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MULTITEXCO - High Performance Smart Multifunctional Technical Textiles for the Construction Sector

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Abstract

The overall objective of the MULTITEXCO project is to scientifically and technologically characterize the latest achievements within the technical textile sector for the development of Guidelines and Pre-normative research, enabling future standards at EU level. These will support the SMEs involved in the construction sector to fully exploit the new generation of multifunctional technical textiles.
MULTITEXCO is focusing on key developments in smart textiles for 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 for the construction sector. In this contribution we will show examples for all three application areas, such as for example the use of textile integrated sensors for tensile architecture applications, sensor embedded soil reinforcing fabrics and meshes for masonry retrofitting.

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Keywords: Smart textiles; structural health monitorring; tensile structures; retrofitting; geotextiles

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1. Introduction

In the last decade, advanced textile materials have been developed addressing in particular the construction sector, which is representing one of the largest markets for textile products. Examples of advanced textiles for the construction sector comprise fabrics used for the rehabilitation of buildings, geotextiles for railway, roadway embankments or coastal protection, high performance technical textiles for tensile structures and textiles used in advanced roofing systems. These materials can provide both strengthening, stabilization and monitoring functions.

The design, construction, maintenance and repair of civil infrastructure is the largest industry in the world representing approximately 10% of world GDP [1].Technical textiles designed for this market can therefore attribute to an important turnover. Textile materials are used in construction in both ground and building structures. The retrofitting of existing masonry walls and soil structures is particularly important for earthquake protection of historic buildings and protection of earthworks against landslides. Unreinforced masonry structures are highly vulnerable because being originally designed mainly for gravity loads they often cannot withstand the dynamic horizontal loads in case of strong earthquakes. Soil structures, such as embankments, are subjected to landslides after heavy rainfalls or during earthquakes. Hence the necessity of efficient methods for the retrofitting of existing masonry buildings and earthworks and of related monitoring systems to possibly prevent the structural damage. In architecture, technical textiles are used in large-span and temporary structures, such as air domes stadiums, air terminals, sport halls, hangars or stations, and are increasingly used in 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.

Despite the demonstrated benefits of sensor embedded textiles for structural health monitoring (SHM) of constructions, 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.

2. Hampered breakthrough of textiles for construction

Technical textile materials are available today for use in a variety of building and construction applications. However, the absence of a complete normative framework (the Eurocode regulations on building practices and materials do not mention the use of textiles for buildings [2]) compromised the spreading of a common design practice as otherwise happens in traditional structures. 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].

The MULTITEXCO project is already anticipating to new regulations by increasing awareness to the sector about the benefits of technical textiles. To gain confidence, MULTITEXCO is merging products and application guidelines into a knowledge base platform that will become available via the project website (www.multitexco.eu). In addition, for each of the targeted application fields, sensor embedded fabrics are developed. These sensor-fabrics not only provide structural stability, but also offer inside information about the structural integrity and validation of the construction design. Meanwhile the sensor embedded fabric can also be used as an early warning system. In this work an example of all three application areas (roadwork and embankments, masonry retrofitting and tensile structures) is highlighted.

3. Examples of sensor embedded fabrics for construction

3.1. Geotextiles indicating looming landslide for road works and embankments

While soil movements are nearly impossible to predict in natural environments [4], the use of smart textiles may offer a solution for manmade slopes and embankments. Geotextiles are used to stabilize soils, to provide barrier layers between different granulates or to confine filler materials in compartments [5,6]. Once in place it is however difficult to estimate if installation was successful. Clearly, small soil movements and instabilities may in time create weak points and become subject to landslides. Several solutions are available to monitor soil displacements or geotextiles performance [7,8]. Novel technologies use optical fibers to indicate soil movement [9]. Some use several fibers combined to correct for temperature variations (Geodetec®, TenCate) or use well placed localized gratings inside the optical fiber (MuST SMARTGeoTex Fabric, Roctest-Smartec). The difficulty is to combine distributed sensing (one does not know in advance where soil movement will occur) with an acceptable displacement resolution and a large strain range at a reasonable pricing. The MULTITEXCO solution includes one optical fiber in a geogrid for soil stabilization. The sensing technology is distributed with a special resolution of just a few mm. In addition, the large deflection capabilities of the fiber allow tracking of the displacement over a large period of time (Fig. 1). One readout unit is sufficient to cover over 100m of geogrid and switching between fiber sections will result in important cost savings for long distance monitoring.

