Proceedings of the TensiNet Symposium 2019
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Alessandra Zanelli, Carol Monticelli, Marijke Mollaert, Bernd Stimpfle (Eds.)

New Hybrids

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Abstract

Today's challenges in Architecture and Engineering arise from an ever more complex network of boundary conditions, which often address apparently contradicting environmental, social and economic aspects. Within this context, we may not find a single best solution for a construction type or planning method to solve these challenges. In pursuit of efficient solutions for both the digital modelling and the actual construction, we are discovering new hybrids as forerunners of our creative profession. In this context we are also discovering new fields of application for textile architecture for both products and planning techniques beyond their classic application for membrane structures. The talk on 'new hybrids' will address this potential and highlight some challenges of our industry.

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SOFTENING THE HABITATS
SUSTAINABLE INNOVATION IN MINIMAL MASS STRUCTURES AND LIGHTWEIGHT ARCHITECTURES

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Lightweight and durable materials for thermal, acoustical and illuminance performance of building envelopes

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Abstract

The envelop is a key component in achieving the comfort in buildings, comfort being considered as the result of the thermal, acoustical and illuminance performances. Fortunately, architectural membranes offer a wide range of solutions and many projects have already achieved good performance by combining several materials in a multilayer composite and/or by using different materials or composites for separate parts of the envelope. The aim of the present study is to showcase few projects that illustrate how flexible materials can contribute to very performing building envelops. For all the projects presented, the actual performance of the building is achieved thanks to a comprehensive analysis of the building and a strong attention paid to detailing.

Keywords: lightweight structures, structural membrane, durability, performance, thermal, illuminance, translucency, transparency

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1. Introduction

Translucency has always been a strong advantage of architectural fabrics compared to other construction materials. Membranes even offer the possibility to play with light and colors by creating variations along the day. A very large variety of building facades, designed by architects, strongly highlight the freedom that is offered by membranes. Among these building facades, we can distinguish two different type depending the function of the membrane: being part of the envelope or not. If no, the membrane mainly provides solar gain control in addition to architectural identity; if yes, then airtightness, water tightness and thermal insulation must also be considered. Each building is then a specific case, each building envelop function need to be studied in detail and proven to the shareholders of the building construction project.

The first part of the present communication focuses on natural daylight then, in the second part, few examples of buildings for which the envelop brings benefits in term of natural daylight, thermal performance and/or acoustical comfort are shown.

2. Natural Daylight

As mentioned earlier, translucency / transparency is a strong advantage of lightweight construction with fabrics compared to other construction types. In most technical documents, this property is given as “Tv” (in percentage) and measured according to EN 410 standard. The aim of this paragraph is to focus on the benefits that daylight provides to people in the building and to the building itself. The physical measures are then different than translucency.

2.1. The benefits of natural daylight

When speaking about the benefits of natural daylight, there’re two mains categories to consider: the benefits to people living in buildings and the benefits to the environment (by reducing the footprint of the buildings):

- Well being and performance of people inside the buildings

From Robbins (1986) who has established that daylight improves mood, enhance morale and reduce fatigue and eyestrain, until the latest findings from Heschong (2019) there’s a countless number of academic studies about the benefits that natural daylight provide to people. It’s now well established that the eye and brain functions respond better to natural light, so concentration capacity is increased. In many different environments: factories, offices classrooms, scientific studies have proven that people perform better with natural light: productivity, attendance rate, even exam results are improved. Some studies even show improved patient recovery rates in hospitals.

- Energy savings from electric lighting

The energy savings for electric lighting from using daylight depends on many factors: the building type (residential, school, office, warehouse, etc), the location of the building, the lighting control system, the occupancy of the building and the behavior of occupants. According to Galasiu (2007) the energy savings for electric lighting from using daylight can range from 20 to 60%. Of course the environmental footprint of a building requires a multiple criteria analysis, it's a matter of optimization.

2.2 Daylight metrics

Over the past decades, the architecture industry has experimented with many metrics for measuring daylighting:

Illuminance

In photometry, illuminance is the total luminous flux incident on a surface, per unit area. It is a measure of how much the incident light illuminates the surface, wavelength-weighted by the luminosity function to correlate with human brightness perception. Similarly, luminous emittance is the luminous flux per unit area emitted from a surface. Luminous emittance is also known as luminous exitance. In SI derived units these are measured in lux (lx), or equivalently in lumens per square metre (lm/m^2).

