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BKCity Stay. Renovation of lecture Room A of the Faculty of Architecture of the Delft University of Technology

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Abstract
Following the fire in the former faculty building in 2008, the Faculty of Architecture of the Delft University of Technology moved temporarily into the former main TU Delft building. Later it had been decided that Architecture will remain in the building, now renamed BK City, for the longer term (30-50 years). For the longer term, the building needed an indoor climate upgrade and sustainable repair of the structure was necessary. This renovation program is called 'BK-City Stay!' and intends to improve the comfort and the structure in a durable and sustainable way.
Students of the Master Track Building Technology have a course in which they study the indoor comfort in buildings through surveys and measurements of the four different indoor comfort aspects, thermal, visual, and acoustical comfort and indoor air quality. The aim of the course is that the students learn how they can determine and predict the indoor environmental parameters that affect health and comfort.
Over the years, this led to an overview of indoor air temperatures and CO_2 levels in several rooms in the faculty of Architecture before, during and after the renovation period. This paper presents the results of the indoor comfort before, during and after the renovation in the largest lecture room of the Faculty of Architecture, lecture room A
From this case study it must be concluded that after the physical renovation is finished, it still takes a long time before the indoor climate in the building is well regulated. It might be caused by the way in which the renovation of a complex building and its installations are managed. Or it might just be a problem of modern complex energy renovations where monitoring after the physical renovation needs to be included in the renovation process.

Keywords – renovation; indoor air quality, thermal comfort; measurements

1. Introduction

Following the fire in the former faculty building in 2008, the Faculty of Architecture of the Delft University of Technology moved into the former main TU Delft building. The building was initially regarded as a temporary home, but it has now been decided that Architecture will remain in the building, now renamed BK City, for

the longer term (30-50 years). BK City must therefore be made more efficient and sustainable to meet future needs.

Therefore, the building needed improvement, especially for what concerns the indoor climate (upgrade) and sustainable repair of the structures. This is the focus of the second phase of the intervention, 'BK-City Stay!', improving the comfort in a durable and sustainable way [1].

Figure 1: Faculty of Architecture, Delft University of Technology [2]

2. Method

For the students of the Master Track Building Technology of the Faculty of Architecture, their own Faculty was an excellent opportunity to study the indoor climate. Master students determined, within the course "Technoledge Climate Design" in diverse rooms the indoor comfort. The aim of the course is that the students learn which indoor environmental parameters are important for health and comfort and that they can determine the indoor comfort parameters using measurements and questionnaires. Over the years, this led to an overview of the indoor air temperatures and CO_2 levels in several rooms in the faculty of Architecture before, during and after the renovation period.

In this paper the data gathered for lecture room A of the Faculty of Architecture is presented and related to the renovation process. Room A is the largest lecture room in the Faculty of Architecture, see figures 2 and 3 for the rooms before and after the renovation.

3. Room A of the Faculty of Architecture

3.1. Before the Renovation

Room A, the largest lecture room in the Faculty of Architecture, has a capacity of 350-400 persons. It is a lecture room with a volume of 3657 m^3. The room has four large windows where the lower chairs are and 9 smaller windows where the higher chairs are, see figures 2 and 4. The height of the room is 11.5 meters. The existing ceiling was taken out as an architectural statement. There are 11 radiators in the room

and a ventilation system. The ventilation is mechanical ventilation from outside ventilation which can be heated in the air handling system. The air enters the room through 6 large inlets under the ceiling and 2 exhaust grills in the front of the room near the speaker [6]

Figure 2: Room A before renovation (February 2009), visible are 6 of the smaller windows [3].

Figure 3: Room A after the renovation, September 2015 [4]. The chairs are new, the ventilation system now consists of airsocks on the ceiling and underfloor supply under the chairs.

