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Durability considerations of refurbished external walls

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HIGHLIGHTS

- We analysed the durability of refurbished concrete walls.
- Our study focused on concrete walls in Nordic conditions with added exterior insulation layer.
- Building physical simulations provided essential data for the study.
- We estimated the benefits of refurbishment on concrete façade and formulated criteria for them.
- Different degradation types were considered such as frost attack, carbonation, corrosion and mould growth.

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ABSTRACT

The paper present results of the European project Sustainable Refurbishment of Building Facades and External Walls. The objective of the research was to analyse the durability of refurbished outdoor walls on the bases of building-physical analyses and estimate the benefits of refurbishment on concrete façade. All analyses were made for concrete walls in Nordic conditions when an exterior insulation layer is added. The major part of building envelope failures was caused by excessive moisture content of building materials. This topic has a high industrial relevance and the results can be utilised as recommendations for refurbishment projects.

1. Introduction

Because of the age of the European building stock and because of the new demanding energy performance regulations, safe and efficient refurbishment concepts have to be developed; refurbishment of external walls is among the most urgent tasks to be undertaken [3]. External walls have an essential effect on building performance and several aspects have to be taken into account when developing new concepts for refurbishment. The optimal solutions vary in Europe, because of the differences in age and quality of the building stock, various building technologies, and various cultural–historic values of buildings, different climatic conditions at present and different foreseen climatic changes because of global warming. Although the optimal solutions vary the methods of assessment may be similar. The European SUSREF project developed methods and concepts for the refurbishment of exterior walls. It stated that the development of a common systematic approach would help to avoid risks, consider all important aspects, pay attention to long-term impacts, and equally compare alternative solutions [4]b). The systematic approach developed covers all essential performance aspects that should be considered when developing improvements and new solutions for the refurbishment of exterior walls. The SUSREF approach includes 15 aspects and durability is one of the most important of these [13,8].

The durability of building materials leading to deterioration is mostly affected by climate factors such as temperature, moisture, sun radiation, pollutants and direct rain. These factors affect different materials in a different way, but as single prominent factors, moisture and temperature significantly affect the durability performance of all building materials. This makes the service life assessment principally a building physical problem.

Most of the durability/deterioration mechanisms of building materials are not possible to predict or model very accurately, since the rate of the process is highly variable. Also the loads, such as the climate factors as well as the quality of detailing that is related to workmanship are highly variable by nature. For some cases as for example concrete in exterior climates, deterministic

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models to calculation the durability do exist with regard to frost damage, carbonation and corrosion of the reinforcement. Models for mould growth on different building materials are also known [18]. These are presented in the following sections.

2. Considerations of durability and service life of external walls and refurbishments

As a prime building physical principle of designing an external wall structure is that the wall must be airtight and the water vapour permeability of structural layers increases gradually towards the outside surface of the wall. A water vapour barrier may be needed near the inner surface of the wall.

Considering the sources of moisture to the external wall, moisture may come from the outside, inside or it may be built in the wall as follows:

- The moisture coming from the outside is mainly the penetration of driving rain to the wall through leaking connections and other details. This may be due to bad workmanship or it may be due to a bad design of the structure.
- The moisture coming from the inside moisture is usually due to air convection caused by air leaks in the wall. Diffusion of moisture from the inside may happen as well, but normally this process is slow and takes a longer time to accumulate high moisture levels.
- The moisture which is built in comes during the building phase, either with materials that are moist due to bad storage conditions or lack of weather protection during construction. Such built-in moisture should not be permitted.

When adding a retrofit insulation and a new outer layer on the outer surface of an existing wall, it acts like a sweater and a raincoat, that is, as thermal insulation and weather protection. The existing wall will become warmer and dryer than before. Technically there is no critical theoretical limit of thermal insulation thickness, the thicker the better usually. If the new outer layer is water vapour tight, a ventilation air gap between the retrofit insulation and the new outer layer is needed to remove moisture from the structure. The old outer layer and possibly the old thermal insulation may also need to be replaced with new ones if these are deteriorated. It should be emphasised, that there is always a mould growth risk, if existing structures are covered by vapour tight layers and there are leakages in the outer layers or the existing wall has originally high a moisture content.

