tensinantes2023 : TensiNet Symposium 2023 at Nantes Université
Membrane architecture: the seventh established building material. Designing reliable and sustainable structures for the urban environment.

Proceedings of the Tensinet Symposium 2023
TENSINANTES2023 | 7-9 June 2023, Nantes Université, Nantes, France
Jean-Christophe Thomas, Marijke Mollaert, Carol Monticelli, Bernd Stimpfle (Eds.)

Swatch Omega Headquarters - Multifunctional ETFE-Modules in Building Envelope

Karsten Moritz*, Koffi Alate *

* Taiyo Europe GmbH, 82054 Sauerlach, Mühlweg 2, Germany

info@taiyo-europe.com, www.taiyo-europe.com

Abstract

Contemporary membranes, i.e., very thin, flexible components made of high-performance fabrics, were developed since the end of the 1950th, 20 years later also made of foils. At first, they were only seen as pre-tensioned sails over exposed open spaces, later also, for example above grandstands of stadiums and arenas. Today they belong in the well-known canon of innovative materials and construction methods. Membrane construction is already taught at universities as part of the study to become an architect or structural engineer. Today, the interested observer will discover membranes also as part of building envelopes in many cities around the world. This is thanks to the evolution of the sophisticated materials and construction methods, from sail to multifunctional and transparent or translucent multilayer-modules. The Swatch Omega Headquarters in Biel, Switzerland, completed in 2019, shows the possibilities like no other building, but also some challenges when using modular elements cladded with membrane materials used in the building envelope - in this case ETFE-foils.

Keywords: Membrane structure, ETFE-foil cushion, building envelope, lightweight construction, multifunctionality, modularity, pre-fabrication, serial production

Figure 1: Bird's eye view, ©Swatch Omega AG

1. Introduction

The s-shaped Swatch-building with an enveloping surface of 11,000m² and a height of 27m measures in plan-view 240m in length and 35m in width. It is an eye-catching and exciting building, but its shape blends harmoniously into the urban environment. The impressive building has been designed by the Japanese architect and Pritzker Prizewinner Shigeru Ban. [1] – [6], (Fig.1).

The spatial structure consists of a barrel-shaped lattice shell made of high-strength glue laminated timber (GL 24h to GL 32h). The wood used, mainly spruce (1.997 m³), comes from Switzerland (1,997 m³) [4]. The lattice structure forms 2,800 honeycombs of very different geometries. In addition, nine balconies (each 10-20m² in size) penetrate the building shell [4]. The honeycombs formed in this way were fitted with precisely produced double curved modular frames also made of glued laminated timber.

Depending on the requirements of the respective interior, the module frames were fitted with different fillings. In addition to many modules with glass panels, some with integrated sun protection, there are 898 modules, some of which are cladded with transparent and some with translucent white ETFE foils, clamped by aluminum profiles making them durable, weatherproof and airtight.

The company Roschmann, located in Gersthofen, Germany, as general contractor was responsible for the planning, manufacturing and assembly of the building envelope's cladding made of hundreds sophisticated wooden modules, equipped with compositions of glass, ETFE-foils, polycarbonate plates and other materials. Taiyo Europe GmbH located close to Munich, specialized on membrane structures, also ETFE-foils, was commissioned by Roschmann with the planning, manufacturing and assembly of the ETFE foil modules, but also with the air supply for all modules, also the ones with glass. Some of the challenges in this construction task are described below.

Figure 2: Exterior view from a balcony, ©Swatch Omega AG

2. Air-flushed CCF building-envelope

The air flow through the ETFE foil modules ensures a low nominal overpressure of 250 Pascal. As a result, the ETFE foils are doubly curved, i.e., synclastic and prestressed. In this way, they can absorb loads from wind and snow via tensile forces and transfer them to the module frame, from there to the grid shell primary structure. In addition, the pretension causes the foils to tighten and, therefore, to prevent wrinkles.

The blown-in air flow is cleaned and pre-dried using air filters and adsorption dryers in order to avoid the accumulation of dust and the formation of condensate in the intermediate space. The modules fitted with glass also have this air flow. This type of façade-construction, used here for glass and membrane structures is called “closed cavity façade” (CCF). This technology has been used in ETFE-foil constructions since the early 1980’s. It has proven itself, therefore, for many years in building construction. In this way, also components integrated, such as sun protection slats and retractable curtains, remain permanently dust-free.

