Adding glazing as an energy saving renovation measure in cold climates

Birgitta Nordquist[1] and Kimmo Hilliaho[2] and Petter Wallentén[3]

[1] Building Services, Building and Environmental Technology, Lund Institute of Technology, Lund University, Lund, Sweden
[2] Service Life Engineering of Structures Group, Structural Engineering Unit, Dept. of Civil Engineering, Tampere University of Technology, Tampere, Finland
[3] Building Physics, Building and Environmental Technology, Lund Institute of Technology, Lund University, Lund, Sweden
birgitta.nordquist@hvac.lth.se

Abstract Adding exterior insulation as an energy saving renovation measure is not always possible for cultural heritage reasons. This study explores the energy saving that can be made if glazing instead is added to a heavy structure as a brick building creating a double skin façade. Extensive measurements have been made in a full-scale building. The building has then been modelled in IDA-ICE and simulations, validated by the measurements, have been made for both an outdoor climate representing the southern part of Sweden, Malmö and for one climate representing the northern part of Finland; Sodankylä. The annual heating energy savings have been calculated for various design combinations; different U-values and for both mechanical exhaust respectively mechanical supply and exhaust ventilation systems. The results show that an energy saving is achieved in the order of 8-38% depending on the design of the building; the glazing and the ventilation system. As both a southern and northern climate of Scandinavia are studied the results indicates how this type of renovation measure would perform in general in this part of the world.

Keywords: energy saving, double skin-façade, renovation, brick building, simulations

1 Introduction

If the environmental challenges are to be met in terms of reducing the total energy use in the building sector, renovation measures of the existing building stock must be included, since the majority of houses in e.g. 30 years are already built. Knowledge about different technical measures that can be applied is therefore important to retrieve.

One possible renovation measure is to add glazing to an existing building. Studies including temperate and hot climates are reported [1], [2], [3]. However as the energy demands for lower energy use are getting stronger it becomes increasingly more relevant to also learn even more about the energy performance of the construction in colder climates. This includes attaining knowledge on how large energy saving that is possible to achieve. This knowledge can contribute to the decision making process when choosing between different energy saving measures to apply in existing buildings.

When undertaking several renovation measures on a 1930-ties brick building, situated in a cold climate, adding exterior insulation to the brick façade was first intended. For cultural heritage reasons this was not allowed and the idea of adding glazing to the facades came up. A mechanically supply and exhaust ventilation system with a rotary heat exchanger was also installed. Situated in an area with sustainable renovation goals the building was extensively equipped with temperature, relative humidity and air flow sensors in several points of the building and ventilation system to allow study of the performance to be possible.

Double skin facades are extensively studied for double glazing. However adding glazing on heavy structures as brick is not that widely studied especially lacking field-measurements and simulations [4]. This paper will contribute with knowledge about the possible energy savings for full scale buildings to this identified gap by studying this for the 1930-ties brick building. The aim is to attain values of the possible energy saving that can be achieved with this type of renovation measure in cold climates.

As a colder climate is in focus calculations should be made for both southern and northern parts of Scandinavia with the aim to cover the borders and thereby most outdoor climates of Scandinavia.

This article focuses on the heating period and the possible energy savings for this period of the year. The conditions for the thermal indoor climate and performance during the summer period should also be addressed but is excluded here. It is also limited to the saving in terms of kWh and the cost and monetary consideration is not included.

2 Method

2.1 Description of the building and the installation systems

The building envelope consisted of 1 ½ bricks. 8 mm single glazing with a U-value of 5,8 W/m^2 K and double glazing on the top with 2,6 W/m^2 K had been added 0,75 m outside the brick walls on the south, east and west facades. Adding glazing on the north façade was not possible for space reasons and is usually not done due to lack of insolation. The building and the added glazing on the south and east façade can be seen in Figure 1.

Different installation systems were installed to address the heating and cooling needs during the year.

