RENOVATION OF CONCRETE FACADES BY MEANS OF EXTERIOR THERMAL INSULATION COMPOSITE SYSTEMS (ETICS)

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RENOWACJA BETONOWYCH FASAD BUDYNKÓW METODĄ LEKKĄ MOKRĄ

Fasady betonowe często nie zapewniają wystarczającej ochrony przed deszczem. Jeśli zewnętrzna warstwa takiej fasady ulegnie karbonatyzacji, wysoka zawartość wody, przy wilgotności względnej przekraczającej 80%, może spowodować korozję zbrojenia. Renowacja przy zastosowaniu metody lekkiej mokrej chroni ścianę przed zawilgoceniem od tzw. zacinającego deszczu, dzięki przerwaniu ciągłości warstw, w których występuje podciąganie kapilarne, co pozwala na wyschnięcie konstrukcji. Po kilku latach wilgotność względna w miejscu występowania zbrojenia spada poniżej krytycznej wartości, wynoszącej 80%, co chroni przed dalszym postępem procesu korozji. W pracy przedstawiono i omówiono wyniki symulacji komputerowych, dotyczących tego problemu, otrzymanych za pomocą programu WUFI-POL dla polskich warunków klimatycznych.

ABSTRACT

Concrete façades often lack a good rain protection. If the concrete of the rain screen of such façades is carbonized, the high moisture content with a relative humidity above 80%RH can cause corrosion of the reinforcing steel. A renovation by applying an External Thermal Insulation Composite System (ETICS) protects the façade from wind driven rain due to the capillary break of the insulation layer thus permitting drying out of the construction. After a few years the relative humidity at the position of the reinforcing steel falls below the critical value of 80% RH what prevents further corrosion damage. Some results of computer simulations, related to this problem, obtained by means of the WUFI-POL computer code for the weather conditions of Poland, are presented and discussed in the paper.

1. INTRODUCTION

In the past two layer core insulated concrete constructions were very common for apartment buildings in Poland, especially those constructed in 70-ties and 80-ties. The interior concrete layer in such buildings serves as load bearing structure and the exterior layer as rain screen. After several decades the carbonation of the exterior concrete layer has proceeded and in many cases it reached the reinforcement. Since the rain screen layer becomes wet due to wind driven rain, especially for western and northern façades, the corrosion of the reinforcing steel can become a serious problem. In this paper we evaluate by means of hygrothermal simulations, if the application of an External Thermal Insulation Composite System (ETICS) can solve the corrosion problem, providing at the same time a significant energy improvement of the wall. The simulations are performed with the WUFI-POL [1] software, the recently developed Polish version of well known WUFI® software, [2], elaborated at Fraunhofer Institute of Building Physics in Holzkirchen, Germany.

2. ORIGINAL SITUATION

As a first step the conditions within the core insulated concrete construction are calculated to determine the equilibrium water content of the exterior concrete layer. This construction consists, from inside to the out, of 15 mm gypsum plaster, 150 mm reinforced concrete layer (load bearing structure), 60 mm Expanded Polystyrene (EPS) insulation and a second layer of 60 mm reinforced concrete which serves as a rain screen (see Fig. 1). The calculations are performed by means of the WUFI®, a well verified simulation tool for the transient heat and moisture transfer, [2].
The required material properties are taken from the WUFI®-Material-Database. For the outdoor climate hourly meteorological data of the TMY for Warsaw are used, [3], while the indoor climate corresponds to a normal use as residential building. The heat transfer coefficients are set to 17 W/m²K at the exterior, and 8 W/m²K at the interior surface. The initial moisture content in the construction corresponds to the equilibrium moisture content at a relative humidity of 80 %RH - this is approximately the annual mean value of the relative exterior air humidity. The calculations start on October 1st and are performed over a time period of five years.
Figure 2 shows the temporal development of the water content within the exterior concrete layer (top) and the relative humidity at the position of the reinforcement (bottom) for the different orientations. The changes of the total water content show that in every case a dynamic equilibrium is reached after approximately two years. The maximum water content with about 110 kg/m³ in summer and 90 kg/m³ in winter appears in the west facing façade due to the highest driving rain load at this orientation, [4]. For the other orientations the total water content stays between 75 and 100 kg/m³ during the year.

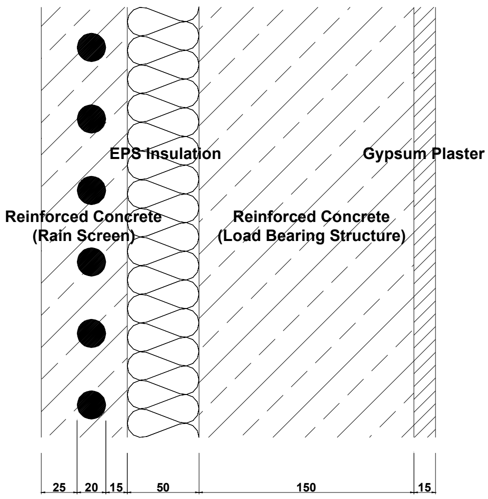

Fig. 1. Schematic of the concrete façade before the renovation
Rys.1. Schemat betonowej ściany budynku przed dociepleniem.