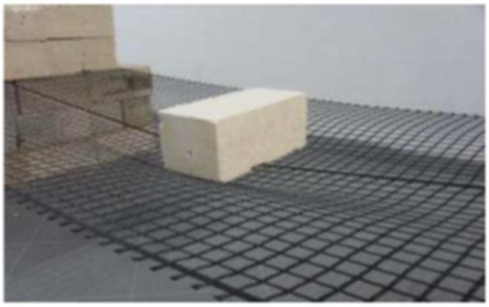

Fig. 1: Distributed strain sensing on geotextile for soil displacement monitoring.

3.2. Grid reinforcement with crack propagation sensor for wall retrofitting

Unreinforced masonry wall are vulnerable to in plane and in particular out of plane movements [10,11] as can be endured during earthquakes. Several methods have been developed to reinforce brick walls or to retrofit damaged buildings using fibers or textiles embedded in polymers or mortar composites [12-14]. Once repaired, the cracks are usually covered with aesthetic façade elements or interior decorations. As a result, it is difficult to keep track of crack propagation to validate the retrofitting or stabilization of a damaged building. Based on commercially available fabrics for in plane and out of plane reinforcement of brick walls, MULTITEXCO introduced sensors to these materials to monitor such crack opening and propagation. For exterior retrofitting, the Eq-Grid® is particularly useful to compensate for in plane deformations and has been fitted with fibers sensitive to crack opening. Also for retrofitting of interior walls susceptible to out of plane deformations, a printable sensor has been developed for the Eq-Top® fabric. The printable sensor is particularly useful to add sensing capabilities as a patch on localized, susceptible areas on the wall (Fig. 2).

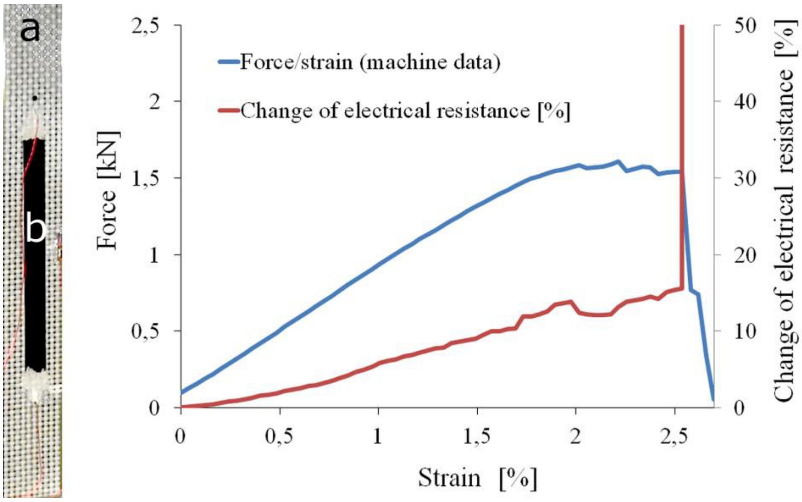

Fig. 2: Eq-top fabric (a) with printed sensor (b) under tensile load (left) and corresponding sensor output (right).

3.3. A new generation of architectural fabrics

Recent developments in the building industry have shown a clear evolution of traditional constructions into buildings with sensible and adaptable envelopes equipped with sensors and able to interact with the surrounding environment on the basis of inputs such as temperature, humidity, solar radiation etc. For structures designed for extreme applications (e.g. large span structures prone to fluttering and ponding, industrial applications characterized by high working temperatures, biogas basins 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.

The progressive miniaturization of the sensor and the innovative manufacturing techniques for technical fabrics and foils resulted in new prospects for a new generation of sensible technical fabrics equipped with sensors. 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 [15, 16]. At these temperatures, the polymer will become weaker and welded seams will slowly extend or even detach while being under tension [17]. 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. 3). After confection, these leads are available for connecting monitoring devices at the edge of the construction.