When adding retrofit insulation in the wall cavity, care must be taken that there will not be any voids left. Sprayed PUR foam may expand so intensively while hardening that the pressure may break the wall. There are some foam types that stay soft after hardening and these pose less risk. The bindings in between an inner and outer layer, which are mechanically needed for stability, reduce the effectiveness of the added thermal insulation because of cold-bridging.

When adding retrofit insulation on the inner surface of a wall, it must be ensured that there will not be water vapour tight layers left in the existing wall. Otherwise there will be a condensation risk in the wall. Typically there are intermediate floors and separating walls that make it impossible to add retrofit insulation on the whole inner surface of a wall. The junction of floors and exterior walls are already cold and they will become even colder when adding retrofit insulation on the inner surface of the wall. This may cause condensation at wall junctions. The condensation risk increases if thermal insulation thickness increases, outdoor temperature decreases or indoor air humidity increases. The wall structures and their thermal insulation level affect the condensation risk also. The effectiveness of an internal retrofit insulation is not as good compared to external retrofit since cold bridges normally cannot be avoided.

From a service life perspective of refurbished walls the following principals are significant:

- Ensure that the walls and connections are airtight and the water vapour permeability of the structural layers increases gradually towards the outside surface of a wall.
- It is more effective to add insulation on the outer surface of a wall.
- The thicker retrofit insulation on the exterior surface of a wall the better.
- The thicker retrofit insulation on the inner surface of a wall the worse.
- Design the structure and connections, sealing and supports carefully.
- Prevent driven rain to flow into a wall structure and especially to the warmer side of a cellular plastic thermal insulation.
- Ensure the water tightness with good detailing between window, wall and external window sill.
- Control the quality of manufacturing and installation.
- Make inspections periodically to the building site.
- Repair found defects in time.

3. Earlier studies and experiences

During the last few decades a well-insulated and not ventilated timber stud wall has been very popular in Sweden. The durability issues from these relatively new buildings have been reported in references [10,9]. The wall structures are made of adding an expanded polystyrene (EPS) insulation layer directly on the wind barrier and wall frame and applying rendering on the external surface. These are called external thermal insulation composite system (ETICS) structures. This structure has shown however to be sensitive to moisture. Swedish experience from surveys of more than 800 buildings show that the problem results from moisture penetration to the structure from the outside due to driven rain at joints, poor connections to windows or doors. This is a result of either bad design or bad workmanship. This has increased the moisture content of the materials inside the wall and has caused mould growth conditions in them. The damage is usually not visible on the surface of the wall and the only way to detect the damage is to measure the moisture conditions inside the wall. The damage was found in all wall directions and all parts of Sweden except in the northern regions. Building physical calculations have also shown that when a wall with EPS as the exterior insulation is exposed to a leakage of driven rain, this will induce a higher moisture content at the wind barrier sheet than if mineral wool is alternatively applied. Applying more insulation at the outside of the wind barrier sheet, leads to a dryer climate for the sheeting improving the situation. This is valid for both normal conditions and when exposed to rain water leakage. Good planning of details and good workmanship is required for a satisfactory performance of such structures. There is a need to provide a drainage possibility of leaked moisture to escape making the wall less vulnerable.

Aalto University, Laboratory of structural engineering and building physics carried out a research project ‘The effect of maintenance on the service life of concrete facades' during 2003–2007 [11]. The aim was to find out the factors affecting the deterioration of concrete facades. Analysis of decay and ageing of concrete facades was carried out along with surveys of condition of refurbished facades. The refurbished facades were of ages 7–25 years. In 2 out of 8 refurbished façade cases the freezing resistance was noted to be insufficient on the rendering, otherwise the conditions were good. Curvatures of concrete panels were measured. No