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SUSTAINABLE INSULATION SYSTEM BASED ON FABRICS

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Abstract

Nowadays, new as well as refurbished buildings are supposed to be environmentally sustainable with regard to energy consumption, CO2 emission, occupant comfort and indoor air quality. A research team of architects, civil engineers, designers and economists of our university, including partners from industry (membrane construction, manufacturers of warp-knitted and woven fabrics and of insulating materials), proposes new solutions for the interior insulation of older sports and industrial buildings which no longer meet today's requirements for energy efficiency. The focus for refurbishment concepts, the selection of materials and their application lies on energy efficiency and economy.

The principal object will be a multi-layered construction system based on fabrics and insulation with green attributes. All components of the internal insulating system can be segregated for recycling at the end of the building's life without major effort. Mineral wool from regional stone and recycled mineral wool is used as an insulating material. Thanks to its loose form, the injectable insulating material adapts itself optimally to the most diverse hollow spaces when filling. Every insulation thickness and every geometry can be filled without joints. In addition to excellent thermal properties, the granulated material also has unmatched acoustic and fire retardant characteristics. The innovative "TexLining" system may replace traditional batt insulation by a minimum of materials, production steps and effort while providing superior performance, innovative and adaptable shaping and aesthetic appeal for building design. Because of the named positive aspects, this novel insulation system can be a valuable effort to fight today's energy and CO2 problems.

Keywords:

Novel retrofitting; textile fabrics; thermal comfort; internal building insulation; textile aesthetics

1 INTRODUCTION

Energy saving measures will play an increasingly important role in society in future. To fulfil the demanding tasks of today's times, a research team at the Lucerne University of Applied Sciences and Arts, consisting of architects, civil engineers, designers and economists from the Schools of Engineering & Architecture, Design & Art, and Economics is studying the field of the building envelope refurbishment of industrial and sports buildings that were constructed between 1970 and 1990. The research work focuses heavily on current events with respect to the Swiss Energy Strategy 2050. The focus for refurbishment concepts, the selection of materials and their application lies on energy efficiency, sustainability and economy [1]. Together with our economic implementation partners, such as processors in the field of membrane construction and in the textile and insulation material industry, innovative textile refurbishment concepts are being developed that combine functional properties with aesthetic qualities.

The concept of TexLining is to develop textile interior insulation to improve the energy efficiency of existing hall structures. The textile chamber system is precisely tailored to the existing structure and mounted to create an inner lining. A refurbishing system was developed that uses a combination of materials, finishing and mounting to achieve the highest possible efficiency. Its application is primarily aimed at girder hall structures. Unlike conventional refurbishing systems, prefabricated refurbishing textiles also have economic advantages due to their very low weight and simple mounting. Produced in ideal conditions that are state of the art in the field of textile processing, they are highly precise and contribute to a good handling quality on the building site.

2 MATERIALS AND METHODS

Demands on the selected textiles vary depending on the application. It is essential for the refurbishing system to fulfil technical, structural and aesthetic requirements [1,2,3]. These include tensile strength, density, vapour diffusion, resistance to weathering and fastness to light. Minimum requirements for a textile exterior shell lie in resistance to weathering, tensile strength and UV resistance [4]. By contrast, textile inner linings should have tensile strength and a certain amount of breathability. Available textiles are initially selected and studied together with economic partners. If necessary, textiles must be developed that have specific qualities and can be combined at a later date when applied. Mineral wool from regional stone and recycled mineral wool is used as an insulating material. The properties of mineral wool fibres are diverse. They have a low thermal conductivity and ideal heat storage qualities. They are also breathable, i.e. water-vapour permeable and do not absorb any humidity, making them resistant to mould, rot and vermin. Non-inflammability and a high melting point round off their numerous properties. They are processed simply and can be used universally, allowing them to be applied in projects as fine granulate in interiors. The fine granulate itself consists of loose, impregnated mineral wool that is blown into the insulating textile chambers through tubes using air pressure. Inaccessible hollow areas are insulated in a joint-free way, thereby reducing energy losses as a result of thermal bridges, which in turn leads to lower heating costs. The high own weight and ideal fibre structure also ensure optimal sound absorption. Depending on the on-site situation, it is possible to do without expensive scaffolding since the insulation blowing work no longer requires any scaffolding to pneumatically apply the material.