In total 898 of the spatially curved glued laminated timber modules are equipped with two layers of ETFE-foils. Thereof 721 modules (2,726m²) are additionally equipped with double-web polycarbonate-plates bended around both axes in the space between two separate foils (type I). These modules are located in areas with high thermal insulation requirements. They deliver the best possible protection, with a simulated thermal transmittance (U-value) around 0.6 W/(m²K) depending on the module’s composition and geometry. 170 modules (170m²) have been realized as conventional double-layer ETFE-foil-cushions above open spaces (type 2). 74 modules (309m²) are openable to naturally ventilate the interior (type 3, see Fig. 4). More than 3,500 m² of the envelope’s surface (in total 11,000m²) are showing modules equipped with ETFE-foils. Figure 3 shows number and location of the module-types used.

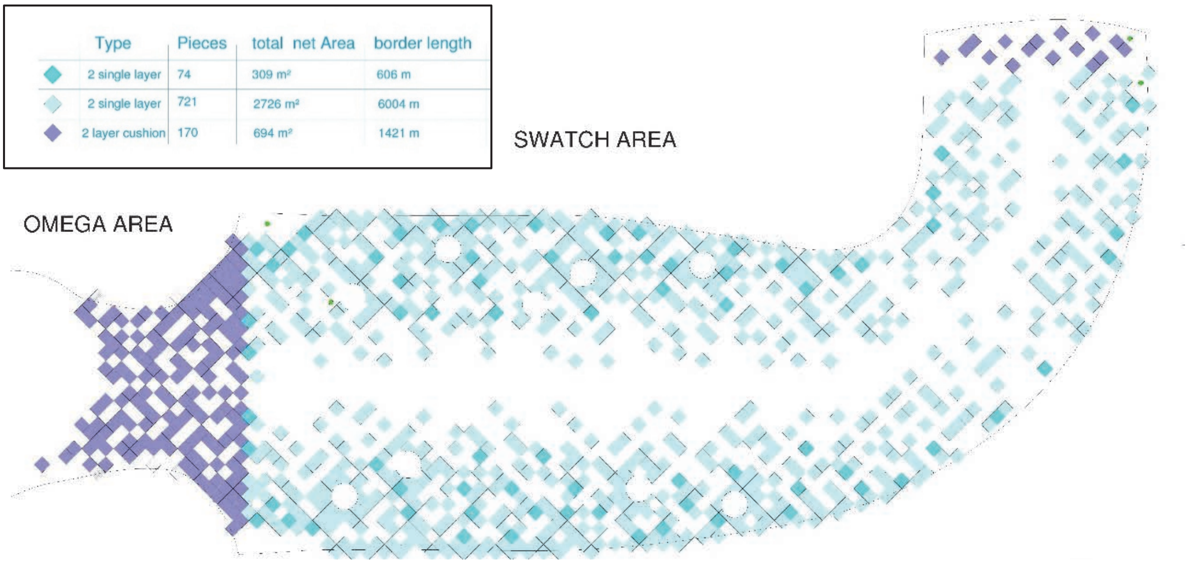

Figure 3: Ground plan view of the Swatch building – 3 ETFE-module types, ©Taiyo Europe

The architects also attached great importance to good room acoustics. For this purpose, a large number of cross-shaped soft surface elements were attached to the inside of the roof skin. The ETFE foils also contribute to good room acoustics, as they are soft and therefore sound-absorbing. They reduce the time of reverberation compared to hard materials.