Table 1: Typical illuminance values and minimum levels required for some tasks and activities

Typical illuminance values		**Minimum levels tasks and activities**	
Direct sunlight	100,000 lux	Residential room	200-500 lux
Diffuse skylight	3,000 – 18,000 lux	Classrooms (general)	300-500 lux
		Workspace lighting	200-500 lux

Daylight Factor

Daylight factor (DF) is a daylight availability metric that expresses as a percentage the amount of daylight available inside a room (on a work plane) compared to the amount of unobstructed daylight available outside under overcast sky conditions (Hopkins,1963).

As Daylight Factor is entirely independent of location, climate, and building orientation, it does not give any information about the actual performance of the building. Point-in-time measures (e.g. illuminance on September 21st at 3:00pm) can still be useful for understanding best- or worst-case scenarios, but don't give a good picture of whether a space or building is performing well overall.

In order to quantify the amount of daylight in a building's interior considering the availability of natural light outside at that location, as well as the properties of the building spaces and its surroundings, a dynamic calculation is needed. The daylight autonomy metric has been developed in that way.

Daylight autonomy

The daylight autonomy "DA_X", given as a percentage, represents the ratio of hours during a period (i.e., year or the occupation time over one year) when the natural indoor illuminance value in an area overcomes a predefined threshold x. As an example, a room achieving 50 of DA_{300} means that for 50% of the occupation time of the room, the target illuminance level of 300 lux is obtained without artificial lighting.

Useful daylight illuminance

Useful daylight illuminance (UDI) is a daylight availability metric that corresponds to the percentage of the occupied time when a target range of illuminances at a point in a space is met by daylight. Daylight illuminances in the range 100 to 300 lux are considered effective either as the sole source of illumination or in conjunction with artificial lighting.

2.3. Codes standards, labels, recommendations

It exists a lot a recommendation guides and specification documents that define minimum lighting levels for wide range of activities. Examples of recommendations for indoor activities are given in Table 1. For sport facilities, depending on the sport league and the competition level the requirement goes from 180 lux to more than 2000 lux (for televised events).

Despite the multiple recommendations for illuminance, there is no building code that enforces a minimum level of daylighting. The design for daylight autonomy is promoted by health authorities (for healthy indoor environments) and sustainable construction institutes like LEED and BREEAM (to reduce environmental footprint of buildings). Applying these recommendations for daylight autonomy require a good understanding of how the entire building is affected by the dynamic nature of daylight. Therefore, they require dynamic simulation programs to be used by both architects and engineers.

3. Combination of daylight, thermal performance and acoustical comfort

In this section, three examples of buildings for which the envelop brings benefits in term of natural daylight, thermal performance and/or acoustical comfort are shown.

3.1 Miramas athletics arena

Stadium Athletics Stadium Miramas Metropole is the largest indoor athletic hall in France. It allows the welcome in track and field configuration of 5,500 spectators. Its gauge can be worn 7,500 spectators for handball and basketball events. The equipment benefits from an incomparable luminous atmosphere thanks to the canvas that covers it, diffusing a homogeneous light at the heart of the project. This performance is achieved thanks to a wooden truss spaning over 80 meters and the use of a double membrane to cover the arena. This specific design provides diffused light, thus blocking sun glare and preventing shadows,

