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INNOVATIONS AND DECISIVE PERFORMANCE ANALYSIS OF MEMBRANES IN ARCHITECTURAL TEXTILES

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ABSTRACT

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This paper deals with the flexible membrane structures that propose limitless design possibilities, usual interior illumination and beautiful roof surfaces. Following a brief introduction to the general field of architectural textile, the comparison of textile membrane structures are presented as well as advantages of architectural textiles such as the lightweight construction, less structural support, low cost of construction, easily repairable, large free spans, and freedom of design, printability, recyclability and exchangeability of material etc are described. Thorough emphasis is addressed to the use of this specialized material in respect of sustainability, market price, development and uses in different sectors. The high performance synthetic coated materials also have good properties with regard to textile structure (high tensile strength, water repellence, rot and fungi resistances, UV resistance and transparency, resistance to rain and sun, resistance to buckling, wind tightness and high flexibility, acoustic and thermal insulation etc.). The paper concludes with examples which illustrate different structures made by architectural textile.

Key words: *architectural textiles, textile membranes*

INTRODUCTION

Textile materials have a number of advantages over conventional roofing materials-like prefabricated hard panels of metal or plastic. The advantages incorporate flexibility, light weight, low cost and high coverage. These properties facilitate architects to include wider and longer panels into their designs. Today, the use of textiles in architecture is commonplace throughout the world in a number of structures, including public buildings, auditorium, open-air theatres, railway stations, airports, shopping centres, parks and landscaped spaces, entrances and walkway areas and many more. Temporary structures such as tents, marquees and awnings are some of the most apparent and perceptible applications of textiles. Textiles are also widely employed in the course of construction operations themselves.

Construction with textile is successful because they express an impression of sophistication and weightlessness. Textile structures allow solutions to all needs and the results are economic and energy saving structures. These characteristics, coupled with efficient energy and cost savings, have helped this type of architecture to break - through in very different areas. The semi-transparent textiles are suitable for use in different applications and make sure a pleasant working atmosphere. And double — coated, insulated structures help to save energy. In sports and leisure facilities, it is possible to break away from the dry, straight lines of structures. The requirements of translucency, energy control, noise insulation and acoustics demanded entirely new approaches and new developments in the area of materials. Low-emissivity material was developed and used for this purpose. Membranes structure can be divided into four categories, like Tents, Clear-span structures, Tension fabric structures and Air structures (Tarafder and Banarjee, 2006).

The desires that lead to the development of new products often arise directly during work on the project, where architects, engineers and the construction companies are involved as co-worker. These contribute to the dynamic growth of new technical functions of the membrane materials. High-quality membrane materials production is an industrial process using the most modern production techniques and applying the most exacting principles. Architectural characteristics discernible from a great distance turn airports, stations and other transport facilities into creative meeting places. If these objects are harmoniously integrated into the surrounding architecture of a town or into the local landscape, they often become architectural attractions. Clever use of the architectural transformability of the fabrics attracts even greater attention. The very versatile uses of textile fabrics are evident when it comes to the area of environmental protection. Flexible heat exchangers make use of environmental energy to save resources.

TEXTILE MEMBRANE COMPARISON

A membrane is a flexible building element that is stabilized only under tension, its mechanical tensile strength and elastic qualities are important criteria. Architectural membranes used as structural materials are as bellows. PVC membranes are polyester base fabric coated with PVC – often have supplementary protective PVDF fluoropolymer a coating on both faces, which facilitates protect the surface, and also creates a membrane that is simple to clean. This type of fabric is the most common in textile architecture. PTFE membranes is known as most resilient membrane used in textile membrane structures includes of a woven glass fiber base fabric and coated with polytetrafluoroethylene (PTFE fabric). This coating is extremely inert and usually unchanged by environmental contaminants and ultra-violet light, and as well has higher fire resistant properties. The major issue discussed regarding membrane materials used for roof structures of buildings is the relatively low thermal insulation capacity compared to the classic building materials (Lingyun Zhang 2006).

