

Renovation and design of double casement windows with regard to the occurrence of water vapour condensation or mould on the interior surface of the window jamb

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Abstract. The condensation of water vapour on the interior surface is an indicator of construction dysfunction or ignoring of the surroundings temperature and relative humidity. This paper deals with analysis of the occurrence of condensation on the jamb of double casement windows (windows with two window casements). More precisely, this is a surface in the interior where water vapour condensation or mould occur. For the renovation of existing double casement windows, there are different solutions based on window design: application of double insulating glazing on the interior window casement, application of double insulating glazing on the exterior casement, or installation of a simple window. We first describe measurement of an existing double casement window located in a mountain cottage. Second, the results and comparison of 2D thermal model of different types of double casement window construction. Also, the external insulation of the peripheral wall was included in the model.

1. Introduction

Nowadays, the topic of renovation or replacement of double casement windows made in the early 20th century is quite common. The windows no longer meet functional requirements, and the physical condition of the wooden parts of the window is poor, which leads to substantial heat loss and inadequate acoustic insulation. This topic is very common for designers, conservationist and also common population. For the renovation of existing double casement windows, there are these possible solutions: A) refurbishment of the existing double casement window B) using double insulating glazing on the interior window casement C) using double insulating glazing on the exterior window casement D) replacement with a new structure (simple window). In the case of building renovation, there is also the possibility of using external insulation. [1] [2]

Critical internal surface humidity for the window pane is $\phi=100\%$ (risk of condensation) and for other structures $\phi=80\%$ (risk of mould). With regard to the window's surroundings, in rooms meant for habitation (20 °C, 50%) vapour condensation takes place at 9.3 °C and a high risk of surface mould at 12.6 °C. These temperatures are the evaluation criteria for the tested interior surface area with regard to outcomes.

2. Description of existing double casement window

The window in question is located in a mountain cottage at 800 m.a.s.l. The window is situated on the east facade on the second floor. It is a double casement window, the outer casement is outward-opening, the interior casement is inward-opening, with single glazing on both the interior and exterior panes. The external window size (on the interior side) is 667 x 915 mm. The exterior wall (wood), including both



interior and exterior panelling is 298 mm thick. The external frame of the window is located 20 mm from the interior face of wall. The distance between the two panes is 119 mm. The sill (wooden panelling) is 99 mm deep. Figure 1 and 2 depict the double casement window in question. [3]

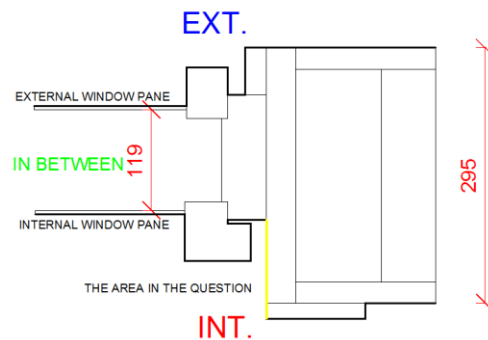


Figure 1. Cross-section of the window.



Figure 2. Photo of double casement window.

3. Measurement

3.1. Measurement conditions

Measurement of existing window were taken in two periods (in November and in March). The reason were the first availability of measurement, the second measurement in winter season. The jamb framework was fitted with dataloggers and temperature probes. Dataloggers (Comet 3120) that measure and record temperature and relative humidity of air and temperature of connected probes at regular 15 min intervals were placed on the exterior, in between the two window panes and in the interior (on the window sill). The measuring accuracy of datalogger is $\pm 0,4^{\circ}\text{C}$ and $\pm 2,5\%$ relative humidity. The dataloggers were connected to probes (Comet Pt 1000) that measure surface temperature. The measurements were taken in two time periods: November 2016 and March 2017. The interior surface probe was located on the surface of the jamb, approximately 20 mm from the face of the interior window pane. The second probe was situated in the middle of the window pane. Figure 3 and figure 4 depicts how the dataloggers were fitted.[4]



Figure 3. Placement of dataloggers and probes on the double casement window.

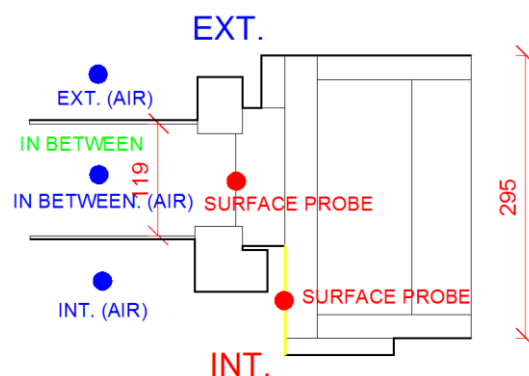


Figure 4. Cross-section with probes

3.2. Measurement data

The following figures (Fig. 5 through Fig. 8) depict variables measured over the observation period. Each datalogger measures the values of air and of surface probe. Table 1 shows the minimum, maximum and averaged values.

