

JAN CREMERS*

SOFT SKINS – INNOVATIVE FOIL
AND TEXTILE ARCHITECTUREMIĘKKIE PRZEGRODY ZEWNĘTRZNE –
INNOWACYJNA ARCHITEKTURA FOLII I TKANIN

Abstract

Besides glass, a variety of other translucent and transparent materials are just as highly attractive to architects: plastics, perforated metal plate and meshing, but maybe most of all membrane materials which can also withstand structural loads. The development of high performance membrane and foil materials on the basis of fluoropolymers, e.g. translucent membrane material such as PTFE-(poly tetrafluoroethylene) coated glass fibres or transparent foils made of a copolymer of ethylene and tetrafluoroethylene (ETFE) were milestones in the search for appropriate materials for the building envelope. The variety of projects that offer vastly different type and scale shows the enormous potential of these high-tech, high performance building materials which in its primordial form are among the oldest of mankind. Transparent and translucent materials play an important role for the building envelope as they not only allow light to pass through but also energy [1–4].

Keywords: membrane, PTFE/Glass, ETFE Foils, low-E coatings, flexible PV, insulated membranes

Streszczenie

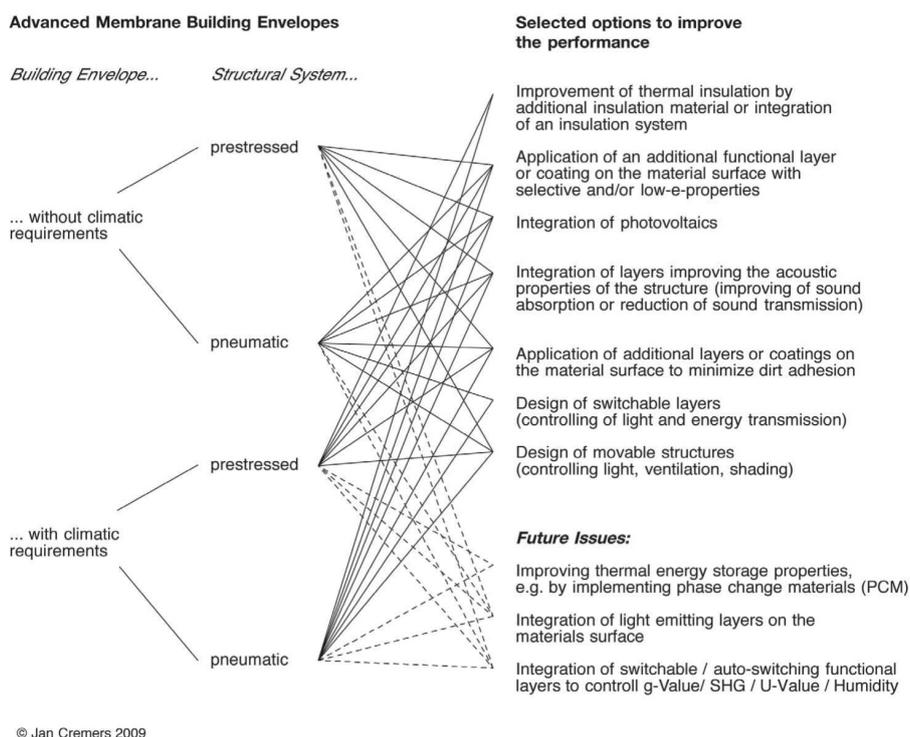
Dysponujemy różnymi przezroczystymi i prześwietlającymi materiałami poza szkłem. Są one również wysoce atrakcyjne dla architektów: tworzywa sztuczne, płyty metalowe, perforowane siatki. Najbardziej atrakcyjne są membrany mogące również przenosić obciążenia konstrukcyjne. Rozwój wysokosprawnych membran z materiałów foliowych na bazie fluoropolimerów, np. prześwitujące membrany jak PTFE (politetrafluoroetylen), pokruszone włókna szklane lub folie przezroczyste z kopolimerów etylenu i tetrafluoroetyleny (ETFE), to krok milowy na drodze poszukiwań odpowiednich do przegród zewnętrznych. Różnorodność projektów w zakresie typów i skali wskazuje na ogromny potencjał materiałów high-tech o wysokiej sprawności w budownictwie. W swojej pierwotnej formie należą do najstarszych stosowanych przez człowieka. Przezroczyste i przeświecające materiały odgrywają ważną rolę jako przegrody zewnętrzne budynków, ponieważ przepuszczają nie tylko światło, ale także energię słoneczną.

