PlusMinus

Pneumatic gridshell

Winner oft the
Bauwelt Preis 2011

Info

Building with positive and negative pressures

Self-righting tubes: fast assembly time without time-intensive auxiliary constructions

PlusMinus is a project initiated by students of the University of Stuttgart, Architecture Faculty, Institute for Lightweight Structures and Conceptual Design, in cooperation with the Bionic Learning Network of Festo.

In the field of architecture and civil engineering, the gridshell is regarded as one of the most efficient load bearing structures. The latticework of linear, rod-like elements can span large areas without support and with a minimum of material. It can also be formed into almost any shape. The joints where the rod elements cross obviously play a key role. During assembly, the joints are fixed in position, but can still be turned. The latticework is subsequently given its final shape with the aid of an auxiliary construction, whereby the orthogonal meshes are pushed into diamond shapes. By rigidly fixing the joints, the gridshell becomes firm and can thus bear any load acting on the structure.
The project "PlusMinus – the pneumatic gridshell" goes one step further: by reassessing the materials and method of assembly, and reinterpreting key structural points in order to make gridshells even more efficient. The idea is take a new approach with regard to the structure's own weight, keeping it as light as possible. At the same time, however, the ratio of load bearing capacity to weight must not be compromised.

In addition to the constructive targets, aesthetics and spatial awareness also play a major role. The lightness of the structure should also be visually apparent to the observer – firstly, through the choice of a suitable material and secondly through the spatial quality defined by the latticework structure.

In order to meet these modified requirements, only one material was used for the construction: transparent plastic film. The latticework is formed by inflated film tubes which are flexibly connected with each other via the joints. By inflating the tubes, the structure erects itself – thereby doing away with the need for time-intensive auxiliary constructions.

In order to preserve the structure's stability, the tubes must be continually supplied with an air pressure of approx. 0.5 – 0.7 bar. The gridshell can only bear loads when all joints have been fixed and the construction has thus become rigid. In order to achieve the reinforcement effect, two shell films are vacuum sealed above and below the tube latticework and press the air-filled tubes to the joints.

The pneumatic gridshell is a product consisting of various system components designed to minimise materials and costs while enabling fast construction.

Ground membrane: textile floor plan
The tensile stress resulting from the structure is transferred to a ready-made, coated textile fabric on the floor. Base elements are fixed into the fabric and connected with each other along the two longer sides. The ground membrane is thus responsible for fixing the gridshell in position and providing the floor plan.

Base elements: modular air and power supply
22 trapezoidal supply elements of a modular couplable system are positioned along the ground membrane. Each individual base element is designed in such a way that it can be supplied via connectors with air for the tubes, as well as electricity for light and the negative pressure ventilators. Each unit also has two guide rails in which the tube feet are anchored. The vacuum is generated by fans which are installed in every second element. In order to aid transport, a base dimension of 1.2x0.36m was chosen so that the elements can be easily stacked on Euro pallets. For reasons of efficient production and sustainability, the modules are made from wood-based materials.

Feet: set at any angle
The gridshell's feet play an important role in the overall construction. Each individual element has several, integrative functions: a ball joint connects the tubes with the base elements and allows them to adopt any angle required. With the aid of various clamping mechanisms, the tubes are kept airtight and firmly fixed with the foot. The high inner pressure prevents them from slipping out.
At the same time, the supply lines for electricity and air are led through the extremely compact component. The tubes are lit from within by high-performance LEDs.

Tubes: stable inflatable latticework
34 polyamide film tubes with a thickness of 55mu form the latticework of the structure. In order to give them greater stability, the tubes are made of two-layer film. The lengths of the individual tubes are calculated by a 3D scan of the concept model as well as by a computer model. In the entire construction, only two diagonal tubes are connected at both ends with the feet. The ends of the other 32 tubes overhang freely and are sealed by airtight clamp beading.

Shell films: vacuum reinforcement
The two shell films consist of ready-made polyethylene film and provide the necessary reinforcement for the gridshell. Parts of the film are clamped to the base elements. In the two entrance areas, the films are welded on site. Together, the clamping strips and weld seams ensure an almost airtight system for the negative pressure.

Supply unit: semi-automatic external control
The provision of air and power, as well as negative pressure for the shell films, is regulated semi-automatically by an external control device. The gridshell can therefore be supplied autonomously and any leaks can be compensated for.

The pneumatic gridshell is designed for temporary use. Its key benefits are its low weight and fast assembly and dismantling times. The gridshell's ability to create spatial environments opens up a wide range of applications, such as for concerts, events or exhibitions. The versatility of its inner space and the eye-catching effect of the material used are strong arguments in its favour. PlusMinus subtly combines efficiency and aesthetics. Structures using pressurized tubes reinforced with vacuum shells are an innovative construction possibility for architects. Similar construction methods in which pressure differences in cell structures provide stability can be found in nature. A dragonfly's wing, which generates its shape and stability via internal pressure, is similar to the positive pressure of the tube latticework. The suction cups of the squid or great diving beetle achieve tremendous holding forces with the aid of negative pressure. This principle is applied for the shell films of the pneumatic gridshell in order to give the structure its rigidity.

The LRP-1/4-2.5 pressure regulators and MS maintenance device combination from Festo provide precise pressure regulation for the tubes and thus ensure the stability of the temporary structure. The positive pressure in the tubes is detected with SDE5 D10 sensors from Festo. In the field of automation, these Festo components secure the daily operation of factories around the world.

Festo stands for innovation with pneumatic and electric drives. With their PlusMinus design, the students of the University of Stuttgart have demonstrated that new membrane-based structures using positive and negative pressures are possible. PlusMinus represents a new and unique structure in the field of temporary membrane construction.

Technical details

Length:	16,50 m
Width:	10,40 m
Height:	3,60 m
Capacity:	270,00 m^3
Covered area:	112,20 m^2
kg per covered m^2:	3,78 kg/m^2
Total weight:	423,20 kg
Transport volume:	2,60 m^3
Operating pressure:	0,40 and 0,65 bar with two feedback control systems
Initial assembly:	25,00 h with latticework construction
Further assembly:	6,00 h
Material base elements:	Waterproof laminated wood
Tubes:	Polyamide
Shell film:	Polyethylene
Control Supply:	Compressed air supply via loop with several independent feedback control systems
Type of operation:	Automatic pressure regulation

Project partners

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