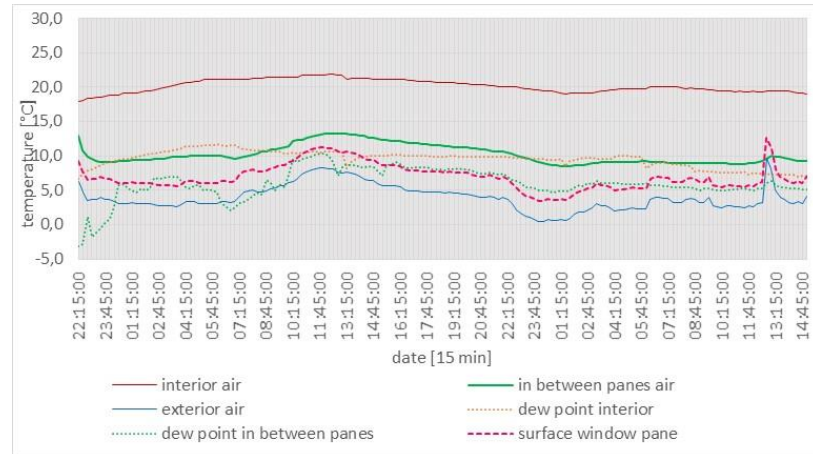


Figure 5. Evaluation of variables (temperature) during observation period, November 2016.

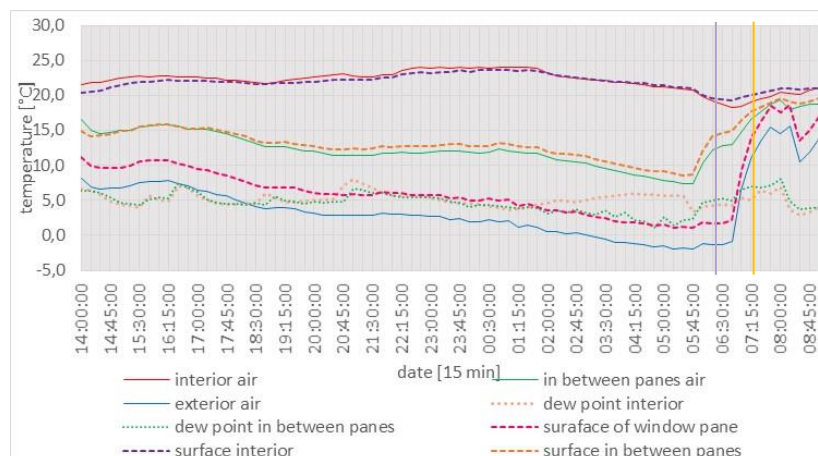


Figure 6. Evaluation of variables (temperature) during observation period, March 2017.

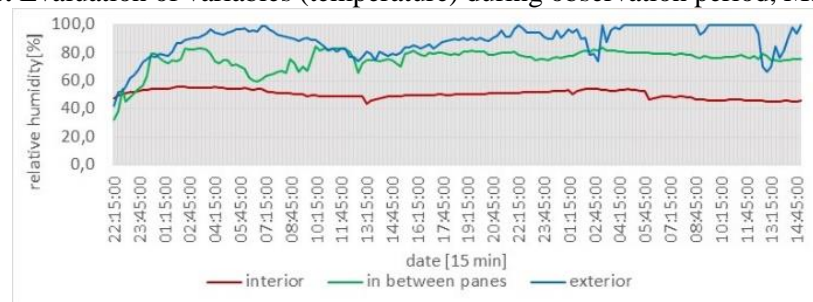


Figure 7. Evaluation of variables (relative humidity) during observation period, November 2016.