Ethylene Tetrafluoroethylene (ETFE) tenders a innovative and lightweight substitute to glass. This membranes are transparent extruded foil with similar light transmission to glass, but is just 1% of the weight. Due to the life duration of over 20 years with excellent weathering properties, ETFE foil has been used on many high profile projects and sport arena around the world. (Structurflex, retrieve from : <http://structurflex.com/about/pvc-ptfe-and-etfe-fabric-types/>)

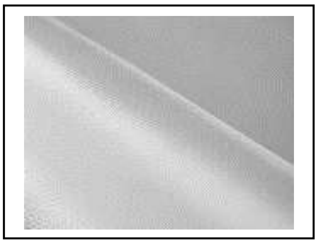
Table 1. Comparison of Properties of major Architectural Textiles

Belongings	Polyvinylchloride/PES	Polytetrafluoroethylene/Glass	Ethylenetetrafluoroethylene foil
Tear resistance	60-196 kN/m^2	40-150 kN/m^2	50-160kN/m^2
Life time	Exceeding 20 years	30-40 years	Over 20 years
Fire class	Self-extinguishing and flame resistant according to DIN 4102 B1	PTFE fabric is classified B1 according to DIN 4102	ETFE membrane is incombustible (Building material class DIN 4102 B1)
UV Resistance	Good	Very Good	Very Good
Stain resistance	Good	Very Good	Very Good
Washing	Medium dirt-resistance, cleaning intervals vary according to the appearance required	Self-cleaning.	Self-cleaning and hence retains its high translucency throughout its life. Any accumulated dirt is washed off by normal rain
Flame retardency	Yes	Yes	Yes
Environmental compatibility	Recycling of PVC-PE after its useful life has been reached is becoming increasingly standard practice	Does not degrade during its useful life, it can be reprocessed	ETFE membranes are 100% recyclable
Thermal insulation	Excellent	Excellent	For single-layer membranes ≈ 5.1 W / m² K
Transparency	10- 40% available in a range of different colors	5–30% light level of 5% sufficient to replace artificial light during daytime	Up to 95% within the range of 400- 600 Nm, with 12% scattered light and 88% direct light

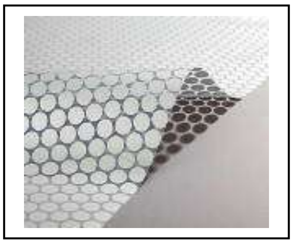
Fiber materials are processed into technical fabrics by specialist weavers. The strength of the material is determined by the choice of weave, the thread thickness and the number of threads per centimeter. It has proved practical to produce the fabric material for textile structures in five different quality levels. The above material types are the standard products used for well over 90% of all textile roofing.

Table 2. Plastic-coated polyester fabric of 5 different quality level (Sattler Group AG, 2010)

Properties	Type I	Type II	Type III	Type IV	Type V
Threads in warp and weft	9/9	12/12	10,5/10,5	14/14	14/14
Yarn density (dtex)	1100	1100	1670	1670	2200
Total weight (gr/m^2)	800	900	1300	1300	1450
Tear strength (N/5 cm/warp/weft)	3000/3000	4400/3950	7450/6400	7450/6400	9800/8300
Tear growth resistance (N, warp and weft)	310/350	520/580	1100/1400	1100/1400	1600/1800
Low flammability	yes	yes	yes	yes	yes



PVC-coated polyester fabric



Partially coated fabric

Table 3. ETFE Standard parameter

Thickness	100µm	150 µm	200 µm	250 µm
Length	200m	133m	100m	80m
Width	2 m			
Weight	70 kg			
Core	150 mm			

WEATHERING AND APPLICATIONS

Toughness in use is dependent principally on the material's resistance to UV light, resistance to hydrolysis and to alkalis. In movable membrane constructions the limiting factor tends to be the resistance to mechanical wear and the material's tolerance of bending and folding. Materials or coatings that do not contain plasticisers and made purely of fluoroplastics, such as PTFE coated glass fabric or ETFE foils, show no appreciable deterioration in quality due to the exposure to sun or the weather, even after 25 years of use. PVC material have proved themselves in use for 20 years, however their tendency to soil easily detracts from their appearance.

