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Service Life Assessment for refurbishment concepts of concrete façades

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ABSTRACT
The EU Research Project SUSREF proposes new sustainable concepts and technologies for the refurbishment of building facades and external walls. As one part of the project it was necessary to identify the volumes of needs of refurbishment in the EU and in neighbouring areas and to evaluate the meaning of this in terms of environmental and economic impact and business potential. Within the tasks of the SUSREF project was also the service life assessment of the proposed refurbishment concepts of building facades and external walls. A simulation software, developed at the Technical Research Centre of Finland, was used to assess the performance and possible durability risks of the refurbishment concepts. The simulation software is able to emulate the temperature and moisture variations in a cross-section of the wall and to apply temperature and moisture sensitive degradation models at critical points of the structure. The software was applied for analyses of the refurbishment concepts in several European climates and with various material options. In this paper some results of the analyses are presented.

Key words: service life assessment, refurbishment, concrete, carbonation, mould, corrosion.

1. INTRODUCTION

The EU Research Project SUSREF proposes new sustainable concepts and technologies for the refurbishment of building facades and external walls. Within the tasks of the SUSREF project was the service life assessment of the proposed refurbishment concepts. The analyses were conducted for various European climates (sites) and with various materials for the outer core and thermal insulation. The use of coatings was also an option (Vesikari 2011).
A simulation software, developed at the Technical Research Centre of Finland, was used to assess the performance and possible durability risks of the refurbishment concepts. The simulation software is able to emulate the temperature and moisture variations in a cross-section of the wall and to apply temperature and moisture sensitive degradation models at critical points of the structure.(Vesikari 1999).
The studied degradation mechanisms were frost at-tack and carbonation of concrete and corrosion of reinforcement. The interaction of degradation mechanisms was also considered (Vesikari & Ferreira 2011). Possible mould growth was also evaluated us-ing the method of Viitanen (Vitanen et al. 2011).

The following concepts of refurbishment were studied: - E1: External insulation with rendering. The additional insulation is laid on the original outer core of the sandwich and covered by a layer of rendering; - E2: External insulation with panelling. The additional insulation is laid on the original outer core of the sandwich and covered by a panel board. A ventilation cavity is left between the additional insulation and the panel; - R1: Removing outer layers and adding a new thermal isolation with rendering. The original outer core and the original thermal insulation are removed and replaced by a new thermal insulation which is covered by rendering; - R2: Removing outer layers and adding a new thermal isolation with panelling. The original outer core and the original thermal insulation are removed and replaced by a new thermal insulation which is covered by a panel board. A ventilation gap is provided between the thermal insulation and the panel; and *I*: Internal insulation. The additional insulation is laid on the original inner core of the sandwich. The additional insulation is covered by a coating.

In this paper only the first two repair concepts are referred to. Five European sites (defining the weather) were used in the calculations: Jyväskylä (Finland), Frankfurt (Germany), Oostende (Belgium), Modena (Italy), and, Krakow (Poland). In this paper only Jyväskylä was treated.
The weather data used was the same as that applied in the thermal and moisture mechanical program WUFI. The weather data define the weather strains of a typical year on a vertical wall to the worst com-pass point (south or south-east). In the VTT software the weather of the year is repeated over and over again until 150 years covering the whole service life of the structure. As the combinations of variables are so many both in the original structure and in the refurbished structure, insulation materials, concrete quality, coating materials, refurbishment concepts and climates only certain case studies were selected for analyses. The case studies were selected in such a way that they probably reveal the greatest risks that may be en-countered when using different materials, structures in various environmental exposures. The determined degradation rates and service lives give indicative data on the risk of degradation that may happen in refurbished façade walls. The calculated degradation data give also a basis for comparing the relative rate of degradation with different refurbishment concepts and in different parts (climates) of Europe. The analyses of the refurbished walls were done as a continuation of the analyses of the original wall. Thus the moisture content, corrosion and mould conditions that were monitored from the original structure were continued in the analysis of the refurbished structure. This was done to uncover possible risks in the original structure and the refurbished one. The time of refurbishment was always assumed to be the time of service life of the original outer core based on corrosion of reinforcement.