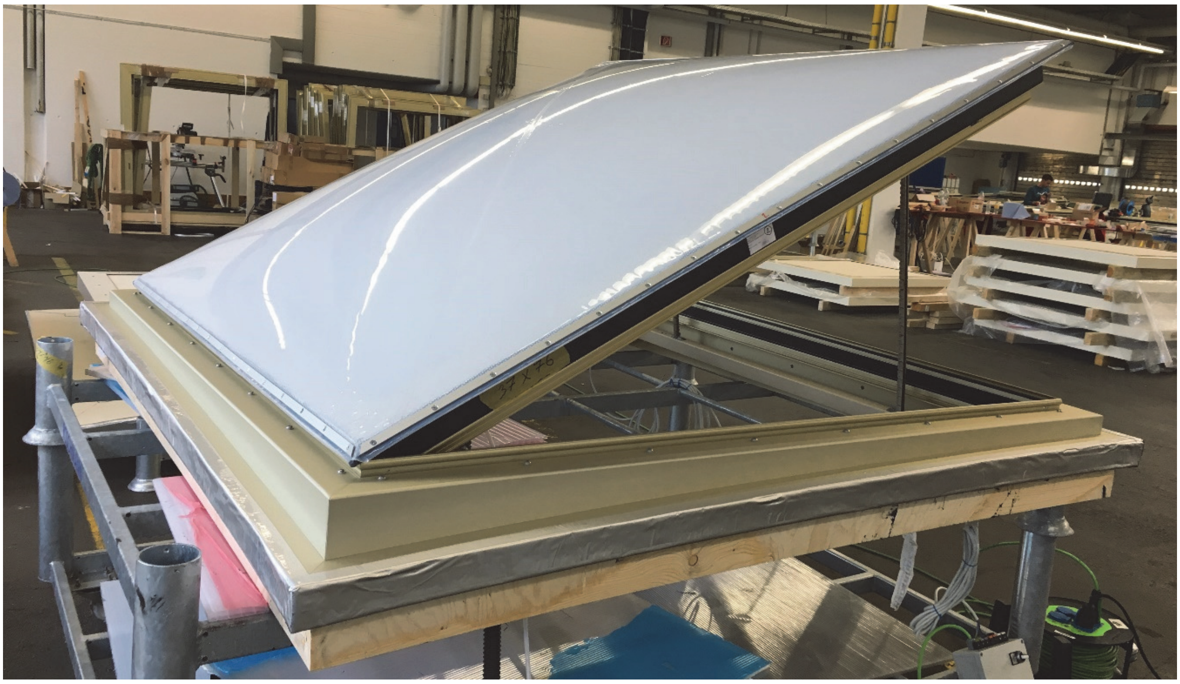

Figure 4: Dry run of an openable module (type 3), Roschmann workshop, ©Taiyo Europe

3. Prefabrication

Each honeycomb has its own double-curved geometry. Therefore, cutting pattern generation, foil-cutting and welding of the ETFE-element's boundary (keder-pocket) were time-consuming. Additionally, the uneven barrel-shaped lattice shell geometry led, in some cases, to very small modules and to extremely sharp corners of the ETFE-elements (Fig. 5 and 7).

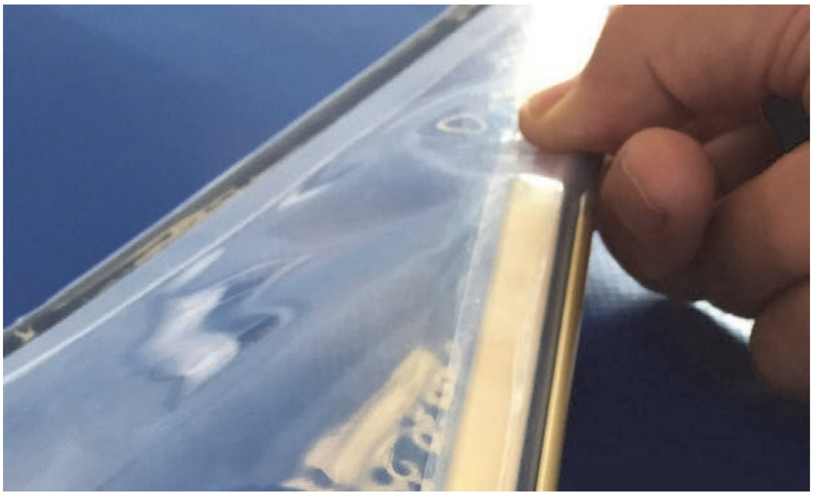

Figure 5: 1:1 test sample of a sharp ETFE-foil-corner produced by Diaferia, ©Taiyo Europe

All ETFE-foil elements were precisely welded together in the factory according to the cutting planning and the static analysis, taking into account the materials and systems rigidity. The edges of each element were formed by a circumferential welt pocket, also made of ETFE foils. A so-called “keder”, i.e., a round cord, for example made of EPDM and with a diameter of 4.5mm, was then drawn into this pocket (Figures 5 and 6). Then the prepared clamping profiles, were pushed onto the welt pockets in order to fasten the entire element to the inside of the wooden frame with a precise fit. Prepared means in this case: cut to length, pre-bent, pre-twisted, drilled, deburred, anodized, stamped with an individual number and cleaned. Due to the three different module types, there were a number of different profile-types. At the request of the architects, all visible profiles were anodised in a gold tone (Fig. 8-11).