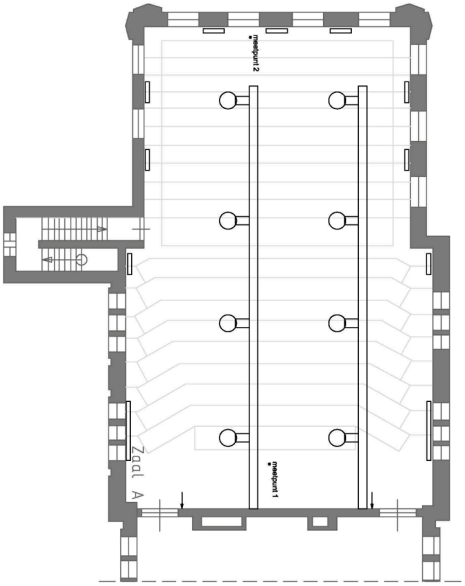

Figure 4: Plan of room A before renovation (February 2009) [3]

3.2. The Renovation

Demands

The BK City Stay renovation program [5] demanded the following: A heat exchange unit, with an efficiency of at least 50-60 % leading to an inlet temperature between 16-26 °C. The inlet air should consist of 100 % fresh air, filtered according to class EU7. The amount of fresh air must be 20 m^3/hour per person with a minimum of 1.1 l fresh air per m^2 floor space. The ventilation system must be CO_2 controlled, and the CO_2 concentration must be measured in the outlet. The CO_2 concentration in the outlet air must be less then 1200 ppm, with a target value of 800 ppm. The temperature should be between 21 °C (winter) and 25 °C summer (at a 30 °C outside temperature). The air velocity in the room needs to be less than 0.2 m/s in the living zone. The noise from the installations must be less than 35 dB(A).

Changes

The new installation scheme for lecture room A is given in figure 5. The inlet air is heated first with the heat recovery wheel and, if necessary, with extra heating. The air inlet in the room now consists of not one but two systems: 50 % of the fresh air is supplied through air socks in the room, the other 50 % is supplied under the podium and supplies the air through grills in the vertical partitions of the stairs. Floor heating is applied at the location of the speaker. The new outside windows have insulated glazing, with a low g-value. Room A received new chairs to improve the acoustics. The new

chairs have recycled polystyrene fabric on the backs and the seats of the chairs [5], see figure 3.

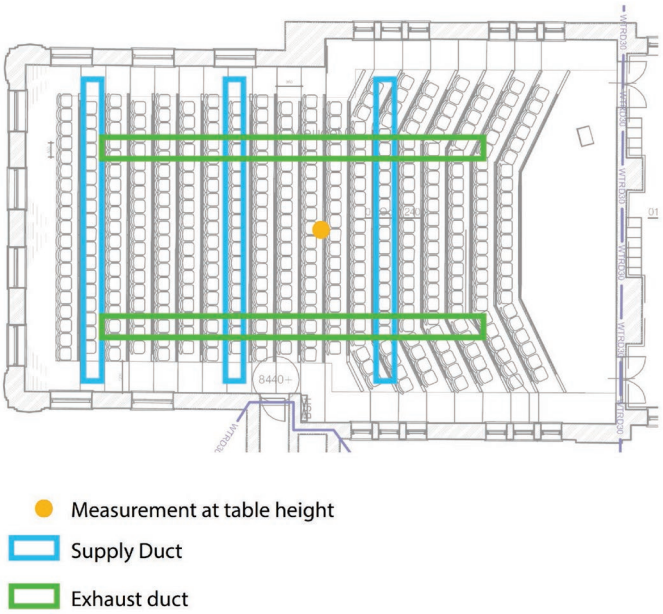

Figure 5: Plan room A and measurement locations after the renovation [4]

When a room has outside windows, radiators need to be positioned under the windows to compensate for the downdraught and the radiators need enough capacity to keep the room at a temperature of 15 °C under night reduction. The noise from the installations must be less than 35 dB(A).

4. Results

4.1. Before Renovation:

Measurements were performed on Friday 13/2/2009 and Wednesday 16/2/2009, see figure 6 and 7. The measurements on Friday 13 February 2009, were performed during a lecture from 10:30 till 13:30 in which the room had around 100 students. The blinds in front of the windows were closed and the heating was on. The outdoor temperature was ~3 °C. The measurements on Monday February 16, 2009 were performed during a lecture from 8:45-10:45 in which the room was filled with ~150 students. The blinds in front of the window were closed and the heating was on. The outdoor temperature was ~7 °C.

