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(ARCHI)TEXTILES PARTITIONS: DESIGN SPECIFICATIONS FOR REUSE AFTER DECONSTRUCTION

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Abstract: The use of membranes in the interior of buildings, particularly on their wide application possibilities as lightweight and innovative partitions systems, is not a major architectural concern. But membranes can contribute to different types of space partitioning in: housing, offices, hospitals, sports facilities, etc., in other words, in all occasions where spatial flexibility and reversibility are essential. This paper presents the result from a research project oriented to the concept and an adjustable partition system – which acronym is AdJustMembrane. This papper intends to communicate the result of the project AdJustMembrane. It presents the design and construction technology processes and potentials explored with architectural membranes in the conception and construction of non-load bearing partition walls. Some solutions available on the market were analysed from the design and building technology poit of view. Interior conventional partitions have significant cost and environmental impacts in a house and do not allow flexibility in the use of the space. Textile partitions promote modular, reversible (without use of permanent fixations or glue), and ease construction and deconstruction design specifications to achieve less environmental impacts and increase flexibility. The aim of this paper is to present some design specifications in the conception of textile partitions, to reuse after deconstruction.

Key words: Textiles, membranes, design, non load bearing partitions, interior space.

1. INTRODUCTION

The evolution of architecture involves, not only improvements in building construction techniques, methods, but also in materials research and development. The research of architectural textiles and membrane materials is extending its possibilities also to interior partitions in order to fulfil contemporary demands of comfort. The textile industry is undergoing a major reorientation toward technical applications, to areas where added value and sophistication emphasize their competitive advantages. Technical textiles, like membranes, account for about 40% of the production and consumption of textiles overall, and at a 4% annual growth rate, it is the fastest-growing sector of the global textile market [1]. Textiles for home furnishings are growing at about 1% per year. Architextiles [2] is a term given to textile products manufactured for their performance and functional properties, with applications in architecture/ building sector. Architextiles can include smart that sense and react to environmental conditions, such as electrochromic and thermochromic. Other new innovations involve nanotechnologies that have created new products such as textiles that detect chemicals and gases, generate mobile power, and incorporate sensing systems or light emmiting. Moreover, research is ongoing to develop textiles that can transport data and electric current, which could open a whole new area of product building applications, especially in interior spaces.

1.1. Textiles and polymer consumption in building construction

The technical textiles are produced in industrialized countries and this involves different sectors of industry and market segments. The use of textile in construction is becoming ever more common. According to Sabit Adanur [3], technical textiles, such as membranes, are replacing traditional textile materials, as well as metals, glass and other building materials. According to Englemasn et al [4], the building construction sector is the second higer of polymers, around 25%, just after the packaging industry The worldwide demand for textile fibers is increasing. It can be verified at Tabel 1, that the

cotton and polyester fibers are the two types of fiber that dominated this growing market in 2005. Demand for polyester fibers has surpassed the cotton in the beginning of the 21st century. While the volume of production of natural fibers has remained relatively constant, the demand for cotton has increased in the last decades [5].

Tabel 1: Worldwide demand of fibers in 2005 [5].

	Worldwide demand of fibers (millions of tons)
Natural Fibers	
Raw cotton	24.40
Virgin wool	1.23
Virgin silk	0.13
Total	25.76
Processed fibers	
Cellulosic	2.53
Synthetic	2.63
Acrylic	3.92
Nylon	24.70
Polyester	31.25
Total of synthetic	33.78
Total demand of fibers	**59.54**

1.1.1. Textile interior partition walls

The natural fibers from plants and animals have been used since antiquity for clothing and shelter. Nowadays, fibers are more commonly used as insulating materials in interior partitions and pavements and in exterior walls and roofs, especially inorganic fibers. Fibers are also used to make textile fabrics for several types of interior uses in buildings, such as carpets, curtains, blinds, wall finishings, among others, Architectural membranes are generally used in the exterior of buildings. These are flexible, thin and tensile resistant composite materials, consisting of a base fabric (with a structural role) and a coating (with a protection role to extend its durability, even in exterior exposure conditions). Membranes are mainly: coated fabrics, meshes, sheets or films. The table below shows the fibers and polymers nowadays commonly used in interior partition walls, alone or mixed in composites or combined in sandwich panels or just juxtaposed layers.