So that the foil-element is wrinkle-free under overpressure at the end, the foils are cut smaller along the element’s boundary than the boundary-lengths are occupies when installed. This means that you have to pull the respective profiles together with the ETFE-element to the wooden frame so that you can connect the assembly with the prepared wood screws. With the partially doubly curved and axially twisted wooden frames, this work step was like a game of patience, especially in the sharp corners (Fig. 5 and 7). To make matters worse, the seal previously glued between the clamping profile and the wooden frame must not be damaged. After installing the foil elements (and in Type 1 also the polycarbonate sheet between the two individual layers), the entire module was subjected to an airtightness test lasting half an hour (Fig. 8 and 9). If the overpressure applied in a defined manner and measured with a calibrated manometer was not constant during this time, the element was opened again, the leak searched with the help of a foam-forming liquid and sealed. The element was then re-assembled and the leak test repeated. No module left the production hall without the proof of airtightness.

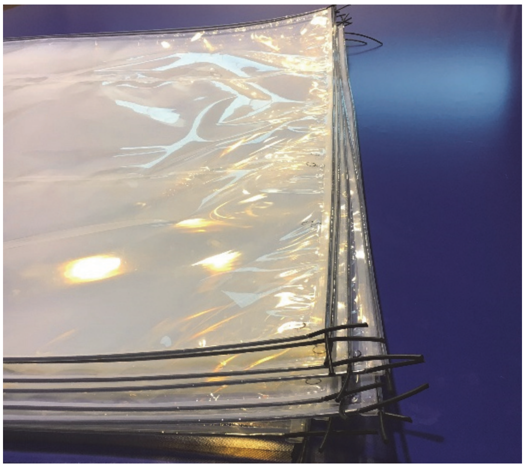

Figure 6: Welded transparent ETFE-foil elements, produced by Diaferia, ©Taiyo Europe

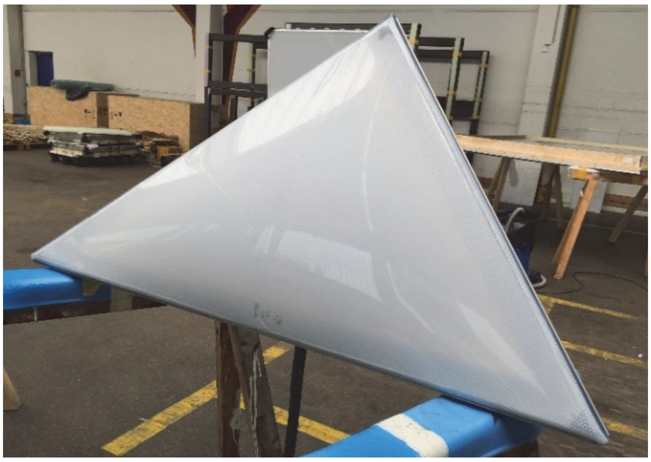

Figure 7: White ETFE-foil element mounted on a timber frame and tested with an internal overpressure, ©Taiyo Europe

The factory assembly of the prefabricated wooden frame modules with an average of 40 component categories (clamping profiles, fasteners, ETFE foils, polycarbonate plates, seals, gaskets, inlet and outlet valves, pressure sensors, bushings for sensor cables, …) was carried out with meticulously pre-planned work processes, i.e., serially to a certain extent. The prefabrication took place in a workshop in Gersthofen, which was provided by Roschmann especially for this project. However, since there were no identical modules among the 898 modules, the relatively light wooden frames were turned manually so that they could be processed and fitted from both sides (Fig. 7 – 17). In hindsight, this decision also proved to be the right one, as leaks could be identified, and the process could be optimized quickly.

Ultimately, however, the construction industry must also admit that other economic sectors are significantly more advanced in terms of serial and automated production methods.

