Monitoring of changes of external climate influence on inner microclimate of sacral building

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Abstract The paper deals with the internal environment of the side chapel of the important sacral building in Kutna Hora and its changes in relation to changes of selected parameters of the external environment. One of the important phenomena affecting the durability of construction materials (especially plasters and their surface treatments) is the existence and frequency of water vapor condensation on the surfaces of these structures. The formation and presence of condensation on interior plasters is, in a simplified view, dependent on the parameters of the internal environment (air temperature and relative humidity) and the surface temperature of the structure itself. The aim of the article is to map the state of the inner microclimate of the sacral building at a selected location of the side chapel in close proximity to the stained glass at the interface of the window and the window sill. Attention is paid to the existence and frequency of condensation and condensation zones and changes of specific air humidity from the position of long-term empirical monitoring of selected parameters of indoor microclimate.

Keywords: inner microclimate, condensation, construction durability, long term monitoring

1 Introduction

Maintenance of sacral buildings and approach to their repair and reconstruction cannot be done without an objective and comprehensive view of the technical condition of the building and of the conditions in which the building is located. Years of experience point to the fact that each historical sacral building has its specific characteristics and therefore it is necessary to approach each of them individually in terms of maintenance and operation. The technical condition of individual structural elements and their service life is undoubtedly influenced also by the environment in which they are located, both the external (conditions under the external terrain and the influence of outdoor climate), as well as the internal. This is an complex issue in which the internal microclimate is influenced by changes in the exterior microclimate but also by the technical condition of the structural elements (the presence of moisture, the existence of leaks, the presence of salts in the masonry) and structural arrangement of the building (the presence of building openings and the links between levels etc.). The internal microclimate in turn influences the structural elements and the interior furnishings of the space.

2 Aim of the experiment

The aim of the performed long-term measurement was to evaluate the characteristics of the inner microclimate of the side chapel with attention paid in particular to the reference comparison of the microclimate in the space of the chapel itself and the microclimate in close proximity to the window panel. The stated objective was based on the assumption that the behavior of the indoor microclimate in the vicinity of the window panel will be significantly influenced by solar radiation or sunlight, its thermal component that passes through the glass panel. Expected severe temperature fluctuations should affect the formation and development of condensation zones as well as changes in specific humidity. To a certain extent, the specific air circulation along the window panels also contributes to the specific characteristics of the microclimate at this point.

3 Method of the experiment

For a purpose of the experiment to obtain the values of the microclimate parameters the monitoring devices sensing selected parameters of indoor microclimate were installed in the side chapel of the Cathedral of St. Barbara in Kutna Hora. It is a chapel in the southwest corner of the cathedral. The sensors were placed so as to monitor selected parameters of the indoor microclimate both in the interior of the inner chapel and in the micro-space, which is located in close proximity to the contact of the glass window panel (stained glass) and the adjacent stone block (window sill). The overview of sensors and sensing points is shown in Table 1 below. These were measuring instruments (data loggers), measuring relative humidity and air temperature. Data were taken from 24. 7. 2018 to 19. 11. 2019 and was automatically stored in the device at regular 4-hour intervals. Outdoor temperature sensors were connected to these data loggers.

Table 1 Description of measuring instruments

Sensor number	Sensor type	Placement height above the church nave floor (m)	Further placement specification	Measured parameter
1	Data logger Comet 3631	3	interior	temperature ˚C, relative humidity % rel.
2	probe	3	interior by glass window	temperature ˚C
3	Weather station Vantage Pro2	tower of the Church of All Saints in Sedlec near Kutná Hora	exterior	temperature and humidity °C, % rel.

