DIFFUSION-OPEN AND DIFFUSION-TIGHT INTERNAL INSULATION SYSTEMS

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Abstract
The current energy performance requirements extend beyond new buildings, including existing and historic buildings. Improving the thermal performance of buildings is an important factor for energy consumption reduction. Usually, an external insulation system is used in order to enhance thermal performance. This method of insulation is preferred as the safest. For listed buildings, this method of insulation is often not feasible due to legislative constraints. In such cases, internal insulation becomes an alternative, despite the number of risks it poses. New so-called capillary-active materials are currently being developed. This article is focused on the principle of diffusely open and diffusely closed internal insulation systems.

Keywords
Interior insulation, diffusion-tight, diffusion-open, hygrothermal performance

1 INTRODUCTION

In recent years, there has been a steady tightening of energy consumption requirements [1]. Most of the energy consumption in buildings is related to heating. In order to reduce heating energy consumption, it is necessary to optimise the thermal performance of the building envelope. Improving the thermal performance of structures is one of the key parameters influencing building energy performance [2]. For new buildings, improving the thermal performance of the structures is already a common practice. The standard solution is the application of an external insulation system. This method of insulation is currently considered to be the least risky [3]. In recent years there has been a growing concern for the energy performance of historic buildings. It has been shown that improving the thermal performance of structures in these buildings can lead to significant energy savings [4]. In such cases, however, the application of an external insulation system is often impossible due to legislative constraints, leaving internal insulation systems as the only possible solution.

Internal insulation is one of the riskiest approaches to improve the thermal performance of a building envelope. Moreover, the application of an internal insulation system will significantly change the thermal and humidity behaviour of the structure [5]. This solution introduces notable disadvantages, including the imperfect resolution of thermal bridges, and a reduction in floor area. A diffusely closed system is considered to be the common approach to internal insulation, typically consisting of thermal insulation combined with a vapour barrier. The thermal insulation in these systems is often mineral wool based. The main disadvantages of a diffusely closed system include the high diffusion resistance of the vapour barrier and as a result, moisture is prevented from drying out from the structure towards the interior. Consequently, the masonry may be exposed to persistent moisture leading to damage [6].

Diffusely closed systems with a vapour barrier are sensitive to the method of installation and often require individual attention and assessment. Moreover, the lifetime of the vapour barrier is limited, making it susceptible to both mechanical damage during construction or during the subsequent use of the building. Due to the problems and risks associated with diffusion sealed internal insulation systems, alternative approaches have been developed in recent years. Much attention has been directed towards diffusely open internal insulation systems with calcium silicate (CaSi)-based thermal insulation. The properties of these internal insulation systems facilitate the redistribution of condensed moisture towards the interior, eliminating some of the risks of masonry damage.

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2 PRINCIPLE OF DIFFUSION-OPEN AND DIFFUSION-TIGHT INTERNAL INSULATION SYSTEMS

There is a large number of materials available on the market for internal insulation systems. For diffusely open systems, thermal insulation based on calcium silicate, cellular concrete or autoclaved cellular concrete are the most commonly used. Materials made from renewable sources are also currently available on the market. They are intended to provide an environmentally friendly alternative to current thermal insulation materials, especially in the context of tied up non-renewable primary energy sources. These materials include, for example, thermal insulation made of fibreboard. This insulation is vapour permeable and can transport moisture along the fibres of the wood. Cellulose-based thermal insulation also has relatively good properties.

Other alternatives include systems composed of a combination of materials, including polyurethane combined with a capillary active material, or hydrophilic mineral wool with a vapour retarder. The latter systems are more diffusely closed than the systems with standard capillary active thermal insulation. Materials for internal insulation can be classified on the basis of the systems in which they are used. Fig.1 shows an overview of thermal insulation materials depending on the internal insulation system.