Figure *8:* *Clamping profiles anodized in a golden tone, straight, pre-bended and pre-twisted, ©Taiyo Europe*

Figure *9:* *Fixation test of a clamping profile with inserted keder-pocket, ©Taiyo Europe*

Figure *10:* *Each profile was given an individual stamped number for correct placement on the component, ©Taiyo Europe*

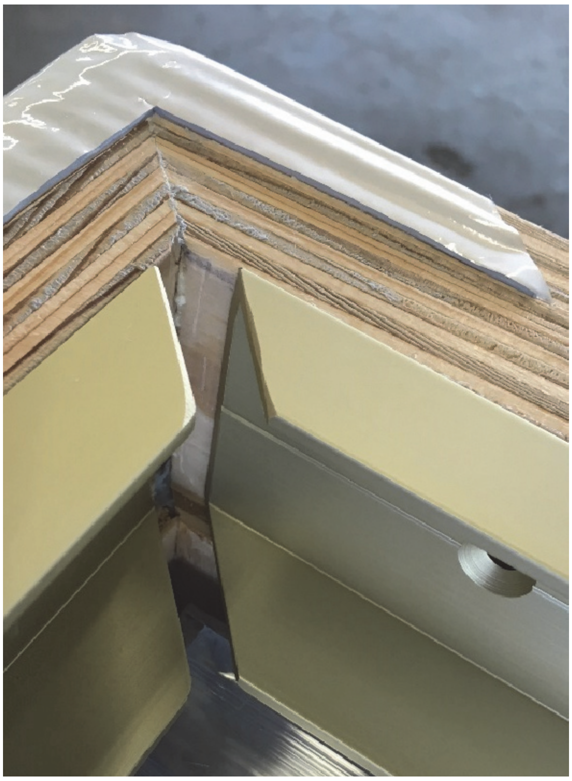

Figure 11: *Corner assembly of the cut-to-length, pre-drilled, deburred and polished profile, ©Taiyo Europe*

Figure 12: White ETFE-foil element mounted on a curved timber frame (balcony area), ©Taiyo Europe

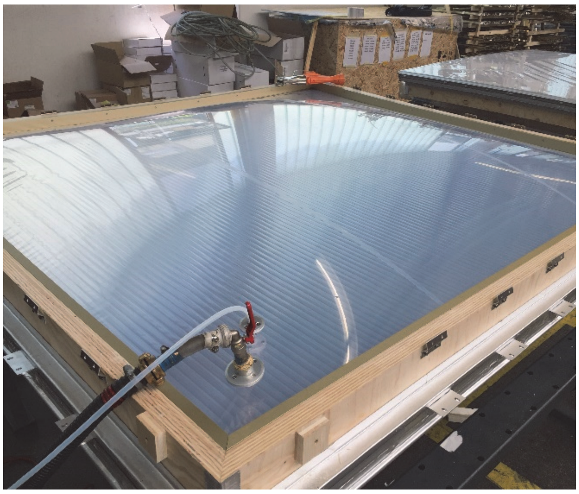

Figure *13: Rectangular ETFE-element with integrated bended double-web polycarbonate-plate, air-leak-test with overpressure, ©Taiyo Europe*

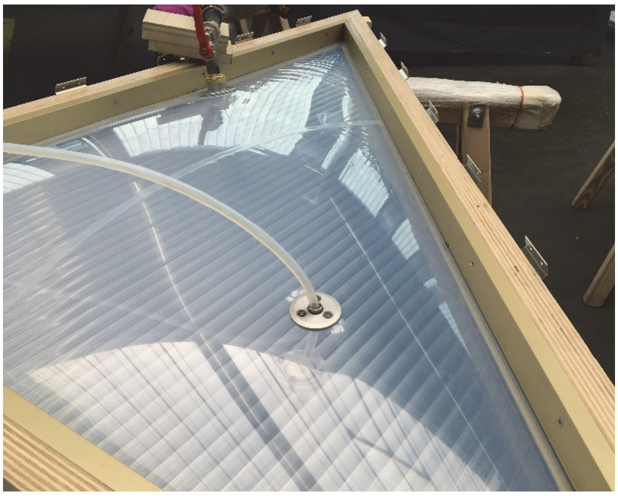

Figure *14: Triangular ETFE-element with integrated bended double-web polycarbonate-plate, air-leak-test with overpressure, ©Taiyo Europe*

To ensure that no moisture gets between the foils before installation, Roschmann supplied all elements with filtered and dried air during transport (Fig. 16 - 17). The mobile blower stations drove to the construction site with the elements on the loading areas of the trucks.

