

## ADVANCED TEXTILE MATERIALS FOR HERITAGE BUILDINGS/

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**Abstract.** Although present in traditional architecture for millennia, textiles have been neglected by architects as reliable construction materials due to their short(er) lifespan and lower strength. The 20th century brought us synthetic materials which, for several decades, produced a boom in the multiplication of the uses of textiles which, being man-made, could be imprinted with the desired characteristics right from the time of manufacture. In the last decades, Nano, IoT and Smart technologies have allowed the application of specific characteristics corresponding to precise uses on both synthetic and natural materials. This, together with the diversification of the sources of raw materials, allowed the expansion of the uses of textile materials, which are present today from the structure of the constructions to the finishes and interior fittings. The main qualities specific to textile materials – a low weight per volume unit, flexibility, easy and reversible installation – represent an asset in their use in the restoration or protection of heritage buildings and sites. The current principles of restoration, which require a discreet and reversible intervention on the building itself, lead to the search for new materials solutions that are resistant but not structurally or visually invasive. Just as minimally invasive solutions are sought in the medical field, the same is happening in the field of restoration - healing of buildings. The fragility of monuments, which we often face, can be reinforced and/or protected with the help of textile systems of high resistance but with a minimal presence. The problem we have faced for decades, that of the restoration of modern materials (such as reinforced concrete), can be solved with the help of textiles and the technologies included in them. In the present article we will present some examples of textile materials that are already or could be included among those used for heritage buildings.

**Textiles and Architecture.** Today, textile materials are ubiquitous in the field of architecture and construction, emerging from the two paradigms in which they had been confined: ephemeral constructions and decorative elements for the interior. The term Architextiles synthesis this: "A hybrid of 'architectures' and 'textiles,' the word 'architextiles' refers to this body of projects and the ways of thinking and making that join the two." [1]

They "lost" their ephemerality by accumulating properties that transformed them from simple tents and coverings into complex envelopes with multiple advantages. Some of these are, we might say, traditional: light weight, flexibility, variable shape, easy assembly and disassembly etc. Others are brought in the last decades by the Nano, IoT and Smart technologies that have allowed the application of specific characteristics corresponding to precise uses on both synthetic and natural materials:

self-cleaning, absorption or chemical transformation of atmospheric pollutants etc. This, together with the diversification of the sources of raw materials, allowed the expansion of the uses of textile materials, which came out of the purely decorative sphere in which they were confined for hundreds of years and are present today from the structure of the constructions to the finishes and interior fittings.

But would they also be good for heritage buildings?

First of all, in general, heritage (classified) buildings that require restoration and conservation operations are mostly made with natural materials and more than often with traditional construction techniques. That is why the interaction with modern building materials, used for decades in consolidation and restoration, even if they have provided a momentary solution to some problems, are not always fortunate in the long term.

In an era where research on all materials is moving towards finding solutions based as much as possible on nature and sustainable, textile materials are no exception. That is precisely why the use of technical solutions made with the help of textile materials can represent an answer from a constructive point of view and which also corresponds to the modern principles of restoration [2], not only for old buildings but even for the most recent.

On the other hand, heritage buildings are not just a shell, an envelope with a compartmentalized interior, which must be consolidated, restored and returned to private or public use. In most cases they also have a content. This content, classified as "movable property", was often, over time, extremely... mobile. But nevertheless, what remains must be restored and preserved, preferably in a form accessible to use. This content, often left, theoretically but also practically, to the care of art historians, represents objects that define the architectural interior and therefore, would fall within the scope of the architect's concerns who, as a general designer, must have an overview of the project. But textile materials are present in extremely diverse objects that define the architectural interior: wallpaper, curtains, draperies, dividing panels, screens, furniture, objects with a decorative role - tapestries. So, the restoration of the building should also include their restoration if the spirit of the building is to be respected and restored to its former glory.