The measured temperatures are too low for comfort. Comfort is assumed to be reached at an indoor air temperature above 20 °C in winter. Figure 6 on the right shows

that the indoor temperature rises during the morning; this is assumed to be caused by the presence of the ~150 students. The low temperatures are probably caused by a high air change rate with unheated outside air of ~ 7 °C. The indoor air quality is reasonable, with a measured CO2 concentration of 900 ppm on February 16, 2009, see figure 7.

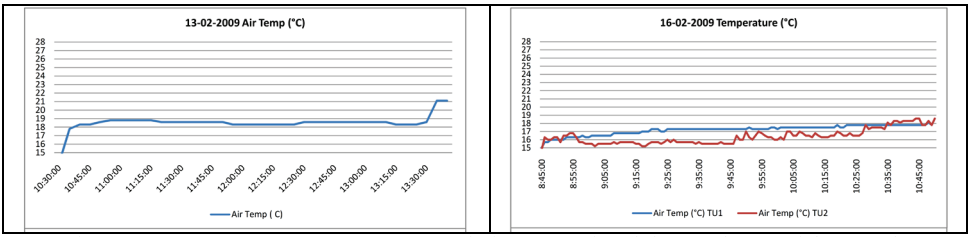

Figure 6: Temperature measurements room A before renovation (left: 13 February, right: 16 February 2009) [3].

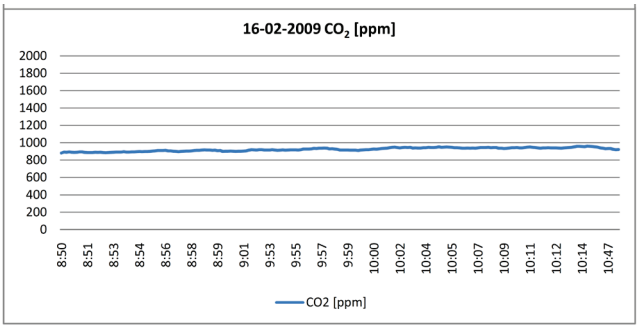

Figure 7: CO2 concentration in room A on 16-2-2009, before renovation [3].

The measurements show that there is room for improvement in room A. After the renovation, the minimum indoor temperature should be 21 °C in winter where 19 °C is measured on February 13, 2009 and an even lower 16 °C is measured on the morning of February 16, 2009. As far as the indoor air quality in concerned: the ideal CO2 concentration after the renovation should be 800 ppm where 900 ppm is measured on 16 February 2009.

In addition, the students investigation room A noticed that the ventilation system is on at all times, even when there is no lecture or during a break. When the ventilation is on at all times, a lot of extra energy is consumed due to both the heating of the excess outdoor air and the pumping of the fresh air to and from lecture room A

.

4.2. During Renovation

During the renovation, on September 15 2014, measurements were performed in room A by one of the teachers of the faculty of Architecture, see figure 8. The number of students is unknown but probably > 200 as it was a bachelor course. The outside temperature was ~21 °C.

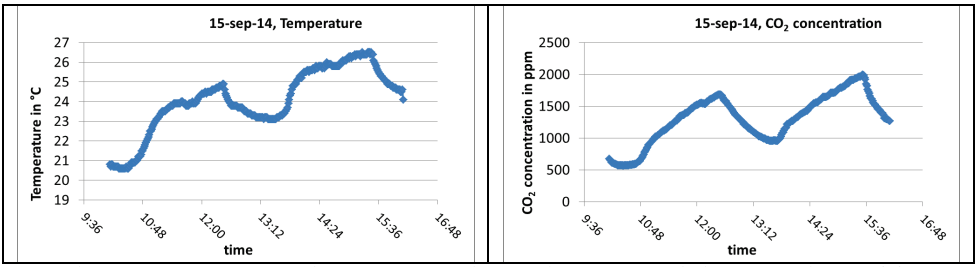

Figure 8: Measurement of temperature and CO2 in room A, during renovation (15/9/2014, measurements by E. v.d. Ham), outside temperature ~21 °C..