2. ANALYSIS OF CONCEPT E1 – JYVÄSKYLÄ (FINLAND)

The original wall was assumed to be a typical sandwich wall as presented in Figure 1. Both the inner and the outer cores of the sandwich are of concrete. The thermal insulation between the cores is mineral wool. It was assumed that the thickness of the outer concrete core of the original sandwich is 30 mm and it is centrally reinforced with a steel net. The diameter of the steel bars of the net is 5 mm and they are of normal corroding steel. The concrete cover is only 10 mm on both sides of the core slab. The nominal strength of concrete is 25 MN/m^2 and the air content is 2 %. There is no ventilation gap between the thermal insulation and the outer core slab.
Concept E1 was used in the refurbishment. A mineral wool or a polyurethane insulation board is placed on the outer core of the original sandwich and a layer of rendering (mortar) on top of the insulation board. The reinforcing network of the rendering is assumed to be of zinc coated steel which is not assumed to be corroded in a carbonated rendering. So the corrosion of reinforcement in the rendering is not considered. However corrosion of reinforcement may occur in the original concrete outer core. A cross section of the system is presented in Figure 2.

There were two options for the thermal insulation material: 1. Mineral wool boards (MW) or 2. Polyurethane boards (PUR). For the mineral wool thermal insulation the analysis results were the following. The time starts from the fabrication of the original wall and the time of refurbishment is 65 years.

