# Architectural Design of Big Lecture Hall in Relation to Air Conditioning System

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# Architectural Design of Big Lecture Hall in Relation to Air Conditioning System

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**Abstract**. The paper is focused on architectural design of big lecture hall while considering the requirements of air conditioning system. Correct architectural design and design of air conditioning system is immensely important for students in the interiors of a university. Fulfilling $CO_2$ values is inevitable not only from physiological point of view but also for achieving the desirable students' performance. Good architectural design must enable to apply the optimal air conditioning system, which ensures acceptable $CO_2$ concentration. The high $CO_2$ concentration is related to incorrect and insufficient ventilation in the big lecture hall and causes students to feel distracted and tired. Experimental measurements were carried out in the winter season in the big hall to evaluate the $CO_2$ concentration. The device Testo 480 was used for the measurements. Obtained values of $CO_2$ concentration are presented in the charts. Architectural design and mechanical ventilation system of the big lecture hall were evaluated based on the parameters of $CO_2$ concentration. The paper concludes on how to create a harmony between architectural design and design of air conditioning system in the lecture hall.

## 1. Introduction

Architectural design of big lecture hall is significantly influenced by air conditioning system. Part of air conditioning system are vents for supply air and extract air, their correct position is very important in big lecture hall [1]. The good architectural design must enable the application of the optimal air conditioning system and correct position of supply air and extract air, which ensures acceptable $CO_2$ concentration [2]. Mechanical ventilation or air conditioning in the big lecture halls mean the exchange of the air in a room with the fresh outdoor air [3]. Insufficient supply of oxygen, a high concentration of $CO_2$, excessive air humidity, various types of odours, toxic pollutants, aerosol and microbial pollutants threaten students when there is insufficient ventilation or air conditioning of big lecture hall [4]. It can cause distractibility and feeling of tiredness, various skin diseases, respiratory diseases, the emergence of allergies, the emergence of oncological diseases and others [5]. Therefore, the correct and the sufficient ventilation of big lecture hall is very important because students spend most of their time in school in the lecture hall [6]. Sufficient exchange of air influences the $CO_2$ concentration; therefore, this is the most important point to consider when designing the air conditioning system or mechanical ventilation system [7]. The correct position and the distance of supply air vents and extract air vents from the floor in the big lecture hall are very important to consider when designing the air conditioning system or mechanical ventilation system [8]. The position of supply air vents and extract air vents significantly influences architectural design and eventually an architectural expression in big lecture hall. The major problem in the big lecture hall is the draught that is caused by incorrect position, a distance of supply air and extract air from the floor, and the incorrect velocity of the air flow. Therefore, this research was focused on the interaction between architectural design and air conditioning system and the evaluation of $CO_2$ concentration in the big lecture hall.

## 2. Analysis of Architectural Design in relation to Air Conditioning System

It is very important to create architectural design of big lecture hall in relation to air conditioning system from the first phase of designing. The architectural design of big lecture hall is determined by numerous factors, including the forming of the hall and creating an interestingly designed quality seating for students. Except for these factors, a very significant aspect in big lecture hall is a quality of air conditioning system with the correct position of vents for supply air, which should ensure air quality ranging from air temperature to bearable $CO_2$ concentration. Students have to feel pleasantly warm without the feeling of draught. The correct architectural design has to enable the application of the optimal air conditioning system and correct position of vents for supply air and extract air. The architectural concept of big lecture hall has to consider optimal deployment of vents for supply air and vents for extract air. Architectural forming of the interior of big lecture hall has to be derived from the air distribution from the bottom towards the top which is the most suitable one. During this air distribution, air velocity in vents for supply air can be very low and thus a sitting student does not have a feeling of draught. It is not suitable to install inversely oriented air distribution from the top towards the bottom inside of modern big lecture halls. Also, the air distribution from the front to the back wall is not suitable. In both unsuitably distributed directions of air, a high air velocity is created in the place of students' seating which causes the feeling of draught, dissatisfaction and worse concentration during the lecture.

