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Indoor environment in a high-rise building with lightweight envelope and thermally active ceiling

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Abstract
The aim of this study is to evaluate the impact of the new lightweight envelope on the indoor environment quality in a high-rise building of the Slovak University of Technology, conditioned by a thermally activated ceiling system, also called CRITTALL. Retrofit of the envelope and of the heating system of this 23-floor high-rise office building was carried out recently. Representative spaces were selected and equipped with sensors for monitoring the room temperature, surface temperatures, relative air humidity, outside weather conditions, etc. Presented are the data obtained in the four reference rooms in 2014, sorted out according to the working hours (8:00 AM - 4:00 PM) and assessed in accordance with the current European standard EN 15251:2007. The results indicate overheating of the rooms, in particular during transition periods and in offices with double skin façade oriented to the South-West.

Keywords - retrofit, CRITTALL, indoor environment, cooling, heating, light-weight facade

1. Introduction

Decades have passed since the high-rise office building of the Faculty of Civil Engineering of the Slovak Technical University in Bratislava was constructed. After 35 years, the old facade panels with steel frames and double float glazing were in a poor physical condition, barely able to fulfil the criteria on thermal insulation of buildings and had to be replaced. Simultaneously, the heating system of the object was reconstructed. Subsequent monitoring of the thermal conditions in the building is necessary to confirm that the system components and technology are correctly designed and adjusted to achieve a healthy and comfortable indoor environment at decreased energy consumption. For this purpose, sensors for monitoring various indoor environment indicators were installed in selected spaces and different variables such as air temperature, temperature of surfaces, relative humidity and CO_2 concentration were recorded.

2. Building description

Two main factors of the buildings have the highest impact on the indoor environment quality. First, thermo-physical properties of the building envelope, which should be designed so to reduce the heat loss during the heating period (winter) and solar heat gains during the cooling period (summer). Second, an efficient heating system with optimized operation to achieve satisfactory indoor environment at low energy consumption.

3.1 The light-weight façade

The original façade, constructed from prefabricated panels consisting of a steel frame, float glass and opaque parts of the parapet, was replaced by new prefabricated aluminum blocks.

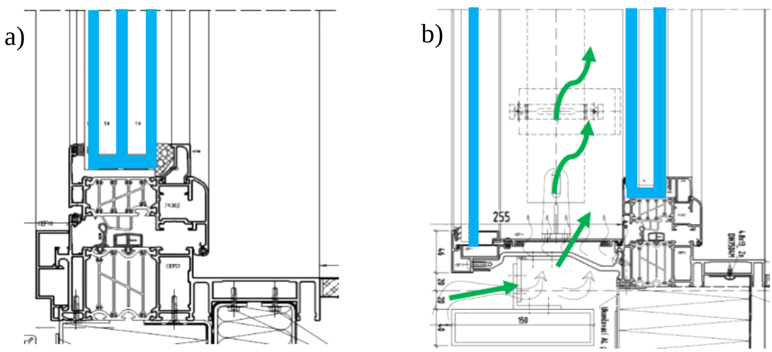

Fig 1: a) simple facade facing North-West, b) double skin facade facing South-East.

On the North-West, the façade is simple, with triple glazing and the possibility to open the windows to the exterior (Fig. 1a). On the South-East, the facade is double-skin, with a gap between the two windows, not providing any possibility to open the window directly to the exterior, but only to the gap (Fig. 1b). Within the gap, the outside fresh air is allowed to flow, accessing the gap by openings in the facade. Both façade types contain blinds, installed on the inner window surface in case of the simple façade, and in the gap between the windows in case of the double skin facade.

Figs. 2 and 3 depict visible-light and infrared thermal images of the North-West facade and the South-East façade, respectively. The red dots in Fig. 2a in the infrared image are caused by opening the windows to the exterior. The yellow spots in Fig. 2b in the infrared image are caused by opening the inner windows into the gap between the two skins.

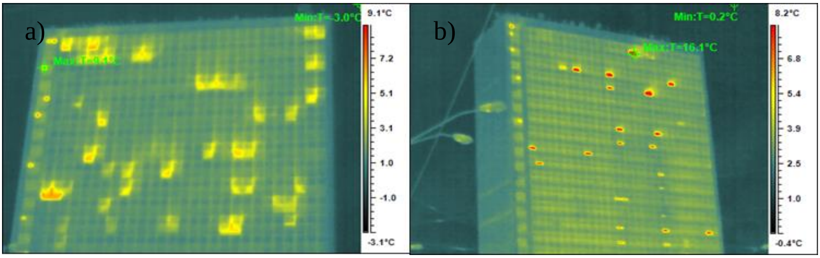

Fig. 2: a) Simple facade with triple glazing, facing North-West, b) Double skin facade, facing South-East. Photo: Michal Lukačovič

3.2 Heating system

The high-rise building is connected to district heating (Fig. 3). The heat is exchanged from the primary to the secondary pressure independent circuit by heat exchange stations. The primary heat exchange station for the entire building is located in another, adjacent block of the Faculty. The secondary heat exchange station is located in a technical room in the high-rise building.