Investigations described in [5] show that the corrosion of the reinforcing steel of accelerated carbonated concrete specimens, which were stored at different levels of relative humidity, continues only, if the relative humidity of the surrounding air is higher than 80 %RH. At values below 80 %RH no further corrosion could be observed. For the concrete façade investigated here, we get the values temporary above 80 %RH in the rain screen for the south and east facing façades and permanently above 80 %RH (up to 93 %RH) for the west and north facing façades. Therefore, there is a significant risk of ongoing corrosion for the all analyzed cases. The most critical conditions occur at the west façade with a relative humidity at the reinforcing steel between 85 %RH in summer and 93 %RH in winter.

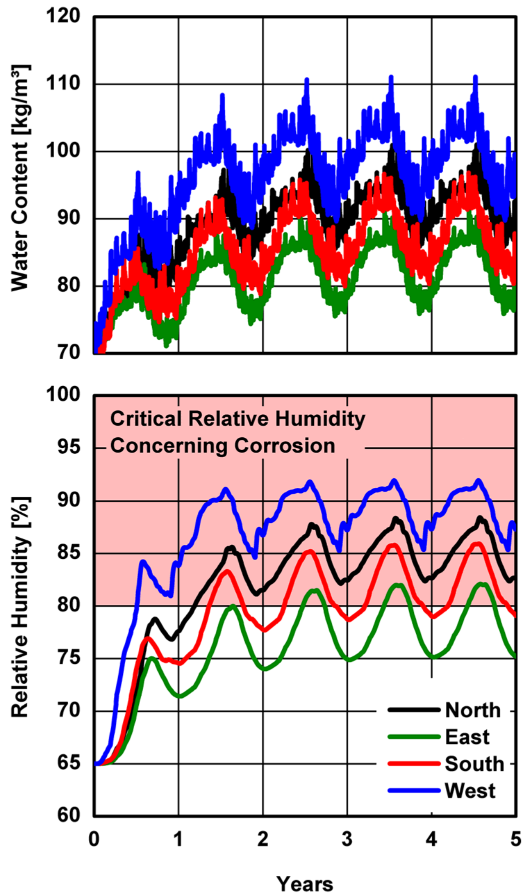

Fig. 2. *Calculated developments of the water content in the rain screen (top) and the relative humidity at the position of the reinforcement (bottom) for different orientations of the wall before the renovation.*

Rys.2. *Obliczone zmiany zawartości wody w warstwie osłonowej (na górze) i wilgotności względnej powietrza na głębokości zbrojenia (na dole) dla różnych orientacji dla ściany przed dociepleniem.*

3. RENOVATION BY USE OF AN EXTERIOR THERMAL INSULATION SYSTEM (ETICS)

In order to improve the existing situation, two different ETICS are applied on the exterior surface of the original concrete rain screen - one with mineral wool insulation and the second one with EPS insulation beneath the finishing render.

ETICS usually consist of an insulation layer which is applied by a mineral

adhesive and sometimes by additional screw fixing on the sub-construction and one or more layers of reinforced external render. ETICS represent a good rain protection as in the insulation layer no liquid water transport is possible – so the insulation serves as capillary break which only allows vapor diffusion transport to the sub-construction. As ETICS are applied from the outside they are also particularly suitable for a subsequent thermal renovation.
In this case the applied ETICS consists of 60, 100 or 140 mm of insulation and 10 mm of hydrophobized reinforced external render (Figure 3, case with 60 mm insulation). The first considered insulation thickness was commonly used in Poland up to a couple years ago, but recently this thickness usually exceeds 10 cm. In the following only the west façade is investigated, due to the most critical results in the rain screen layer for this orientation. The initial moisture content of the original rain screen is now set to the equilibrium conditions at 93 % RH (maximum reached relative humidity in this layer due to the results before) the moisture content in the other materials is at 80 % RH. The further settings are as before.

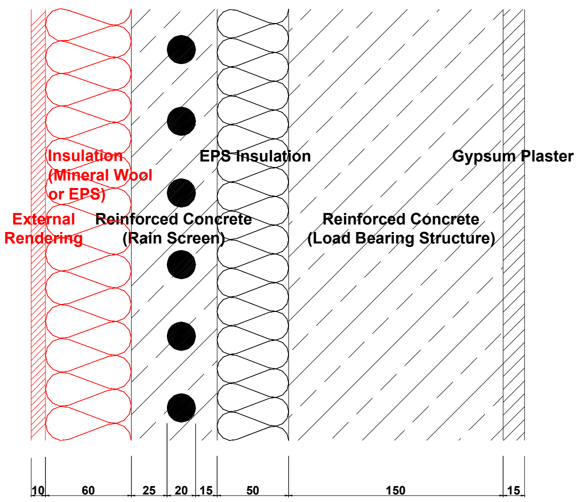

Fig. 3. Schematic of the concrete façade after the renovation.
Rys.3. Schemat ściany betonowej po dociepleniu.