Therefore, the architectural design in relation to placement of vents for supply air in big lecture hall was closely analysed. The air distribution from the bottom to the top was analysed. Most often, the vents for supply air in big lecture hall are located in the stepped floor which is built because of stepped seating. Figure 1 depicts the position of rectangular continuous vents for supply air in the stepped floor in the big lecture hall of Vienna University of Economics and Business. It is main big lecture hall which has interior significantly segmented. The interior is harmonized with the continuous vents for supply air in the stepped floor. Shape of the hall is significantly segmented which is harmonized with vents for supply air in stepped floor. Modern look of big lecture hall is harmonized with unobtrusive and modern vents for supply air, which does not disturb architectonic appearance of the interior. Suppressed design of vents for supply air contrasts interestingly with bright red armrests and seats.

**Figure 1.** Main big lecture hall of Vienna University of Economics and Business

Figure 2 shows the placement of circular vents for supply air in the stepped floor in university lecture hall [9]. Denser placement of circular vents for supply air in stepped floor enables very well-balanced airflow because air velocity can be low, and it is appreciated by students. Vents for supply air have a conspicuous shape and colored arrangement which is in harmony with the architectural design of lecture hall. Thus, it does not look distracting. Vents for supply air are promoted to become a decorative interior element.

**Figure 2.** Lecture hall with circular vents for supply air

The next alternative is the application of direct perforated oppenings into the stepped floor, figure 3, [10]. Circular perforated oppenings of smaller diameter create interesting compositional element in the interior which is simple and unobtrusive at the same time. This type of vents for supply air fits into the simple naturalistic style. The example points out on the beauty in simplicity to which the vents for supply air are adapted. The advantage is that there is no need for other covering elements for vents for supply air.

**Figure 3.** Big lecture hall with circular perforated openings for supply air

The next very interesting solution is the supply air through the writing part of a desk in the big lecture hall University of Vienna, figure 4. The air comes through the narrow, continuous vent in the front writing board of the desk. The coming air does not directly blow at the student, but the student is directly surrounded by air of high quality. The vent does not have a disruptive effect on the design of the desk, it becomes its natural part. The colourful presentation of vents is in harmony with the colour of chairs. This solution is very impressive architectonically and at the same time it provides air of highest quality. Vents for supply air harmonically form the fresh and youthful touch of the interior.

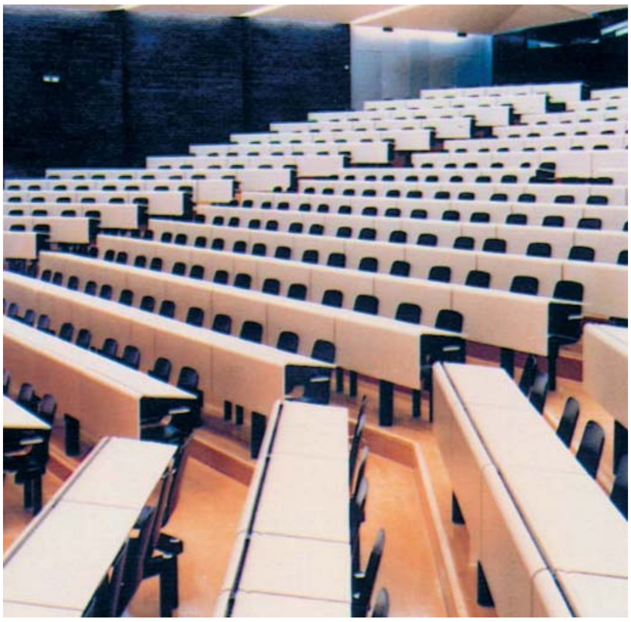

**Figure 4.** Big lecture hall of University of Vienna

**Figure 5.** Big lecture hall of Budapest University of Technology and Economics

A particular attention can be given to the arrangement showed in figure 5 in the big lecture hall in the Faculty of Electrical Engineering and Informatics of Budapest University of Technology and

Economics where circular vents for supply air are embedded directly onto the floor at individual step levels. Yellow floor enlivens the overall appearance of the interior and distinctive circular vents for supply air form these enlivenment. The architecture of big lecture hall is based on the striking floor in harmony with distinctive and noticeable circular vents for supply air on the floor. The colour of the walls and the ceiling is a classic unobtrusive white colour, which is in good contrast with the floor and the vents for supply air.