An important part of the European Green Deal 2019 [3] on construction concerns the renovation of existing buildings. It goes without saying that heritage buildings cannot be destroyed and replaced with new ones, but rehabilitation and/or modernization are also important because this process is less expensive and less polluting than demolition and reconstruction. Research directed towards the innovation of materials or products is thus encouraged, in order to find the most efficient and sustainable solutions.

In what follows, we will analyze some examples of textile solutions for several categories of interventions on heritage buildings, from structural to interior ones.

**Advanced Textiles Solutions for Heritage Buildings.** As the textile industry is one of the largest consumers of physical, economic and even human resources, the research in this field is oriented both towards

improving the qualities of textile materials or that can be instilled to them, and to the discovery of new sources of raw materials or the revaluation of traditional ones. Many of today's results are due to the use of nanotechnology, widely present in most industry areas. The field of architectural heritage restoration already benefits from some of these innovations and ongoing research is constantly bringing new solutions.

### Structural solutions

The issues raised by sustainability today present us with excess carbon (actually carbon dioxide) as dangerous for the future of our planet. But this element also has a positive role and without it there would be no life, as it is essential for plants for photosynthesis. Applications for the reinforcement of masonry with carbon fiber membranes, are already known and used extensively. In addition, there are some products that also provide fire protection through Carbon Fiber Reinforced Polymers (CFRP) bonded through an Epoxy Resin [4], used in both public and private buildings, whether classified or not.

Although it is not recommended to use reinforced concrete for interventions on heritage buildings, there are cases where this is unavoidable. Carbon fiber reinforcement is a possible solution, these being lighter than metal ones, do not degrade over time (do not rust, for example) and, being made of carbon, are neutral to other natural materials. Also, carbon fiber nets could be used to replace the metal ones, sometimes used to reinforce masonry.

Figure 1 below shows the latest solution for hollow beams reinforced with carbon fiber, a 3D textile lattice girder for sustainable production of lightweight carbon concrete precast hollow core elements, the result of research carried out by a complex team that brought together researchers from the textile field from the Institute for Textile Machinery and Textile High Performance Materials Technology (ITM) and the construction field from the Institute for Concrete Structures (IMB), both from the Technical University of Dresden, Germany. The presented solution won the New Concept Innovation Award at Techtexil, Frankfurt-am-Main in April 2024 [5]. FIGURE 1.

Basalt fiber is a natural element, which is not harmful to the environment, and so neither for humans and can be also used as concrete reinforcements. Woven or braided can be transformed into objects with a protective role, with great mechanical resistance and lifetime. Basalt Fibertec [6] offers a wide range of products for the construction industry (Figure 2), products that can be safely used in the consolidation and restoration of heritage buildings. FIGURE 2.

If we move on to mortars, one of the latest technologies for heritage buildings is textile reinforced mortar (TRM) [7]. It can be used to improve the earthquake behaviour of brick masonry, and the still undergoing research through the European CONNECT Project [8], is studying its effectiveness, which depends on the connectors that are used to fix the reinforcing layers to the substrate. Now, different type of connectors are tested, and will develop recommendations for correctly designing TRM-strengthened interventions. The monitoring of the state of the masonry is done by introducing optic fibers and sensors into the textile reinforcement layer [9]. Of

course, the TRM composite has to be designed using a binder which has to be compatible with the physical and mechanical properties of historic masonry (for example pure natural lime and geo binder and cement-free).

Although difficult to use in many situations due to the architectural value of the exterior of the heritage building and its requirements, an insulating layer is many times necessary to improve its energy performance. A combination of several systems - consolidation, insulating, monitoring - can be achieved by using an innovative system (capillary tubes) instead of the conventional insulating materials and smart textiles [9].

As a final example of reinforcement, one can use glass fiber combined with elastomer, for three-dimensional double-curved textile concrete envelope building structures. The material called CurveTex [10] was realized through the collaboration of the companies Penn Textile Solutions with Institute of Textile Technology of RWTH Aachen University and Stanecker Betonfertigteilewerk GmbH.

