POSSIBILITIES OF AEROGELS APPLICATION FOR ARCHITECTURAL HERITAGE CONSERVATION

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ABSTRACT

Reconstruction of buildings has strategic importance for ensuring energy efficiency in the future. According to the current situation, it is estimated that in 2050 approximately 80% of energy consumption of buildings will be consumed by the current building stock [1]. A special category of building improvement is the reconstruction of historic buildings with structured or valuable facade surfaces or details, where insulation retrofit from the exterior side is undesirable for the loss of its cultural values. Although the architectural heritage buildings are not subject of the conditions for absolute achievement of energy efficiency, less energy consuming buildings increase the perspective of their future sustainability in all aspects. This assumption recognized that achieved effective conservation (preservation) of the existing cultural values is addition to the active use of older modernized buildings.

On the market there are new progressive materials containing aerogel, which announce an exceptional combination of properties, suitable for historic structures. The current scientific articles concentrate on research and development, however the articles do not follow the obtained results or caused effects of application on building structures. However, some insulation products based on aerogels are already offered on the construction market. The paper discusses the possibility of the use of new aerogel based materials for increasing energy efficiency while preserving the cultural values of the architectural heritage based on literature and market review.

International Charters and recommendations for the protection of cultural heritage define the principles and professional standards for the use of new materials: "*Where traditional techniques prove inadequate, the consolidation of a monument can be achieved by the use of any modern technique for conservation and construction, the efficacy of which has been shown by scientific data and proved by experience*." (Venice charter, Article 10.). In the absence of reliable information on the effects and impacts of aerogels on historic building materials, a series of experiments were conducted [2] to obtain their effects in key aspects of historic building preservation. An inventory of disposable materials based on aerogels from literature was prepared. Individual insulation materials have been classified according to the criteria for maintaining the authenticity and integrity which are the well-grounded attributes of preservation of cultural heritage values.

It seems that in the legislation or in the methodology there are no obstacles that limit the use of new materials in the restoration of monuments. As aerogels expand the variety of forms and intended use, they represent a potential material that can effectively contribute to improving of energy efficiency of historic buildings, but more targeted experiments and a long-term monitoring of impacts are required.

Keywords: aerogel, insulation materials, building retrofit, architectural heritage, historic building, building envelope

INTRODUCTION

The current standards reflecting the recent requirements for living and work space invoke the need to reduce the energy demands of the existing buildings which show significant energy losses.

Reconstruction of buildings by using additional insulation is a way to enhance the balance of the internal environment without dependence on supply. [2] The reconstruction of some types of structures is confronted with architectural limits related to materials or aesthetics. Materials that represent the architectural style by their color, texture or structure (stone, brick, exposed wooden structures, timber framing, etc.), or a work of art (paintings, frescoes, reliefs, decorative elements) are the direct bearer of cultural values [3]. It is therefore necessary, that the new added insulation and its attachment does not cover or degrade them. The new intervention to increase the insulation performance of the original building must fulfill several key requirements or criteria [4]. These must be respected on historically valuable objects and they should be applied also to other unregistered (unlisted) historic buildings that bear individual architectural features.

Figure 1: Rendering Fixit 222 with aerogel (EMPA) [5], Ultra-thin transparent insulation paint coating [6] (Industrial Nanotech) aerogel insulation blanket Spaceloft [7] (Aspen Aerogels)

The studied materials containing aerogel [3], which in the recent period are emerging on the construction market, appear to be potentially appropriate in the reconstruction of historic buildings to improve their energy performance. The real effect of these materials is however necessary to be examined and determined adequacy of use in terms of their impact on historic values of structures at their restoration. [4]

The current scientific articles indicate a much about research and development of these materials [7 - 24], but only few follow their interaction with building materials or issues related to practical application in building structures [25, 26, 27]. The presented paper shows an overview of applications of aerogel insulation materials and demonstrates the possibility of their use in reconstruction of historically valuable architecture by additional retrofit insulation, while pursuing key criteria that the new material should satisfy in interaction with the original material.