During the heating season the building was heated with a hydronic radiator system supplied by district heating. The intention was also to pre-heat the outdoor air by letting it pass through the cavity between the old brick façade and the added glazing before passing through the ventilation unit. When the temperature was above 20°C in the cavity the air path was changed so that the outdoor air entered the ventilation unit directly without being pre-heated in the cavity. The outdoor air was then passed through an air intake on the north façade.

During the summer season the outdoor air was always passed directly to the ventilation unit. To reduce the possible over-heating in the cavity, several cooling options were installed including a separate ventilation system. A concrete duct had been placed in the ground. Outdoor air entered the duct via a vertical concrete duct situated among trees. A supply fan was located in the vertical duct. The air was intended to be cooled in the ground and then supplied to the bottom of the cavity. A corresponding exhaust fan removed the same amount of air from the cavity via high placed ventilation ducts. It is worth mentioning that the cooled air, with an increased relative humidity due to cooling, is not intended to be supplied to the building. The building was equipped with another ventilation unit previously mentioned.

Ventilation windows, which were opened by motors when the cavity temperature exceeded 23° C were placed at the top of the cavity.

The air supply rate to the building is 50 l/s fulfilling the Swedish building regulation of 0,35 l/s m^2 floor area for dwellings and the exhaust rate is 53 l/s. The summer air flow through the cooling system of the cavity is designed to be 150 l/s for both supply and exhaust sides.

Fig. 1. The studied building located in Sege Park in Malmö, with the added glazing visible on the south and east façade. The inlet pipe to the added concrete duct for the cooling of the cavity can be seen on the left part of the picture.

2.2 Energy calculation

An extensive set of sensors for temperature, relative humidity, air flows etc were installed in the building and measurements were performed over in total 2 years. The existing (as designed) building was modelled in IDA-ICE. The IDA-ICE model was validated for winter, spring/autumn respectively summer conditions by these measurements. A detailed description of the model and the measurements are made in [5].

Two locations in Scandinavia, shown in Figure 2, has been studied, Malmö in the southern part of Sweden and Sodankylä in the northern part of Finland. A climate file for the year of 2014 was used for Malmö. The specific year of 2014 was used to make it possible to validate the model with the full-scale measurements which comprised of values attained during 2014. The Sodankylä weather file in the simulations was the test reference year for heating and cooling of buildings in Finland (version 2012). The Finnish test reference year, 2012, is based on the weather logs at Vantaa, Jyväskylä and Sodankylä weather stations from 1980 to 2009. They consist of weather data for twelve months, which have weather conditions close to the long-term climatological average [6].

Fig. 2. The two studied locations; Malmö in Sweden and Sodankylä in Finland.

Full year simulations were made and a large amount of parameters were attained. In this paper the energy use for heating has been retrieved and summarized.

3 Results

3.1 Energy saving of renovated building

The simulated energy need for heating during the heating season in Malmö are presented in Table 1 for a number of different designs; before renovation and after with various characteristics.

Table 1. Need of heating energy and energy saving in percentage of energy need before renovation in Malmö, southern part of Sweden for two types of ventilation systems; exhaust respectively mechanical supply and exhaust system.

Case	Annual Heating energy need (kWh)	Energy saving in whole percentage
Before energy renovation measures (exhaust ventilation)	20 558	-
Exhaust ventilation		
Only glazing, no pre-heating of outdoor air via cavity	18 709	9 %
Glazing + pre-heating of outdoor air via cavity below 20°C	17 850	13%
Glazing + pre-heating of outdoor air via cavity below 30°C	17 262	16%
Glazing + pre-heating of outdoor air via cavity below 50°C	17 124	17%
Supply and exhaust ventilation with heat exchanger	16 384	20%
Only glazing, no pre-heating of outdoor air via cavity	14 672	29%
Glazing + pre-heating of outdoor air via cavity below 20°C	14 686	29%
Glazing + pre-heating of outdoor air via cavity below 30°C	14 355	30%
Glazing + pre-heating of outdoor air via cavity below 50°C	14 332	30%

The same design values as in the existing building were applied in the simulations. The set point of changing the path of the outdoor air between pre-heating in the cavity respectively directly to the ventilation unit was in the existing building 20° C. The measurements showed that the air temperature in the cavity can increase above 20° C during the winter depending on among all the insolation [7]. This means that there may exist a heating need also when the outdoor air is not passed via the cavity. The effect of a set point of 30°C and 50°C were therefore also studied.

