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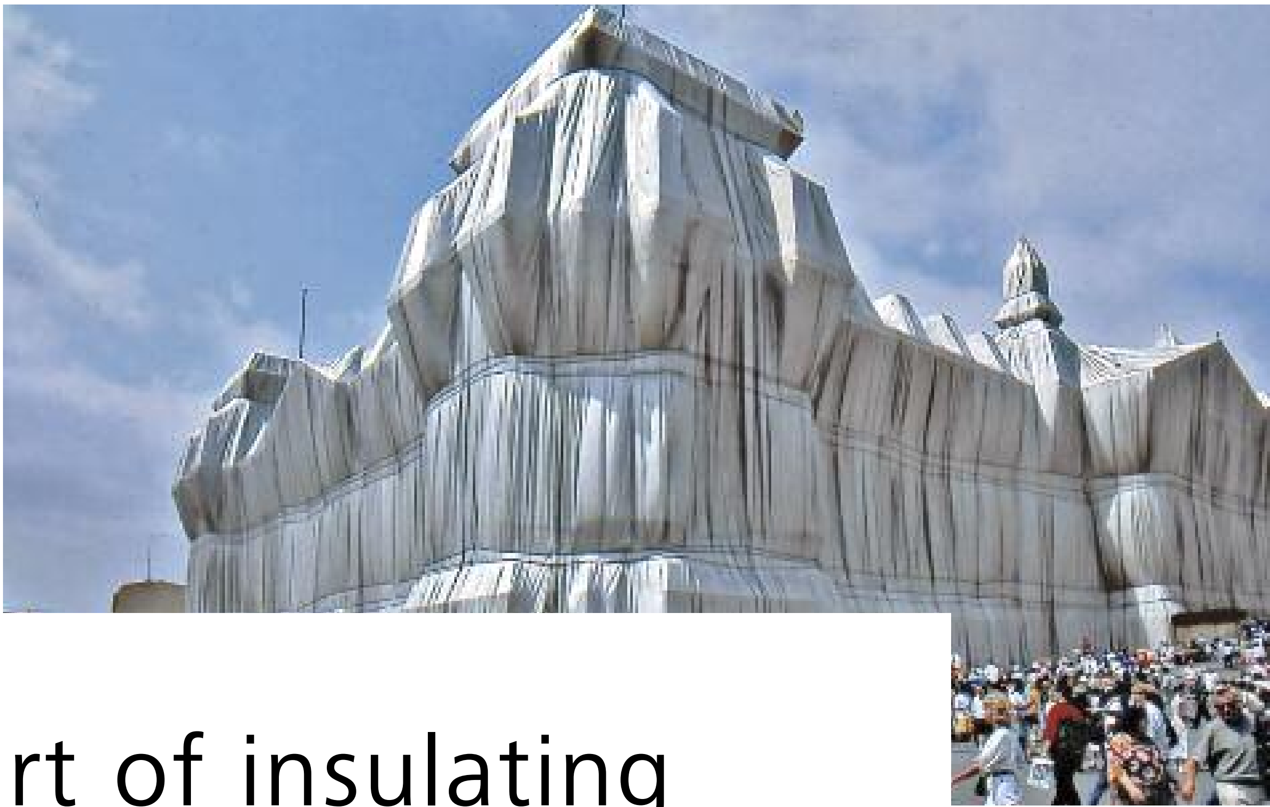

The art of insulating

New technologies such as vacuum insulation panels, vacuum glazing and aerogels are the future of building insulation. Empa is investigating opportunities and optimising materials in order to minimise heat losses in buildings.

TEXT: Peter Merz

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A building turns to art: in summer 1995, the artist couple Christo and Jeanne-Claude wrapped the Reichstag in Berlin. Efficient and elegant insulation can also be considered an art in some ways, even if based primarily on know-how. (Photo: txmx2, Flickr)

2
Modern high-performance insulating systems such as vacuum insulation panels offer excellent insulation even at low thickness. (Photo: Empa)

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Aerogels consist of more than 90 per cent air, which is enclosed in pores with sizes in the nanometre range; as a result, these materials are excellent thermal insulators. In addition, they allow light to pass through and thus make it possible to have natural lighting, for example in a gym.
(Photo: Scobalit AG, Empa)

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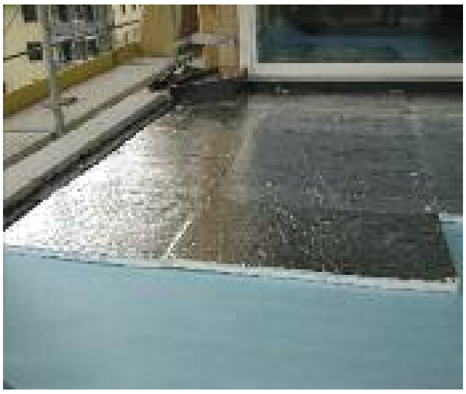
Vacuum glazing can achieve superior thermal insulation performance. The challenge consists in sealing the panes of glass in such a way that the vacuum in the space between can be maintained over decades. Empa researchers have patented a method whereby the two panes are sealed with a tin-based alloy and an electric potential. The ultrasonic image of a laboratory experiment (right) shows that the bonding with the tin was successful throughout. The air-tightness was confirmed with leak test measurements. (Photo: Empa)

During winter, many poorly insulated houses make it easy for energy and thus money to literally “walk out the door”. There are a variety of approaches to renovating buildings and to making them more energy efficient. Empa is particularly interested in high-performance systems which dramatically increase insulation ratings while reducing the overall material thickness. The Laboratory of Building Science and Technology researches and improves various systems of this type, some of which are still in development and some of which are commercially available.