METHODS

The current content periodicals of international significance provide a wide range of scientific articles on topics related to aerogels [8, 12, 13], as well as on the topics of restoration of historic facades, and reduction of historic buildings´ energy demands [2, 27]. Articles which would present the intersection of these aspects, however, do not seem to exist. Following the observed lack of references on the use of aerogel insulation in exterior / interior locations of buildings, this article reviews commercial information provided by producers and fundamental research.

The current scientific and technical literature and commercial offer of aerogel was analyzed. The data obtained from the literature are summarized in tabular form, reflecting the impact of interferences. The

experience gained in the implementation of experiments [3] was developed into an applicable methodology for testing new materials.

A review of internationally accepted conceptual documents [4, 30, 31] on conditions of use of new materials in preservation of architectural heritage (= monument preservation) has been made. Documents set out the principles (conditions, criteria) of use of the new materials. In the case of retrofit insulation use in the refurbishment of historic buildings certain criteria must be followed.

RESULTS

Aerogel based applications are developed especially for the reconstruction of the existing buildings (Table 1) as the reconstruction constitutes a real opportunity for the future reduction of energy demands of the building. The developed materials with aerogel are intended mainly for the use in applications with limited space [1]. Historically valuable structures represent a specific group of refurbishment, where it is necessary to contend with the physical lack of space for additional thermal insulation and also with restrictions related to the requirements that the original character of the building is not changed and that the insulation will be compatible with the original material.

An assembled list of aerogel based products (Table 1) shows different materials are available in the reconstruction of buildings as for retrofit insulation. The base silica aerogel can be used in pure or composite form. As pure it is used in the form of granules of affordable different fractions, which are used as an addition to other composites. The solid - monolith pieces of the material in pure form for building construction are the subject of research [18]. The composites offered on the market are available in fibrous form or as mixtures. The available number of compositions can be used for refurbishment just as an added retrofitting insulation. (Table 1)

Table 1: Inventory of disposable materials with aerogel [2] for new construction (N) or refurbishment (R). 0 filling/ingredient material, 1 retrofit material without need of fixings/anchoring, 2 retrofit materials with fixings, 3 self-supporting construction materials

material		*class*	*form*	*use*		*type*
Silica aerogel SiO_2	basic material	compact form (monolith)	solid sheet, boards and blocks of different form	N/R	3	Constr. element
			films and sheets	N/R	3	
		grainy	grains, granules, pellets, powder	N/R	0	Ingredient material
				N/R	0	
	composite	with fibres (*crosslinked, filled, layered*)	insulation blanket, fabric	N/R	2	Retrofitting material
			solid panels, boards	R	2	
		mixtures	paints and coatings	R	1	
			plaster (interior/exterior)	R	1	
			poured construction materials	N	3	Constr. material
			building blocks, construction panels	N	3	

The available range of materials observed by inventory shows possible uses and applications for large-scale use and/or for details, the direct use for the perimeter masonry, or indirectly with the maintenance of structured expression by insulation improvement of other buildings components. There are also transparent forms and vacuum insulation panels (VIP) being researched currently [16]. Translucent panels are available and affordable. Transparent and translucent forms of products have the potential to reduce the energy requirements of the buildings of cultural heritage by improving the thermal performance of the original illumination openings: eg. tabular fillers of industrial windows, large-scale skylights of lofts, or large-scale diffuse glazed illuminating walls. Thermal insulation and other building materials follow the trend of improvements with the help of aerogel properties, which

are pursuing the objective to offer more efficient insulation at smaller thickness to construction market. The favorable combination of properties of available retrofit materials - strong thermal insulation properties at lower thickness, no wettability and water vapour permeability appear to be compatible and also potentially useful in restoring architectural heritage. These effects, however, need to be tested with respect to a number of the monument protection criteria. (Table 2)

International conventions and documents [4, 30, 31] permit the use of new materials in restoration of architectural heritage buildings in case they are compatible and have been tested, and their effects on the original material are not negative. Applied Materials shall meet the conditions for compatibility with the physical original, minimize invasive intervention in the authenticity and integrity of the original and should satisfy the condition of reversibility of intervention. [3]. Therefore the required criteria were summarized in the matrix, with grade of suitability. (Table 2)

Table 2: Methodological criteria for selection of a new retrofit material for case of monument refurbishment. Refurbishment of architectural heritage = thermal improvement of building and the preservation of cultural values