The last example shows vents for supply air in a wall in the lecture hall in the Faculty of Economic and Social Sciences of Budapest University of Technology and Economics, figure 6. These vents for supply air are only complementary. In this case, vents for supply air are geometrically interestingly placed on the back wall and complemented by clothes hooks. By this composition, vents for supply air are promoted to decorative elements of the interior. Their placement forms an interesting playfulness of the modern interior.

**Figure 6.** Lecture hall of Budapest University of Technology and Economics

## 3. Research of ventilation system in big lecture hall in relation to architectural design

Research of ventilation system in big lecture hall in relation to architectural design continued with measurements. Experimental measurements were carried out in the big lecture hall – figures 7, 8 at the Slovak University of Technology in Bratislava, Faculty of Architecture.

### *3.1. Methodology of Research*

The aim of the measurements was to record the $CO_2$ concentration and air velocity.

The measurements were carried out in the big lecture hall in figure 7 with the sizes 15.7 x 14.4 m and with the height between 3.9 and 5.9 m in the centre of the room in the height of 1.1 m above the floor level. The big lecture hall is partially placed into the ground. It is heated with two large column radiators. The mechanical ventilation system has vents for supply air placed into the frontal wall (figure 7) and the vents for extract air are placed into the back wall (figure 8). It also has new quality wooden windows with interior shielding. The first measurement was carried out without mechanical ventilation with twenty-eight students, figure 9. The second measurement was carried out without mechanical ventilation in its first phase and with mechanical ventilation in its second phase, figure 10. Sixty-four students participated in the second measurement. Mechanical ventilation unit of type BKL-KD in Figure 6 was in operation during the second phase of the second measurement. In the second measurement, the performance was set to 50%, thus 3675 $m^3$/hour, which represents the air exchange three times per hour. Mechanical ventilation unit does not contain humidification component.

**Figure 7.** Big lecture hall with the vents for supply air

**Figure 8.** Big lecture hall with the vents for extract air

Therefore, the air treatment was not complete. Both measurements were carried out from 8 to 9:45 in the morning during ordinary lectures. $CO_2$ concentration and air velocity were recorded with the device Testo 480. Outdoor air temperature and air relative humidity were measured and recorded by the separate device. Outdoor air temperature increased from value 6.1 °C to value 8.8 °C during the first measurement and from value 9.8 °C to value 11.5 °C during the second measurement. Outdoor air relative humidity decreased from the value 83% to the value 74% during the second measurement.

**Figure 9.** First measurement in the centre of the room in the height of 1.1 m above the floor level

**Figure 10.** Second measurement in the centre of the room in the height of 1.1 m above the floor level

### *3.2. Results and Analysis of Research*

Figure 11 shows the values of $CO_2$ concentration from the first measurement during 105 minutes in the height of 1.1 m above the floor level in the centre of the room. At the beginning of the measurement, the values of $CO_2$ concentration were sufficient, but the values were gradually increasing and at the end of the measurement, the admissible values of $CO_2$ concentration were exceeded. The big lecture hall has 210 seats; the inadmissible value of $CO_2$ concentration was already reached with twenty-eight students after two hours. This concludes that the big lecture hall cannot be operational without mechanical ventilation or air conditioning.

Values of air velocity were measured individually in the centre of the air flow between supply air openings and extract air openings. The value of air velocity fluctuates in the range from 0,0 to 0,02 $m.s^{-1}$ which are sufficient values. It was caused by the switched-off mechanical ventilation, so there was no air flow.