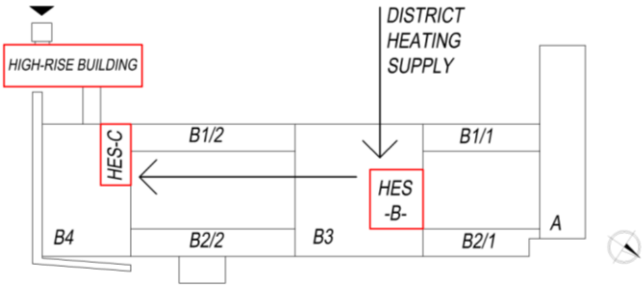

Fig. 3: Heat supply to the building and location of heat exchange stations (HES).

The heating system of the high-rise building is divided into two pressure zones, the first ranging from the 1st to the 10th floor, the second from the 11th to the 23rd floor. Each pressure zone has its own manifold, dividing the zone into four circuits, two of them supplying heat to the South-West and two of them to the North-East part of the building. The manifold for the 1st pressure zone is located on the 1st under-ground floor and the manifold for the 2nd pressure zone is located on the 10th floor. Each circuit is equipped by a circulation pump, a three-way valve and other corresponding armatures.

The offices of the high-rise building are heated by a thermally activated concrete ceiling - CRITTALL. This hot water heating system was patented as early as 1907, but its first practical applications in Slovakia are dated to the 60s, when it was particularly used in large office buildings. In the present case the ceiling heating consists of a reinforced concrete slab 210 mm thick, in which steel tubes with the inner diameter of 15 mm are embedded, forming a meander with the spacing of 150 mm (Fig. 4a). The integrated tube registers are embedded at the bottom of the ceiling structure, about 20 mm distant from the surface. The design temperature gradient of the heating medium is 55/45 °C (sup-ply/return temperature). The ceiling heating covers up to 50 % of the ceiling area in each room (Fig. 4b). During summer, the CRITTALL is used for cooling, the primary cooling medium being supplied from underground water reservoirs and exchanged to the secondary circuit through a set of heat exchangers.

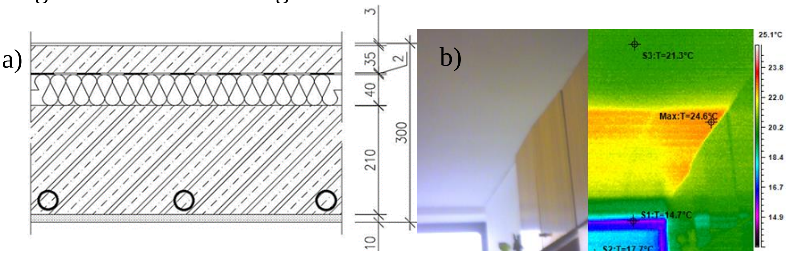

Fig. 4: a) detail of the ceiling structure, b) infrared image of the thermally active ceiling.

The technical room supplying heat to the high-rise building was significantly reconstructed in 2011. The main goal of this retrofit was to increase efficiency of energy transmission from primary to secondary circuit and to minimize the operation costs. Renovation and adaptation of the system was also necessary so that the new facade can take the energy saving effect. The central control is done through three-way mixing valves on the individual branches for the respective building zones. The temperature of the heating medium is related to the ambient temperature according to heating curves that are individually adjusted based on the experience of the dispatcher. There is no possibility of control for the individual offices.

3. Monitoring of the indoor environment

For monitoring of the various indoor environment indicators such as air temperature, relative humidity, carbon dioxide concentration, illuminance, etc., measuring sensors were in-stalled in selected offices in 2013. Based on the recorded data it is possible to evaluate the indoor environment quality and subsequently to suggest measures or further measurements to optimize the indoor environment quality and energy consumption if needed.

Four offices were selected for monitoring of the indoor environment, differing from each other by location and orientation. Two of the offices were located on the 6th floor, one of them facing North-West (office 620) and the other facing South-East (office 609). The other two offices were located on the 14th floor, one oriented to the North-West (office 1415) and the other one to the South-East (office 1406). One of the offices is shown in Fig. 5.