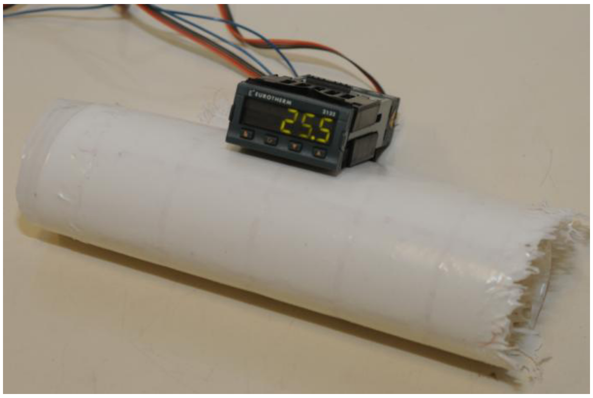

Fig. 3: Temperature responsive fabric using electronic sensor integrated inside the fabric.

Electronic sensors are well known for their accuracy and ease of data acquisition, but for fabrics, connecting the monitor to the sensor fabric remains an issue of intense research [18]. Alternative to electronics, thermochromic pigments also respond to variations it temperature. Apart from liquid crystals, temperature resolution of these materials is limited [19]. However, integrated in a coating, the spatial resolution is considerably higher than the point wise electronic sensors. In addition, a quick visual inspection will indicate 'hot spots' in real time. Although 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. 4).

One of the critical steps from concept to realization of a tensile structure is to define the form of the construction and with this, the forces endured by the fabric. The so called form finding techniques and related finite element modeling of the conceptual design are key to develop a reliable and stable tensile structure [20].

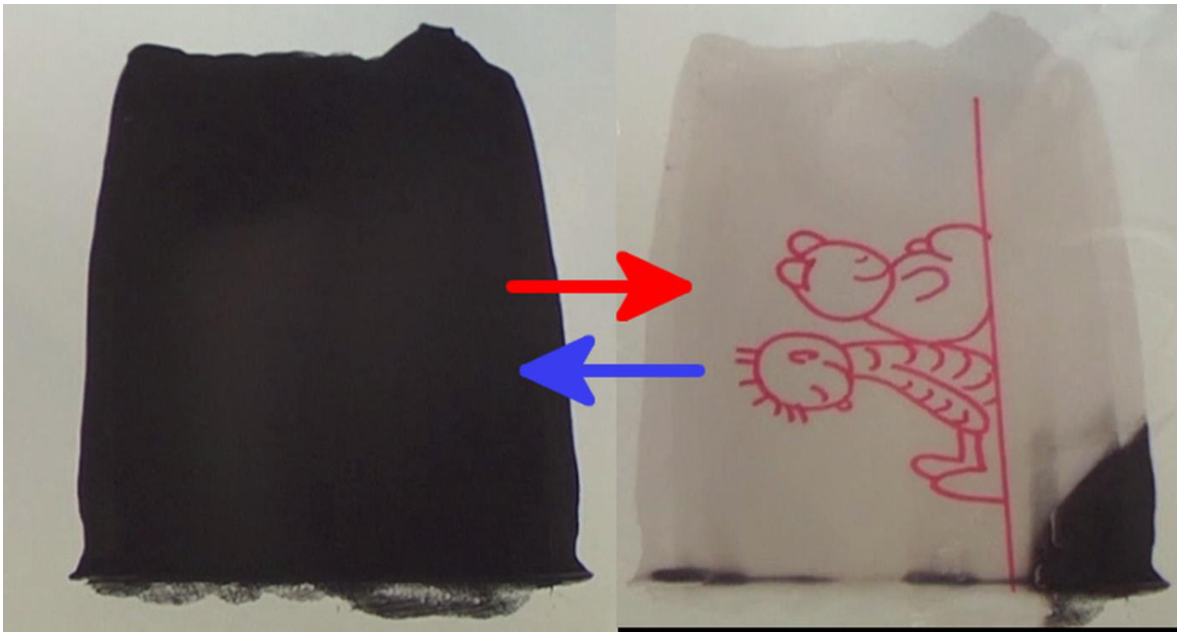

Fig. 4: Textile coating with thermochromic pigments. The coating becomes transparent at temperatures above 70°C (red arrow) and returns black when cooling down (blue arrow).