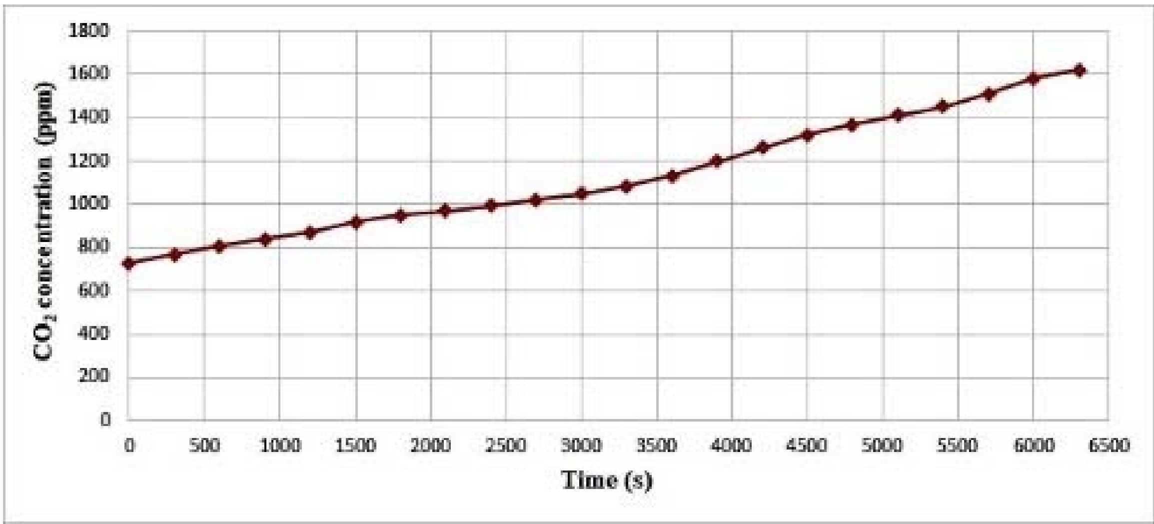


**Figure 11.** Values of $CO_2$ concentration during the first measurement

Figure 12 shows the values of $CO_2$ concentration from the second measurement during 105 minutes in the height of 1.1 m above the floor level in the centre of the room. At the beginning of the measurement, the values of $CO_2$ concentration were increased and quickly reached inadmissible values. The big lecture hall has 210 seats and the inadmissible value of $CO_2$ concentration was already reached with sixty-four students after thirty minutes. Then, the mechanical ventilation was turned on and the value of $CO_2$ concentration gradually decreased on admissible values. This measurement showed the necessity of mechanical ventilation in the big lecture hall. Only correctly designed and operated air conditioning system can bring the optimal solution for the fully occupied big lecture hall.

Values of air velocity were measured individually and intentionally in the centre of air flow between supply air and extract air vents where most of the students were seated. At the beginning of the measurement, the values of air velocity were admissible but after turning on the mechanical ventilation, the values gradually reached inadmissible high values. The students started complaining about the unbearable draft. This was caused by the incorrect design of mechanical ventilation which creates the air flow in the incorrect trajectory through seated students. The outputs from the measurements showed that it is very important to correctly place the supply air vents and extract air vents such that the values of air velocity are admissible during the operation of mechanical ventilation or air conditioning system in the places where the students are seated.

