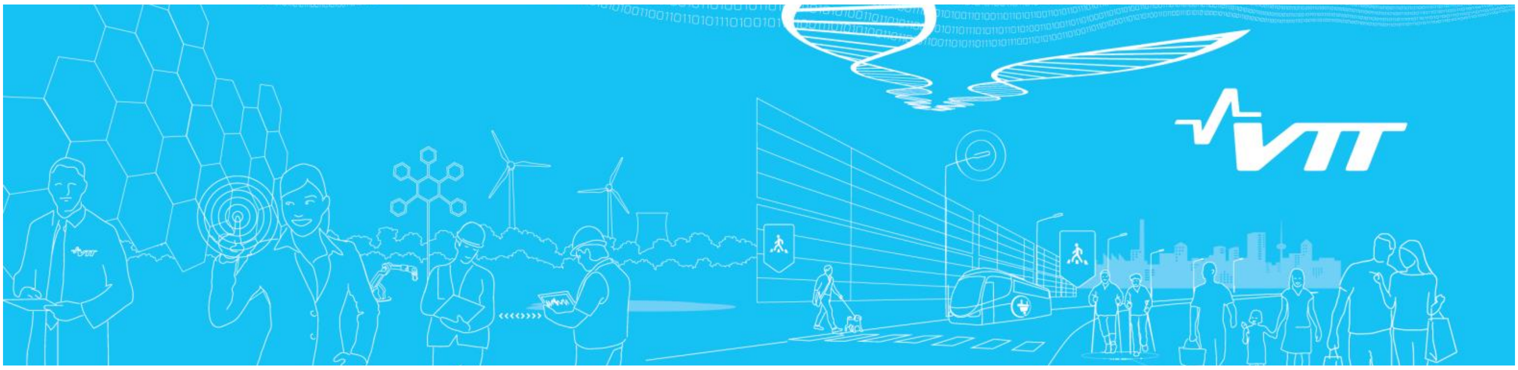

CUSTOMER REPORT

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Climatic corrosion classification of Stofix factory prefabricated brick slip cladding system

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Report's title

Climatic corrosion classification of Stofix factory prefabricated brick slip cladding system

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Climatic corrosion classification of Stofix factory prefabricated brick slip cladding system, case London	108305

Summary

The heat and moisture transport were simulated in Stofix factory prefabricated brick slip cladding system exposed to climatic conditions that closely correspond to those in London, UK. For the simulations, a worst case scenario among the Ruskin Square building structures was chosen so that the ventilation is as low as possible, thermal insulation as high as possible and rain conditions realistic; these typically account for the highest risk for condensation and thus corrosion.

The simulations showed that maximum detected yearly condensation time (on the inner surface of the brick cladding) was 128 h/a (5.3 days), corresponding to less than 1.5 % time of the year. Condensation conditions do not occur in the ventilation air space or structure parts having the same humidity and temperature conditions as the ventilation air.

The ventilation cavity is an indoor space that does not involve any polluting process. Therefore, it may be treated as indoor corrosivity category. Closer analysis using the simulated condensation times reveals corrosion rates which are "low", corresponding to corrosivity category C2.

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Contents

1. Description and objectives

The objective was to study and classify the climatic corrosion conditions on the steel parts of the Stofix factory prefabricated brick slip cladding system assembled in a building in London, UK.

The analysed structure and structure ventilation conditions are meant to correspond to those in a specific building site in Ruskin Square, where the Stofix system will be applied. Due to the several variations in the prefabricated brick slip cladding system structure with respect to ventilation scheme and thermal insulation levels, all the different cases of structures are not studied individually. The focus is on the cases having the highest risks of condensation and overall humid conditions. Therefore, one case was chosen to represent the worst case scenario for humidity loads and risk for corrosion.

2. Worst case definition principles

When analysing the humidity conditions of a ventilated cavity behind brick cladding, the following criteria was used:

1) Low ventilation of the structure

When the ventilation is increased, the conditions in the ventilation cavity approach to these of the outer climate, but sheltered against driving rain. The moisture loads to ventilation cavity are caused by the drying of the interior wall and the loads from indoor air through the interior structure, drying of the brick slips after wetting by driving rain, and by the outdoor air. Lower ventilation means higher humidity in the ventilation cavity.