These measurements show too high values for the CO_2 concentration. The values are much higher than before the renovation. However, rumour has it that the educational board complained so much about the noise of the ventilation system that somebody decided to shut down the ventilation system, not realising that it was also the ventilation system of lecture room A. Here the design of the ventilation system crossed the new purpose of the room. Before the renovation it was a storage room, where an extra vertical duct was not a problem. After the renovation it became the room of the educational board.

4.3. After Renovation

September 2015

Temperature measurements were performed on Wednesday 3 September 2015, during a lecture on Urbanism with 77 persons in the room, see figure 9. The outside temperature was ~13°C. The temperature only reached 20 °C after the lunch break. The CO_2 concentration stayed below 540 ppm during the lecture, except for one time, where one student was seen to breathe in the measurement equipment. The ventilation on this day was running at maximum capacity even when nobody was in the room.

Besides measurements, the students in the room were also asked about their subjective evaluation of the indoor comfort in room A. As far as the temperature was concerned, 16 % perceived room A as cold, and 41 % perceived the room as cool. Of these students, it was mainly the females that perceived room A as cold, see figure 10. The fact that quite a lot of students experienced the lecture room as rather cold is confirmed by the measurements. Building maintenance told us that the new ventilation system in room A was still not fully functional. There were large problems with the CO_2 sensors in all the lecture rooms as the CO_2 values in the rooms were not visible in the building management system.

The students were also asked about the indoor air quality of room A. The indoor air quality of room A has improved according to the students, although a large number of students noticed no difference, see figure 11. The results of other questions showed that the students do not rate the room as fresh and odourless. On the other hand, students that started in 2015 at the faculty, rate the room slightly better than the students that

have started earlier. This shows that the renovation probably did have a positive effect on the indoor air quality of the room, see figure 12.

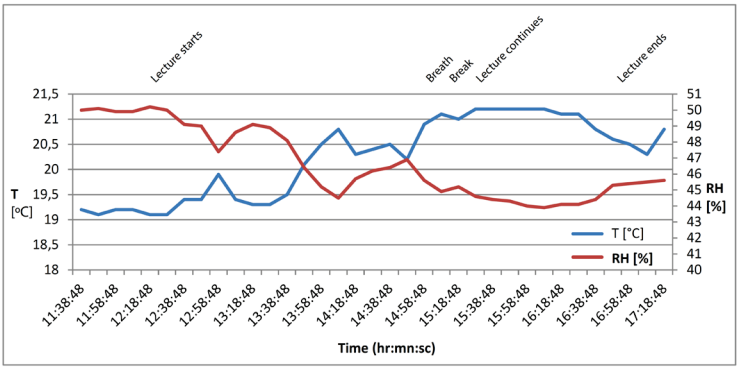

Figure 9a: Room A, Temperature and relative humidity on Wednesday 30 September 2015. Outside temperature ~13°, 77 persons in the room [4].

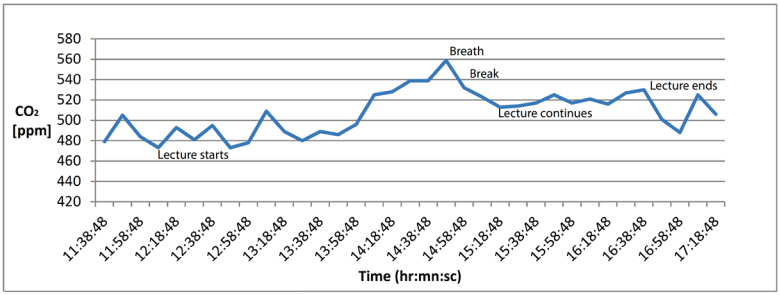

Figure 9b: Room A, CO2 concentration on Wednesday 30 September 2015. Outside temperature ~13°, 77 persons in the room [4].

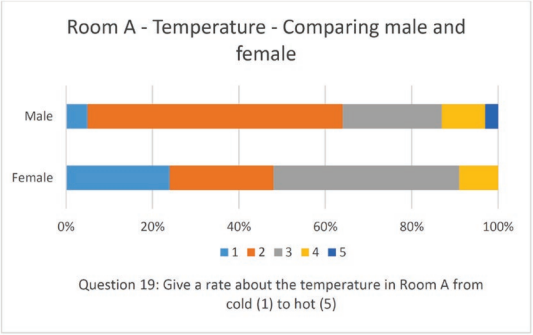

Figure 10: Room A: Rate the temperature form cold (1) to hot (5) for males and females , September 2015, 77 respondents [4].