Słowa kluczowe: membrany, PTFE/szkło, folie ETFE, warstwy niskoemisyjne, elastyczne systemy fotowoltaiczne, membrany termoizolacyjne

* Prof. Dr.-Ing. Jan Cremers, Architekt BDA Hochschule für Technik Stuttgart (HFT), Faculty of Architecture and Design.

1. Innovations

In the last few decades, rapid developments in material production types (e.g. laminates) and surface refinement of membrane materials (e.g. coatings) have been constant stimuli for innovation. As a result, modern membrane technology is a key factor for intelligent, flexible building shells, complementing and enriching today's range of traditional building materials (III. 1) [5].



III. 1. Selected issues for future membrane research activities (source: J. Cremers)

II. 1. Wybrane kierunki badań naukowych i poszukiwań dotyczących przyszłych membran (źródło: J. Cremers)

1.1. Second skin façades

The Centre for Gerontology, a spiral building in the South of Germany, houses a shopping area on the ground floor and provides office space on the upper floors (III. 2). A special characteristic is the horizontal walkway arranged outside of the standard post and rail facade which forms the thermal barrier. The walkway is protected from the weather by a secondary skin. The complex geometry, the creative ideas of the architect and the economical conditions have been a special challenge and led to the implementation of a highly transparent membrane façade with high visibility between the inside and the outside due to its much reduced substructure. Moreover, because of this 'climate envelope', an energy saving intermediate temperature range is created as a buffer, which can be ventilated naturally by controllable, glazed flaps in the base and ceiling area. This secondary skin has

a surface area of approximately 1550 m² and was constructed by the Hightex Group as a façade with a pre-stressed single layer ETFE membrane with a specially developed fixing system using lightweight clamping extrusions. This was the first implementation of this type of facade featuring a second skin made of single layer stressed ETFE membrane anywhere in the world.



III. 2. Second skin façade of the Centre for Gerontology, Bad Tölz (source: J. Cremers)

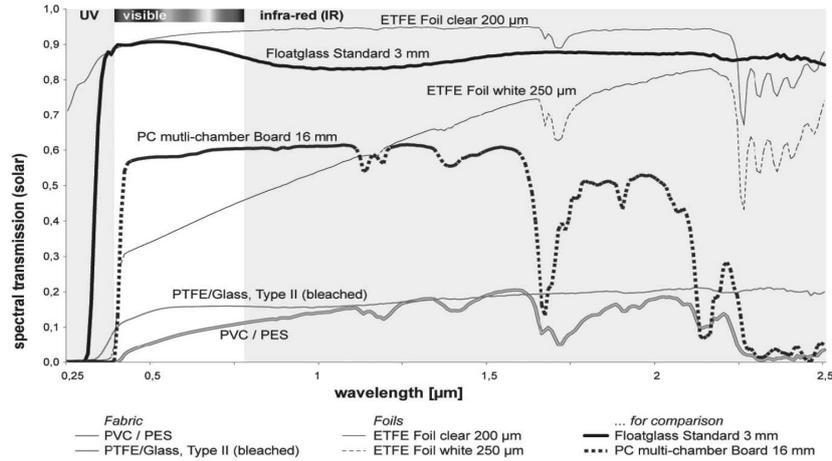
II. 2. Podwójna fasada Centrum Gerontologii w Bad Tölz (źródło: J. Cremers)

Printing the transparent membrane with a silver dot fritting pattern serves as light scatter and sun protection. The fluoropolymer-plastic ETFE used, which until then was mainly used for pneumatically pre-stressed cushion structures (comp. III. 4 and 5), has a range of outstanding properties which predestinates it for building envelopes:

- The life expectancy is far beyond 20 years if the material is used according to specifications
- The ETFE-membrane is flame retardant (B1) according to DIN 4102 and other international standards. Tests have shown that, due to the low mass of the membrane (which is only between 0.08 and 0.25 mm thick, with a density of approx. 1750 kg/m³); there is minimal danger of any material falling down in the event of fire [9].
- The ETFE membrane is self-cleaning due to its chemical composition, and will therefore retain its high translucency throughout the entirety of its life. Any accumulated dirt is washed off by normal rain if the shape and the connection details are designed correctly.
- The material is maintenance-free. However, inspections are recommended in order to find any defects (for example damage caused by mechanical impact of sharp objects) and to identify and repair such damage as early as possible. It is also recommended that the perimeter clamping system and the primary structure are regularly inspected.
- The translucency of the ETFE membrane is approximately 95% depending on the foil thickness, with scattered light at a proportion of 12% and direct light at a proportion of 88%. Compared to open air environment, the dangerous UV-B and UV-C radiation (which causes burning and is carcinogenic) is considerably reduced by filtration (comp. III. 3).
- ETFE membranes can be 100% recycled. Additionally, this membrane system is extremely light (about 1/40 of glass). The ETFE system is unmixed and therefore separable.

