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ATRIA IN SHOPPING CENTRES, OFFICE BUILDINGS AND HOSPITALS

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1. Introduction

A growing number of buildings is being provided with large, glass-roofed spaces, often called *atria*. They have utilisation of daylight and a public or traffic function in common, but differ greatly in dimensions, and secondary functions. From the viewpoint of building physics, the domain of our consultancy, interesting topics are connected to the climate, both thermal and acoustical. In both fields two aspects can be distinguished: the reduction of outdoor climate to the rooms facing the atrium and the climate in the atrium itself as perceived by the occupants. Examples of the first are reduction of aircraft noise or, if the atrium has one or more glass facades as well, traffic noise load at the inner facades. Other points of interest are the the prevention of condensation at the glass surfaces and the use of natural ventilation and convection for controlling temperatures (and their distribution) in summer as well as in winter.
The subject of this paper however is the acoustical climate in some types of atria.

2. Requirements

First of all the acoustic climate must be in accordance with the visual impression of the atrium: the larger the atrium, the more spacious the room is, the more reverberation is expected and should be realized.
Assuming that the dimensions of the atrium are fixed, an inventory of the functions of the atrium must be made up, which can comprise:
- expositions;
- restaurant;
- shopping;
- promenade;
- sporting facilities;
- kindergarten;
- musical performances;
- public address;
- receptions;
- etc.

Next these functions have to be judged regarding sound production, interfering sound levels and the required reverberation times. Conflicts can rise between functions mutually. Because the reverberation time of large atria has a lower limit (result of the decrease in surrounding surface to content ratio as scale increases), the required shorter reverberation times for some functions can be beyond reach.
The most common problem however is controlling the sound levels caused by the occupants of an atrium.

3. Control of sound levels

If the amount of sound absorption in a room and the sound power level (PWL) are known, the resulting sound level can be calculated easily. The PWL in atria can be divided in a part originating from the occupants, mostly talking people, and the basic PWL from other sources like ventilation or external noise load. The problem with the PWL of talkers is, that it tends to rise in increasing noise levels; this effect is known as the Lombard sign and makes the calculation of sound levels in atria less straight forward. This is also the reason that the sound absorption has such a central place in the next diagram, showing the governing factors and their connections. The reverberation time is added for completeness.

volume basic PWL vocal output

a b s o r p t i o n

T 60 sound level

Given the volume of the atrium and the number of occupants to be expected, the amount of sound absorption can be varied and the resulting sound level and reverberation time calculated. From these the most suitable can be chosen, yielding the proper amount of sound absorption to be added. Note however that reverberation time is not the only and rarely the major criterion.

4. Shopping centres

To enhance the impression of being in a public space, a difference between the acoustical climate in an glass-roofed shopping centre is desired, indicating a longer reverberation time than in the shops e.g. more than 1 s. If however a (simple) electronic public address system is installed not only for distributing background music but also for commercial messages, speech intelligibility requires an upper limit of 1.2 to 1.4 s so the range of favourable reverberation times can be very limited.
Another point is the control of sound levels caused by the occupants, occasionally in vast numbers, as shopkeepers prefer. This requires an amount of sound absorption in the range of the floor area, which is often difficult to realize.
In a global way it can be concluded from the above that the height of shopping atria where commercial messages are broadcast, should be in the range of 6.. 8.5 m. Otherwise the height may be greater.

In the newly built city of Almere near Amsterdam we had the opportunity to design the acoustical treatment of a glass-roofed shopping centre, which was similar in shape to a nearby existing one. The latter was not very agreeable, so after having been used as a bad example, and after the construction of the new centre, it was refurbished. Again we were invited to consult on the acoustical treatment.

