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Durability evaluation of adhesive tapes for building applications

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HIGHLIGHTS

- Durability tests and evaluation methods used for tapes used in building is discussed.
- Accelerated ageing procedures for tapes used for indoor and outdoor is proposed.
- Adhesive degradation and a consequent sliding of the tape across the wind barrier due to wind load.
- Possibility of using standard substrate to evaluate the actual substrate/interface property.

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ABSTRACT

In the building sector, various adhesive materials are experiencing an increased usage for sealing of overlaps and joints between most commonly used building materials, around penetrations, pipes and windows for increasing the moisture tightness and the airtightness of buildings. Among the adhesive materials are adhesive tapes that are used to ensure adequate airtightness of a building and thus must be able to withstand severe environmental conditions without significant long-term deterioration. Durability test methods are needed to evaluate whether the tapes fulfill their performance requirements for the service life of the whole building. However, there is a lack of reliable test methods and evaluation procedures for tapes used for building applications. This study was performed to evaluate tape durability testing and evaluation methods, which hence form a basis for further improvements of the existing methods.

1. Introduction

Adhesive materials, mainly tapes, and sealants, are becoming increasingly popular for maintaining and/or increasing the moisture and airtightness of buildings [1]. These products are used to seal joints and overlaps in the wind- and vapour barrier layers, to repair damages, and to tighten ducts (see Fig. 1). One benefit is the practical application of adhesive joints, which is simple and quick compared to mechanical tightening solutions. Most importantly, the application of adhesive tapes is essential in order to meet increased airtightness requirements. Both the airtightness of the wind barrier layer on the outside and the vapour barrier on the inside of the building play indeed a major role for the energy efficiency of state of the art buildings. For example, in Norway, since January 2017, the requirement in the Norwegian building regulation (TEK 10) for the infiltration rate at 50 Pa is set to 0.6 h^{-1} for residential buildings, and 1.5 h^{-1} for apartment buildings [2]. Compared to the previous regulation, the current required infiltration rate for residential buildings corresponds to about 25% of the original requirement. Hence, adhesive joints have a double role: they ensure both energy efficiency and protection of the building (e.g. avoiding moisture damages).

Adhesive tapes should adhere satisfactorily to the surfaces of end use materials, they should remain unaffected by temperature extremes and the presence of moisture and they should tolerate surface contaminants. As adhesive tapes are concealed in the building envelope and hence less accessible, they need to maintain their sealing function for the intended service life of the envelope (e.g. 50 years, 100 years or longer). The influence of cyclic and climate exposure conditions such as temperature, liquid water and

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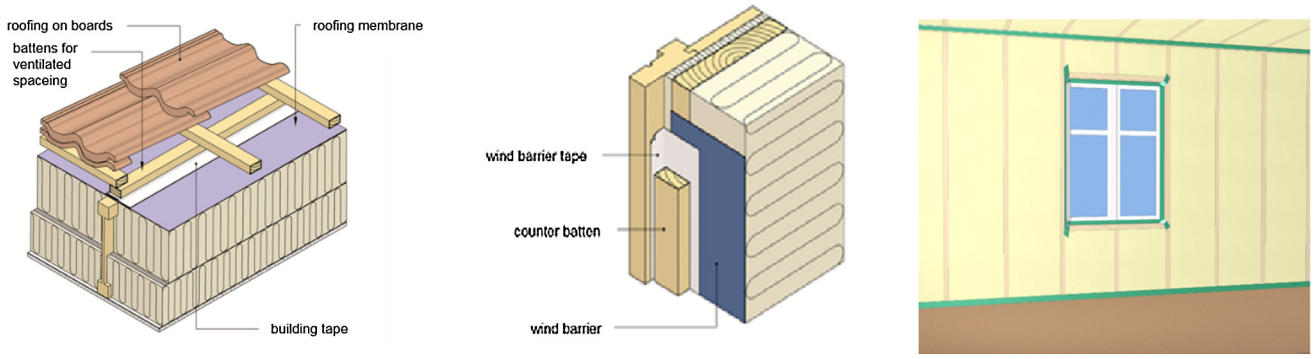

Fig. 1. Examples for the use of tapes to increase airtightness in the building envelope. Left: seal an overlap in the roofing membrane. Middle: Seal between the wind barrier and a window frame. Right: vapour barrier tape for sealing of vapour barrier and a window frame (figure adapted from SINTEF).

humidity on durability of adhesive tapes used in the building industry is obvious. It is important to identify the adequate properties with their corresponding requirements for specially formulated and targeted adhesive tapes which are able to withstand these exposure conditions and thus are suitable for their intended applications.