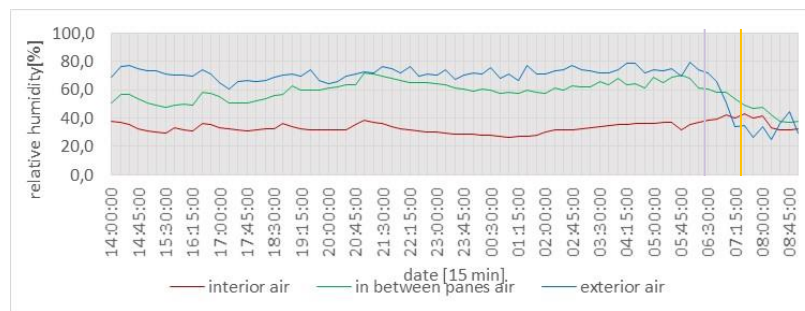


Figure 8. Evaluation of variables (relative humidity) during observation period, March 2017.

Table 1. Minimal, maximal and averaged values measured for temperature and relative humidity at individual location.

	Temperature [°C]			Relative humidity [%]		
	min	max	average	min	max	average
November 2016						
exterior	0.5	9.6	3.9	42.2	100	88.8
in-between window panes	8.5	13.3	10.2	32.5	84.3	75.2
interior	17.9	21.9	20.2	43.3	55.5	50.5
March 2017						
exterior	-2	15,7	8,9	24,9	79,4	67,2
in-between window panes	7,4	19,4	12,8	36,8	71,5	58,3
interior	18,3	24,1	22,1	26,5	42,6	33,2

3.3. The results of measurement

- Data are used for evaluation of real surroundings and surface temperature on the existing windows construction and for comparison with 2D model calculation.
- Temperature and relative humidity of each space (exterior, in-between windows panes and interior) specifies surroundings from occurrence of quantity of water in air and influence to construction of window (see Mollier diagram). Also there is shown dew point of temperature in interior and in between the window panes.
- During measurement there was visible condensation on the exterior panes in between the window panes. See Fig.5 and Fig.6 where is temperature of window pane under dew point of air in this space and condensation occurs.
- The graphs show the visible influence of sun exposure (yellow vertical line) and opening of the interior pane (violet vertical line) to surface temperature in interior.
- Surface of the interior wall is made of wood lagging. This surface temperature is higher than what would be found when using plaster on surface. Wood has higher thermal conductivity coefficient.
- Ratio is capacity of humidity [g/kg s.v.] in different microclimates equal for data in November (interior 1, in between window panes 0.78 and exterior 0.6), in March (interior 1, in between the window panes 0.98 and exterior 0.87).