2) High inside thermal resistance

High thermal resistance of the inside structure leads to temperature levels close to outdoor air in the ventilation cavity. When the heat losses of the wall structure are low, there is no warming of the structure parts in the ventilation cavity.

Due to this reason the fasteners that penetrate the thermal insulation layer are thermal bridges that have almost always slightly higher temperature levels than structures without any thermal bridge effect. Therefore the thermal bridge sections have lower humidity conditions and lower risks for corrosion than the ‘ideally’ insulated intersections of structure. The precondition for this behaviour of the thermal bridges is that the indoor air space is heated.

3) High driving rain

The driving rain wets the brick layer of the façade and causes increased moisture loads in the ventilation cavity area. The driving rain conditions were selected to correspond to high realistic loads.

3. Numerical analysis

3.1 Simulation model

Numerical simulation model WUFI 5.3 // was used in the analysis. The software allows realistic calculation of the transient coupled one-dimensional heat and moisture transport in multi-layer building components exposed to natural weather. Thus the analysis was carried out using the 1-D intersection of the selected worst case structure.

3.2 Climate conditions

The simulations use hourly values of outer climate conditions. London climate was not available in WUFI database, so the conditions of substitutive climates were used in the analysis. In the selection of the substitutive climate, the criteria were the yearly temperature, relative humidity and rain fall. Brussels (Belgium) and Trappes (France) climate data was used in the simulations instead of London.

Table 1. Correlation of the climatic conditions in London. Brussels and Trappes.

Location	T,av. °C	RH,av. %	Rainfall, mm	Wind speed, av. m/s	Main wind direction
London*	10,4	79,5	594	3,5	SW
Brussels**	10,3	81	1024	4,4	SW
Trappes**	10,9	81	817	2,6	SW

**http://www.london.climatemps.com/* , *http://www.metoffice.gov.uk/public/weather/climate/gcpvj0v07* , *https://weatherspark.com/averages/28726/London-England-United-Kingdom*

*** WUFI climate data*

The temperature and relative humidity levels are closely the same within these three climates. The rain fall in both the climates used in the simulations is on the safe side when compared to the information of yearly rainfall in London.

3.3 Structure

From a series of different structural solutions presented for the Ruskin Square building, a worst case example was formed. This worst case example structure is based on the information given by the customer. This case represents a structure with long ventilation route and high thermal insulation level. It is meant to represent the column V2 ventilation principles, but also other structures having higher ventilation or lower thermal insulation levels than used in this case. Because the selected structure case represent the worst case scenario from the moisture performance aspect, structures having more ventilation (open ventilation routes at each storey) or less thermal insulation, perform better than the analysed case. If the worst case structure study shows acceptable performance, also the other structures should thus have at least as good performance.

The selected case structure was assumed to have 120 mm of Kingspan Kooltherm K15 thermal insulation and 150 mm mineral wool insulation layers. Such high thermal resistance leads to low heat losses and almost insignificant warming of the ventilation air, which represents the worst case conditions with respect to thermal resistance.

The ventilation cavity was assumed to be 74 mm thick having a 25 mm narrow gap between each floor (fire protection detail). The ventilation cavity was assumed to be 9 floors high, in total 27 m in height, without any other ventilation openings except the bottom and top openings to outdoor air. This approach also represents the worst case scenario. There exists typically horizontal ventilation routes connected to outside air, sometimes in every floor. These openings enhance the ventilation of the structure.

The simulated building façade was assumed to face the highest driving rain, southwest. The height of the structure was over 20 m and the rain hitting the structure was assumed to correspond to that on the top part of the building in Trappes climate and that in the middle part of the high building in Brussels climate. The lighter approach in Brussels climate is due to the very high yearly rain fall in Brussels compared to that in London.