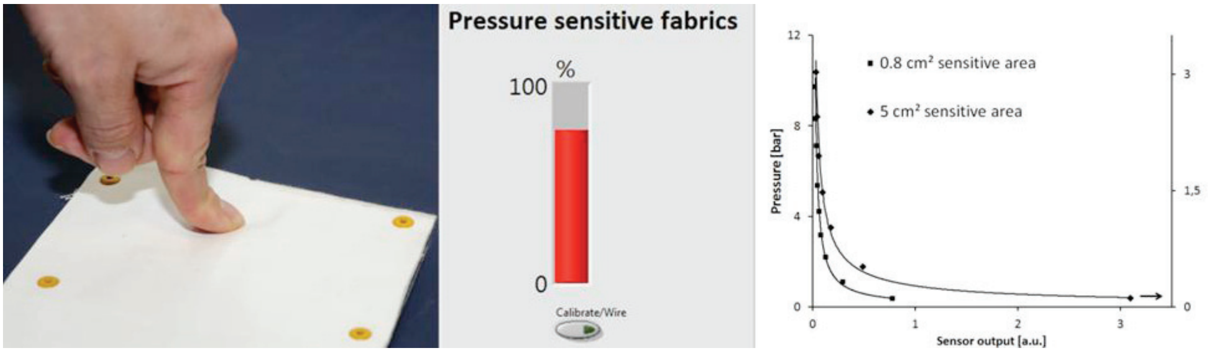

Fig. 5: Pressure responsive sensor integrated in PVC coated polyester fabric (left), response on acquisition software (middle) and calibration curves of small and large area sensors (right).

However, the transformation of a digital geometry into a real structure is a process characterized by several inaccuracies and minor errors in textile strength, confection and build-up may result in unforeseen instabilities. This is particular of interest for wind loads causing fluttering, water ponding and snow pile-up on the fabrics [17]. These dynamic loads can result in extreme tension inside the fabric causing tears or unpredicted forces on rigid restraining devices. Signaling increased loads endured by the fabric may be useful as early warning system but it may also act as a feedback loop between modeling and real life conditions refining the design and computational processes. As an example, thin, flexible pressure sensors were integrated in a PVC coated fabric similar to the temperature sensors. Connecting the sensor to integrated electric leads in the fabric and subsequent coating, the sensor is well protected. In addition, the pre-integrated leads allow for easy connection of the sensor to the readout at the fabric brim (Fig. 5).

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. Unfortunately, tensile structures are not always used for what they are designed for. In case of a defect, the user easily points to the manufacturer, while misuse is sometimes the real cause of failure [21, 22]. Common failure is caused by corrosive gases emitted by for example cattle or biological waste. For two of such gases, an irreversible indicator patch has been developed. Color will change upon exposure to ammonia or hydrogensulfide indicating that the fabric properties can no longer be guaranteed (Fig. 6).

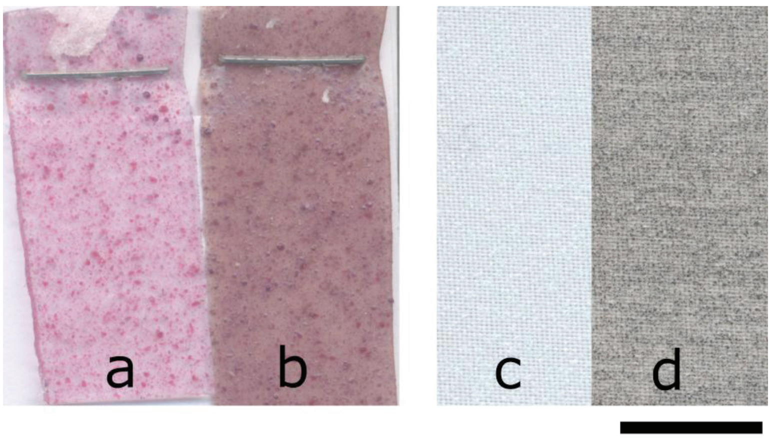

Fig. 6: Fabrics responsive to corrosive or toxic gases. Left: ammonia sensitive (a. no NH_3; b. in presence of NH_3). Right: hydrogensulfide sensitive (c. no H_2S; d. exposed to H_2S). Scale bar is 1cm.

4. Conclusion

Technical fabrics for construction offer a wide range of new possibilities in building applications. However, the lack of clear standardization and harmonized legislation hamper full exploitation of its assets. The MULTITEXCO project aims to increase developers confidence in technical textiles for constructions by generating an overview of current materials, legislation and standardization. In addition, examples of sensor integrated fabrics demonstrate the new opportunities of technical textiles for sensing, monitoring and early warning systems for geotechnical, masonry and retrofitting application and tensile structures.

Acknowledgements

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