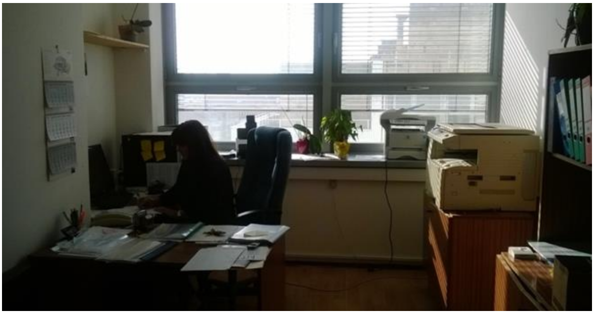

Fig. 5: Reference office on the sixth floor (office 609).

The sensors connected to the centralized computer were:

- Window surface temperature sensors (Fig. 6a);
- Illuminance sensors (Fig. 6b);
- Air temperature, relative air humidity and air quality sensors (Fig. 6b).

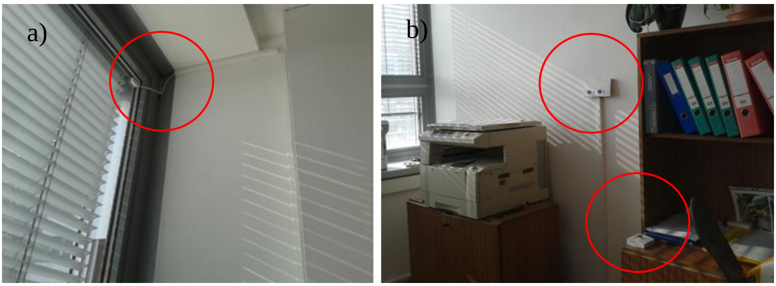

Fig. 6: a) window surface temperature sensor, b) illuminance sensor (bottom), air temperature, relative air humidity and CO2 concentration sensor (top) in the office 609.

Location of installed sensors:

- Window surface temperature sensors - upper right corner of the window;
- Illuminance sensors - about 0.7 meter above the floor on the working desk;
- Group of the air quality sensors: 609 – on the wall, 1.7 meters above the floor; 620 - 1.1 m above the floor; 1406 - on the wall, 1.61 m above the floor; 1415 - on the wall at a height of 1.735 m above the floor;
- Sensors of the ceiling heating – built in the ceiling.

4. Results

The samples were collected over one year (2014) and the data was sorted out according to the working hours (8:00 AM - 4:00 PM) and evaluated in accordance with EN 15251:2007.

4.1 Air temperature

According to EN 15251, the room is classified into one of the four categories of the indoor environment. The nominal level of expectations for new and renovated buildings is represented by category II (20 to 24 °C for heating, 23-26 °C for cooling). Results of the air temperature and classification into the four categories of thermal comfort (I to IV) are shown in Fig. 7. Category IV can be accepted for only a very limited time period. The results indicate that the desired thermal environment was achieved for only a limited period of time.

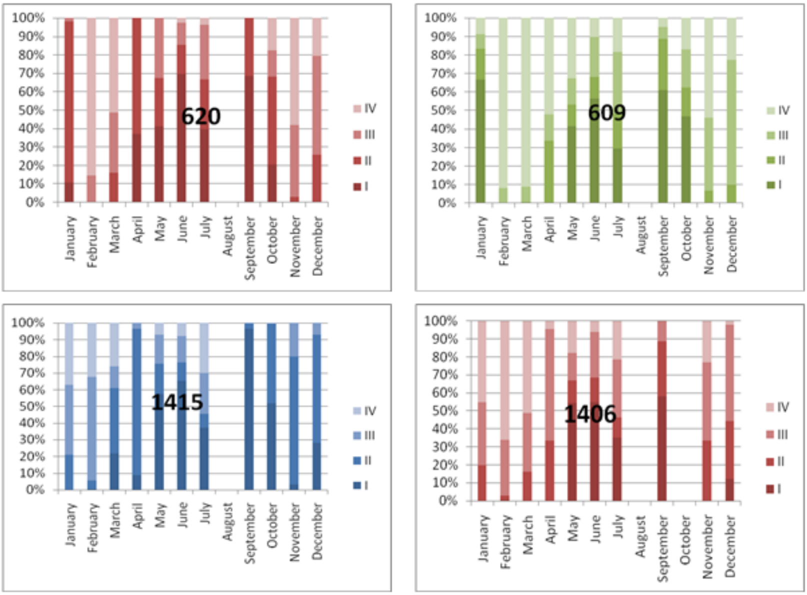

Fig. 7: Classification of thermal environment into 4 categories in accordance with EN 15251, 4 reference spaces of the high-rise building.