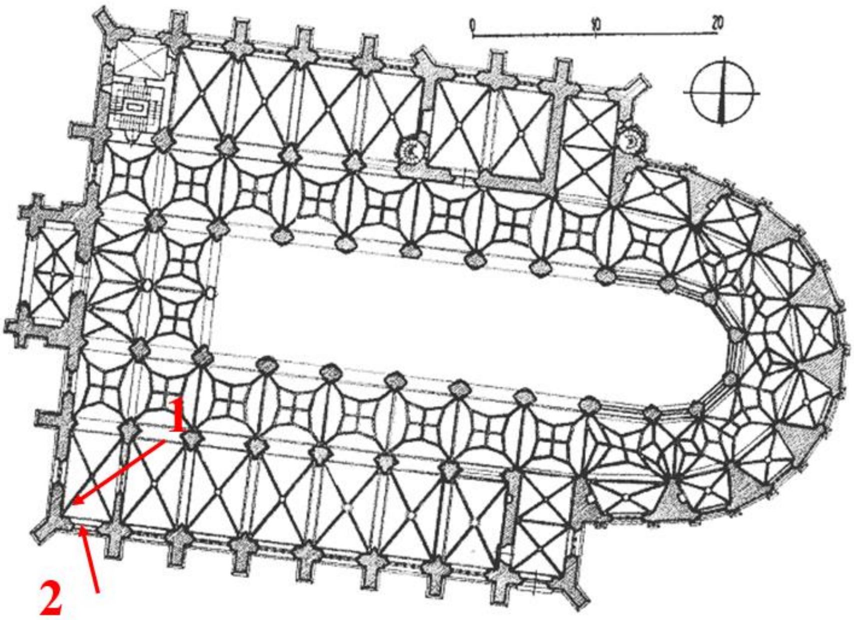

Fig. 1 Drawing of sensors placement in the temple plan

4 Results of experiment

Direct monitored parameters were temperature, relative humidity and dew point temperature. Parameter derived was specific air humidity. Correlations of temperature, relative humidity and specific humidity in the comparison between exterior and interior were also calculated. The graphs of temperatures and specific humidity in the whole monitored period are shown in the following graphs Fig. 2 and 5. Detailed reference comparison of temperatures and dew points of the measured points of selected (critical) time periods is shown in graphs Fig. 3 and 4. Detailed reference comparisons of specific humidity of measured points of selected (critical) time periods are shown in Fig. 7. The summarizing information on the measured parameters is contained in Table 2. Table 3 clearly summarizes the frequency of condensation occurring at the point of contact between the stained glass and the stone sill.

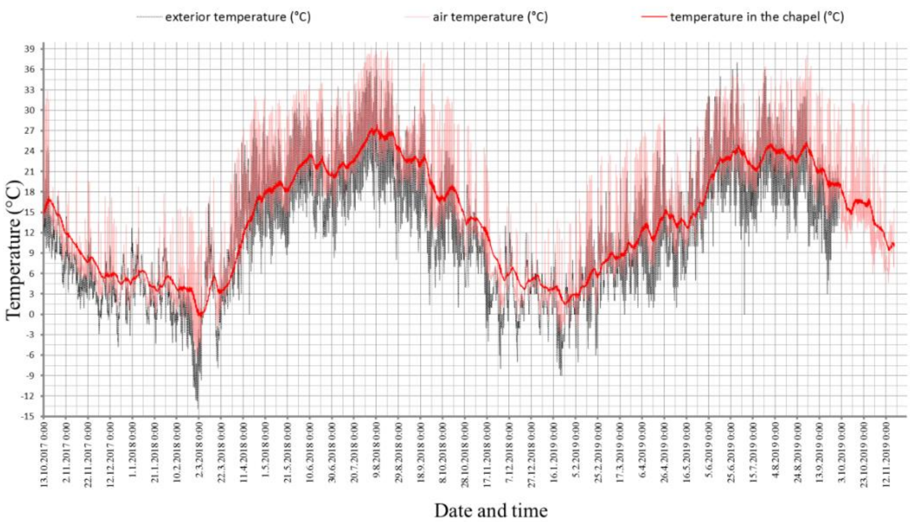

Fig. 2 Course of temperatures in the chapel (space and immediate proximity of the window panel) and exterior in the period October 2017 to November 2019