Tabel: Relation between density and termal conductivity of fibers and polymers for termal insulation materials used in interior partitions (adapted from [6]).

Material	**Density (kg/m^3)**	**Thermal conductivity (W/mK)**
Aerogel	60-80	0,017 – 0,021
Cotton	20-60	0,040
Linen	20-80	0,040 – 0,050
Hemp	20-68	0,040 – 0,090
Aglomerated wood fibers	30-270	0,040 – 0,090
Wood wool	350-600	0,090
Coconut fiber	70-120	0,040 – 0,050
Cork	100-220	0,045 – 0,060
Melamine foam	8-11	0,035
Mineral wool	20-200	0,035 – 0,045
Polyester fibers	15-20	0,035 – 0,045
Polyethilene foam	50-110	0,033
Rigid polyurethane foam	30-100	0,024 – 0,030
Sheep wool	25-30	0,040 – 0,045
Straw	120-225	0,055 – 0,090
Insulation panel in vacuo	150-300	0,002 – 0,008
Cellulose fibers	30-80	0,040 – 0,045

Generally, the polyurethane (PU) coated fabric has coating on one side only. The PU coating tends to be thicker than the common coatings. In comparison with the PVC coatings, the PU coatings are more expensive. This may be influenced by the fact that it requires an accurately and thicker polymer layer. Normal use of PU coated fabric puts the coated side on the "inside" and leaves the tissue on the outside. This protects the PU coating from abrasion and humidity. The PU coating allows the slow diffusion of water vapor, what makes the membrane to be "breathable". The poliester (PES) membrane with PU coating is lightweight, it has high elasticity and provides a diversity of colors.

When used indoors, it is applied a layer of fire retardant on the fabric. The table 2, presented below, includes a number of membranes used in most architectural interior partition walls.

Tabel 2: Potentialities of membrane and its properties *[7].

Properties	Membranes			
	PES membrane and PVC coating	**FG membrane and PTFE coating**	**FG membrane and SI coating**	**PES membrane and PUcoating**
***Cost**	15 €/m^2	150 - 230 €/m^2	-	20 €/m^2
Weight	0,6 – 1,7 kg/m^2	0,4 – 1,6 kg/m^2	2,0 kg/m^2	2,5 kg/m^2
***Tensile resistance**	2 – 10 N/5cm	1 – 8 N/5cm	1 – 8 N/5cm	1 – 8 N/5cm
***Light transmission**	0 – 25 %	4 – 22 %	25-30%	5 -20%
Light reflection	50 – 70 %	65 – 75 %	70 – 85 %	50 – 70 %
***Colours**	White and pigmented with all colors (these, reduce the durability).	White and some metallized fabrics.	White and limited selection of other colors.	White and other colors.
Union methods	High frequency. Welding by impulse.	Welding boost with intermediate film.	Vulcanization or sewing and gluing.	Metallic or plastic profiles.
***Durability**	15/ 20 years.	+ 25/ 30 years.	+ 25/30 years.	15/ 20 years.
***Self-cleaning property**	Good.	Excellent	Good.	Good.
***Chemical resistance**	Good.	Excellent.	Good.	-
Handling	Easy to bend.	Criticizes.	Criticizes.	Easy to bend/stretch
***Recicling**	Good.	Neutral.	Good.	Good.
***Fire resistance**	B1	A2 (type I and II) B1 (type III and IV)	B1	B1
***Thermal insulation (U value)**	2,6 W/m^{2}K for two membraneswith 200mm of air gap.	4,6 W/m^{2}K	-	-
Cracking sensibility	High resistance.	Without resistance.	Low resistance.	High resistance.