		Methodological criteria					
		Preservation / *Primary*				**Energy Efficiency / *Secondary***	
		Authenticity	**Integrity**	**Compatibility**	**Reversibility**	**Energy savings**	**Effectivity of intervention**
the suitability of intervention / description of the effects	**+**	• Added material preserves the original appearance and materiality	• The new material is added to the original • The integrity of the original remains intact	• Symbiotic or irrelevant interaction of materials after application	• It is possible to completely remove the new material to original authentic state, with no need of restoration of original material	• Added material brings significant energy savings • Significant reduction in energy consumption • > 30% of former consumption	• Interventions are simple and convenient for construction and maintenance • Without secondary effects
	±	• Partially added of replaced material preserves the original appearance	• The new material enters the original and partially undermines the integrity of the original	• Insignificant impact on properties resulting from interaction	• Removal of new material to original is possible with the need of small, manageable adjustments	• Added material brings small reduction in energy consumption • < 30% of former consumption	• Unknown and unaccountable efficiency factors • Secondary effects are unclear
	–	• Added material changes the appearance of the original material while maintaining the former properties	• The new material fully enters the volume of the original and disrupts its integrity	• One-off deterioration of visual/utilitarian properties after application	• The new material and its anchoring leaves readable traces after removal • Low possibility of new material removal	• The new added material insignificantly reduces energy consumption • Energy savings are not observed or clear	• New material brings obvious disad-vantages in construction and maintenance • Secondary impacts are negative
	!	• Added material completely changes the appearance and properties of the original material	• The new material extensively disrupts the volume and changes the properties of the original	• Significant or progressive deterioration after application of new material with aggressive and destructive effect	• The new material does not allow reversibility to the original condition • There is a loss/destruction of the original material after removal	• The new added material doesn´t heal persistent energy leaks, • Unbearable energy consumption, waste of energy or numerous heat bridges remains	• The intervention with new material is costly and technically complicated • Disadvantages in comparison with established procedures

The mentioned methodological criteria for selection of new materials for refurbishment should be used not only in buildings that are registered (listed) as cultural monuments but can be used also for other historical buildings that may contain a specific value of uniqueness. When selecting new materials for refurbishment, achievement of higher ratings (+ or close to this grade) by submitted criteria (Table 2) can objectively protect the values of old buildings, which are not registered as heritage.

The table of criteria (Table 2) shows the suitability of the material for its use in restoration of historic buildings. The potential use of new materials with aerogels is rated by four grades (from "+" to "!"), which can be objectively tested, observed or predicted. The first three grades ("+", "±" and "-") refer to the level/adequacy of intervention. The "+" when the used new material is seen as the best in all evaluated criteria. Material with this assessment is highly suitable for the use in the reconstruction of historical architecture. The "±" shows certain negative impacts on the monitored criteria. Application of the material should be reconsidered. The "-" grade indicates that the observed negative aspects are

significant. The material that achieves these values is inappropriate for the use in preservation. The fourth grade of extreme action marked with "!" is described as highly inappropriate in terms of monuments in all evaluated criteria. This grade indicates inappropriateness and restriction of use in refurbishment of monuments.

DISCUSSION

The review of available aerogel based materials (Table 1) shows the current offer of the materials and direction of their development as well as their applications due to their additional insulation properties and their suitability for renovation and refurbishment. For historical structures, it to test / verify application in terms of visual impact and ways of attachment (or conditions requiring additional anchoring system of materials) proves necessary. It is necessary to evaluate the impact of the application of any new retrofit products in terms of the monuments protection criteria. (Table 2) The way of physical performance of application in combination with material affordability also affects the selection of material for the use. It is necessary to observe the long-term effects on hygro-thermal performance of the building and explore the nanosafety of new aerogel based materials.

CONCLUSION

The need to reduce energy demands of the existing buildings is a hot topic. The permanent solution is achieved by additional insulation. The new aerogel-based materials bring new challenges in this respect. Highly efficient thermal insulation materials with a wide range of applications represent specific group of materials especially for historic buildings. Development of new materials with aerogels should respect the criteria for protection of monuments. Reliable verification of the complex impacts on the structure (ie, the thermal effect and impact on appearance) should precede the implementation of new materials into the process of restoration of historic buildings.

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