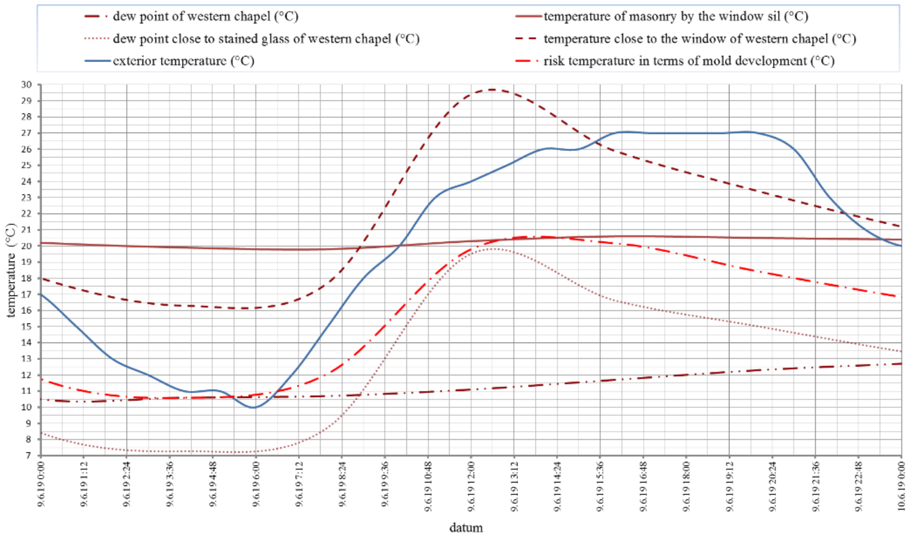

Fig. 3 Graphs of selected temperatures on the surface of the stone window sill of the stained glass window as of 9.6. 2018

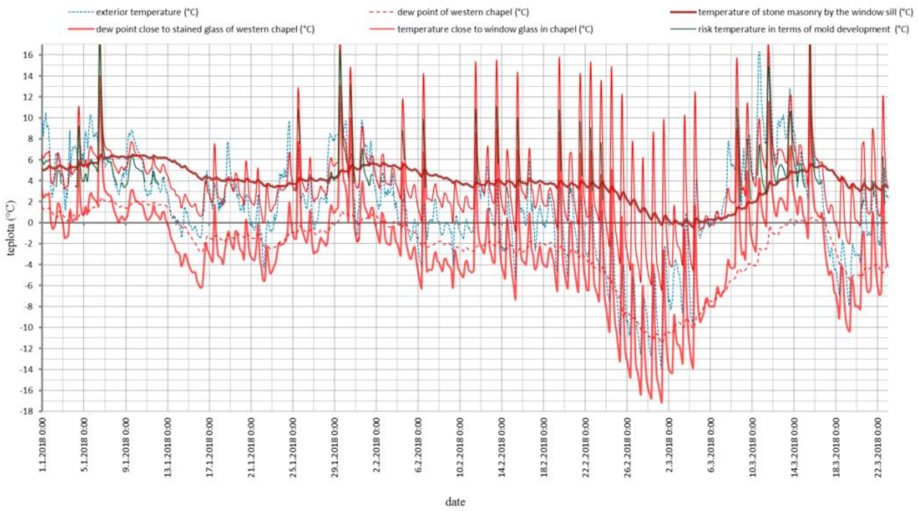

Fig. 4 Waveforms of selected temperatures and dew point near the contact between the glass window and the window sill