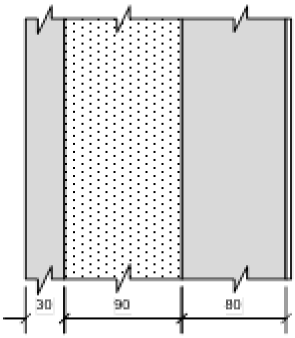

Figure 1 – Original unrefurbished sandwich wall

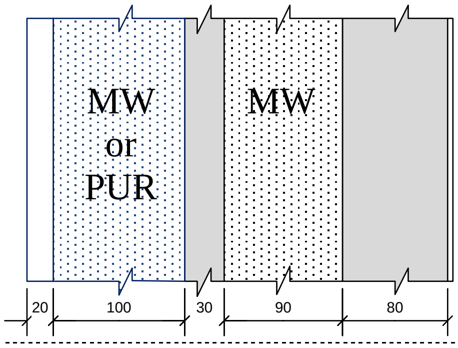

Figure 2 – Refurbished sandwich wall, concept E1

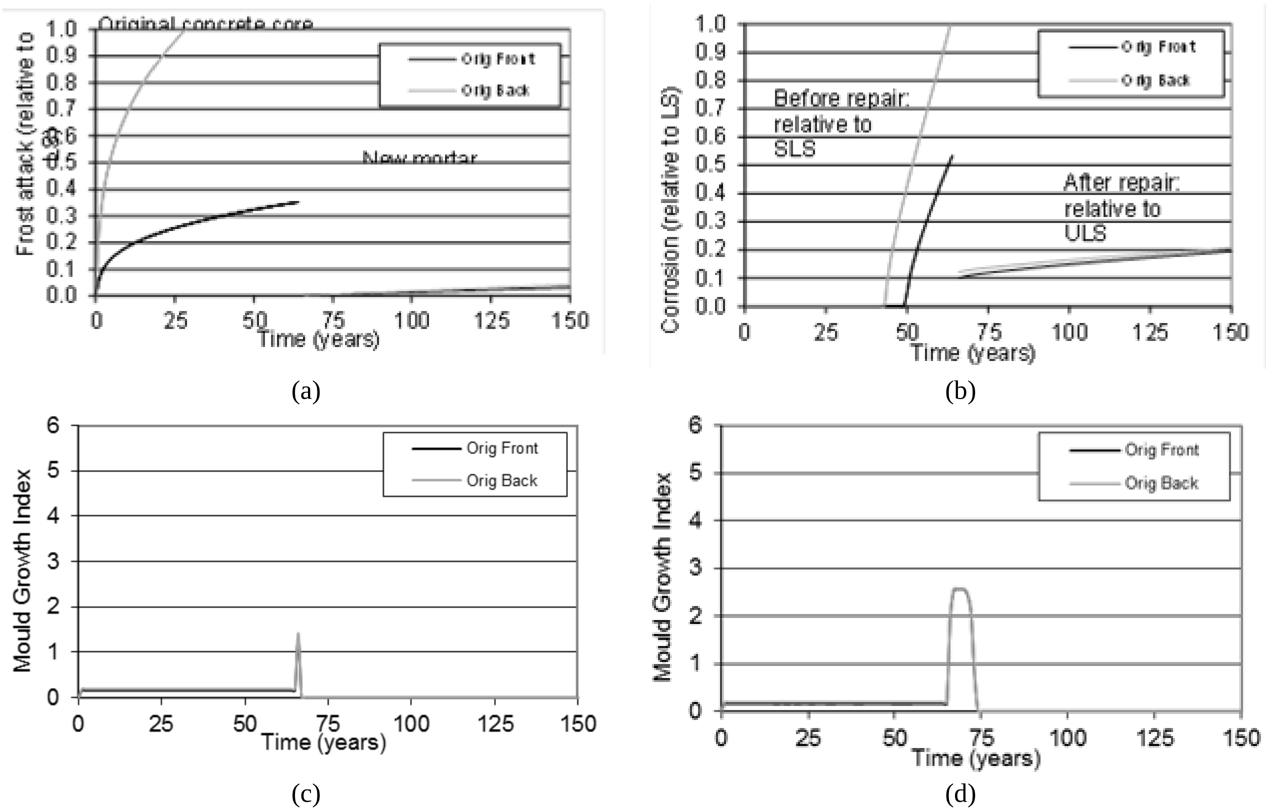

Figure 3 – Results for the refurbished façade with E1 concept and mineral wool option (a) frost attack (b) corrosion of reinforcement, (c) mould growth in the front and back side of the original outer core before and after refurbishment, and (d) mould growth in the refurbished façade with concept E1 and PUR option.

Frost attack was observed in the original outer core before the refurbishment in Jyväskylä. The Frost attack was heavier at the back side of the outer core than at the front side. The risk of rendering seemed to be small in this case but it depends much on the rendering quality.

The serviceability limit state (SLS) with respect to carbonation and corrosion was reached in the original outer core at the age of 65 years. After the refurbishment the corrosion continues in the original outer core but the rate of corrosion is low. The risk of attaining the ultimate limit state (ULS) is very small. The mould growth index in the original concrete core rises up rapidly as a result of higher temperature after the refurbishment. However it descends rapidly within 1 year when the relative humidity goes below the critical limit (85% RH). In the case of polyurethane option for thermal insulation (Concept E1 in Jyväskylä) the analysis results related to frost attack and corrosion of reinforcement were similar to those in Images 3(a) and 3(b). The curve for the mould growth is presented in Figure 3(d). The mould growth index in the original concrete core is low but it rises up rapidly after the refurbishment and it stays high for a longer period of time (about 7-9 years). After this period it reduces rapidly to 0.

3. CONCLUSIONS

Computer simulation was used for uncovering possible risks in the long term performance of refurbished concrete sandwich walls. The calculations were done so, that the whole service life of the original sandwich and a part of the service life of the refurbished wall were continuously monitored. The results of the simulation tend to show the average values among a great dispersion of values which can be real with the same material, structural and weather parameters used in calculations. Another reason for bias in the calculation may be simplifications in the modelling of parameters. Although all parameter values used in the calculations are based on some measurements not enough measurement data is available to quantify reliably their all dependencies.

For the refurbishment concept E1 considered,- the additional insulation is laid on the original outer core of the sandwich and covered by a layer of rendering. – the selection of thermal insulation material was not in-different. PUR thermal insulation cannot be used if the thermal insulation of the original sandwich was of ESP. This is because the original concrete core is left between two layers of insulation the water vapour diffusion coefficient of which is very low. The moisture which was left to the original concrete core can-not dry out in a reasonable time. That is why there is a great risk of mould growth and also a risk of continued corrosion of reinforcement in the original concrete core. As a result of corrosion which can continue for decades there is a risk of collapse of the whole wall.

If the original thermal insulation is of mineral wool and the additional insulation is of polyurethane the mould and corrosion risks are much smaller as the moisture can move towards the interior. However, there is an intermittent risk period of about 10 years after the refurbishment when the mould growth may be high. The rapid increase of the mould risk is a result of higher temperature inside the wall and the rapid decrease of mould growth after the risk period is a result of relative humidity decreasing under the critical limit which is 85 %.

Risk of frost attack exists in countries where the temperature goes below -5 °C. The risk of frost at-tack is increased when the rendering is let to be ex-posed to rain water and freezing immediately after manufacture – without sufficient hardening.

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