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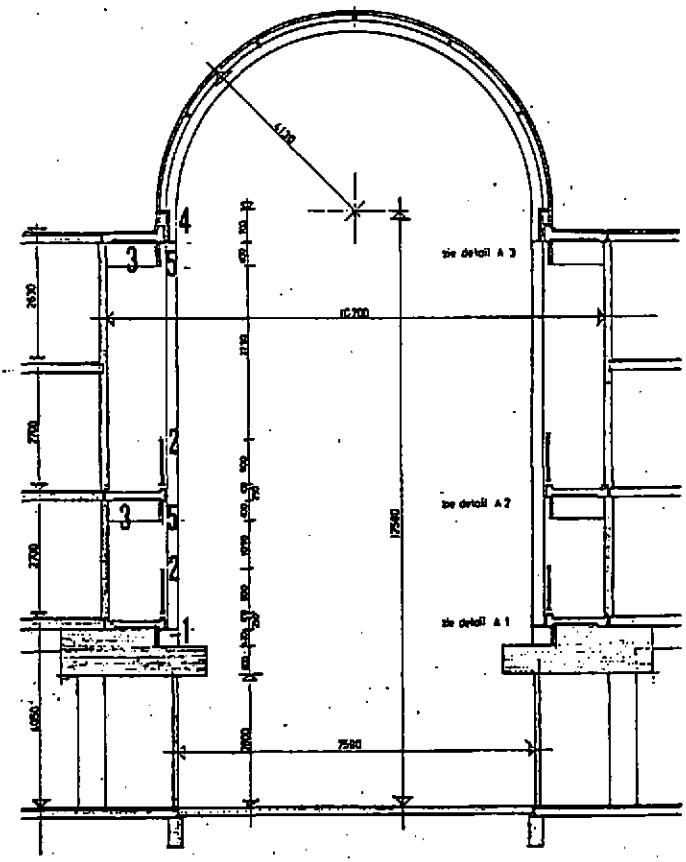

1 to 5 : sound absorbing elements

Picture 1 Section of shopping centres Almere

Picture 1 shows a section which applies to both malls. The effective height is about 15 m. The typical figures: reverberation time in the mid-frequencies and the amount of sound absorption related to floor area are:

	reverberation time	A/S
old mall	3.4 s	0.8
new mall	1.5 s	1.7
refurbished	1.6 s	1.6
street	1.4 s	--

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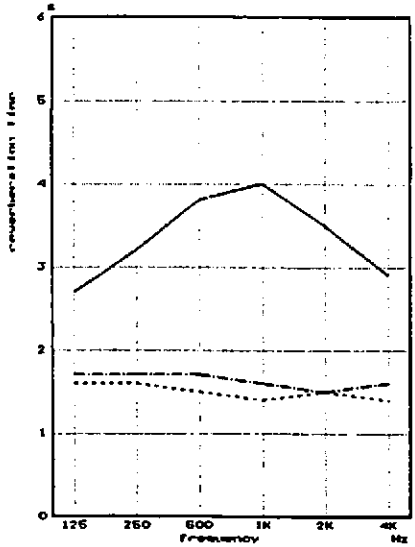
REVERBERATION TIME SHOPPING CENTRE ALMERE

NR. OMSCHRIJVING

——— T=3.4sec OLD MALL
- - - T=1.5sec NEW MALL
—·— T=1.6sec REFURBISHED MALL



freq.	125	250	500	1K	2K	4K	Hz
———	2.70	3.20	3.80	4.00	3.50	2.90	s
- - -	1.60	1.60	1.50	1.40	1.50	1.40	s
—·—	1.70	1.70	1.70	1.60	1.50	1.60	s

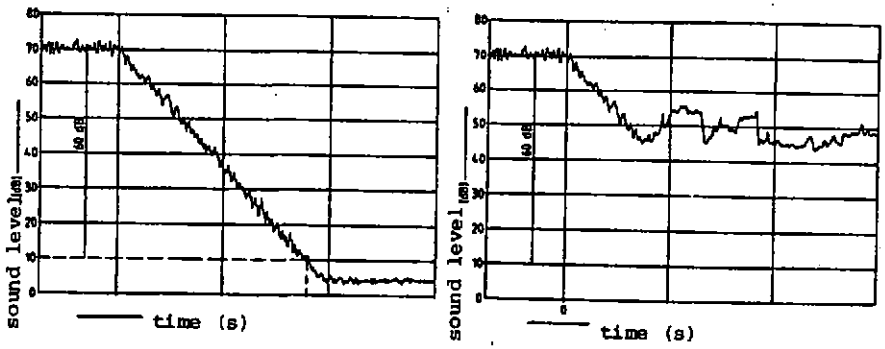
Graph 2

In graph 2 the reverberation times are plotted agains frequency.