To develop the internal insulation system consisting of textiles and mineral wool, it was necessary to design constructive solutions and continuously adapt existing materials to the requirements of the future refurbishment system [5]. One important tool was always physical and practical implementation in material tests, models, mockups and a prototype to examine the theoretical findings (see Fig. 1).

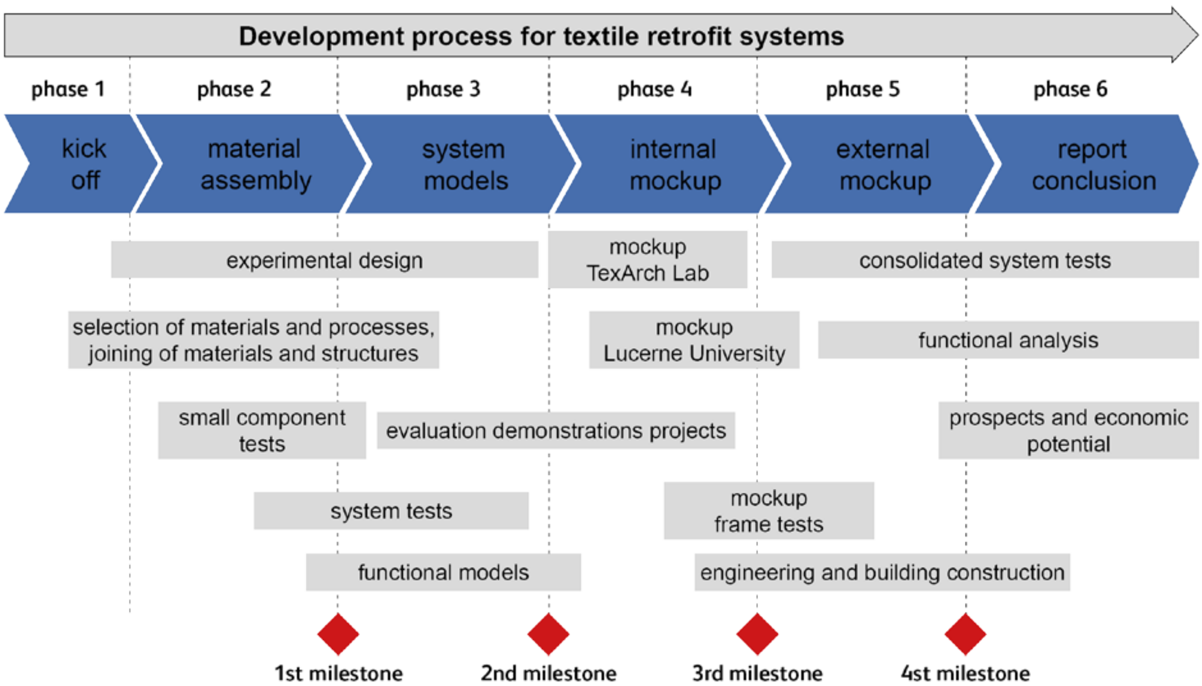

Fig. 1: Development process for textile retrofit systems.

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2.1 Material combinations

In a first step, an experiment plan was developed that included a wide range of potentially applied materials (textiles and filling materials), processes and joining principles, which served as the basis for conceiving the newly developed textile refurbishing systems [1,6]. Small-scale experiments examined the evaluated textiles and insulating material with respect to their ability to be combined with and integrated in different ways in later systems. At the same time, parallel system experiments were carried out in which construction principles were investigated and assessed. In each series of experiments and at every stage of development, the aim was to weigh up appropriate material combinations and also examine the feasibility and procedure [7].

2.2 System models

Based on the results of the small-scale and system tests, this stage of system development focused on larger models. Various functional models were used to develop the textile chamber system with respect to the optimized use of materials, production and interaction between materials. The architectural and aesthetic potential of the refurbishing system was evident in its production, dimensioning and the surface of the outer layer. Using scaled models, the posited working theses were investigated and tested, as well as evaluated with respect to their plausible implementation. To create a sturdy envelope for the mineral granulate, textile layers had to be bonded to produce a double membrane. During system model development, two versions proved to be expedient. In Version 1 the entire envelope was divided by sewing vertical strips inside to create chambers. In Version 2, the two membranes were joined at selective points using pins, in a method similar to the production of upholstery.

