Architecture for every listener

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1. ABSTRACT

'Ontwerpen voor Iedereen' (Universal Design, UD) beoogt gebouwen en omgevingen die toegankelijk, efficiënt en comfortabel zijn voor iedereen, en dit doorheen hun hele levensloop. In architectuur denkt men daarbij vaak direct aan toegankelijkheid. Akoestische voorwaarden kunnen echter ook een belangrijk effect hebben: de bruikbaarheid voor auditieve communicatie en het akoestisch comfort zijn belangrijke vereisten, zeker voor mensen bij wie de gehoorfunctie verzwakt is. In onze studie onderzoeken we 'akoestisch comfort for iedereen' in de context van de Grote Aula van het Maria Theresiacollege in Leuven, die een beschermd monument is en aan een grondige opfrisbeurt toe is. De studie gebruikt state-of-the-art akoestische meet-, simulatie- en evaluatietechnieken om de diverse opties voor aangepaste ruimteakoestische voorzieningen tegen elkaar af te wegen.

2. INTRODUCTION & OBJECTIVES

Inclusive Design in architecture and urban planning tends to focus on accessibility of city environments, buildings and spaces by their users, but to our knowledge, acoustic comfort has received little attention so far. The impact on the built environment created by sound has a rather invisible character and thus in the stage of architectural design acoustical aspects are often suppressed. As a result, most of the acoustical problems usually show up only later, once a building or space is built and already used. Some of the acoustical defects can be solved later, but most of them cannot be repaired and they just degrade the quality of an otherwise nice brand-new building. In this way many buildings suffer from acoustical problems and acoustical comfort is often not reached, not even for healthy listeners.

Hearing provides us with auditory information, which is important in human communication and spatial orientation. Good speech understanding and localization of sound sources is crucial. Bad speech intelligibility during the educational process leads not only to tiredness and lack of concentration among students, but people who do not hear well can even end up in social isolation as communication becomes difficult. Legislation is usually less strict with regard to acoustics than in relation to other building physics categories, and moreover differs from country to country.

The attitude of different countries towards Inclusive Design in acoustics varies from prescription of imperative guidelines to simple recommendations (Karabiber and Vallet 2003). However, little attention is paid to the diversity in people's hearing capacities and needs in general.

The study reported on in this paper attempts to contribute to the knowledge base by exploring the idea of acoustic comfort for all listeners in university education.

3. PROGRESS & ACHIEVEMENTS

3.1. Interviews

To get an idea about the acoustical comfort in the auditoria at K.U.Leuven, a series of in-depth interviews were conducted with various users/experts, e.g. students and personnel with a hearing impairment, students with a visual impairment, and students who attend the University for the Elderly. All interviewees were asked to nominate the best and worst auditorium in terms of acoustic comfort, and to indicate problems they experience when attending lectures. During the interviews, the 'Grote Aula' (Big Auditorium) of the Maria-Theresia college was labelled by several users as the worst. This has motivated us to select the Grote Aula as reference auditorium for our case study.

3.2 The Grote Aula of the Maria-Theresia college

The Grote Aula of the Maria-Theresia college is situated in the city centre of Leuven and since 1975 is officially listed as protected monument. In the past, many interesting activities were performed in this college to which the auditorium also belongs. One of the most famous events was the seminar of Theology in this former Jesuit college accommodated by Maria-Theresia (in 1778).

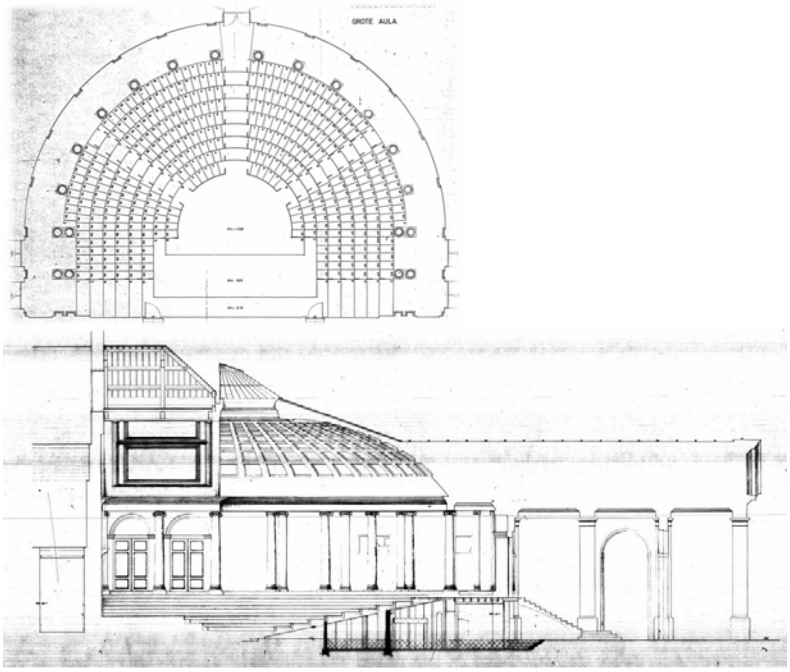

Fig. 1 - Ground plan and cross-section of the auditorium as found in the archives (De Leye & Dooms 2007)

