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Use of sensitivity analysis to evaluate hygrothermal conditions in solid brick walls with interior insulation

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ABSTRACT

Solid brick-buildings dating from 1850-1920 have rich ornamented facades which are typical for that period. To improve their energy performance, only measures that do not change the overall exterior architecture are acceptable; in practice this means interior insulation.
Most recommendations and chosen solutions in case studies are based on simulations with climate data from a standard test reference year. However, they do not take stochastic variations into account. At the same time practice has shown examples of interior insulation without moisture problems, where calculations predicted problems and vice versa. Therefore, sensitivity analysis has been used in this paper in the endeavour to find the parameters that are important to consider when insulating solid brick walls internally.

The sensitivity analysis is illustrated by an example where the calculation is based on a 29 cm thick brick wall. The internal insulation can be up to 20 cm thick. The insulation material is mineral wool. The inner layer is a 12.5 mm coated gypsum board. There is a vapour barrier between the gypsum board and the insulation.

The statistical simulation is done with SIMLAB coupled with the MATLAB model of the case. SIMLAB has standard routines for different statistical distributions and can be used to make sensitivity analysis based on different methods.

The Morris analysis gave information on the important and unimportant parameters. This can also be seen from the plot of the parameter variations against for instance the moisture content. The simulation used 400 random cases as in figure 1.

The Sobol method is a quantitative method that gives the percentage of total output variance that each parameter accounts for. The method is a variance based method to quantify the impact of uncertainties in random variables on the uncertainty in the model output. This method is more computationally expensive than the Morris method.

Fig 1 shows that driving rain is an important parameter for the moisture content throughout the brick wall as a reduction in driving rain reduces the moisture content. A low amount of driving rain gives low moisture content in the bricks. The two lines in the diagram are trend lines for the outermost and innermost moisture content of the brick. A reduction in the driving rain will have a very important effect on the moisture levels.

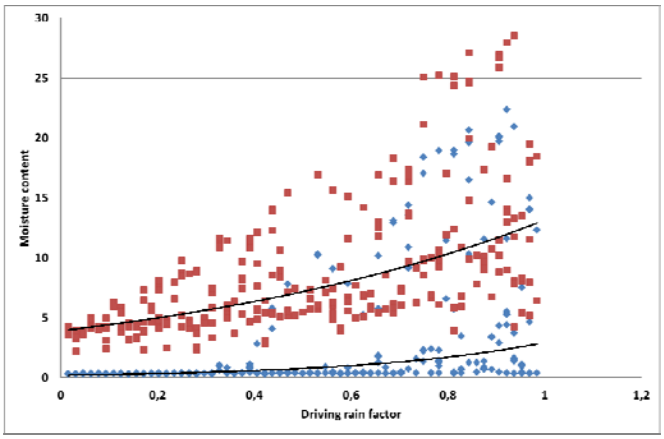

Fig. 1. Moisture content in outermost (square points) and innermost (rhomb points) layer of brick wall versus driving rain parameter

The sensitivity analysis show that the insulation thickness is the most important parameter for the temperature level in a post-insulated brick wall. This was also expected from previous work. The most important parameter for the average moisture level was the driving rain and the wall orientation – two interacting parameters. More secondary effects are the indoor moisture level and the moisture resistance of the internal vapour barrier.

The simulation, the Morris analyses and the Sobol indices all showed the same results; driving rain and wall orientation are the most decisive parameters for the moisture content throughout the wall. The effectiveness of the vapour barrier is not important. While insulation thickness is only important for the temperature in the wall, the influence is weak at the outside for higher thicknesses but always strong at the inside.

The results are strongly influenced by the moisture transport mechanisms. Therefore further investigations should be made on how different material properties affect the results; e.g. moisture properties should be treated as variables. An interesting observation is that the statistical coefficients vary with time at the outer surface from the highly un-linear behaviour of driving rain.