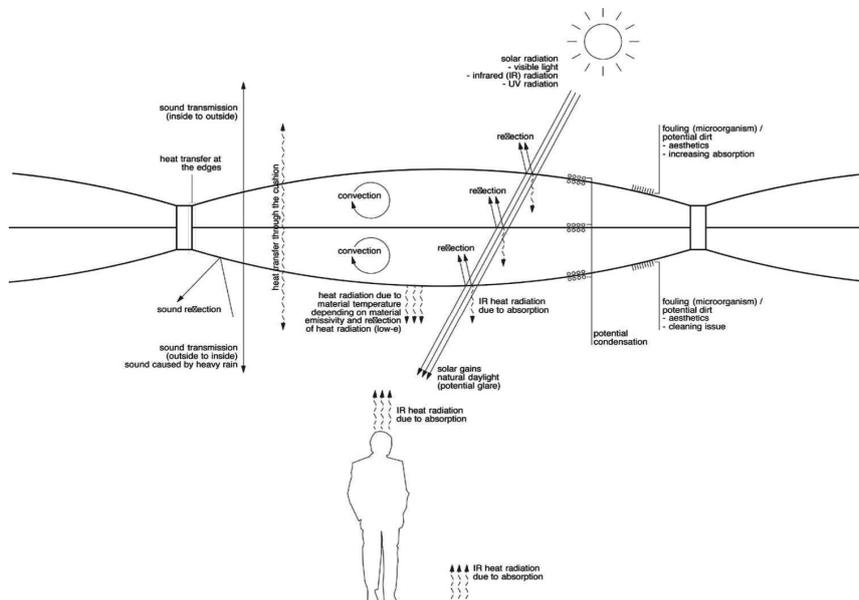
- In order to reduce solar gain or to achieve specific designs while maintaining the transparency, two dimensional patterns can be printed on the membrane.
- Because of the zero risk of breakage, unlike glass, no constructive limits have to be considered when used as overhead glazing.

The outstanding properties of this membrane material ensure a constant high-quality appearance lasting over decades.



III. 3. Solar Transmission of different envelope materials (source: J. Cremers/ZAE-Bayern)

II. 3. Przepuszczalność energii słonecznej różnych materiałów przegród zewnętrznych (źródło: J. Cremers/ZAE-Bayern)



III. 4. Building physics of a pneumatic cushion structure (source: J. Cremers)

II. 4. Zjawiska fizyczne struktury poduszki pneumatycznej (źródło: J. Cremers)



III. 5. Slovenská Sporiteľňa Bank Headquarters, Bratislava, Slovakia (source: J. Cremers)

II. 5. Siedziba Slovenská Sporiteľňa Bank Headquarters, Bratysława, Słowacja (źródło: J. Cremers)

1.2. A modular approach to membrane and foil façades

Most projects incorporating textile constructions are prototypes and have an extremely high share of innovative aspects, which have to be solved and also impose a certain risk to the designer and the executing companies. Therefore it looks promising to closely look into the options of following a modular approach. Most of the activities are still in an R&D phase, however, a first important building has been realised: For the Training Centre for the Bavarian Mountain Rescue in Bad Tölz a modular facade has been developed together with the architect Herzog+Partner which comprises of approx. 400 similar steel frames with a single layer of pre-stressed ETFE foil (III. 6).