The Grote Aula is a neo-classicist auditorium, designed by Martin Hensmans, with a half-round ground plan. The volume of the auditorium is 3600m^3 and contains around 500 seats. Nowadays the Grote Aula accommodates undergraduate and graduate students on a daily basis. Once a week, students of the University for the Eldery attend lectures here, and at night or in between semesters, the auditorium is available for musical activities. Both types of events, lectures and concerts, require different reverberant conditions. A speaker demands a much shorter reverberation time than a musical performance, but in both cases low levels of background noise are desired. For people with hearing disabilities are the limits of speech intelligibility even more pronounced (De Leye & Dooms 2007).

Fig. 2 - Photo of the interior of the Grote Aula

Interviewed users/experts especially complain about the difficulty to clearly understand the speaker during lectures. Comparison with other auditoria at the K.U.Leuven confirmed that the acoustic conditions in the Grote Aula show considerable room for improvement. The planned renovation in 2009 provided extra reason to submit this auditorium to an in-depth analysis and to propose interventions that improve the acoustic comfort for all.

3.3 Measurements

Measurements in the Grote Aula were performed on 16 receiver positions chosen in the audience area (Fig.3). Firstly, to obtain the most accurate information about the reverberation time and sound pressure level distribution in the room, impulse response measurements according the ISO 3382 were performed by using omnidirectional sound source B&K 4295 and omnidirectional microphone B&K 4130.
Later, for calculation of interaural cross correlation coefficients (IACC) describing the spaciousness, measurements with artificial head on the same 16 positions were done.
A third experiment was based on usage of the directional sound source (RASTI-speaker) with directivity close to a speaking person, to get the most realistic impression about the speech transmission index (STI) values.

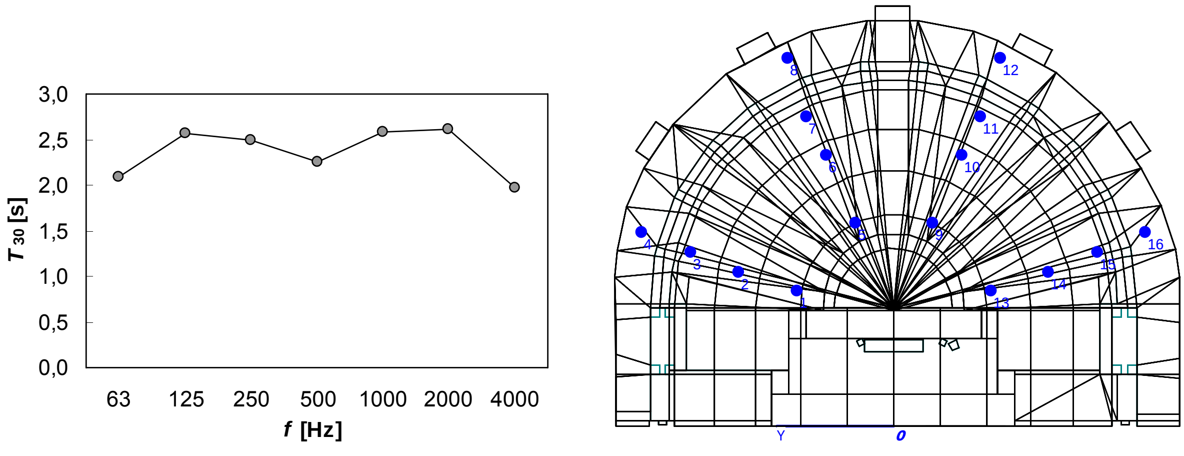

Fig. 3 - Average reverberation time T_{30} [s] as measured (left). Ground floor plan of the auditorium with 16 receiver positions (right)

Impulse response measurement in the Grote Aula has confirmed too long reverberation. Measured T_{30} has reached 2,4 seconds, which is too long not only for lectures but also for music and if we like to provide acoustical comfort for all, this value should be diminish drastically. Since no norm exists we have to base our proposal on experience. For speech we would like the value of reverberation time RT = ca. 1 second, while for music 1,8 seconds would be ideal. Here the administrators and management have to decide what is preferred.

3.4 Simulations

Simulations of a virtual 3D model of the auditorium were performed in the ODEON ®software v.8, in nine alternatives. These alternatives were based on different combinations of additional sound absorption in order to reduce reverberation time and to improve the speech intelligibility. As the auditorium is a historically protected monument, discrete solutions of extra absorption addition were provided.