Durability of joints is therefore important, and accurate and reproducible test methods should evaluate their adhesive properties. Small-scale and large-scale accelerated climate laboratory ageing are widely used as durability evaluation methods. With such methods, main properties of building components or systems and their durability towards climate strains can be investigated within a relatively short period of time. Thus, various accelerated ageing apparatuses are utilized in the laboratory according to different ageing methods and standards. The selection of the apparatuses depends on a number of factors including the type of product or material to be tested, the end-use application, the main degradation modes, and budgetary restrictions. For adhesive tapes, UV resistance, moisture resistance, and thermal resistance properties are important to withstand degradation during the actual construction period and use phase of the building. Thermal resistance is of special importance when adhesive tapes are to be subjected to high temperatures, which may be the case during the construction period or around windows and the roof area [3]. Accelerated ageing experiments may provide information related to the expected service life, the deterioration processes and maintenance schedules of the new systems during their real applications.

To the authors knowledge, such reliable durability test methods (e.g. accelerated ageing procedures and long-term performance prediction methods) are lacking for adhesive tapes used for outdoor building applications [4], despite the existence of different standards [5–8] relevant to tapes used for other application areas. There is only one standard, DIN 4108–11 [9], recently developed by German Institute for Standardization, which describe the minimum requirements to the durability of adhesive tapes used for buildings. However, this national standard is used only for adhesive tapes applied for sealing of vapour barrier layers.

SINTEF Building and Infrastructure (SINTEF) evaluates and documents the performances of building materials, components and construction systems used in Norwegian buildings. This is a requirement given by the Norwegian building authorities (Direktoratet for Byggkvalitet) in the building engineering regulation [2], for building materials used in Norwegian buildings. Among others, SINTEF has performed testing and evaluation of the durability of tapes used in buildings according to SINTEF guidelines for tapes used in buildings [10], in order to evaluate the suitability of the tapes for the use in buildings exposed to the harsh Norwegian climate.

SINTEF guidelines for tapes used in buildings provide test methods for tapes used for sealing both wind barrier and/or vapour barrier building layers. The guideline is based on the standard test methods used for testing roof membranes [11–13], considering the tapes are expected to be exposed to similar climate conditions like the roof membranes. According to the guideline, the durability of the adhesive tape joints is evaluated by exposing the test specimens to main environmental conditions (i.e. water, UV, freeze/thaw and heat) in accelerated laboratory ageing. The durability of the adhesive tapes and adhesive joints is evaluated using two weeks of accelerated ageing in a climate simulator with four repeated cycles, according to NT Build 495 [14], and 24 weeks of heat ageing at 70 °C in accordance with NS-EN 1296 [15]. The tensile strength of the tape and the shear and peel resistance of the adhesive joints are evaluated before and after ageing, and for different tape/substrate interfaces. However, the test is time-consuming (e.g. accelerated ageing tests need 24 weeks), and expensive (e.g. testing of one tape with two end-use substrates leads to testing of more than 30 test specimens). In addition, there is uncertainty on the exposure condition of vapour barrier tapes and wind barrier tapes in the accelerated ageing chamber. The objective of this study is twofold, i.e. to evaluate existing tape durability test methods and explore possible future research perspectives. These results from this work are expected to help establishing guidelines for a new testing scheme. Possible future perspectives are also discussed.

2. Methodology

The methodology section of this paper is divided into two parts. The first part outlines the durability test and evaluation methods, designed and performed. It includes the description of materials used for testing, accelerated ageing test method used to evaluate the effect of different weathering factors and description of the test methods used to evaluate the performance of the adhesion bonds. This first part also describes the statistical and sensitivity analysis used for the evaluation of the adhesion test results. The second part outlines the test method used to quantify the effect of wind load on the adhesive properties of wind barrier and adhesive tape joints.

2.1. Test methods

2.1.1. Materials

Adhesive tapes are viscoelastic materials (i.e. have both viscous and elastic properties) that adhere to a surface only by applying a light pressure [16]. Because of their viscous properties, they can flow easily and be able to dissipate energy during the adhesive bonding process to the substrate. They also resist separation under stress due to their elasticity. The degree of wetting is one of the criteria for good adhesion and it mainly depends on the difference