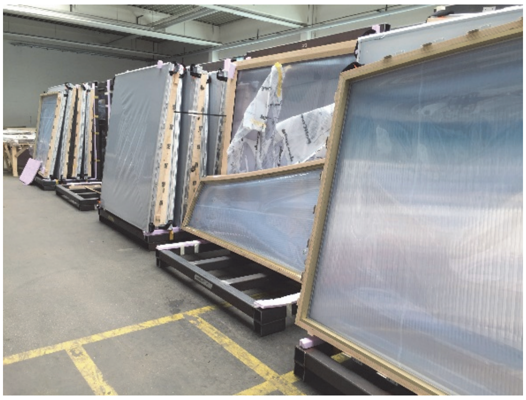

Figure 15: ETFE-modules completed and released, ©Taiyo Europe

Figure 16: ETFE-modules on transport racks, ©Taiyo Europe

Figure 17: ETFE-modules with temporary air supply for their transportation, ©Taiyo Europe

4. Air Supply Duct System

A total of about 8 km of air ducts were laid in the building envelope, risers, mains and stubs (Fig. 18). They supply all CCF modules, those made of glass and those of ETFE foils, with a standard overpressure of 250 pascals (Fig. 19). The fans are able to generate a higher overpressure of 600-1000 Pa in the modules, which can be increased automatically (sensor-controlled) or manually in the roof area when the snow load rises. The pressure measurement and the pressure control of the fans are carried out using pressure sensors, integrated into the modules at defined points. They deliver their data via sensor cables to the 5 blower stations, which are placed at three locations (in the basement and in the roof area).

Risers, mains and stubs are invisible because they were laid in the double floors or in recesses in the wooden structure and covered with wooden cover profiles. The covers can be removed easily to allow maintenance of the lines. Only the flexible, translucent hoses that connect the modules at the end, are partially visible along the timber construction. They are protected from damage by decorative perforated panels made of anodised aluminium (Fig. 20).

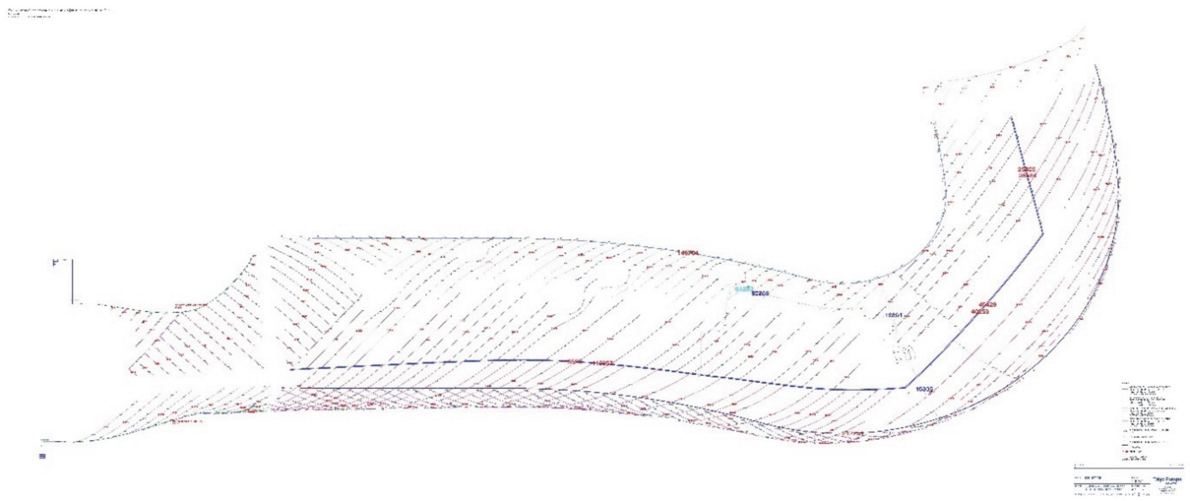

Figure 18: Air supply duct system for air-distribution (risers, mains and stubs), ©Taiyo Europe