A rough estimation of the ventilation flow rates in the 74 mm air cavity is shown in Figure 1. This has been evaluated using the resistances of 25 mm narrow parts between floors, the inlet and outlet resistances and the roughness of the ventilation route. It is an approximation, but gives idea of the possible ventilation air flow. For example the 5 Pa pressure difference leads to about 0.16 m/s air flow velocity in the 74 mm gap and causes about 22 1/h air change rate in the cavity. This ventilation rate can be considered relatively high and would be quite sufficient to maintain a structure of typical apartment or office building dry from internal moisture loads.

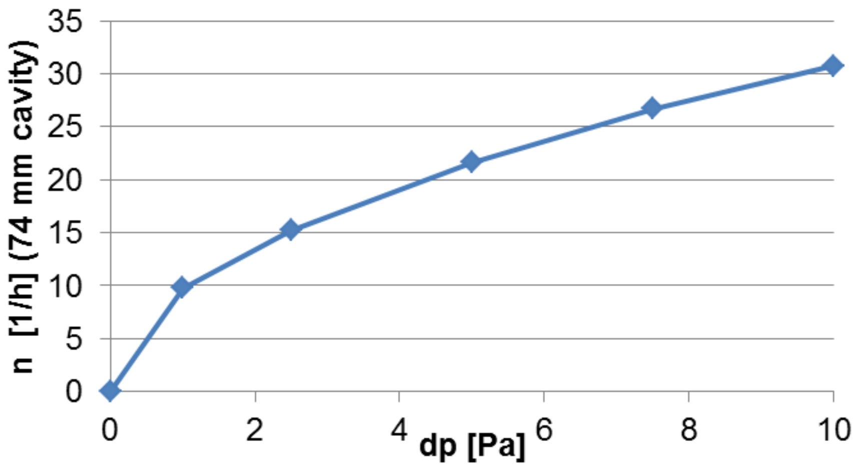

Figure 1. Air change rate as a function of the pressure difference between 27 m high structure ventilation flow route.

The intersection of the analysed structure is presented in Figure 2.

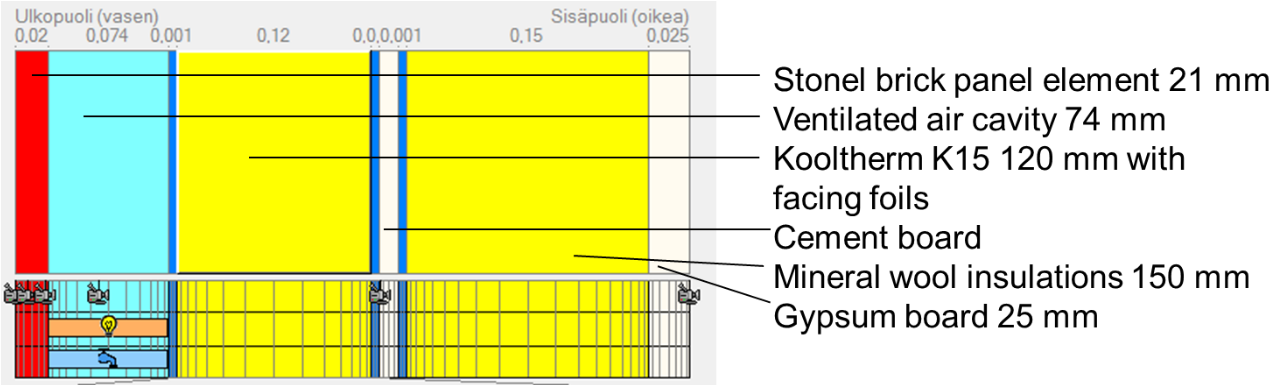

Figure 2. Intersection of the analysed structure representing a worst case study for Ruskin Square wall structure. Note that the simulated structure has some additional thermal insulation as compared to normal case to impose stronger condensation effect.

3.4 Analysed cases

Two case with 22 1/h and 31 1/h ventilation rates were studied using Brussels and Trappes climate conditions.

4. Analysis results

A three-year numerical simulation was carried out using the hourly given climate conditions for Bussels and Trappes. The condensation conditions of the ventilation cavity and the inner surface of the brick cladding were of interest.