### Covering solutions

For heritage buildings it is preferable that a new roof system be lightweight and also have a high efficiency as well as a low environmental impact.

The smart conductive textiles are used for years now and Smart roof systems (SRS) [11] imagined by CITEVE Textile Technology, Saint-Gobain, Texteis Penedo, CeNTI and Itecons uses them as a reinforcement structure which integrates active heating yarns for dry/curing as well as a temperature and moisture sensing systems that predicts cracks in the membrane, in combination with a quick-drying water-based polymeric membrane with IR reflection. The sensors help prevent water infiltration over its lifespan. The product does not use solvents and the smart layer is made of 100% recycled polyester yarns, and the whole ensemble helps to use less or even no HVAC. The product was awarded the New Product prize at Techtexil Frankfurt 2024. FIGURE 3.

Many times, archaeological sites require as discreet protection as possible but at the same time resistant to climatic factors. The Ettlín company has elaborated a material, Ettlín TransProof® [12], that combines for the first time four properties: it is waterproof, it breaths, it is UV resistant and transparent. It is a woven material extremely light and thin, designed to offer sun and weather protection with a minimal visual impact. The innovative material was awarded the 3rd place at the materialPREIS 2018, Germany.

The New Technologies on Sustainability and Recycling second prize was awarded at Techtexil Frankfurt in 2024 to the ultra-performance insulating textiles made by SA-Dynamics from Aerogel fibers (100% cellulose) [13] which consist of over 90 percent air and can be processed on existing textile machines. FIGURE 4. SA-Dynamics is a start-up proposing a pioneering material in the field of natural/bio/sustainable insulation. Unlike rigid aerogels, this innovation is adaptable to the textile industry, enabling applications from clothing to construction. The environmentally friendly solution offers superior thermal insulation without microplastic emissions which is also preferable when interacting with old buildings.

### Interior Solutions

If textiles have been used outdoors for millennia for tents or similar structures and some decorative effects, the complex ones with special properties being a relatively new presence favoured by the technological advance of the last century, indoors, the textiles were very present and widely used. And here, for a long time, their role was decorative, or with certain values of thermal insulation and acoustic properties used empirically. The researches of the last decades on the acoustics and thermals of the interior space have revealed the possibility of using high-performance textile materials for this purpose. At the same time, the combination of textile fibers with other materials allows instilling new properties to the final material, including structural resistance (with certain limits), which allows their use for the creation of independent objects. Last but not least, the research is directed towards sustainable, bio, renewable solutions, which address the problems of the present but looking towards the future.

#### *Materials with structural properties*

A sustainable composite material made from pure cellulose, Purcell [14], is used as a high-strength reinforcing fiber and as a matrix component, in many cases replacing glass-fiber reinforced plastics (GFR) which are not truly recyclable. It works with two types of natural polymers: PLA (poly lactic acid - bio sugar polymer) and PHA (poly hydroxi alkanooat - natural bacterial polymer). The dispersion does not require solvents and degrades over time without emitting harmful particles to the environment. It can be used in many products for interior, like: wallpaper, flavor-based insulating composites, carpet doubles etc. FIGURE 5.

#### *Acoustic solutions*

Although they have been used indoors for millennia, textiles have not necessarily been credited for their qualities as acoustic shapers of interior spaces. After decades of minimalism - however, if we look at the achievements of its great personalities, textiles are permanently present and sometimes even with the aim of improving the acoustics of buildings, see the example of Le Corbusier in Chandigarh, India - in which textiles were neglected or omitted from interior spaces, in recent decades they are being reconsidered. The extended technical possibilities and the creativity of architects and designers allow today the realization of architectural elements or furniture and lighting fixtures from textiles, these, having implicitly or explicitly a role in improving the acoustics of the space in which they are located.

Unlike smooth, even glossy finishes and materials (glass, for example), wallpaper, curtains, drapes, blinds and other elements in this family can discreetly but substantially improve acoustic comfort by reducing reverberation and echo in the space.