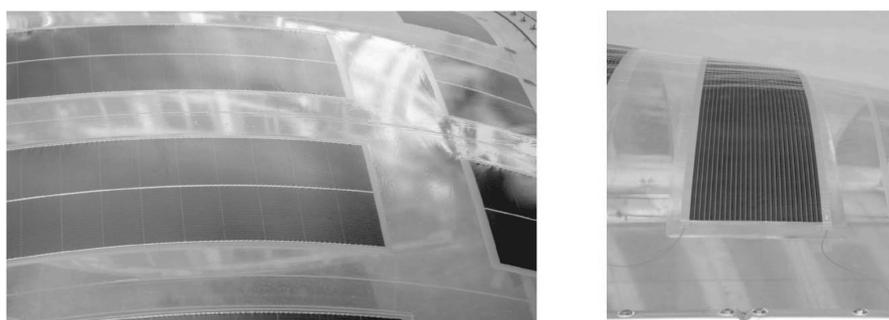
III. 6. Building physics of a pneumatic cushion structure (source: J. Cremers)

II. 6. Przegroda przezroczysta z poduszek pneumatycznych (źródło: J. Cremers)

1.3. Flexible photovoltaics integrated in translucent PTFE- and transparent ETFE-membrane structures: 'PV Flexibles'

Hightex is working together with its sister company SolarNext on significant innovations to improve building with advanced membrane material. Among them are new 'PV Flexibles' that are applied on translucent membrane material or fully integrated in transparent foil structures (Ill. 7 and 8). The technology being developed is flexible amorphous silicon thin film PV embedded into fluoropolymer foils to be used on PTFE membranes and ETFE foils. These complex laminates can be joined to larger sheets or applied in membrane material and be used on single layer roofs or façades. They can also be used to replace for example the top-layer in pneumatic cushions [6].

PV Flexibles do not only provide electricity – in an appropriate application in transparent or translucent areas it might also provide necessary shading which reduces the solar heat gains in the building and thereby helps to minimise cooling loads and energy demand in summer. This synergy effect is very important because it principally helps to reduce the balance of system cost for the photovoltaic application. In a report, the International Energy Agency gives an estimation of the building-integrated photovoltaic potential of 23 billion square meters. This would be equivalent to approx. 1000 GWp at a low average efficiency of 5%.



Ill. 7, 8. PV Flexibles, flexible a-Si-PV integrated in ETFE foils

Il. 7, 8. Elastyczne elementy fotowoltaiczne zintegrowane z folią ETFE

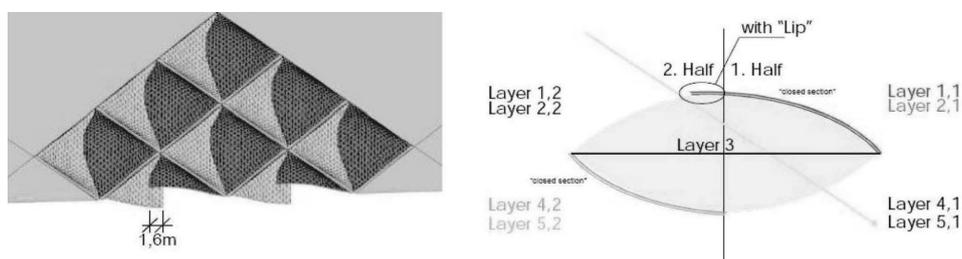
Up to now solutions for the integration of photovoltaic in free spanning foil and membrane structures have not been available, although these structures are predestined for the use of large scale photovoltaic applications (shopping malls, stadium roofs, airports etc.). PV Flexibles allow addressing market segments of the building industry which are not accessible to rigid and heavy solar modules in principle. The basic PV cell material is very thin (only approx. 51 μm) and lightweight. Therefore, it is predestined for the use in mobile applications. But as it is fully flexible at the same time, it is also an appropriate option for the application on membrane constructions [7].

PV Flexibles can be directly integrated in ETFE and PTFE membranes for the generation of solar energy. First applications have been executed successfully in the South of Germany and are currently monitored with regard to their output performance (Ill. 7 and 8).

1.4. Functional coatings for membranes

The development of functional coatings on membrane material has a special impact also. In the past this has led to the development of low-E-coated and translucent PTFE-Glass fabric (emissivity less than 40%) which has been applied for the first time by for the new Suvarnabhumi Airport in Bangkok, Thailand which was opened at the end of 2006 [8].

The development of transparent selective and low-emissivity functional layers on ETFE film consequently has been the next step to allow accurate control of the energy relevant features of the material. The first project to make use of this newly developed type of material will be the large shopping mall “Dolce Vita Tejo” near Lisbon in Portugal with a roof area of approx. 40,000 m² (Ill. 9 and 10).