Table 3 presents the yearly numerically solved condensation conditions (>99,999 % RH) in these critical parts of the structure under Trappes and Brussels climate and also the condensation conditions of these climates. The structure ventilation was assumed to correspond to 5 Pa and 10 Pa pressure difference causing n = 22 1/h and n = 31 1/h air change rates, respectively.

Table 2. Yearly condensation times according to simulations in outdoor climates and in the critical parts of the ventilated structure.

	Brussels			Trappes		
Case	Outdoor climate	Brick cladding, inner surface	Ventilation cavity	Outdoor climate	Brick cladding, inner surface	Ventilation cavity
n = 22 1/h	134 h/a	128 h/a	0 h/a	584 h/a	93 h/a	0 h/a
n = 31 1/h	134 h/a	127 h/a	0 h/a	584 h/a	90 h/a	0 h/a

The main humidity load to the ventilation cavity and structure is originated from the driving rain hitting the brick cladding and temporarily wetting it.

The results show that:

- Condensation conditions do not occur in the ventilation air space or structure parts having the same humidity and temperature conditions as the ventilation air.
- Condensation time on the inner surface of the brick cladding is of the same order or lower than that in the open air of the climate, but when sheltered against rain.
- Maximum detected yearly condensation time was 128 h/a (5.3 days), corresponding to less than 1.5 % time of the year.

5. Classification of climatic corrosion conditions

The metallic components of the Stofix factory prefabricated brick slip cladding system are located in the ventilation cavity. The ventilation cavity is an unheated indoor space with varying temperature and relative humidity. As the cavity does not include any production processes that create pollution, such as food processing plants, laundries, breweries or dairies, it may essentially be considered as indoor corrosivity category C2, as shown in Table 4.

Table 4. Description of typical atmospheric environments related to the estimation of corrosivity categories [1].

Corrosivity category[a]	Corrosivity	Typical environments — Examples[b]	
		Indoor	Outdoor
C1	Very low	Heated spaces with low relative humidity and insignificant pollution, e.g. offices, schools, museums	Dry or cold zone, atmospheric environment with very low pollution and time of wetness, e.g. certain deserts, Central Arctic/Antarctica
C2	Low	Unheated spaces with varying temperature and relative humidity. Low frequency of condensation and low pollution, e.g. storage, sport halls	Temperate zone, atmospheric environment with low pollution (SO_2 < 5 µg/m^3), e.g. rural areas, small towns Dry or cold zone, atmospheric environment with short time of wetness, e.g. deserts, subarctic areas
C3	Medium	Spaces with moderate frequency of condensation and moderate pollution from production process, e.g. food-processing plants, laundries, breweries, dairies	Temperate zone, atmospheric environment with medium pollution (SO_2: 5 µg/m^3 to 30 µg/m^3) or some effect of chlorides, e.g. urban areas, coastal areas with low deposition of chlorides Subtropical and tropical zone, atmosphere with low pollution
C4	High	Spaces with high frequency of condensation and high pollution from production process, e.g. industrial processing plants, swimming pools	Temperate zone, atmospheric environment with high pollution (SO_2: 30 µg/m^3 to 90 µg/m^3) or substantial effect of chlorides, e.g. polluted urban areas, industrial areas, coastal areas without spray of salt water or, exposure to strong effect of de-icing salts Subtropical and tropical zone, atmosphere with medium pollution
C5	Very high	Spaces with very high frequency of condensation and/or with high pollution from production process, e.g. mines, caverns for industrial purposes, unventilated sheds in subtropical and tropical zones	Temperate and subtropical zone, atmospheric environment with very high pollution (SO_2: 90 µg/m^3 to 250 µg/m^3) and/or significant effect of chlorides, e.g. industrial areas, coastal areas, sheltered positions on coastline

ISO 9223 classifies the atmospheric environment into 5 corrosivity categories, as shown above. According to it, low-corrosivity indoor atmospheres are indoor atmospheres with C1 (very low) and C2 (low) corrosivity categories. However, the classification in ISO 9223 is too broad for some purposes in low-corrosivity indoor atmospheres, e.g., places where electronic devices, sophisticated technical products or works of arts and historical objects are stored. For such purposes, it is necessary to subdivide the corrosivity categories C1 (very low) and C2 (low) into indoor corrosivity categories. A detailed description of types of indoor environments within corrosivity categories C1 and C2 is given in ISO 11844-1, in which indoor corrosivity categories IC1 to IC5 are defined and classified. This description is given in Table 5.