Many furniture companies, both home and office oriented, offer acoustic solutions through pieces upholstered with felt or other highly sound-absorbing materials. Lighting fixtures can also have textile coverings, reminding us of the elegance of past centuries lampshades, made of precious materials such as silk brocade or satin.

#### *Removable compartments*

The refunctionalizing or conversion of heritage buildings often involves a

re-compartmentation to correspond to the new function. In some cases, given the status of the building, this is not fully possible through interventions with traditional or more durable construction materials. Textiles thus represent a solution that is both easily reversible and much lighter, literally and figuratively. The assembly and disassembly of lightweight self-supporting structures that are covered in textile material or even the installation of self-supporting textile structures represent flexible solutions for spaces with generous dimensions.

For example, the designers Stephanie Forsythe + Todd MacAllen are proposing a temporary and non-invasive partition solution for heritage buildings, with textile walls with a flexible freestanding and easy to modify configuration. Based on a foldable structure, they can be connected by magnetic end panels and packed into an extremely small space.

#### *Natural light regulators*

Heritage buildings, once restored and repurposed, often function as museums. This implies that the objects exhibited inside are also heritage objects, whose fragile existence must be protected. Natural light, so beneficial to life, is however an enemy of the longevity of natural materials, especially textiles and colour pigments. Therefore, precise control of natural lighting is necessary, which today is possible to achieve through textile materials with specific properties according to any requirements.

The Mermet Sun Control Textiles company is providing a large range of products, some of them suitable for heritage buildings. The Mastaba Hall in Louvre Museum, Paris, is using the SV 5% material (Gauthier et Compagnie, Mermet SAS) [15], in colour White Linen, in order to provide an as natural as possible shade and protection for the delicate antique artefacts exposed there. FIGURE 6.

**Conclusions.** Obtained from a huge variety of fibers and combinations of these, with the help of complex contemporary technologies, textiles are the ideal material both for the fashionable contemporary forms resulting from the parametric architectural design and for the heritage buildings restoration. As seen above, the textiles are now able not only to withstand the complex requirements of buildings, but even to contribute to their improvement.

As can be seen from the examples analyzed, the intelligence and creativity of engineers, architects and designers come together to create new materials or new products for our buildings, to rehabilitate existing ones, so that they continue their valuable journey through history for the use and delight of future generations.

#### **References.**

1. M. Garcia, "Architecture + Textiles = Architextiles", in AD 76, no. 6 (2006), pp. 6-7.
2. ICOMOS, International Charter for the Conservation and Restoration of Monuments and Sites, Venice 1964, pp.2-3. [online]. ICOMOS: Paris. [Accessed March 2020]. Available from: [https://www.icomos.org/images/DOCUMENTS/Charters/venice\\_e.pdf](https://www.icomos.org/images/DOCUMENTS/Charters/venice_e.pdf).
3. COM (2019) 640 "The European Green Deal - Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions". [online]. European Union official website: Brussels; 12 November 2019 [Accessed

September 2020]. Available from: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0640>.