The simulated energy need for heating during the heating season in Sodankylä are presented in Table 2.

Table 2. Need of heating energy and energy saving in percentage of energy need before renovation in Sodankylä, northern part of Finland for two types of ventilation systems; exhaust respectively mechanical supply and exhaust system.

Case	Annual Heating energy need (kWh)	Energy saving in whole percentage
Before energy renovation measures (exhaust ventilation)	49 167	-
Exhaust ventilation	45 054	8%
Only glazing, no pre-heating of outdoor air via cavity	43 467	12%
Glazing + pre-heating of outdoor air via cavity below 20°C	43 467	12%
Glazing + pre-heating of outdoor air via cavity below 30°C	43 147	12%
Glazing + pre-heating of outdoor air via cavity below 50°C	43 080	12%
Supply and exhaust ventilation with heat exchanger	40 706	17%
Only glazing, no pre-heating of outdoor air via cavity	37 859	23%
Glazing + pre-heating of outdoor air via cavity below 20°C	37 460	24%
Glazing + pre-heating of outdoor air via cavity below 30°C	37 422	24%
Glazing + pre-heating of outdoor air via cavity below 50°C	37 409	24%

The energy saving in terms of percentages was larger for Malmö. The reductions in terms of kWh was however larger for Sodankylä.

The design of the glazing were also changed for the Malmö location to study the effect of double respectively triple glazing as well. This is presented in Table 3.

Table 3. Need of heating energy and energy saving in percentage of energy need before renovation in Malmö, southern part of Sweden with improved glazing for two types of ventilation systems; exhaust respectively mechanical supply and exhaust system.

Case	Annual Heating energy need (kWh)	Energy saving in whole percentage
Before energy renovation measures (exhaust ventilation)	20 558	-
Exhaust ventilation		
Only Single glazing, U-value=5,7 W/m^2 K, g=0,82	18 709	9 %
Single glazing + pre-heating of outdoor air	17 850	13%
Only Double glazing, U-value=2,6 W/m^2 K, g=0,73	17 310	16%
Double glazing + pre-heating of outdoor air	16 125	22%
Only Triple glazing, U-value=1,7 W/m^2 K, g=0,63	16 642	19%
Triple glazing + pre-heating of outdoor air via cavity	15 364	25%
Supply and exhaust ventilation with heat exchanger	16 384	20%
Only Single glazing	14 672	29%
Single glazing + pre-heating of outdoor air	14 686	29%
Only Double glazing U-value=2,6 W/m^2 K, g=0,73	13 367	35%
Double glazing + pre-heating of outdoor air	13 376	35%
Only Triple glazing, U-value=1,7 W/m^2 K, g=0,63	12 766	38%
Triple glazing+ pre-heating of outdoor air via cavity	12 728	38%
Only Triple glazing, U-value=0,7 W/m^2 K, g=0,24	13 313	35%
Triple glazing+ pre-heating of outdoor air via cavity	13 429	35%

U-value is the heat transfer coefficient for the glazing, the g-value is the solar transmittance of the glazing.

The energy saving of the heating energy need was between 8-38% depending on the design. Both the U-value and the g-value and the combination of them have influence on the energy need.

4 Discussion

In the existing building the outdoor air is not passed through the cavity when the cavity temperature exceeds 20° C. The increased set point from 20°C to 30°C resulted in somewhat increased energy savings. However increasing further to 50°C was marginal. There will also emerge disadvantages with increasing the supply air temperature for air quality reasons which also must be considered.