Generally, the air temperature was lower, and thus more comfortable in offices with simple facade. In the offices with the double-skin facade oriented to the South-West the air temperature was less stable and varied more throughout the day than in the offices with the simple façade oriented to the North-East.

No European or Slovak standard considers the simultaneous relation of air temperature and relative humidity. These two indicators of indoor air quality both affect the thermal comfort [3]. Fig. 8 presents presumptive perception of indoor air humidity depending on indoor air temperature in 4 monitored offices during one workweek in the heating period (1.12. - 5.12.2014). The best environmental comfort was achieved in the office number 15 on the 14th floor. During none of the measured time period was in one of the reference offices uncomfortable moisture or drought.

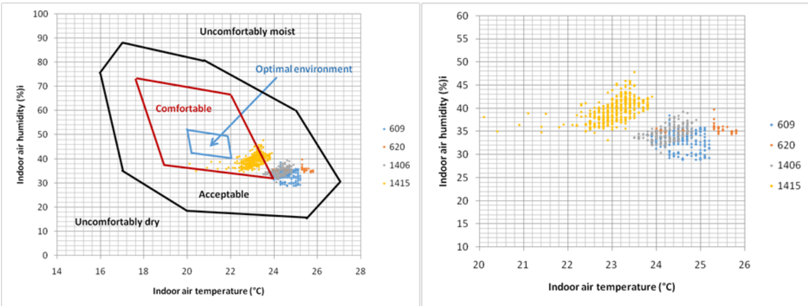

Fig. 8: Classification of the reference rooms according to the perception of indoor air humidity depending on indoor air temperature [3].

4.2 Relative humidity

The relative air humidity was satisfactory during more than 90 % of the time (Fig. 9). The not satisfactory values were due to the relative air humidity too low.

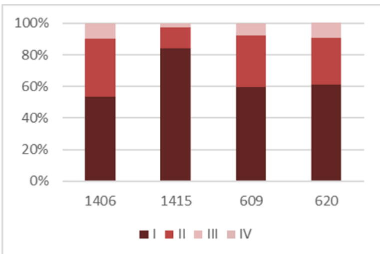

Fig. 9: Classification of the reference rooms according to indoor air humidity into 4 categories.

4.3 CO_2 concentration

The CO_2 concentration outside was not measured during the whole period considered. In the evaluation, the CO_2 concentration outdoors was considered 420 ppm. The maximum limit for category II, 500 ppm above the concentration outside, was reached during 60 % of the time (the best of all results) in the office 1406 due to low occupancy (1 person) and less frequent presence of occupant in the room (Fig. 10). The second best result was achieved for the office 1415 despite of its occupation by two occupants. The worst results were obtained for the offices on the 6th floor despite of low occupancy (1 person), due to low frequency of window opening.

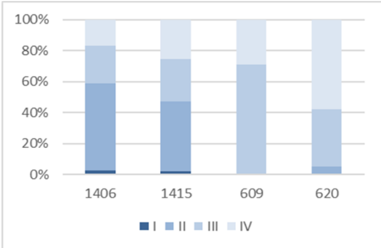

Fig. 10: Classification of the reference rooms according to the indoor air quality into 4 categories.

5. Discussion and conclusion

The outside weather conditions, solar irradiance, changes in internal heat gains and small heat accumulation capability of the light-weight facade can result in relatively dynamic changes in thermal balance of the building. Due to the high time constant, i.e. slow reaction of the thermally activated ceiling, the heating system may not be able to respond to these changes fast enough to assure a comfortable thermal environment. This, together with insufficient hydraulic balance and the absence of individual control results in excessive air temperature in the building, in particular during the transition periods and in the offices with the double skin façade oriented to the South-West. Although this cannot be completely eliminated, a partial remedy could be proper hydraulic balancing and a more sophisticated control of the heating/cooling system, e.g. control according to indoor air temperature in the reference rooms.

References

[1] EN 15251:2007 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics, 2008
[2] BABIAK, J., OLESEN, B.W., PETRÁŠ, D. Low Temperature Heating and High Temperature Cooling. REHVA Guidebook No 7: Rehva Brussels, 2007
[3] HAUSLADEN, G. & TICHELMANN, K. Interiors Construction Manual: Integrated Planning, Finishings and Fitting-out, Technical Services, Birkhauser Verlag AG, 2010, p. 37
[4] NEMETHOVA,E. & KRAJCIK,M. Impact of lightweight envelope retrofit on the indoor air quality in a high-rise building. In E-NOVA 2015 : Internationaler Kongress. Nachhaltige Gebäude. Pinkafeld, Österreich, 26. - 27. 11. 2015. 1. vyd. Graz : Leykam Buchverlagsgesellschaft, 2015, p. 229-235.