As a comparison the reverberation time as measured in an (open) street, some 8 m wide and flanked with buildings of ca. 12 m height was added.
Both the new and the refurbished shopping centre have an agreeable acoustical climate, in contrast to the old one, which was found unpleasant and noisy.
The sound absorbing construction used in large quantities in both projects was perforated metal sheet with a mineral wool backing.

5. Office buildings and hospitals

Although small atria occur, in many buildings large atria are found being considerably higher and/or wider than in shopping centres. A wider choice of the possible functions as stated in chapter 2 must be regarded.
In the recently built Hospital of the University of Utrecht glass-roofed streets have been treated with sound absorbing baffles to reduce the reverberation time from 3.9 s to 2.8 s. The street measures 15 x 50 m and is 25 m high. The still long reverberation time does not lead to a noisy ambience: in fact the effect of reverberation is only notable when very loud sounds are produced. In graph 3 the meaning of "perceived reverberation time" is pointed out: as only a small portion of the decay curve is heard, the sensation of reverberation is decreased.



Graph 3 Decay curves. At the right the level difference is small, giving less sensation of reverberation

Two identical small atria have been realized in an office building in Amsterdam, with only two functions: daylight access in the offices and "coffee corners" for the employees. A floor plan and a section are given in pictures 4 and 5. Because of architectural reasons, the amount of sound absorption had to minimal. The basic issue being the speech transmission between the coffee corners, sound absorbing ceilings in those rooms were sufficient. The reverberation time came out slightly under 2 s, which is rather long for an atrium of 1600 m^3, but reasonable in practice.

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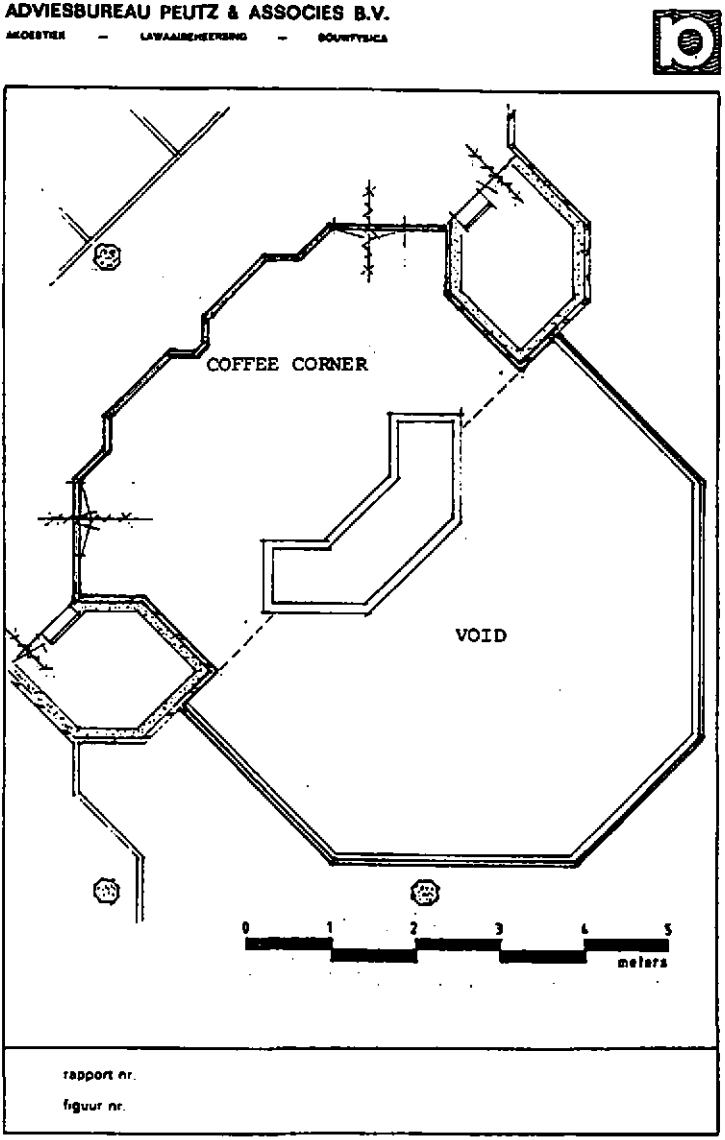