Abreviations: PES (polyester); PVC (polyvinyl chloride); FG (fiberglass); PTFE (polytetrafluoroethylene); SI(silicone) and PU (polyurethane).

2. USE OF MEMBRANES IN THE INTERIOR OF BUILDING SPACES

Architectural membrane partitions present several advantages in comparison to conventional rigid wall systems (such as plasterboard, metal or hollow brick) in an economy where being flexible is an important issue [8]. From the "classical" curtain, to sliding padded lamella structures, to spanned canvas elements: textile partitions allow different spatial situations to be created as required, so that individual areas can be used simultaneously for different functions [2, 8]. Partitions can usually be guided horizontally along ceiling tracks or can be vertically raised and lowered; their design incorporates storage room for folded textile when not in use. Various degrees of separation can be created, depending on the transparency and volume of the material – from lightweight solely visual separation to acoustically protected partition [8]. The figure below shows different textile applications that can be explored in the interior of buildings.

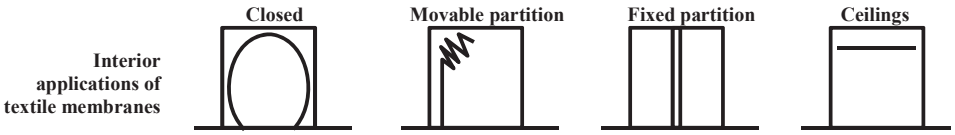

Figure 1: Classification of the different textile membranes applications in the interior of buildings.

3. PARTITIONS DESIGN TO REDUCE ENVIRONMENTAL IMPACT WITH TEXTILES MEMBRANES

A partition wall is a thin element built to divide the indoor space into rooms or other compartments. Additionally, it is used to enable more effective space organization and to improve comfort and safety [9]. Addis and Schouten [10] refer that partitions have emerged as building sub-systems, as result of several factors, including the development of frame construction where internal walls are no longer required to have a load-bearing function. In previous studies [9] it was concluded that textile partitios have a low environmental impact when compared with conventional partitions.

Textile interior partitions design has been developing significantly, since last decade [8]. The design of elements with architectural membranes combines the skills from several areas. In the process of designing with membranes, all project phases are interdependent: the area of materials (selection of membranes), the selection of the fixation method and the design of the structure so that, together, it influences the structural and functional performance of the element to design and build. Textiles partition walls can be: pneumatic (air-inflated), tensioned, multilayer sandwich panels (filled with fibers/polymer material), robotic, or composed with modular elements [8].

3.1. Design specifications to reuse after deconstruction

According to Lewis [11] and Addis & Schouten [10], it should be used fastening methods that allow the easy separation and recovery, such as: eliminating gluing and other systems which difficult and increase the number of steps taken to disassemble the partition, or turning this even impossible in part or in the whole. In an increasing rate, are appearing on the market innovative systems to integration of installations - pipework, cabling and interface mechanisms - which allow disassembly and deconstruction (inside or outside partitions walls) while maintaining the functional and aesthetic aspects. The following design specifications reveal the importance of textile partitions in the design to reuse after deconstruction.

3.1.1. Connections types

The construction process of membrane partition walls start with the idea of the designer and ends at the assembly. The first thing to explore is the form. The membrane is a lightweight material, for that reason it is designed to have minimal surfaces. The second step consists in selecting the connection solutions between the membrane and other components of the structure to allow reuse after deconstruction. The connection can be continue (figure 2a) or punctual (figure 2b). This decision has influence in the type and size selection of structural parts such as: profiles, straps, cables, ropes that can be used to transmit membrane efforts to the main parts of the structure.

Membrane partition wall solutions are characterized by lightweight materials and aggregation modules or profiles systems that allow tensioning of the membranes in the vertical plane. These solutions present the advantage of incorporating the finishing in themselves. Therefore, they do not require any further step in the assembly process, as it happens with the hollow brick partition solution or with plasterboard walls where is necessary to apply a finishing material to hide joints and offer a plain white or other coloured or textured surface.