The resistance of membranes to soiling is an important criterion for their appearance and the regular costs of cleaning. Thanks to their molecular structure and their surface qualities, fluoroplastics are superior to all other materials. These include surfaces made of ETFE (transparent foil), PTFE and related fluoropolymers and also PVDF (topcoat to PVC coatings) (Koch and Habermann, 2004).

Tents

Tents and shelters were the first constructions in which textiles were used as building materials. Tents have been traditionally used as building materials. Tents have been traditionally used for various purposes by nomadic people, traders, military, explorers and campers. New tent constructions were developed for building construction, business, exhibitions, entertainment, leisure and recreation. The most widely used fabrics for tent walls are polyesters and vinyls.

Clear-Span structures:

Clear-span structures provide clear space beneath the fabric, free of poles and other supporting elements. Clear span tents are more permanent than tents and less permanent than air or tensile structures. Clear spans can accommodate doors, flooring, insulation, electricity and HVAC easier than tents. PVC coated polyester is the most widely used fabric for clear span structures.

Tension structures:

In tension structures, metal pylons, tensioning cables, wooden or metal frameworks are used to support the fabric. A relatively minimal support system, which must be rigid, is required for these structures because the fabric carries most of the load.

Air Structures:

Air pressure inside the envelope provides tensioning and maintains required configuration and stability. The main components of an air supported system are the envelope (fabric), inflation system (fans), anchorage system (cables and foundation) and doors and access equipment. PVC coated polyester is the most widely used fabric. There are approximately 150 big structures in the world which were built within the last twenty years including Silver Dome in Detroit (where Teflon coated glass fabric was used).

Textiles as Roofing Materials:

Single-ply and multi-ply materials are used in the roofing market to protect buildings. In traditional built-up roofing (BUR), alternating plies of felts, fabrics or mats are assembled in place and bonded together with layers of bituminous products such as asphalt or coal tar. (Textiles in an architect's retrieved from <http://www.fibre2fashion.com/industry-article/pdffiles/14/1309.pdf)

MATERIAL COST

The wholesome material cost of membranes, often a subject of investigations, does not provide much considerable information as it is the total cost of the membrane construction, including the load-bearing structure calculated to provide maximum spans. Due to the entirely different design possibilities offered by membrane materials, economic comparison with other building materials makes sense only in a few cases and even then only to a limited extent. Pure material cost can be anything from under 10% to over 50% of the total cost of the membrane construction. PVC coated Polyester fabric is at the lower end of the cost scale and PTFE coated glass fabric is at the higher end (Koch and Habermann, 2004).

Another example is Hightex, in August 2009 it announced, with its joint venture partners, it had awarded the contract to supply the complete roof system for the new National Stadium in Warsaw, Poland. The roof will consist of radial cable system supporting the fixed outer portion of nearly 55000 square meters of PTFE/glass membrane, with a retractable inner roof in the more flexible PVC/polyester membrane with a surface area of some 11000 square meters. The total contract value for the joint venture is approximately €78 million, of which Hightex's share is about €13million (Hightex Group plc, 2009). With a total area of 66000 square meters of both types of membrane is resulting in a price of €200 per square meter, while the FOB price of PTFE/glass membrane material from Wei&Kai (Shanghai Wei&Kai Membrane Materials Co., Ltd, 2010) vary from €16 to €36, the price depends on membrane's weight and other properties.

For example, the structure of the roof of Allianz Arena in Munich, Germany consists of 3 parts: a main steel structure, a subsidiary steel structure and the cover made of transparent foils. The membrane cover consisting of

2784 cushions made of two layers of a thin foil. The foil is made of ETFE, a copolymer of Ethylene and Tetrafluorethylene. The total costs of Allianz Arena amount €340 million, included 11 million for the cover (without steelwork). With a surface of 65000 square meters resulted in a price of €170 per square meter (Moritz 2007).

PRINCIPALGROWTH

Majority sport events take place in stadiums or sport halls. Progressively more architectural textiles are being used alongside classical building materials such as stone/concrete, steel, wood and glass in both new construction and the renovation of existing sport facilities. The advantages of architectural textiles are especially apparent in roofing: they are lighter than conventional building material, completely or in a large part prefabricated by the manufacturer and are very quickly installed on-site. This not only saves time and offers confidence in the planning but also considerably reduces the construction costs.