2.3 Internal mockups

To make the system development as similar to real conditions as possible, experiments with differently sized mockups on a 1:1 scale followed. The effective behaviour of the materials was investigated using an initial test stand measuring 2.0m x 1.5m (HxW) in the TexArchLab, allowing tests with respect to details of fixing and mounting. During the development process, it was necessary to produce another test stand measuring 5m x 1.5m to simulate actual implementation and test the structural requirements of the future system. This mockup allowed us to test the mounting conditions and the filling of the mineral wool granulate in a realistic way. With respect to the surface finish and mounting elements, it was possible to draw more precise conclusions on their visual effect.

In an additional measure, the textile system was given an integrated vapour barrier in the form of an applied foil. This allowed the textile system to adapt to different existing building structures and make the vapour diffusion processes controllable in future. An additional test frame on a 1:1 scale served to technically record structural values such as the elasticity modulus, shear modulus, wall friction coefficients, pretension, and the filling pressure of the fine granulate on the textile.

2.4 External prototype

The final test for the textile refurbishing system was the prototype in an existing hall, in which all findings were integrated (see Fig. 2). This required adapting the textile refurbishing system to existing local conditions. Many aspects that could be influenced directly in the mockups existed in the prototype. For instance, access for filling the insulation material must be conceived in a practically specific way.

3 RESULTS AND CONCLUSIONS

The analysis of the existing buildings showed that for larger structures with a low proportion of windows, refurbishment from the inside is more feasible, while buildings with a large amount of windows and small rooms are more easily insulated from the outside. Furthermore, it became evident that some studied buildings had only little or no load-bearing reserves. That meant the textile refurbishing system required a considerable weight reduction or structural strengthening for the existing building.

Since the economic partners in the textile industry do not yet produce textiles for the building industry for use as described in this case, it became clear that the selected fabric and mesh required a variety of optimization measures. These included controlling vapour diffusion by means of an appropriate foil, good processing properties and structural burdens, which are only some of the optimization factors.

As the findings of the mockups show, weight reduction and optimizing thermal conductivity are decisive improvement factors for the mineral wool granulate.

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Fig. 2: Prototype of the textile retrofit system.

The textile refurbishing system must be able to react very specifically to the existing building. Not only the access details can vary very greatly depending on the building, but also the chosen insulating measures. Additional heat insulation always leads to a change in the hygric conditions in the building section due to the close interaction between warmth and moisture. Great attention should be paid to moisture management to prevent moisture gradually building up within the construction over the course of time. Generally, two interior insulation system types should be considered. An investigation of capillary-active and vapour-permeable systems was not possible in the time frame of the project. Thus the focus was on vapour-impermeable and vapour-barrier systems. In such cases, insulation with a high vapour barrier should be applied from the inside. The layer can consist of a modified insulating material, a textile with an applied vapour barrier foil, or appropriate vapour-impermeable layers.

The textile refurbishing system provides decisive advantages on several levels compared to conventional methods. In developing a basic logic for the joints, it is possible to react to different conditions. The low thermal conductivity of interior insulation increases the surface temperature in the interior space and therefore improves the comfort level. Thermal comfort levels improve, especially in temporarily used spaces, since they can be heated quickly. With respect to the acoustics, textile surfaces combined with mineral wool granulate achieve an audible improvement of reverberation times, which is especially useful in sports halls. The new surfaces also offer diverse aesthetic advantages due to the textile look and feel. With respect to economic aspects, the fast mounting of prefabricated textiles and the small number of working steps lead to a considerable added value compared to conventional refurbishing systems. A wide range of refinement methods in textile processing also enables the economic production of complex geometries, as already applied in the clothing industry or in upholstery making. That represents a high level of creative potential and also the chance to adapt to the individual form of the existing building.

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4.1 Implementation partners

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- Flumroc AG: Manufacturer of insulating materials
- swisstulle AG: Manufacturer of warp knitted fabrics

- TISSA Glasweberei AG: Manufacturer of fibreglass textiles for industrial applications
- Dr. Lüchinger + Meyer: Civil engineering and structural design

4.2 Research partner Lucerne University of Applied Sciences and Arts

- Departement Engineering & Architecture: FG Material & Structure in Architecture, CC Façade Engineering and Metal Construction
- Departement Art & Design: FG Products & Textiles
- Departement Business: CC General Management

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