The optimum amount of sound absorption in the room usually depends on the activity for which the room is designed. The Grote Aula is an auditorium (for classical lectures) but it accommodates also musical performances. For this reason we explored the possibility of applying movable absorption, which can be adapted to the intended activity.

During the analysis of the data, five different aspects were considered:

1. speech, for which we like the value of reverberation time ca. 1 second and speech intelligibility defined by STI value > 0.6
2. music, where we like the reverberation time around 1,8 seconds
3. maintenance, which describes how easily materials can be cleaned and how fast they get dirty
4. flexibility, which refers to adaptability of the space for music or speech respectively
5. replacement, which shows how easily can be additional absorption removed or replaced.

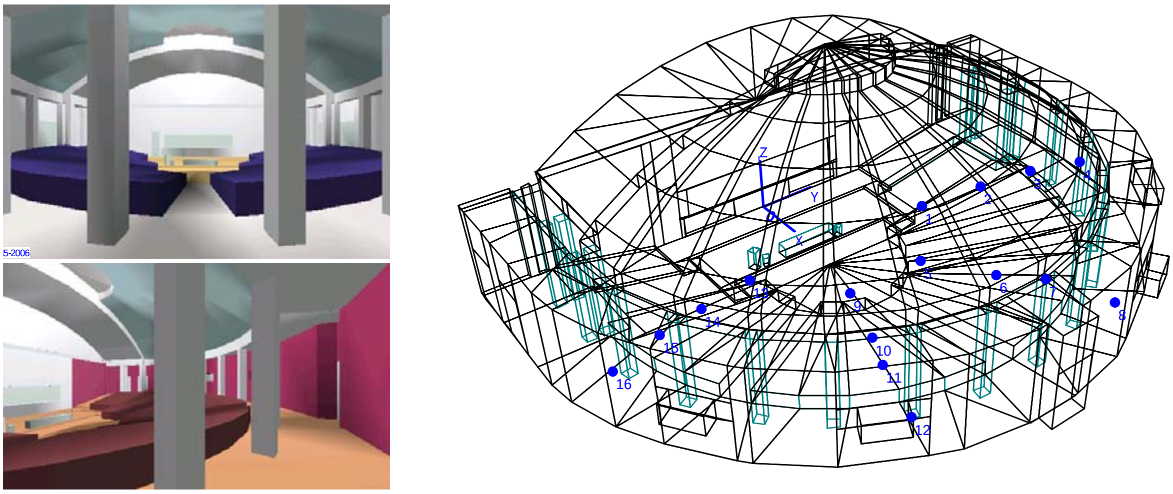

Fig. 4 - 3D computer model of the Grote Aula as used in the acoustical simulations

In the acoustical renovation proposal, the following changes were considered:

a. replacing the present leather-covered seats by slightly stuffed seats covered with cloth
b. replacing the existing linoleum floor by carpet (suggested by the Technical services)
c. applying an acoustic plaster on an acoustic absorption layer to the wall
d. placing removable sound-absorbing wall panels covered with cloth
e. hanging curtains along the wall
f. applying an acoustic plaster to the ceiling above the gallery
g. applying a thin acoustic plaster to the cupola and vault above the podium.

Results form all alternatives are summarized in the Table 1.

Table 1. Comparison of the simulated alternatives

		comparison of the alternatives									
	current situation	Alt.1 (a)	Alt.2 (a,b)	Alt.3 (a,b,c)	Alt.4 (a,b,d)	Alt.5 (a,b,e)	Alt.6 (a,b,c,f)	Alt.7 (a,b,c,f,g)	Alt.8 (a,c)	Alt.9 (a,f)	
music T_{30} [s]	2,48	2,44	1,72	1,18	1,10	1,26	1,17	1,01	1,90	2,22	optimal
speech STI [-]	0,45	0,46	0,51	0,58	0,58	0,59	0,59	0,62	0,52	0,48	
maintenance											moderate
flexibility											
replacement											weak

4. CONCLUSIONS

Measurements in situ confirmed the need for improvements in the Grote Aula from the room acoustical point of view. With the help of acoustical expertise in room acoustic simulations, nine alternatives related to acoustical improvements taking into account the auditorium's historic character were evaluated with respect to five aspects, e.g. speech intelligibility, music performance, maintenance, flexibility and replacement. Analysis shows that the ideal solution does not exist. Depending on the priorities, one can select the most appropriate solution from Table 1. However, application of any additional sound absorption to the room will reduce the sound levels on all positions in the audience areas and thus a well-designed loudspeakers system to amplify sound, will be necessary.

In general, results of the given case study may give an idea when designing or renovating similar places in the future. As such, the study contributes to understanding the importance of acoustic comfort for all, and offers an example of desirable solutions.

4.1 Acknowledgements

The case study reported on is based on the Master thesis of Karolien De Leye and Eva Dooms. Special thanks are due to the experts/users, the Technical services of the K.U.Leuven, and KIDS (Royal Institute for Deaf and Speech Impaired).

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