“Empty space” insulates
Vacuum insulation panels (VIPs) have been used in Swiss construction projects for roughly a decade. Here, core materials with pores in the submicrometre range are wrapped in a protective envelope. This bag is then sealed at a pressure of roughly one millibar. Because the inside pressure is only a thousandth of the ambient air pressure, VIPs are excellent insulators; for panels straight from the factory, their thermal conductivity (lambda value, λ) is measured at 4 mW/m·K and thus is eight times better than conventional insulating materials. Because of their higher prices, VIPs are used primarily in specialty applications such as terrace or interior insulation. If a balcony were to be insulated with conventional materials, its floor would be higher than the floor of the adjacent living area.

The primary question about VIPs being addressed by Empa researchers for quite some time deals with their durability. Can they maintain their performance for 25 years, the minimum service lifetime needed to meet the requirements of the Swiss construction industry? “The panels available in Switzerland are of high quality, and market leaders are thus very interested in maintaining these standards. This includes rigorous control and surveillance of their service lifetimes,” comments Empa researcher and VIP expert Samuel Brunner. He and his colleagues have developed test methods for VIPs to determine their decrease in insulating capability over the years. For this, the panels are stored for roughly six months in an environ-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mental chamber, and afterwards the researchers measure the increase in internal pressure and other ageing-related parameters.

"At this time, VIPs have the highest performance of any commercially available insulating system and make it possible to insulate buildings with a thin layer," adds Brunner. "Our measurements have shown that the latest available VIPs will still have a relatively low λ value of 6 mW/m·K even after 25 years. According to the requirements of standards common in the insulation industry, still 90 per cent of the panels must be below the stated value after 25 years. There is no other insulating material anywhere which can compete with this and exhibit such a low λ value after that many years." For instance, polyurethane insulating panels have a λ value between 22 and 28 mW/m·K depending on whether they are covered with a diffusion barrier, generally made of aluminium foil.

A solid material made of 90 per cent air

If the size of the pores is made even smaller, insulating materials can be manufactured without a vacuum which can still achieve λ values below 15 mW/m·K. Such materials, named aerogels, have nanometre-sized pores and consist of up to 90 per cent air. For quite some time, the Laboratory of Building Science and Technology has been researching aerogel-based materials as well as aerogel systems. For example, starting with commercial aerogel granules, Empa researchers have developed an insulating render which offers an elegant way to renovate historic buildings without changing their outward appearance. Initial field trials are planned for this year.

Matthias Koebel and his team are developing novel aerogel-based materials which are intended to be used primarily as insulating materials but which can also manipulate light. Using this type of translucent aerogels, roofs have already been insulated effectively, at the same time allowing for passive illumination of the interior spaces by natural daylight. Aerogels also offer great promise for artificial lighting. With this aspect in mind, Empa experts are investigating application possibilities in LED lighting technology.

Potential improvements with vacuum glazing

Well-insulated roofs and walls are of little use if the windows are the actual weak points. Vacuum glazing is the second main research area for Koebel's team. "It is true that today's double and triple-glazed windows already exhibit quite acceptable insulating values. However, there is only limited availability of the rare gases krypton and xenon which are used to fill these windows," explains Koebel. "The alternative is a vacuum glazing, which in theory achieves even better insulating values than a state-of-the-art triple glazing." In addition, such a window would be thinner, lighter and yet allow for more light to pass through.

Today's commercial vacuum glazing products are made by sealing two panes along their perimeter followed by evacuation of the cavity space in between them through a pump-out port. The critical problems associated with this type of manufacturing are the high temperatures and the pump-out tube itself, which must be separately sealed off after pumping. This method, common especially in Asia, is able to produce vacuum glazing but only with insufficient insulating performance. In order to make a big breakthrough in European markets, the fabrication process and product performance must be improved and a longer service life guaranteed.

Koebel and his colleagues are following a new approach to sealing the two glass panes. For this, they are investigating vacuum compatible technologies for edge sealing. In one method that has proven successful in the laboratory, the panes are sealed in a high vacuum environment, in other words at a pressure between 10^{-3} to 10^{-4} millibar, using a special tin-based alloy. The pump-out tube is no longer required because the sealing takes place directly in the vacuum, meaning that after the process is done, there is no air left between the two panes. The solder-based sealing technology is patent pending. In addition, the Empa experts have also developed mathematical models to understand the ageing process of vacuum glazing, and can now estimate the magnitude of various contributions to the total pressure increase and ageing using computational tools alone. //