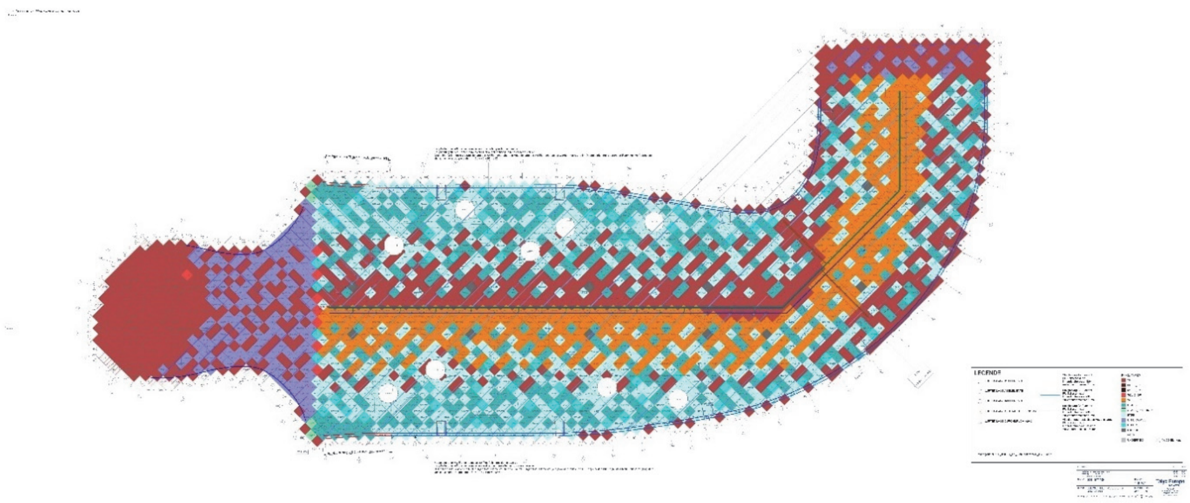

Figure 19: Different modules that are supplied with filtered and pre-dried air, ©Taiyo Europe

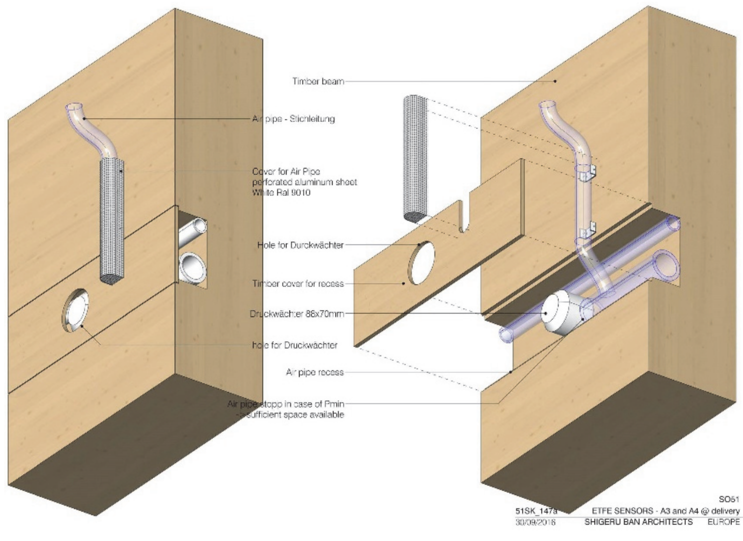

Figure 20: Hidden routing of the air supply ducts in the timber structure and along, ©Taiyo Europe

5. External Quality Control of ETFE-element's production

Due to the large number of small ETFE foil elements difficult to be weld on one hand and due to the tight project schedule on the other hand, Taiyo Europe commissioned two manufacturing companies with the foil assembly: Novum Membranes GmbH in Edersleben, Germany, and Diaferia S.R.L. in Bari, Italy. Both delivered excellent weld seam qualities. The external quality control of the two production facilities and the quality of the weld seams was commissioned in consultation with the project partners and the customer to the accredited membrane testing laboratory Textiles Hub of the Polytecnico Milano (Fig. 21).