One specific year was used as a climate file for the Malmö location to allow validation with the full-scale measurements. The year was compared to a normal year for the period of 1999-2010 in [4]. The weather data match each other pretty closely although the radiation level for the monitored year was higher than for the long-term – average especially for the summer months. Higher radiation levels could imply overestimated energy saving during the winter period and increased over-heating during the summer time. This paper focuses on the heating period and during the months of October-April the deviation is small except for April. So except for April the used whether file should not imply a significant difference from normal conditions for the Malmö location. The assessment is therefore made that the studied data represent normal conditions.

The cost and profitability has not been studied. This depends on a number of parameters such as: energy price, political decisions as subsidies for energy saving renovations, future energy demands and also the condition of the building and cultural heritage aspects. These parameters will vary depending on the conditions and prerequisites that are valid for each object. The level of deterioration of a brick façade and needed measures to repair and subsequent costs for this will affect the economic considerations when choosing between different renovation measures. If the brick façade has deteriorated and something needs to be done to repair it, the studied solution might be an alternative which will stop further deterioration and protect the façade in the future.

The intention of this study was to contribute with levels of possible energy savings for this type of renovation. This can constitute a part of the input to the profitability calculation the designer makes.

Conclusions

The conclusion can be drawn that the calculated energy saving is in the span of 8-38% depending on the chosen type of glazing. For the existing glazing design the energy reduction is 9-30% compared to before the renovation in the southern part of Sweden (Malmö) and 8-24 % in the northern part of Finland (Sodankylä). The saving is about 3000-6000 kWh in southern Sweden and about 6000-12 000 kWh in northern Finland for the existing glazing design.

As both a southern and northern outdoor climate of Scandinavia is studied the results indicates how this type of renovation measure would perform in general in this cold part of the world. The simulation results indicates that energy savings are possible to make which makes this construction worth considering when exploring different options.

5 Acknowledgements

The Swedish Energy Agency and Tampere University are acknowledged for financing the study. The study is also a result of a co-operation between the Tampere University in Finland and Lund University in Sweden. The city of Malmö is gratefully acknowledged for allowing the analysis to be made, for supplying the measurement data, and for undertaking and financing the renovation including the measurement equipment.

References

1. Wong P. Natural ventilation in Double-Skin façade Design for Office Building on Hot and Humid Climate, University of New South Wales, Australia, (2008).
2. Ghaffarianhoseini A., Ghaffarianhoseini A., Berardi U., Tookey J., Hin Wa Li D., Kariminia S. Exploring the advantages and challenges of double-skin facades (DSFs), Renewable and Sustainable Energy Reviews 60 (2016) 1052-1065, Elsevier. (2016)
3. Wang Y., Chen Y., Zhou J. Dynamic modeling of ventilated double skin façade in hot summer and cold winter zone in China. Building and Environment 106 (2016) 365-377. Elsevier (2016).
4. Hilliaho K. Energy Saving Potential and Interior Temperatures of Glazed Spaces – Evaluation through Measurements and Simulations. PhD thesis. Tampere University of Technology, Tampere (2017).
5. Hilliaho K., Nordquist B.; Wallentén P. Energy saving and indoor climate effects of an added glazed façade to a brick wall building: Case study. Journal of Building Engineering 7 (2016) 246-262 (2016).
6. K. Jylhä, T. Kalamees, H. Tietäväinen, K. Ruosteenoja, J. Jokisalo, R. Hyvönen, S. Ilomets, S. Saku, A. Hutila, Test reference year 2012 for building energy demand and impacts of climate change, Reports 2011:6, Finnish meteorological Institute, Helsinki, 2011, 112 p. (in Finnish).
7. Avgenakis G. Inglasning av tegelfasad, Energianalys samt fältstudie på ett flerbostadshus och på Byggnad 22. Report TVIT-5059, in Swedish, Avd. för Installationsteknik, Lund University, (2017).