The assemblies of some membrane partition solutions require professional teams with specialized training, such in the case of tensioned partitions (to give warranty on the workmanship and the safety of the installation). However, it exists membrane partitions with kit systems (thus only needed an instruction manual) with simple accessories and tools.

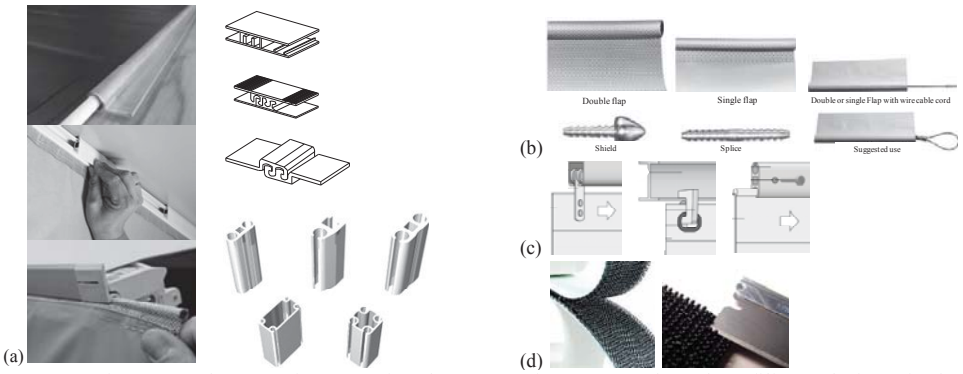

Figure 2: Connection types that permit reuse after deconstruction: (a) Cords and profiling solutions for hemming tensioned membranes; (b) Bead profile connections of polypropylene (PP) or polyethylene (PE); (c) connection types for membrane partitions of industrial spaces; (d) velcros with high strength, available on the market for joints/ trim membrane execution.

The coatings or overcoatings of thermostable membranes (PTFE or PVDF) make them difficult to fix. Before executing the joints or corners by gluing, the thermostable coating layer, in this zone,

should be removed. This means intensive work with potential appearance of defects in the application. In industrial terms, this is obviously an unwanted process. There are fastening systems to overcome these difficulties. These include: fasteners with occluded and detachable bolts, that replace rigid fixation rulers; "velcro" seals; screws combined with other adhesives or permanent connections, such as improved seams or mechanically embedded buttons.

3.1.2. Dimensions

The architectural membranes available on the market for application into partition walls have widths ranging from 1.6 meters to 5 meters and lengths up to 50 meters. This allows to make wall panels with few joints or even a single wall because the heights of the ceiling of a room ranges from 2.40 meters to 2.70 meters tall. In the cases where the ceiling height is double, the advantage is greater.

3.2. Tensioned membrane indoor partitions

Tensioned membranes are often used indoors [8]. Conventional membranes, such as polyester with PVC coating, ETFE membrane or fiberglass with PTFE or silicone coating, need to have a specific geometry (hyperbolic) to assure tension (with cables, cords, etc). However, membranes used in interior partition walls need to be flat and therefore must have some elasticity to achieve tension between special profiles, as can be seen at figure 3. These can take various forms depending on the support and also the applied tension, so they are molded directly onto attachment points. The cotton, nylon and polyester fabric containing a percentage between 3% and 30% of polyurethane elastic fiber. ETFE is widely used today because of its mechanical stability, thermal and chemical qualities. The PTFE combined with fiberglass fibers, constitutes an interesting functional and economic alternative to ETFE membrane.