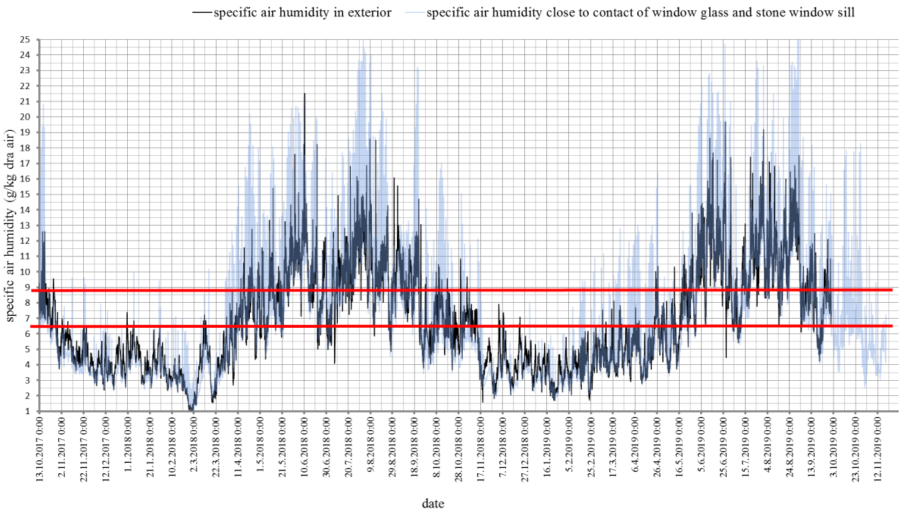

Fig. 5 Specific humidity of selected areas from October 2017 to November 2019

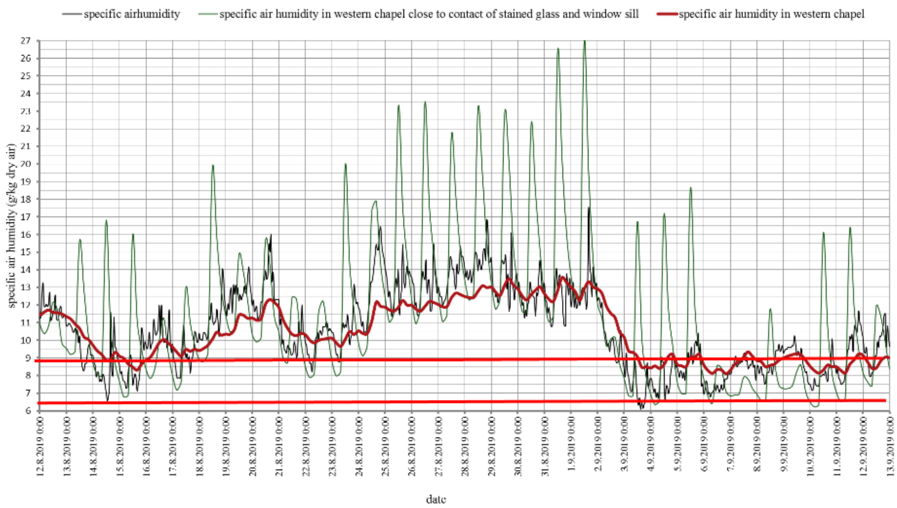

Fig. 6 Specific humidity of the western chapel in the immediate vicinity of the contact between the window panel (stained glass) and the stone sill in the period from 12 August to 13 September 2019