Table 5. Description of typical environments related to the estimation of indoor corrosivity categories [2].

Corrosivity category (IC)	**Corrosivity**	**Typical environments**
IC 1	very low indoor	Heated spaces with controlled stable relative humidity (< 40 %) without risk of condensation, low levels of pollutants, no specific pollutants, e.g. computer rooms, museums with controlled environment Unheated spaces with dehumidification, low levels of indoor pollution, no specific pollutants e.g. military stores for equipment
IC 2	low indoor	Heated spaces with low relative humidity (< 50 %) with certain fluctuation of relative humidity without risk of condensation, low levels of pollution, without specific pollutants e.g. museums, control rooms Unheated spaces with only temperature and humidity changes, with no risk of condensation, low levels of pollution without specific pollutants, e.g. storage rooms with low frequency of temperature changes
IC 3	medium indoor	Heated spaces with risk of fluctuation of temperature and humidity, medium levels of pollution, certain risks for specific pollutants, e.g. switchboards in the power industry Unheated spaces with elevated relative humidity (> 50 % – 70 %) with periodic fluctuation of relative humidity, without risk of condensation, elevated levels of pollution, low risk of specific pollutants, e.g. churches in non-polluted areas, outdoor telecommunication boxes in rural areas
IC 4	high indoor	Heated spaces with fluctuation of humidity and temperature, elevated levels of pollution including specific pollutants, e.g. electrical service rooms in industrial plants Unheated spaces with high relative humidity (> 70 %) with some risk of condensation, medium levels of pollution, possible effect of specific pollutants, e.g. churches in polluted areas, outdoor boxes for telecommunication in polluted areas
IC 5	very high indoor	Heated spaces with limited influence of relative humidity, higher levels of pollution including specific pollutants like H_2S, e.g. electrical service rooms, cross-connection rooms in industries without efficient pollution control Unheated spaces with high relative humidity and risk for condensation, medium and higher levels of pollution, e.g. storage rooms in basements in polluted areas

Overall, the ventilation gap may be considered as an unheated indoor space. The relative humidity is elevated (IC3) or high (IC4). The risk of condensation depends on the exact location in the ventilation cavity. As shown by the simulations above, the condensation within the ventilation cavity is 0, which would give corrosivity class IC3. However, is the metals become in contact with the inner surface of brick cladding, there is some risk of condensation (IC4). Indeed, it is evident that the condensation times that are systematically less than 6 days a year cannot be considered high. No specific pollutants are included in the ventilation gap yet some transfer from external sources through, e.g., air inlet is possible. According to description in Table 5, metallic components in the ventilation gap are therefore exposed to conditions falling within corrosivity categories IC3 and IC4, “medium” or “high indoor corrosivity.

Corrosion rates for zinc in different indoor corrosivity categories are given in Table 6.

Table 6. Corrosivity of indoor atmospheres based on mass loss [2].

Corrosivity category		Corrosion rate (r_{corr}) mg/(m²·a)			
		Carbon steel	Zinc	Copper	Silver
IC 1	Very low indoor	$r_{corr} \leqslant 70$	$r_{corr} \leqslant 50$	$r_{corr} \leqslant 50$	$r_{corr} \leqslant 170$
IC 2	Low indoor	$70 < r_{corr} \leqslant 1\,000$	$50 < r_{corr} \leqslant 250$	$50 < r_{corr} \leqslant 200$	$170 < r_{corr} \leqslant 670$
IC 3	Medium indoor	$1\,000 < r_{corr} \leqslant 10\,000$	$250 < r_{corr} \leqslant 700$	$200 < r_{corr} \leqslant 900$	$670 < r_{corr} \leqslant 3\,000$
IC 4	High indoor	$10\,000 < r_{corr} \leqslant 70\,000$	$700 < r_{corr} \leqslant 2\,500$	$900 < r_{corr} \leqslant 2\,000$	$3\,000 < r_{corr} \leqslant 6\,700$
IC 5	Very high indoor	$70\,000 < r_{corr} \leqslant 200\,000$	$2\,500 < r_{corr} \leqslant 5\,000$	$2\,000 < r_{corr} \leqslant 5\,000$	$6\,700 < r_{corr} \leqslant 16\,700$