Ill. 9, 10. Principle of roof cushion solution for Dolce Vita Tejo, Portugal
(source: Transsolar, Stuttgart)

Il. 9, 10. System dachowej poduszki powietrznej w Dolce Vita Tejo, Portugalia
(źródło: Transsolar, Stuttgart)

The cushions are very with dimensions of 10 m × 10 m very large and made of three layers. Here, the transparent, selective low-E-coatings together with the specific north-shed-like geometry of the foil cushions help to realize the client’s wish to have as much light as possible but also to reduce the solar-gains at the same time: Customers shall feel like being outside but in an environment of highest climate comfort (Ill. 11 and 12).



Ill. 11, 12. Dolce Vita Tejo, designed by Promotorio Architects (source: FG+SG)

Il. 11, 12. Dolce Vita Tejo, zaprojektowane przez Promotorio Architects (źródło: FG+SG)

2. Design Process

The variety of new technologies developed in the field of foil and membrane construction and materials are definitely expanding and enriching architectural design options to realize advanced technical solutions and new shapes. However, a solid background of know-how and experience is needed to derive full advantage of the innovative and intriguing offers. As an architect or designer you can only feel comfortable with technologies of which you have at least a basic understanding. This actually poses a great challenge to the educational system for architecture but also to the membrane industry, which is a comparable small sector. At the end, every new product and technology has to be introduced to the market and made known to the architects and designers, which needs resources for marketing activities and promotion. Also, it requires a great deal of pre-acquisitional activities of direct consulting to planners in early design stages to enable the development of functional and technical sound and also economical solutions. Therefore, it will be a long (but still very promising) road to follow until the technologies described here will be commonly used in the building sector and become something that could be called a 'standard'.

3. About Hightex

Hightex Group is a specialist provider of large area architectural membranes for roofing and façade structures. The membranes are typically used in roofs and façades for sporting stadia and arenas, airport terminals, train stations, shopping malls and other buildings. This type of structure is a competitive alternative to glass as it is lighter and safer as well as being flexible to create complex shapes and it can span larger areas. Hightex uses environmentally friendly materials and is focussed on innovative technology and coatings, which help to reduce a building's energy costs.

Hightex, one of only two international companies to design and install these structures worldwide, has been involved in the construction of a number of very high profile buildings including The Cape Town Stadium and Soccer City Stadium in Johannesburg, both for use in the FIFA 2010 competition, the Wimbledon Centre Court retractable roof, the roof of the Suvarnabhumi International Airport in Bangkok and the grandstand roof at Ascot Race Course.

Part of the work presented in this paper is funded by the German Federal Ministry of Economics and Technology (BMWi) through the R&D-project "Membrankonstruktionen zur energetischen Sanierung von Gebäuden (MESG)", part of the framework „EnOB (Forschung für Energieoptimiertes Bauen)“ [10]. In parts, it has been published before for the international conference at glasstec, Düsseldorf, 29.-30.9.2010.

References

- [1] Cremers J., *Designing the light — new textile architecture*, The Future Envelope 3 – Facades – The Making Of. Proceedings, TU Delft 2009.
- [2] Koch K.M. (Ed.), *Membrane Structures*, Munich-Berlin-London-New York, Prestel 2005.

- [3] Cremers J., *Membranes vs. glass – recent innovations from the world of foils and textiles*, *engineered transparency*, International conference at glasstec, Düsseldorf, 29.-30.9.2010, 535-544.
- [4] Cremers J., *Innovative Membrane Architecture*, Xia international, January 2008.
- [5] Cremers J., Lausch F., *Translucent High Performance Silica-Aerogel Insulation for Membrane Structures*, DETAIL English Edition, Vol. 2008-4, 410-412.
- [6] Cremers J., *Flexible Photovoltaics Integrated in Transparent Membrane and Pneumatic Foil Constructions*, Proceedings of the CISBAT 2007 Conference, EPFL Lausanne 2007.
- [7] Cremers J., *Integration of Photovoltaics in Membrane Structures*, DETAIL Green, Issue 1-2009, 61-63.
- [8] Heeg M., *Suvarnabhumi International Airport Bangkok – Engineering, Manufacturing and Installing the Membrane Roof*, DETAIL 7/8-2006, Munich, 824-825.
- [9] Troitzsch J. (Ed.), *Plastics Flammability Handbook*, Principles, regulations, testing and approval, München 2004.
- [10] Further information about the R&D-project MESG can be found in the internet: (<http://www.mesg.info/>).