MULTITEXCO

HIGH PERFORMANCE SMART MULTIFUNCTIONAL TECHNICAL TEXTILES FOR THE CONSTRUCTION SECTOR

The MULTITEXCO project aims at characterizing and demonstrating the latest achievements in technical textiles for their applicability in the construction sector. This will support the SMEs involved in the construction sector to fully exploit the new generation of multifunctional technical textiles. The project is focusing on applications of smart textiles in 1/ roadwork and embankments, 2/ structure retrofitting and 3/ fabrics for tensile structures. For each field of application a demonstrator is exemplifying the use and reliability of novel, smart multifunctional fabrics. Especially for this contribution, attention will be paid to the application of such smart fabrics in tensile structures.

Introduction

The largest industry in the world is covered by civil infrastructure and has about 10% share in the GDP [1]. As a result, technical textiles for this market may govern an important turnover. Unreinforced masonry walls are particularly vulnerable for earthquakes and landslides. The use of technical textiles as reinforcement in both masonry and ground works is increasing and efficient methods for the retrofitting of existing masonry buildings and earthworks and related monitoring systems make it possible to prevent structural damage. In architecture, technical textiles are used in large-span and temporary structures, such as air domes, stadiums, airport terminals, sport halls, hangars or stations. Fabrics are particularly suited for lightweight façades for new and existing buildings. In addition, due to the intrinsic efficiency of tensioned membrane structures, technical textiles are successfully used in several industrial applications such as biogas plants, floating dams, inflatable flood barriers and flexible tanks.

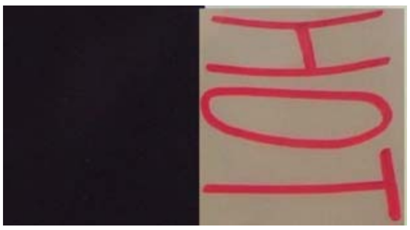
Sensor embedded textiles for structural health monitoring (SHM) of constructions have been demonstrated though many building practitioners are unfamiliar with the behavior and the characteristics of these materials. The lack of information about the use and the properties of these materials limit their implementation and thus prevent achieving the highest possible standards in quality assurance and control for construction projects.

Hampered breakthrough of textiles for construction

Building materials are strictly regulated by the Eurocode building practices and materials. However, despite the fact that technical textile materials are available today for use in a variety of building and construction applications, textiles are not mentioned by the eurocodes [2]. As a consequence, their use is limited to small temporary pavilions or iconic structures and buildings where *ad-hoc* authorization can be obtained. The future Eurocode 12 on membrane structures is currently under development by the European Committee for Standardization - CEN TC250 and it is supported by one of the working groups of the EU funded COST action TU1303 on Novel Structural Skins [3].

A new generation of architectural fabrics

The use of sensible and adaptable envelopes is increasing in recent years and building industry is looking for means to interact with the surroundings via temperature, humidity or solar irradiation monitoring [4,5]. For structures designed for extreme applications (e.g. large span structures prone to fluttering and



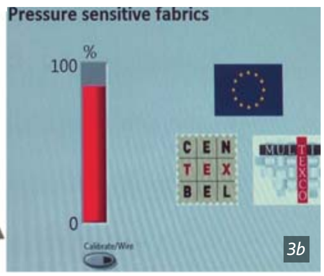
2

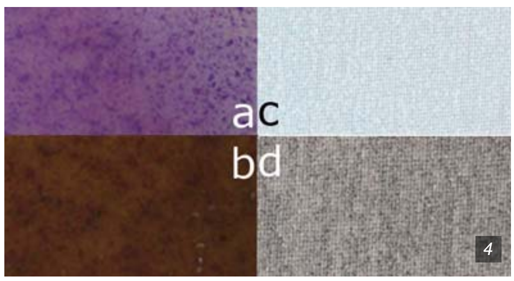
Fig. 1. Temperature responsive fabric using an electronic sensor integrated inside the fabric.

Fig. 2. Textile coating with thermochromic pigments. The coating becomes transparent at temperatures above 70°C (right) and returns black when cooling down (left).

Fig. 3. Pressure responsive sensor integrated in PVC coated polyester fabric (left), response on acquisition software (right).

Fig. 4. Fabrics responsive to corrosive or toxic gases. Left: ammonia sensitive (a. no NH^3; b. in presence of NH^3). Right: hydrogensulfide sensitive (c. no H^2S; d. exposed to H^2S). Samples are 1cm high.





ponding, industrial applications characterized by high working temperatures, biogas reactors with corrosive gases) there is the need of a continuous monitoring in order to highlight anomalies and avoid the progressive propagation of the initial damage. A new generation of sensible technical fabrics equipped with sensors has now become available due to miniaturization of electronic components and new manufacturing techniques for technical textiles. Within the MULTITEXCO project, research on this topic is focusing on temperature monitoring, pressure monitoring and chemical sensing of noxious gasses.