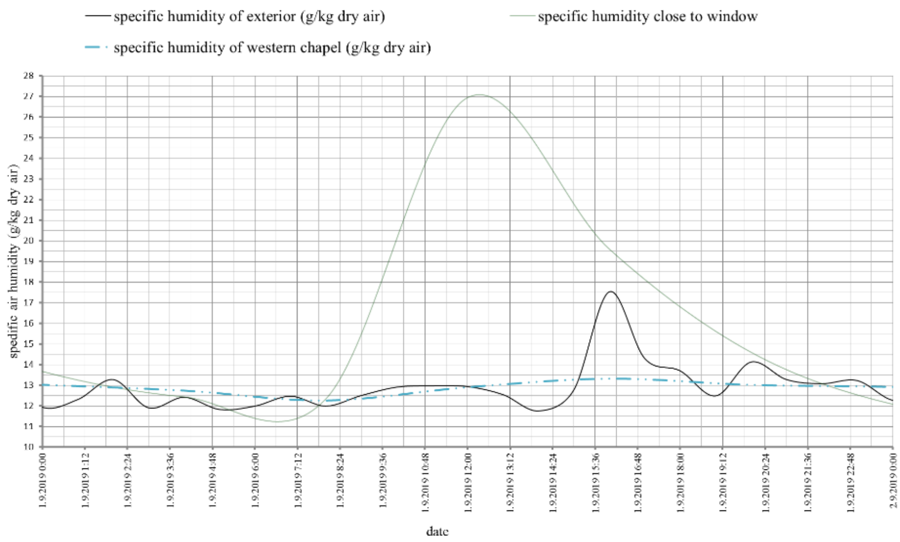

Fig. 7 Specific humidity of the western chapel in the immediate vicinity of the window panel (stained glass) and the stone sill in the period from 12 August to 13 September 2019

On the basis of measurements and comparative analyzes carried out it can be stated:

1) the characteristics of the indoor microclimate in the immediate vicinity of the window panel and stone sill (hereinafter referred to as detail) are significantly different from the microclimate in the open space of the chapel (Fig. 2 and 5);

2) temperatures close to detail oscillated between -14.3 to 37 ° C with average value of 12.5 ° C in the two-year cycle and in the open space between -0.4 to 13.9 ° C with average value of 13.9 ° C;

3) no significant condensation process has been recorded in the side chapel area (on the inner wall surface) (Fig. 4);

4) a process of periodically occurring water vapor condensation has been recorded on the perimeter walls near the detail (Fig. 4);

5) the most risky period in terms of the frequency of water vapor condensation in the vicinity of the detail was recorded in both years of measurement during the March to June (Table 3);

6) the most intense condensation was recorded in vicinity of the detail in October and November 2017, January, March, April and October 2018 and February to June and October 2019;

7) in the area of detail, there is a sharp periodic change of the specific air humidity (Fig. 5, 6, 7) compared to the chapel space, where its changes are significantly attenuated;

8) variations in specific air humidity in the detail area reached up to 16 g / kg dry air at a time interval of 5 hours (Fig. 7);

9) correlation of functional curves of the relative humidity of the interior of the side chapel, even in the vicinity of detail has a lower value (below 0.5) than in the case of correlations of temperature functions of interior and exterior (above 0.8).

Table 2 Condensation of water vapor in place of window stained glass and stone sill

		Space of western chapel		Immediate proximity to the glass window	
Obtained values	Temperature	Dew point	Relative humidity	Specific humidity	Temperature
	[˚C]	[˚C]	[%]	[g/kg d. a.]	[˚C]
Min.	-0,4	-17,1	31,8	1,6	-14,3
Max.	27,9	29,7	80,2	13,6	37
Average	13,9	6,5	59,3	6,4	12,5

Table 3 Frequency of water vapor condensation at the point of contact of window stained glass and stone window sill

Year	January	February	March	April	May	June	July	August	September	October	November	December
2017	X	X	X	X	X	X	X	X	X			
2018												
2019												X

5 Conclusions

The measurements showed that the micro-space in the immediate vicinity of the window panels of churches and chapels has significantly different climatic properties than the open and ventilated space of church navels and chapels. This micro-space is characterized by a frequent and periodic increase of the condensation point above the temperature of the surfaces of related structures (glass, stained glass, plaster or stone elements of the sill). The likely major influence that causes external thermal-humidity changes in this micro-space is the sunlight acting on the window glass panels. Structural elements (plasters, stone, bricks) are absorbing moisture not only by the absorption of condensation water, but also by the absorption of moisture from the air according to the characteristics of the sorption isotherms for the material. The change in the moisture conditions in the sill also causes a change in the thermal insulation characteristics of the masonry and destruction due to the change of the water state in the ice in winter. We consider the most harmful phenomenon to wall paintings, valuable plasters and wooden window elements to be rapid changes in the specific humidity of the microclimate, which cause different dilatation movements of the materials present and stresses at their mutual contacts. The found points pointed out that it is necessary to pay special attention to the behavior and influencing of the microclimate in the micro-space of window panels and related sill in order to solve the question of the interior microclimate of sacral buildings.

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