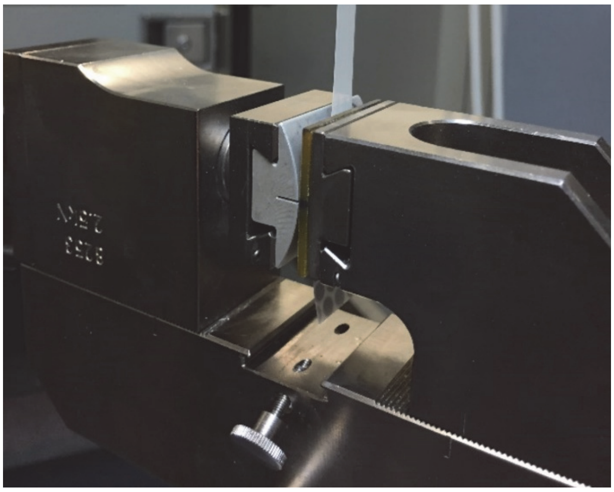

Figure 21: Uniaxial tensile tests on strip-specimens in accordance with DIN EN ISO 527-1, DIN EN ISO 527-3, ©Taiyo Europe

6. Outlook

The Swatch Omega Headquarters in Biel, Switzerland impressively shows that modular construction in the field of membrane structures is on the rise. The membrane world will therefore increasingly deal with the question of how to convert the associated processes into an automatic or serial production. In view of the spatial geometries and the diversity of the elements, however, this task is by no means trivial.

7. Project Participants

Table 1: Project Participants (Building Envelope)

Building owner	Swatch AG, Biel, Schweiz	www.swatchgroup.com
Architects	Shigeru Ban Architects Europe, Paris, France	www.shigerubanarchitects.com
Architects (overall and planning management, submission and implementation planning, construction management)	Itten+Brechbühl AG, Basel, Switzerland	www.ittenbrechbuehl.ch
Projekt Management	Hayek Engineering AG, Zürich, Switzerland	www.hayek-group.com
Timber structure building envelope	Blumer-Lehmann AG, Gossau, Switzerland	www.blumer-lehmann.ch
Wooden frame modules	Georg Ackermann GmbH, Wiesenbronn, Germany	www.ackermanngmbh.de

Structural Engineering of timber construction	SJB Kempter Fitze AG, Herisau, Switzerland	www.jsjb.ch
Façade planning	Leicht, Rosenheim, Germany	www.leichtonline.com
Building physics calculations	Leicht Physics GmbH, Bad Aibling, Germany	www.leichtphsics.com
Building climatic and building physics investigations	Transsolar Energietechnik GmbH, Stuttgart/Munich, Germany	www.transsolar.com/de
Façade/building envelope (planning and execution)	Roschmann-Group, Gersthofen, Germany	www.roschmann-group.de
ETFE foil elements and air supply (planning and execution) commissioned by Roschmann Group	Taiyo Europe GmbH, Sauerlach, Germany	www.taiyo-europe.com
ETFE foil assembly commissioned by Taiyo Europe	NOVUM MEMBRANES GmbH, Edersleben, Germany und DIAFERIA S.R.L., Bari, Italy	www.membranes.novumstructures.com; www.diaferia.it
External quality control of the ETFE-foil element's manufacturing commissioned by Taiyo Europe	Politecnico di Milano, Textiles Hub, Mailand, Italy	www.textilearchitecture.polimi.it
Sanitary, heating, ventilation and air conditioning technology planning	Gruner Gruneko AG, Basel, Schweiz & ISP und Partner AG, Sursee, Switzerland	www.gruner.ch, www.isppartner.ch
Electrical engineering planning	HKG Engineering AG, Aarau, Switzerland	www.hkg.ch
3D implementation planning	Design to Production, Erlenbach, Switzerland	www.designtoproduction.com

8. Referencing literature

[1] Swatch inaugurates its Headquaters in Biel, Swatch Group, Press Release, 03.10.2019, https://www.swatchgroup.com/en/services/archive/2019/swatch-inaugurates-its-headquarters-biel, download: 04.02.2023

[2] The new Swatch Headquarters, https://www.swatch.com/de-de/swatchhq.html, Swatch Group, download: 04.02.2023

[3] Swatch and Omega Campus / Shigeru Ban Architects, ArchDaily, Swatch and Omega Campus / Shigeru Ban Architects | ArchDaily, download: 26.03.2023

[4] Der neue Hauptsitz von Swatch, Text: Charles von Büren, in: AIV issue 6/2019

[5] Swatch Group Hauptsitz, Biel, Leicht, https://www.leichtonline.com/projekte/swatch/, download: 26.03.2023

[6] Swatch Omega Headquarters, Bienne, Switzerland, Transsolar Energietechnik GmbH, Swatch https://transsolar.com/projects/biel-swatch-omega-hauptquartier, download: 26.03.2023