Figure 4 (top) shows the temporal development of the water content in the original rain screen of the renovated western oriented façade for the two different insulation materials. From the initial water content of about 110 kg/m³ all constructions dry out over the whole analyzed period to between 70 and 80 kg/m³ after five years. The capillary break effect of the insulation layer protects the constructions from wind driven rain and so they can dry out. Due to the lower vapor diffusion resistance of the mineral wool this construction dries a little bit faster. The relative humidity at the reinforcement is plotted in the same figure on bottom. Starting at 93 % the relative humidity, for the cases with mineral wool insulation, decreases to between 67 %RH (140 mm of insulation) and 73 %RH (for 60 mm of insulation) at end of the analyzed period.

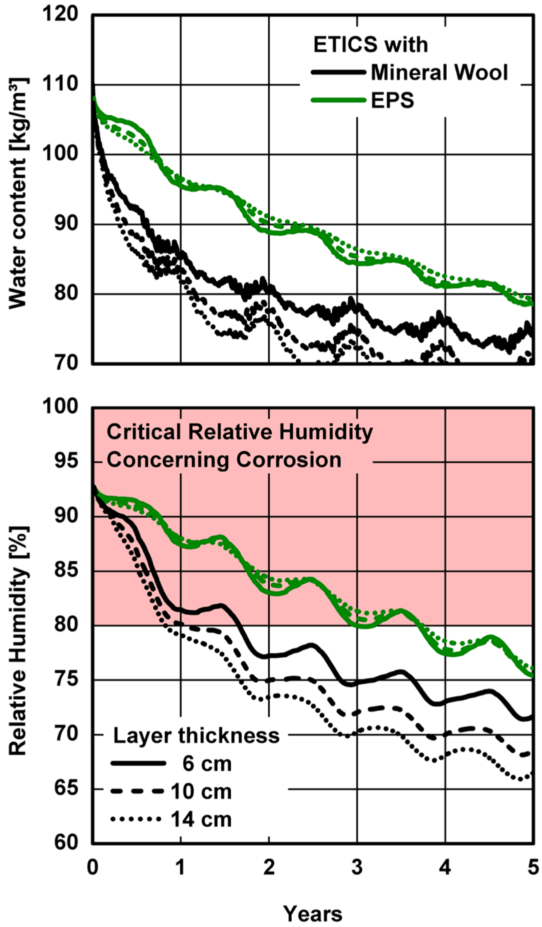

Fig. 4. Calculated development of the total water content in the whole construction (top) and the relative humidity at the position of the reinforcement of the exterior concrete layer (bottom) for the renovation with ETICS of mineral wool or EPS with different thicknesses.

Rys.4. Obliczone zmiany całkowitej zawartości wilgoci w ścianie (na górze) i wilgotności względnej powietrza na głębokości zbrojenia zewnętrznej warstwy betonu (na dole) po dociepleniu ściany metodą lekką mokrą z użyciem warstwy wełny mineralnej lub styropianu (EPS) o różnych grubościach.

Already after less than one year (for 100 or 140 mm of insulation) or one and a half year (60 mm of insulation) the relative humidity falls below the critical value of 80 %RH. Also the original rain screen of the construction with the more vapor tight EPS insulations dries out obviously, but here it needs, nearly independent on the insulation layer thickness, almost four years to leave the critical range of relative humidity above 80 % RH.

4. CONCLUSIONS

The results of this investigation show, that the renovation of concrete façades by applying ETICS provides a good rain protection of the façade and leads to relative humidities in the rain screen layer which prevent a further corroding of the reinforcement steel. This also corresponds to the field tests of [5] (performed in Berlin) with a relative humidity significantly below 80 %RH. Consequently no more corrosion of the reinforcement was observed after applying the ETICS.

So for this renovation an ETICS with both mineral wool and EPS as insulation material is appropriate. If the corrosion of the steel is already in an advanced state and needs fast correction, an ETICS with mineral wool should be preferred, as it allows a very fast dry out of the construction. Application of an insulation layer with a higher thickness accelerates drying of a wall with mineral wool, and is of less importance for the wall with EPS layer.

4. REFERENCES

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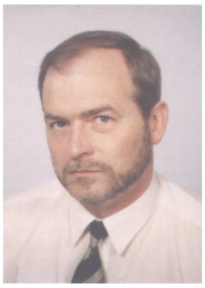

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