One more famous stadium is the 50,000-seat Nelson Mandela Bay Stadium in the Eastern Cape Province of South Africa, built for the Fédération Internationale de Football Association's (FIFA's) 2010 FIFA World Cup™. The Nelson Mandela Bay stadium roof contains some 230,000 square feet of polytetrafluoroethylene (PTFE)-coated fiberglass fabric membrane. Different stadiums were built in South Africa and Brazil for the purpose of World Football Cup 2010 and 2014 (Architectural Textiles, retrieved from http://www.textileworld.com/Issues/2011/March-April/Nonwovens-Technical_Textiles)

Nelson Mandela Bay St.
Mercedes-Benz Arena in Stuttgart, Germany
Mbombela Stadium
Cape Town Stadium,
Soccer City Stadium,
Maracana stadium




Nelson Mandela stadium Mercedes-Benz Arena Germany Cape town stadium Soccer City stadium
Worldstadium retrieve from: http://www.worldstadiums.com/stadium_menu/tournaments/worldcup2010.shtml>

Four of them are covered by textile roof, while only Cape Town Stadium covered by glass panels with underneath ceiling panels made of woven PVC fabric for softening the noise from within. This stadium enveloped by a façade of woven fiberglass coated with Teflon, it will resemble a rose-coloured bowl floating on a base when lit up at night (City of Cape Town, 2009).

MARKET PLACE EXPANSION

Domestic and industrial textiles account for around one fourth of the value and volume of all the application areas for technical textiles. Technical textiles including nonwovens play a very important role for the textile fibre and finishing industry internationally. Growth rates remain above average as further opportunities are taken to introduce textile products into industrial processes. Furthermore, the rapid growth in the use of composites and fibre-reinforced concrete, but also as textile products increasingly replace traditional building materials in the form of both hidden components and end products in their own right.

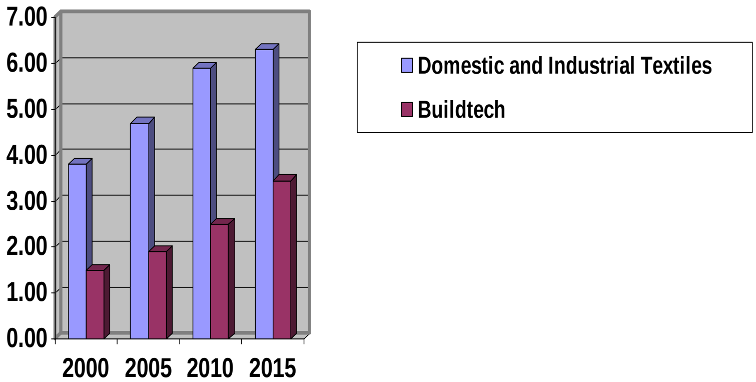


Fig. 1. Consumption technical textiles (In million tons) (Huntsman 2007)

Both the Industrial Textile part and the Buildtech industry are constantly growing. According to techtextil number of companies present at the fair grew even in the crisis year 2009 by seven percent which can be seen as very strong indicator for a booming economy. The buildtech part should even grow stronger not only because of the World championship in soccer in the Africa but because more and more companies discover the advantages of textile architecture. (Techtextil 2009 retrive from: http://www.messetermine24.de/2009/06/techtextil-2009/)

CONCLUSION

The market for textile membrane structure will rise in globe for several reasons, among which the most important character is Light weight – The membrane structure weight 2.5% compare to glass and also reduce the total no of steel and concrete material to holding the top and allowing far greater spans that are possible with glass. This type of structure includes coatings which will reduce ongoing power and cooling costs. Protection is also one of the major considerable factor for building any construction and perception is growing that membrane is far safer material than glass in formation where the public congregate, such as airport, shopping malls or stadium. Now a day's usual sporting arenas are build up using technology which offer rise to the long-lasting need for new stadium as well as beatification. At the end of the day architectural textile industry need to influence the construction engineering that architectural textiles are an smart and feasible alternative compare to traditional building materials.

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