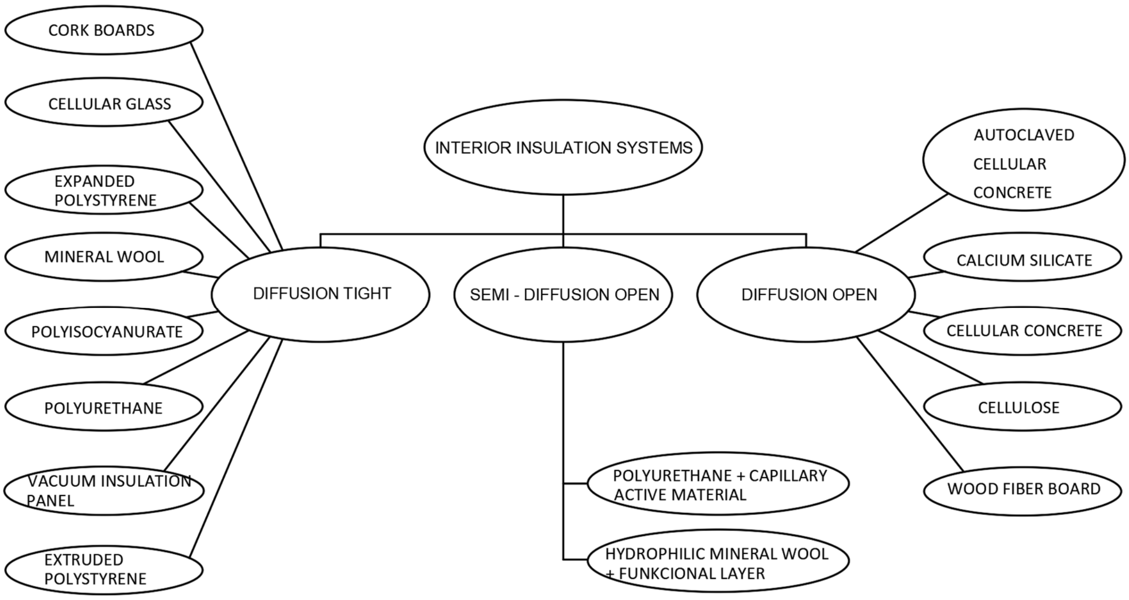

Fig. 1 Overview of materials used for internal insulation systems.

Diffusion-tight insulation system

The standard diffusely closed system consists of a combination of thermal insulation and a vapour barrier layer placed towards the inner surface of the construction. Some thermal insulation materials integrate the vapour barrier as an inherent component. In some cases, the insulation material itself may have a high diffusion resistance, for example foam glass. Thermal insulation material based on mineral wool are frequently recommended for these systems, where the vapour barrier prevents the condensation of water vapour in the structure.

The vapour barrier is characterised by a high diffusion resistance, serving to prevent the drying out of masonry towards the interior. However, this resistance can lead to a number of potential risks and damages to both the masonry and the embedded timber elements. These risks include interstitial condensation [7], damage to masonry due to freeze-thaw cycles [8] and the risk of mould growth [9]. Fig. 2 shows a schematic of the temperature and moisture profile within a structure employing a standard diffusely closed system design.

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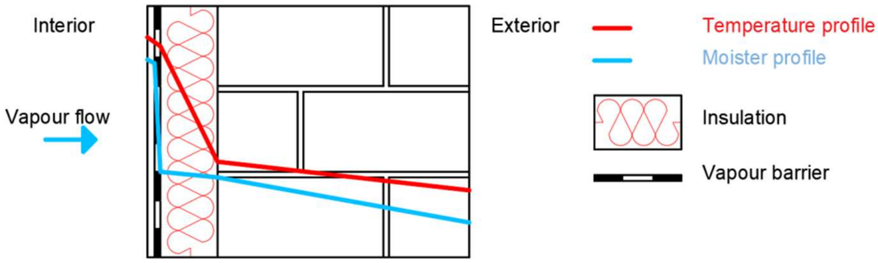

Fig. 2 The principle of a diffusely closed internal insulation system.

Diffusion-open insulation system

Diffusely open systems consist mainly of an insulation material with the ability to redistribute moisture to the warm side of the masonry surface in the interior and the adhesive mortar. Perfect contact between the wall and the thermal insulation by means of the adhesive mortar is essential for the proper functioning of the capillary active material. The capillary active insulation material should have low thermal conductivity and high vapour permeability. The adhesive mortar should simultaneously be able to conduct liquids [10].

If perfect contact of the thermal insulation with the wall is not ensured, the system will not be able to function properly and redistribute moisture to the warm side of the structure. Typically, calcium silicate based thermal insulation material is used in these systems, featuring pore sizes ranging from 0.1 to 1 μm, facilitating moisture transport in the material [11]. Fig. 3 shows a schematic of the temperature and moisture profile in a standard diffusely open system design.

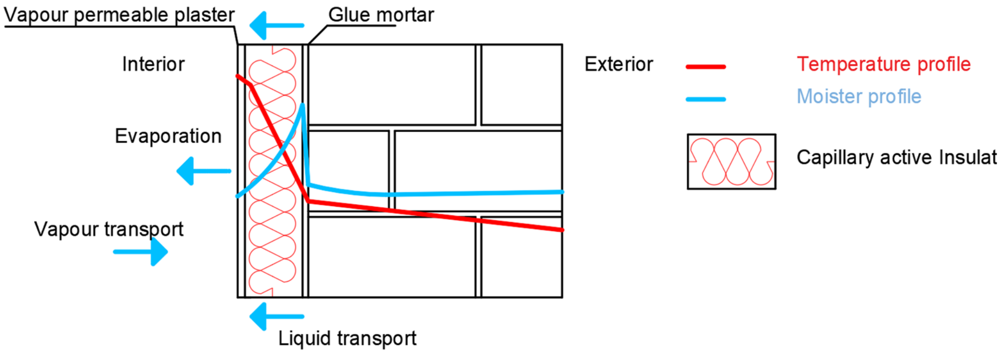

Fig. 3 The principle of a diffusely open internal insulation system.