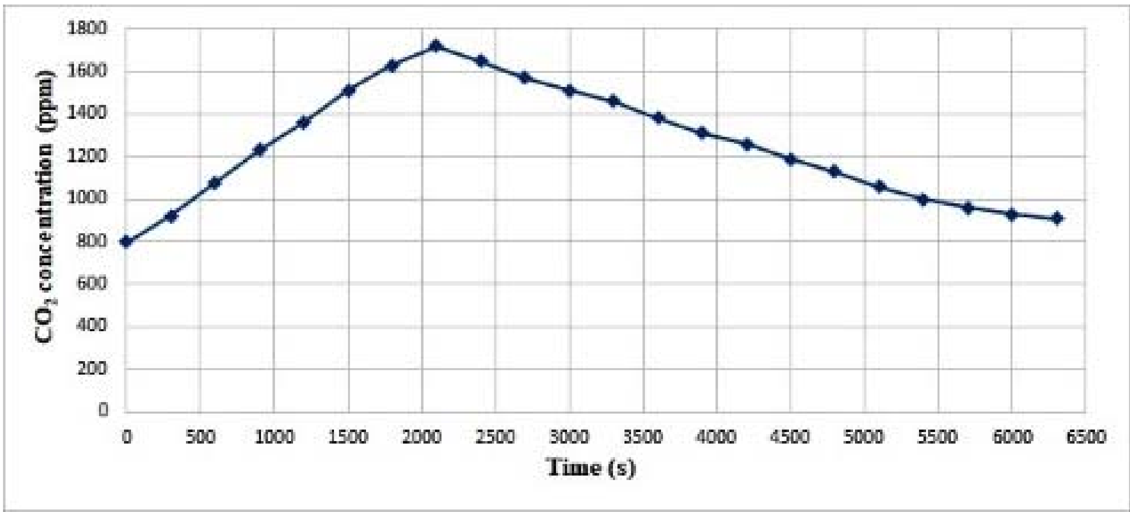


**Figure 12.** Values of $CO_2$ concentration during the second measurement

## 4. Conclusions
Architectural design of big lecture hall needs to be created from the first phase of designing in relation to air conditioning system. Creation of the correct interaction between architectural design and air conditioning system is very important in big lecture hall. The architectural form of the interior of big lecture hall must consider the air distribution while the best air distribution is from below upwards. In this air distribution, air velocity in vents for supply air can be very low and sitting student does not have the feeling of draught. Most often, vents for supply air in big lecture hall are placed into the stepped floor. Three approaches prevail; unobtrusive, shaped and colourful vents for supply air, which contrast with significant colour of armrests and seats. Another approach is where vents for supply air have significantly shaped and coloured solution e.g. they create significant accent with the colour of the floor on otherwise neutral interior. The third approach is simple naturalistic style where the beauty is in the simplicity; the vents for supply air are also adapted to this style. The shape of vents for supply air might be different: rectangular-uninterrupted, rectangular-interrupted, circular and perforated by small circles. Vents for supply air might be promoted to the decorative element of an interior. Another very interesting solution is where supply air goes through the writing part of a desk. This solution is architecturally very impressive and at the same time, it provides the air of the best quality. Interesting alternative is the solution where circular vents for supply air are incorporated directly into the floor on individual stairs. Placement, shape and colouring of vents for supply air must always be in accord with architectural design of big lecture hall.

Experimental measurements in the big lecture hall clearly showed the necessity of air conditioning system. Inadmissible values of $CO_2$ concentration were already reached with 13% occupancy after two hours without mechanical ventilation or air conditioning system. Conclusions of the second measurement show that air conditioning system is more suitable than just mechanical ventilation system – does not include humidification component because it can ensure the optimal value of air relative humidity. The second measurement showed that the correct operation of mechanical ventilation or air conditioning system is very important to ensure the parameters of $CO_2$ concentration at the beginning of a lecture in the morning and then later according to the number of students. The intensity of the air exchange could be regulated by a lecturer who would type the number of students into a control panel placed on a desk or a wall. The second measurement proved that it is very important to correctly place the vents for supply air and extract air during the design of mechanical ventilation or air conditioning system such that the values of air velocity are admissible in the area where students are seated and the unpleasant feeling from the draft is avoided. The second measurement also proved that the air distribution system through seated students, where the vents for supply air are in the frontal wall of the big lecture hall and vents for extract air are in the rear wall, is not suitable and outdated. In older buildings, it is needed to design new air conditioning system and new air distribution system for big lecture halls. These systems must have modern controlling and regulation system.

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