User assessment directly after the renovation showed that the users are still not very satisfied with the indoor climate. Measurements of indoor temperatures and the CO_2 levels supported this user assessment.

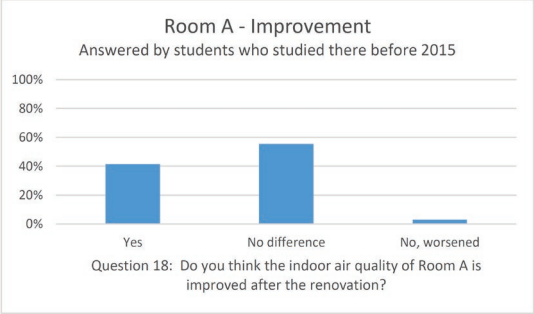

Figure 11: Room A: *Do you think the indoor air quality of room A is improved after the renovation?* 36 respondents, September 2015 [4].

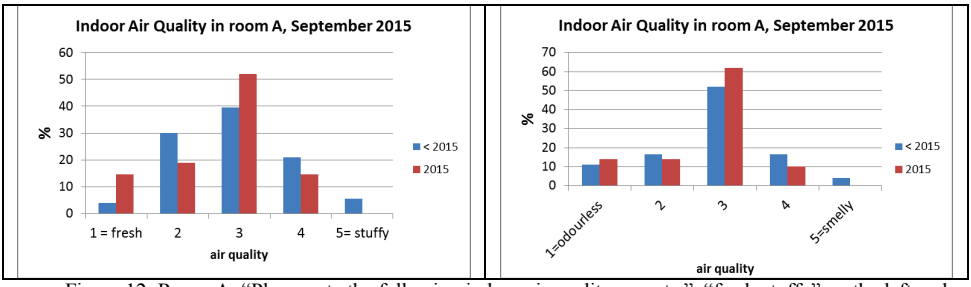

Figure 12: Room A: "Please rate the following indoor air quality aspects:", "fresh-stuffy" on the left and "odourless-smelly" on the right. 77 respondents, September 2015 [4].

January 2016

Measurements on Friday 19 January 2016, with a lower outside temperature of 5°C, and around 70 persons in the room during a graduation presentation, showed a much higher temperature in room A, see table 1.The higher temperatures in room A on Friday January 29 are an indication that the climate system can work properly even at a higher outside temperature. The radiators were on in the morning. The CO_2 values are now also under control as the highest CO_2 value measured was well below the target value of 800 ppm.

However, the renovation is still not finished. It turned out that there was no link between the radiators and the ventilation units as far as heat supply was concerned. The temperature of the radiators is controlled by the outside temperature, and the amount of ventilation is controlled by the indoor temperatures. As the building is insulated and the ventilation has heat recovery and can be preheated, the amount of heat from the radiators is more than sufficient and the radiators in certain cases heat the air in the room above the required temperature. This then sets the extra ventilation in motion to

decrease the temperature. The next step in the renovation process is to couple the heat supply from the radiators and from the ventilation system.

Table 1: Indoor temperatures and CO_2 concentration in room A on 20 January 2016. There were 70 people in the room for a graduation presentation.

time	Temperature	CO_2
9:00	22.9	490
9:30	23.4	528
10:00	23.4	516
10:30	23.5	509

5. Discussion

After the physical renovation is finished, it still takes a long time before the indoor climate in the building is well regulated. It might be caused by the way in which the renovation of a complex building and its installations are managed. The choice to reuse part of the existing HVAC system is apparently much more difficult as there are so many factors to take into account. The fact that the faculty of Architecture is a large building with a lot of different demands, also increases the complexity of obtaining a sustainable, energy efficient and easy to manage HVAC system.

6. Conclusion

For the Architecture building it must be concluded that, after interventions in such a complex building, additional monitoring and adaptations are necessary. In this case, students and staff performed the measurements which had the advantage that the students gained practical knowledge and the building management received valuable data on the performance of its building.

Acknowledgment

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