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The effect of temperature and humidity on the permanence of external thermal insulation composite systems

Eneli Liisma[a,*], Gert Lõhmus[a], Lembi-Merike Raado[a]

[a] *Tallinn University of Technology, Ehitajate Street 5, 19086 Tallinn, Estonia*

Abstract

The purpose of this paper is to analyze the impact of temperature and humidity on external thermal insulation composite systems (ETICS), resulting in internal stresses and frost damages as a serious sustainability problem. In order to predict the behavior of ETICS in different weather conditions, a variety of climatic conditions and cycles were composed on the basis of the Estonian statistical data. All coating components of ETICS were tested separately and as a system for dimensional changes using thin layer measurement principles. This study focuses on three types of plasters most commonly used in ETICS – mineral plasters, acrylic plasters with higher flexibility and silicone plasters. As a result of the research, a potential micro-cracking mechanism of ETICS in Northern climate conditions is presented in this paper.

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Keywords: Façade renovation; External Thermal Insulation Composite Systems; Thin-layer rendering; Cracking mechanism

*Corresponding author. Tel.: +372 620 2453; fax: +372 620 2451 .
E-mail address: eneli.liisma@ttu.ee

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1. Introduction

The housing stock all over Europe is composed of buildings many of which are nearing the end of their service life. Therefore ETICS, with low cost and simple installation, have been widely used to improve the energy efficiency and extend the service life of the housing stock. Although ETICS have been used in Estonia for several decades, materials in this complex system cannot be compared to the materials used in past decades. With the comprehensive usage of ETICS and the development of the field of building materials, several new product types are now in use, offering a variety of different reinforcement meshes and finishing coatings. This paper concentrates on mineral plaster, acrylic plaster and silicone plaster, as well as cement based reinforcement layer and reinforcement mesh with glass textile. With the wide selection of different ETICS components the need of predictions of the systems durability and sustainability and the differences of the plasters arise. According to the research of Sulakatko et al. [1] the degradation factors for ETICS are divided by degradation reasons into three main groups:

- Holistic design and defects caused by moisture
- Composition of render mortars and use of substrates
- On-site application of ETICS

One of the key components in ETICS durability is the degradation of the finishing coating. The finishing coating is usually 1.5-3.0 mm thick depending on the ingredients. This thin layer is exposed to atmospheric factors like wind, temperature changes, UV radiation, rain, snow and different urban environmental pollutants. These factors cause visual defects such as loss of colour, staining and mechanical defects like cracks, local deterioration and loss of adhesion, etc. by Tittarelli et al. [2]. The durability of the exterior layer of building envelopes is mostly influenced by the moisture access by rain. Thin finishing coating layers are porous materials that absorb liquid water into their pores and capillaries. Due to the thin layer format, moisture soon affects the deeper layers, increasing the thermal conductivity and thus the efficiency of the heat insulating layer by Šadauskiene [3]. According to Bochen [4] the open porosity of the finishing coating increases in time, especially in mineral based plasters. All the plasters have macro pore structure with pore radiuses above the value of 100 nm. Plasters with polymeric binders such as acrylic and silicone have a higher proportion of pores under 100 nm. Mineral plasters contain mostly lime, which, during the hardening process, causes larger porosity due to water evaporation. Silicone and acrylic plaster have smaller open porosity due to the content of polymers according to Bochen [4]. Although the total porosity increases over time, the radius of pores decreases by Bochen et al. [5]. The changes in porosity influence the moisture storage regimes of water. Liquid water is absorbed into capillary pores and water vapour adsorbed to the surface of pore walls by Straube [6]. But in northern climates, where it is colder, negative temperatures affect the sustainability of ETICS. In negative temperatures, the base coat and finishing coat are subjected to tensile forces, which occur as the capillary cracks' width increases which allows rain water to reach deeper layers. Wet layers can have reduced tensile strength due to freezing. In high temperatures the base coat and finish coat are subject to compression and adhesion stresses that can lead to deformation of the finish coat by Daniotti et al. [7]. In ETICS the reinforcement mesh is used to distribute the hygric and thermal stresses throughout the system. This allows stress relief to occur as short micro cracks rather than large cracks at a single location Lstiburek [8].

The aim of the research is to reproduce the main climate exposures and assess the effects. To better understand the differences between the usage of reinforcement mesh and glass fibre textile as a net, various scenarios were created.