Semi-diffusion open insulation system

There are currently materials for internal insulation on the market that could be described as semi-diffusion open. These can be composite thermal insulations, such as PUR combined with calcium silicate filled channels, or multilayer thermal insulations. Very often, these are materials based on hydrophilic mineral wool or fibreboard combined with a vapour retarder. In these systems, a condensation plane is expected to form on the functional layer. Subsequently, the condensed moisture is then redistributed to the interior by the thermal insulation.

G. Scheffler and J. Grunewald worked on the development of a calcium silicate variant combined with a vapour retarder. This model proved physically possible, but the thickness of the thermal insulation must be carefully chosen to ensure the formation of the condensation plane between the calcium silicate and the vapour retarder. Fig. 4 shows a schematic of the temperature and moisture profile in a structure with a semi-diffusion open system design.

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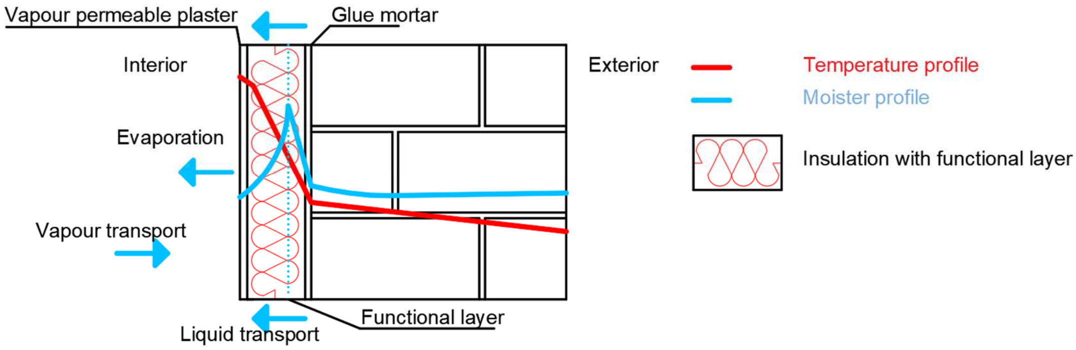

Fig. 4 The principle of a semi-diffusely closed internal insulation system.

3 DISCUSSION

Diffusely open internal insulation systems employing capillary-active thermal insulation offer a solution to the problems associated with diffusely closed systems with a vapour barrier. Systems with capillary active thermal insulation have been the subject of research for many years, experiencing a surge of interest 20 years ago. Early studies dealing with capillary active materials and simulations of the thermal and humidity behaviour of structures with diffusely open internal insulation systems aimed to validate its correct functioning compared to diffusely closed systems [12]. In a study [13], the influence of orientation on the thermal-humidity behaviour of a structure insulated with a capillary active material was observed. Faster drying was observed for the south-facing façade than for the north-facing façade. In study [14], the change in thermal moisture behaviour of Sprandel insulated with Multipor was studied, demonstrating neither risk of masonry damage due to freeze-thaw cycles nor the risk of mould growth.

However, the results of some experiments have shown that the use of diffusely open materials may not be preferable to a standard diffusion closed system in all circumstances. For example, when combined with hydrophobization of the external surface, vapor tight systems appear to be more advantageous [15]. Verrecen et Roels compared several internal insulation systems in a climate chamber. It was found that the diffusely open systems resulted in moisture deposition in the wall and in the glue mortar, while the diffusion closed system appeared to be more advantageous in terms of interstitial condensation. In a study [16], a high moisture gain was observed for walls insulated with capillary active thermal insulation. No increase was observed for the foamed glass system. It was concluded that capillary active thermal insulation is not suitable for cold climate conditions.

4 CONCLUSION

Diffusely open internal insulation systems present an alternative to conventional vapour barrier systems. Their inherent properties have the potential to prevent numerous risks associated with humidity and freeze-up cycles. However, it is important to note that, in specific cases, diffusely closed systems may be recommended. Satisfying results have also been observed with some semi-diffusion open systems. Good thermal and moisture properties have been observed, for example, with mineral wool in combination with a vapour retarder [17]. It is essential to recognize that each internal insulation system has its set of advantages and disadvantages, and the selection of an appropriate system should be considered in the design process.

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