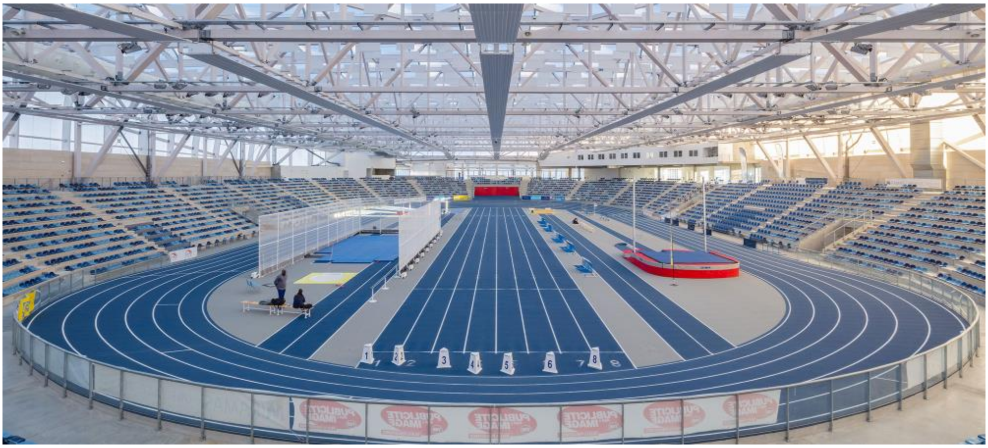

Figure 1: Miramas athletics arena

3.2 The community gym “Julius-Hirsch-Sportzentrum”

The community gym “Julius-Hirsch-Sportzentrum” is located in the German municipality of Fürth. The sport arena is intended to host one indoor soccer/hand ball/basketball match or three small spaces for school sports. The building has a glass façade on the northeast, changing rooms are arranged throughout the basement and ground floor while the sport field is located at the subterranean level of the basement. The membrane roof spans the field and partly the secondary rooms. The scheme of the layer construction of the roof consists of an outer membrane as weather protection, an air space varying from a 0.5 to 2.5 meter thick, a thin cover foil as humidity barrier, a thermal insulation, a small 4 cm air gap and the inner membrane.

Figure 2: The community gym "Julius-Hirsch-Sportzentrum"

Gürlich et al. (2019) carried out a comprehensive study about the daylight performance of the textile roof. The results show that, in comparison to only one glass façade, the additional translucent and thermally insulated membrane roof construction increases the annual daylight autonomy (DA700) from 0% to 1.5% and the continuous DA700 from 15% to 38%. In the roof-covered areas of the sport field, it results in a 30% reduction of the electricity demand for artificial lighting from 19.7 kWhel/m2/a to 13.8 kWhel/m2/a, when a dimming control is used.

3.4 CIRCA

CIRCA is French acronym for Circus Research and Innovation Center, the CIRCA project is an auditorium. The envelop of this building is a double skin system with insulation in between designed by Pauli N. (2015). The distance between the two membranes is 250 mm and insulation panels made of rock wool (160 mm thick, U = 0.2 W/m².K) are supported by the lower membrane. The advantage of this system is to preserve the aesthetics of the project while providing thermal and acoustic comfort comparable to what is obtained in a theater in conventional construction.

Figure 3: The CIRCA auditorium

In order to achieve the performances required for this project, a special attention has been paid to detailing: the inner membrane is made of one single piece of 2,000 m² that ensures the watertight barrier between the outside and the inside, then several connection systems has been specially designed for the project. As the outer membrane is tensioned by lacing, the connecting devices must allow for adjustment of lacing bars while keeping dismantling possible to allow for future maintenance. In addition, in order to preserve the aesthetics of the project, the connection devices have been designed to remain invisible.

4. Conclusion

The main learnings of this study: 1) the three projects illustrate how flexible materials can contribute to very performing building envelops 2) the actual performance of the building is achieved thanks to a comprehensive analysis and strong attention paid to detailing 3) even though the flexible materials generally provide excellent daylight benefits, these benefits are rarely quantified. This last point opens an avenue for future works: in past decades, the tensile membrane professionals, especially material suppliers, had to demonstrate the durability of lightweight architecture, Sahnoune (2016). There're now many projects that have been standing for decades that prove the durability of lightweight architecture. Even if there's still few consultants who need to be convinced, one can consider that durability is now established. In order to further develop our industry, we have now to convince about the benefits that can be obtained with highly performing envelops in terms of thermal, acoustical and illuminance properties. This study modestly wishes to contribute to this objective.

Table 2: a synthetic presentation of the three projects

Project	Roof system	Translucency acc. EN 410	Thermal properties
Miramas athletics arena	TX30-II and 402 HT	Roof: Tv=4,8% Façade Tv=9%	U = 2,9 W/m^2.K
CIRCA project	1002 S2 and 702 S2 opaque with rock wool insulation panels	Opaque	U = 0,2 W/m^2.K
Julius-Hirsch-Sportzentrum	1202 T2 Highly translucent and 1002 S2 Highly translucent with glass wool	Tv=0.74%	U = 0,25 W/m^2.K

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