To assembly the tensioned PVC membrane partition, the procedure is as follows: 1 - the profiles are fastened to a rigid structure; 2 - the membrane is cut at the factory with almost 6% less than local measurements; 3 - on site, the material is heated to 40-46 °C and stretched using special tools - spatulas; 4 - in the final stage are cut and applied reinforcement rings to create openings for devices such as sockets, switches, etc. The installation is quick, clean and efficient. The needed tools to the installation are as follows: short, long and angle spatula; staples (4 or more) for propane forced air heater, a ladder, reinforcing rings (to create openings for outlets, switches, etc.) and glue (for installation of reinforcement rings). To assembly tensioned partitions of polyester membrane with polyurethane coating, the procedure is the same refered before but the heating of membrane is not necessary. There are various tensioning systems (figure 3) which are based on an aluminum frame with a hidden tensioning mechanism that keeps taut the surface of the fabric.

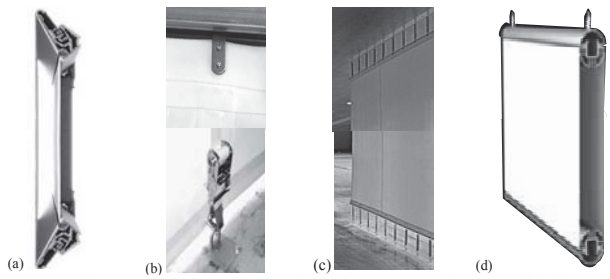

Figure 3: Partitions systems with potential to reuse after deconstruction: (a) hidden tensioning mechanism of polyester membrane [14]; (b) details of punctual connections, rackets and assembly of membranes partitions for industrial spaces; (c) tensioning the membrane by arranged springs in a predetermined measure so that the tension is uniform [15], and (d) double profile for tensioned PVC membranes in two opposite faces [16].

3.3. Inflatable partitions

The laminated fiberglass network with a polymeric film or ETFE are suitable for air inflatable structures because they ensure air-tightness. The inflated membrane partitions can be translucent, and are extremely lightweight, durable, waterproof and washable by hand. This type of partition requires predeterminated measurements and do not allow many changes during the assembly.

3.4. Multilayer partitions

Recent developments in construction materials was accelerated by industry demand for a range of products with higher strength, lower weight and cost as answers for optimization of technical and economic requirements of the 21st century [12]. The sandwich construction is a proven method for achieving greater rigidity by incorporating a core material between two outer layers [13].

According to Mendonça [17], the membranes can have a significant performance in thermal insulation by the addition of multiple layers and insulating material between them, with relatively low costs. Even it their low specific weight makes membranes bad soundproofing solutions, heavier coated membranes with absorbent materials or micro drill can however allow some damping effect. A membrane partition can also be filled with natural or synthetic fibers. An option is to construct the membrane partition in a multilayer sandwich panel with two coating membranes and a filler material between them. For example, the addition of cork or cellulose to the membrane, increase properties of thermal and acoustic insulation. Also can be applied other materials such as coconut fiber, hemp fiber, textile wastes, rockwool or three-dimensional textiles [8].

4. CONCLUSIONS

Textile Membrane partitions, as lightweight solutions, present some advantages when compared with heavyweight solutions, such as: less material used; less cost and impact due to transport to the building site; flexibility; and smaller assembly fittings. The application of membranes in interior dividing walls have several potentialities, such as: lightness and flexibility, ease of construction and deconstruction, mobility, translucency, thermal regulation, acoustic performance, low cost, custom-designed to specific applications, tied into existing walls and upper slab, recyclability and reutilization. Many new materials are still in the product development stage and will find their way into design solutions. The potential of architectural textiles to inform design decisions is limitless and growing as new textiles with improved textile properties are invented.

Interior conventional partitions have significant cost and impacts in a house and do not allow flexibility in the use of the space. Textile partitions promote modular, reversible (without use of permanent fixations or glue), and ease construction and deconstruction design specifications to achieve less environmental impacts and increase flexibility. Lightweight solutions means less material spent, what also means less transport impacts and a low environmental impact – textile membrane partition walls are a very relevant option to consider in the future of building construction industry.

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