4. Carbon Fiber Reinforcing Applications. [online]. BLOC Concrete Solutions: Durban. [Accessed 6 October 2024]. Available from: <https://concrete-solutions.co.za/specialized-coating-application-services/carbon-fiber-reinforcing-applications/>
5. Awards conference and explanatory video and texts, 3D Textile lattice girder for lightweight carbon concrete precast hollow core elements, at Techtexsil, Frankfurt-am-Main, Germany, 23 April 2024.
6. Basalt fibertec, [online]. Basalt fibertec: Langenthal; 2021. [Accessed 15 June 2022]. Available from: <https://www.basalt-fibertec.ch/index.php/en/>
7. E. Bertolesi, M. Buitrago, E. Giordano, P. A. Calderón, J. J. Moragues, F. Clementi, J. M. Adam, Effectiveness of textile reinforced mortar (TRM) materials in preventing seismic-induced damage in a U-shaped masonry structure submitted to pseudo-dynamic excitations, in *Construction and Building Materials* (2020), Volume 248, 118532, ISSN 0950-0618, <https://doi.org/10.1016/j.conbuildmat.2020.118532>
8. Editorial team, Using Textile Reinforced Mortar (TRM) interventions in Masonry Constructions: CONNECT Project [online]. EC-Build up: Brussels; 7 July 2022 [Accessed 8 October 2024]. Available from: <https://build-up.ec.europa.eu/en/resources-and-tools/links/using-textile-reinforced-mortar-trm-interventions-masonry-constructions>.
9. Editorial Team, Smart textiles for the retrofitting and monitoring of cultural heritage buildings. [online]. EC-Build up: Brussels; 14 February 2024 [Accessed 8 October 2024]. Available from: <https://build-up.ec.europa.eu/en/resources-and-tools/articles/technical-article-smart-textiles-retrofitting-and-monitoring-cultural>.
10. Penn Textile Solutions, Curvetex – Fassade. [online]. Penn Textile Solutions Italia: Bregnano; 2019 [Accessed 2019]. Available from: <https://www.penn-ts.com/en/News/CurveTex-Fassade>
11. Awards conference and explanatory video and texts, SRS – Smart Roof Systems, at Techtexsil, Frankfurt-am-Main, Germany, 23 April 2024.
12. Ettlin Incorporated Company, [online]. Ettlin: Ettlingen; 14 June 2018 [Accessed 20 July 2020]. Available from: [https://www.ettlin.de/aktuelles/detail/?tx\\_ttnews%5Btt\\_news%5D=63&cHash=539f01727b5c787341f6e829ae12e40](https://www.ettlin.de/aktuelles/detail/?tx_ttnews%5Btt_news%5D=63&cHash=539f01727b5c787341f6e829ae12e40)
13. Awards conference and explanatory video and texts, High-Performance Insulation Textiles made from Cellulose Aerogel Fibres, at Techtexsil, Frankfurt-am-Main, Germany, 23 April 2024.
14. Awards conference and explanatory video and texts, Purcell – a recyclable, biodegradable, single origin composite material from renewable, domestic resources as a substitute for GFRP, at Techtexsil, Frankfurt-am-Main, Germany, 9 May 2017.
15. Mermet S.A.S. [online]. Mermet: Les Avenières Veyrins-Thuellin; 2024 [Accessed 9 October 2024]. Available from: <https://www.sunscreen-mermet.fr/gammes/sv-5.html>.

## Figures.

FIGURE 1 – 3D Textile lattice girder for lightweight carbon concrete precast hollow core elements, by ITM and IMB from Technische Universität Dresden, New Concept Innovation Award at Techtexsil, Frankfurt-am-Main 2024. Sample of carbon lattice girder assembly and detail. Photos by the author.

FIGURE 2 – Basalt: stone, fibre, rebar, mesh. Products of Basalt Fibertec GmbH. Photos by the author.

FIGURE 3 – Smart Roof System (SRS) by CITEVE Textile Technology, Saint-Gobain, Texteis Penedo, CeNTI and Itecons, New Product Innovation Award at Techtexsil, Frankfurt-am-Main 2024. (a) Normal insulating layers to the left and SRS to the right, which is feeling much cooler when touched. (b) Detail of SRS layers with smart textiles. Photos by the author.

FIGURE 4 – Organic insulation textiles, by SA-Dynamics at Institut

für Textiltechnik der RWTH Aachen University, New Technologies on Sustainability & Recycling Award at Techtexsil, Frankfurt-am-Main 2024. Photo by the author.

FIGURE 5 – From wood to Purcell, by the Institute of Textile Chemistry and Chemical Fibers Denkendorf, at Techtexsil Frankfurt-am-Main 2017. Photos by the author.

FIGURE 6 – Natural light regulators for windows, by Mermet SAS in the Mastaba Hall, Louvre Museum, Paris. Photo by Raphaël Manolesco.



