a structural form involving both tension and compression elements. Tensile structures are the most common type of thin-shell structures [1]. Most tensile structures are supported by some form of compression or bending elements, such as masts, compression rings or beams [2]. A tensile membrane structure is most often used as a roof, as it can economically and attractively span large distances. Tensile membrane structures may also be used as complete buildings, with common applications including sports facilities, warehouses, storage buildings, and exhibition venues.

2. Stretched Nets use a grid of cables to carry internal forces, transferring them to individual elements, such as sheets of glass or wood.

3. Pneumatic Constructions involve protective membrane supported by air pressure. A membrane structure is stabilized by the pressure of compressed air. Air-supported structures are held up by internal air pressure, while a network of cables stiffens the fabric. The assembly is supported by a rigid ring at the edge. The air pressure inside the structure is slightly above normal atmospheric pressure and is maintained by compressors or fans. Airlocks are required at entrances to prevent loss of internal air pressure. Air-inflated structures are supported by pressurized air within inflated building elements that are shaped to carry loads in a traditional manner. Pneumatic structures are perhaps the most cost-effective type of building for spanning large distances, making them highly suitable for long-span applications.

Recent advancements in tent design have led to the integration of mechanical movement, transforming these structures from simple architectural forms to dynamic systems that enhance the comfort of occupants and improve the quality of life in the modern world. This evolution has paved the way for new approaches to building design, offering increased flexibility, energy efficiency, and adaptability to changing environments.

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RETROSPECTIVE ANALYSIS OF GLOBAL EXPERIENCE IN PROTECTING INFRASTRUCTURE FACILITIES

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Energy security is a key factor for stable economic development and welfare of the state. The full-scale invasion of the Russian Federation into Ukraine in 2022 has been accompanied by significant threats to energy infrastructure facilities, primarily through the use of high-precision air attack weapons. Therefore, building an effective infrastructure protection system is an urgent task that requires a comprehensive approach, using the analysis and application of global experience for infrastructure protection.

The history of use of protective structures by humans spans several millennia. The development of underground space began in deep antiquity. In the period before the 4th millennium B.C., natural caves can be considered prototypes of underground protective structures, which were used by our ancestors as dwellings that protected them from bad weather and predators [1]. Beginning from the 4th millennium B.C., people started to conduct significant underground works. The most important types of underground construction at that time were the digging of tunnels, underground communication passages, canals, construction of water supply systems, and even underground cities.

The next phase in the evolution of underground protective structures is represented by the fortification construction of the medieval period, when the progress of armaments and the introduction of artillery systems, particularly cannons, necessitated the protection of strategic elements of fortification structures during siege operations (water sources, gunpowder depots, military premises, etc.), which led to their placement below ground level or behind massive multi-layered defensive walls. Fortifications and castle complexes performed an essential defensive function in the medieval era, resulting in their often containing developed systems of underground communications and engineering structures [1].

Mining workings and caves began to be actively used for military purposes (as protective structures) only in the 20th century due to the emergence and widespread use of bomber aviation in wars. At the same time, many underground industrial facilities (such as pumping and compressor stations, blast furnace pits, etc.) were constructed at shallow depths. Underground factories, which began to be built in the 1930s, are characterized by great depth of placement.