As shown by Table 6, in IC4 the corrosion rate of zinc falls within the range from 700 to 2500 mg/(m^2·a). These correspond to annual mass losses ranging 0.7 to 2.5 g/m^2 and annual thickness losses ranging from 0.1 to 0.35 µm in Table 7. In Table 7, the latter corrosion rates may be classified as "low", with corrosivity category C2.

Table 7. Typical mass and thickness losses for low-carbon steel and zinc in different corrosivity categories [3].

Corrosivity category	Mass loss per unit surface/thickness loss (after first year of exposure)				Examples of typical environments in a temperate climate (informative only)	
	Low-carbon steel		Zinc		Exterior	Interior
	Mass loss g/m²	Thickness loss µm	Mass loss g/m²	Thickness loss µm		
C1 very low	⩽ 10	⩽ 1,3	⩽ 0,7	⩽ 0,1	—	Heated buildings with clean atmospheres, e.g. offices, shops, schools, hotels.
C2 low	> 10 to 200	> 1,3 to 25	> 0,7 to 5	> 0,1 to 0,7	Atmospheres with low level of pollution. Mostly rural areas.	Unheated buildings where condensation may occur, e.g. depots, sports halls.
C3 medium	> 200 to 400	> 25 to 50	> 5 to 15	> 0,7 to 2,1	Urban and industrial atmospheres, moderate sulfur dioxide pollution. Coastal areas with low salinity.	Production rooms with high humidity and some air pollution, e.g. food-processing plants, laundries, breweries, dairies.
C4 high	> 400 to 650	> 50 to 80	> 15 to 30	> 2,1 to 4,2	Industrial areas and coastal areas with moderate salinity.	Chemical plants, swimming pools, coastal ship- and boatyards.
C5-I very high (industrial)	> 650 to 1 500	> 80 to 200	> 30 to 60	> 4,2 to 8,4	Industrial areas with high humidity and aggressive atmosphere.	Buildings or areas with almost permanent condensation and with high pollution.
C5-M very high (marine)	> 650 to 1 500	> 80 to 200	> 30 to 60	> 4,2 to 8,4	Coastal and offshore areas with high salinity.	Buildings or areas with almost permanent condensation and with high pollution.

NOTES

1 The loss values used for the corrosivity categories are identical to those given in ISO 9223.

2 In coastal areas in hot, humid zones, the mass or thickness losses can exceed the limits of category C5-M. Special precautions must therefore be taken when selecting protective paint systems for structures in such areas.

6. Conclusions and summary

The heat and moisture transport were simulated in Stofix factory prefabricated brick slip cladding system exposed to climatic conditions that closely correspond to those in London, UK. The simulations showed that maximum detected yearly condensation time (on the inner surface of the brick cladding) was 128 h/a (5.3 days), corresponding to less than 1.5 % time of the year. Condensation conditions do not occur in the ventilation air space or structure parts having the same humidity and temperature conditions as the ventilation air.

Based on above, we consider the ventilation cavity an indoor space that does not involve any polluting process. Therefore, it may be treated as indoor corrosivity category, meaning overall corrosion category C2, “low corrosion rate”.

References

1. EN ISO 9223, Corrosion of metals and alloys. Corrosivity of atmospheres. Classification, determination and estimation. 2012.

2. EN ISO 118844-1, Corrosion of metals and alloys. Classification of low corrosivity of indoor atmospheres. Part 1: Determination of indoor corrosivity. 2006.

3. EN ISO 12944-2, Paints and varnishes. Corrosion protection of steel structures by protective paint systems. Part 2: Classification of environments. 1998.