4. 2D model calculation

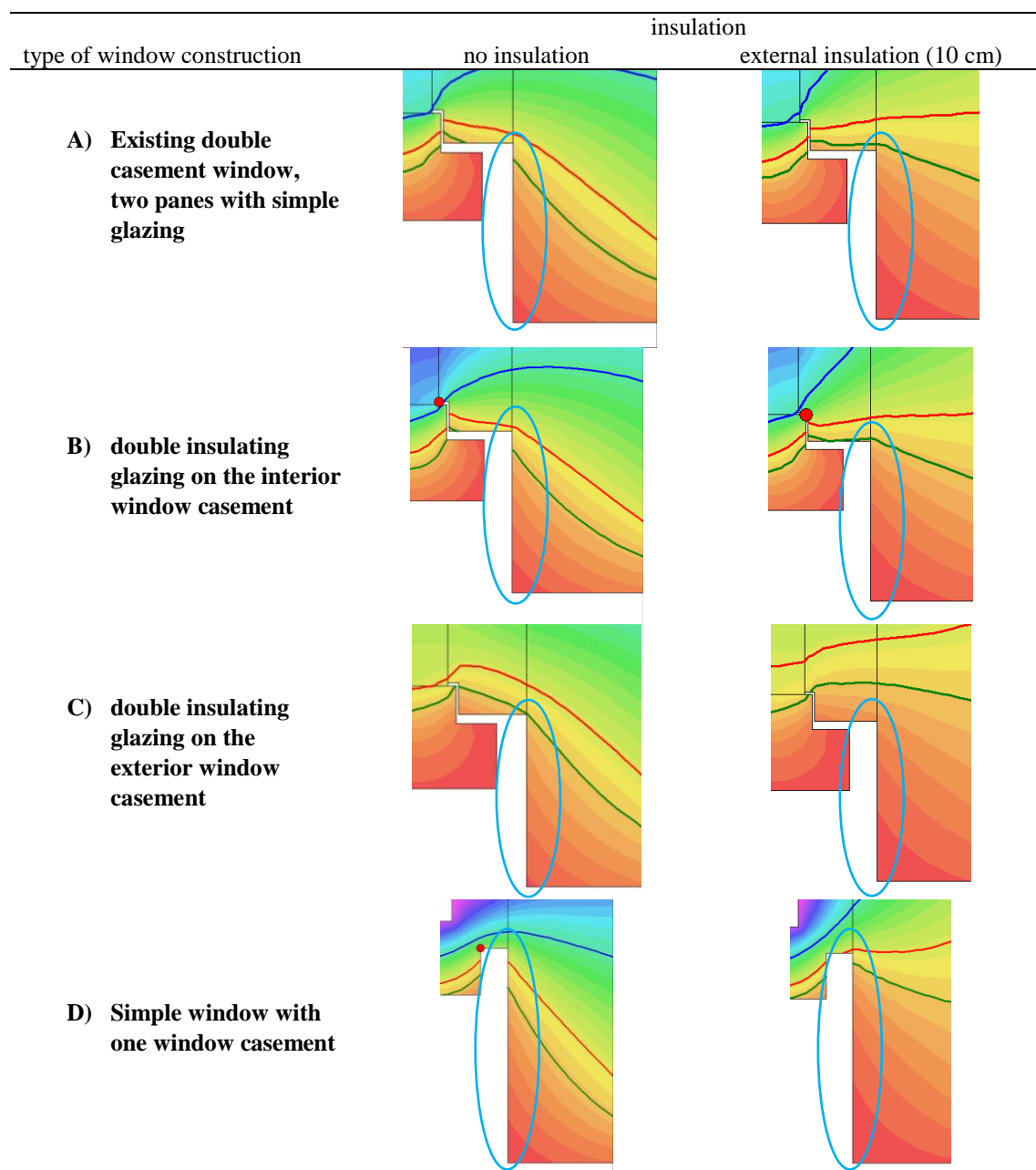
4.1. Thermal-technical assessment

A model calculation for an existing double casement window was prepared using a 2D program (Svoboda software 2014). Calculations were made for four types of window structure (see 1.1 A, B, C, D without or with external insulation on the exterior wall). The calculations were made under the following proposed boundary conditions: exterior -18 °C, 84 % (820 m.a.s.l.) and 20 °C, 50 % (room

for habitation). Window frames and panes were modelled using a simplified model since the calculations were to determine condensations areas on the interior wall surface.

The results show of temperature in the area of the window jamb. The area in question is marked by a blue circle. Also three isotherms are marked: red isotherm (condensation of water vapour in interior; 9.3 °C), green isotherm (boundary of area subject to risk of surface mould; 12.6 °C) and blue isotherm for 0 °C. [5] [6]

Table 2. Detail of the jamb of the window considering the above, noted individual variants with isotherms depicted. Red isotherm (condensation of water vapour in interior; 9.3 °C), green isotherm (boundary of area subject to risk of surface mould; 12.6 °C) and blue isotherm for 0 °C.



4.2. Results of 2D model calculation

Without insulation the detail A and B are in the area, where moulds can occurred. In the case of no insulation, the key barrier between interior and exterior temperature is the double glazing in the exterior

casement. There is a visible shift of the studied critical isotherms to the exterior beside using insulating glazing in the interior pane. In the case of insulating glazing of the internal casement window, the lowest temperature in the studied area is 7.3 °C. When using external insulation, the area in question lies below the boundary where mould can occur and also below the condensation temperature.

5. Conclusion

The paper deals with topic of the renovation of existing double casement windows. This paper was focused on the condensation of water vapour and occurrence of mould on the jamb surface in the interior structure of a double casement window. The first there is measurement on existing double casement window construction, the second there are results of 2D model for possible solutions of renovation of window construction. The measurement methodology (using dataloggers which record values of temperature and relative humidity) on the existing double casement window structure (including 2 periods) is described. Further, the results of thermal-technical analysis of a structure made in 2D software (Svoboda software 2014) are presented. For the 2D model, these types of structure were used: A) refurbishment of the existing double casement window, B) using double insulating glazing on the interior window casement, C) using double insulating glazing on the exterior window casement, D) replacement with a new structure (simple window). In the case of building renovation, there is also the possibility of using external insulation.

The measurement and model calculation led to the following conclusions:

- Correlation between measurement data and 2D model in the area in question (interior surface in the jamb) shows correspondence with maximal differences surface temperature to 1 °C. For this correlation were used data for 2D model of conditions obtained by measurement.
- Measurement data on the existing window show noticeable differences in different microclimates. Primarily the microclimate in between the window panes, there is lower volume of humidity in the air, see chapter 3.3.
- According to the 2D model results, the best design variant with regard to surface temperature and the occurrence of water vapour condensation or mould in the interior is using insulating glazing on the exterior window casement.

Acknowledgments

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