Temperature monitoring of tensile structures is of particularly interest for PVC coated fabrics. PVC coated fabric for tensile structures have a glass transition temperature roughly between 70°C and 90°C [6, 7]. At these temperatures, the polymer will become weaker and welded seams will slowly extend or even detach while being under tension [8]. In order to signal a pending failure, temperature sensors can be mounted on the construction after erection. However, most exposed locations are often difficult to reach and attaching several sensors is laborious. In addition, wiring compromises the aesthetics of the often admired organic shapes that can be achieved in textile architecture. To overcome these issues, miniature temperature sensors are integrated in hybrid fabrics with integrated electric leads. In a second step, the sensor loaded fabric is combined with the traditional fabric and coated with PVC. In this way, the sensors are well protected, no wiring is visible and all leads end up at the fabric side (Fig. 1). After confection, these leads are available for connecting monitoring devices at the edge of the construction.

While electronic sensors are well known for their accuracy and ease of data acquisition, connecting and wiring the sensor fabric remains an issue of intense research [9]. Alternative to electronics, thermochromic pigments also respond to variations in temperature. Although temperature resolution of these materials is limited [10], the spatial resolution of a coated material is considerably higher than the point wise electronic sensors. This allows for a quick visual inspection and real time monitoring of potential ‘hot spots’. Such thermochromic coatings may not be suitable for larger structures, they can be advantageous for quality control during welding of the seams where high enough temperatures have to be reached to insure proper connection of the fabric parts (Fig. 2).

Defining a form for a tensile structure is a crutial step in designing new strcutres. The form finding methods and finite element modeling tools are key to predict the forces and tention distribution along the fabrics ensuring a stable strucutre [11]. However, the transformation of a digital geometry into a real structure is a process characterized by several intermediate steps such as textile production, confection and build-up. In all of these, minor inaccuracies may influence the result and add-up to unforeseen instabilities. This is particular of interest for wind loads causing fluttering, water ponding and snow pile-up on the fabrics [8]. These dynamic loads endured by the fabric, can result in extreme tension or unpredicted forces on rigid restraining devices.

An early warning system may be advantageous for signaling increased loads endured by the fabric, but it may also act as a feedback loop between modeling and real life conditions. This would allow the architect to refine the design and the computational processes. In order to achieve such warning system, thin, flexible pressure sensors were integrated in a PVC coated fabric. By connecting the sensor to integrated electric leads in the fabric and subsequent coating, the sensor is well protected while the leads allow for easy connection of the sensor to the readout at the fabric brim (Fig. 3).

While pressure and temperature can clearly contribute to safer or better designed tensile structures, stability is a combined effort of the designer, developer and end user. It is unfortunately not uncommon that fabrics for tensile structures are used in a way they were not designed for. The user then easily points to the manufacturer in case of a defect, while misuse is sometimes the real cause of failure [12, 13]. Corrosive gases emitted by for example cattle or biological waste may compromise the materials integrity and cause hazardous situations when inadequate materials have been used. For two of such gases, an irreversible indicator patch has been developed. Color will change irreversibly upon exposure to ammonia or hydrogensulfide, indicating that the fabric properties can no longer be guaranteed (Fig. 4).

Conclusion

Technical fabrics for construction offer a wide range of new possibilities in building applications. However, exploitation is hampered by the lack of clear standardization and harmonized legislation. In addition, building practitioners may feel reluctant to use novel materials they have limited experience with. By integrating sensing, monitoring and early warning systems in technical textiles for construction, confidence in textiles as building material may be increased. Moreover, the sensing tools highlighted here may also offer solutions to improve design and modeling of tensile structures and aid to a better understanding between architects, developers and end users.

Acknowledgements

The research leading to these results has received funding from the European Union's Seventh Framework Program managed by REA-Research Executive Agency http://ec.europa.eu/research/rea (FP7/2007-2013) under grant agreement n° 606411.

www.multitexco.eu

Pieter Heyse (Centexbel)
pieter.heyse@centexbel.be
Guy Buyle (Centexbel)
guy.buyle@centexbel.be
www.Centexbel.be

Paolo Beccarelli (Maco Technology srl)
info@macotechnology.com
www.macotechnology.com

REFERENCES

[1] J. Bijen, Durability of engineering structures: Design, repair and maintenance. 2003, Woodhead Publishing Limited.
[2] The eurocodes. What are they?, DG Enterprise and Industry Joint Research Centre.
[3] http://www.novelstructuralskins.eu/.
[4] D. Clements-Croome, Intelligent buildings: Design, management and operation, ICE Publishing, 2013.
[5] M. Crisinel and E.C. C13, Glass & interactive building envelopes, IOS Press, 2007.
[6] A.K. Sen, Coated textiles: Principles and applications, second edition, CRC Press, 2007.
[7] G. Wypych, Pvc degradation & stabilization, ChemTec Publishing, 2008.
[8] J. Llorens, Fabric structures in architecture, Elsevier Science, 2015.
[9] R. Chapman, Smart textiles for protection, Elsevier Science, 2012.
[10] A. Seeboth and D. Lötzsch, Thermochromic and thermotropic materials, Pan Stanford, 2013.
[11] P. Beccarelli, Biaxial testing for fabrics and foils: Optimizing devices and procedures, Springer International Publishing, 2015.
[12] S.E. Craig G. Huntington, The tensioned fabric roof, ASCE Press 2004.
[13] M. Seidel and D.S. Sturge, Tensile surface structures: A practical guide to cable and membrane construction, John Wiley & Sons, 2009.