Picture 4 Floorplan office Amsterdam

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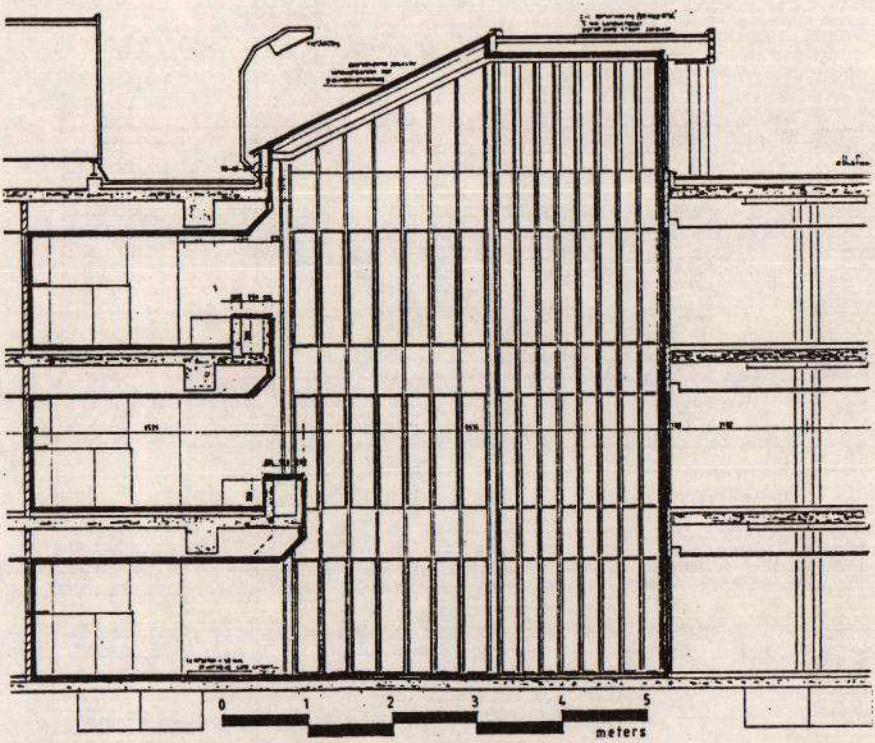

Picture 5 Section atrium office Amsterdam

As a last example one of the buildings in the design stage in which we are involved: the Ministry of Housing, Physical Planning and Environment in the Hague. It consists of a comb-like structure with atria between the teeth of the comb. The atria are large: floor surface 21 x 21 m, height varying from 45 to 60 m. In picture 6 the floor plan shows that the atria have a glass facade as well. In this case the atria were the solution to the problem of conflicting demands: an office building with openable windows in an urban environment with high sound levels. In a both acoustical and thermal way the atria offer a "meso-climate" in which the influence of the exterior factors is reduced.
The inner atrium-facades will be provided with sound absorbing parts, totaling some 1300 m^2. In these atria too, the resulting reverberation time of ca. 2.5 - 3 s will normally not be perceived as a very long one.

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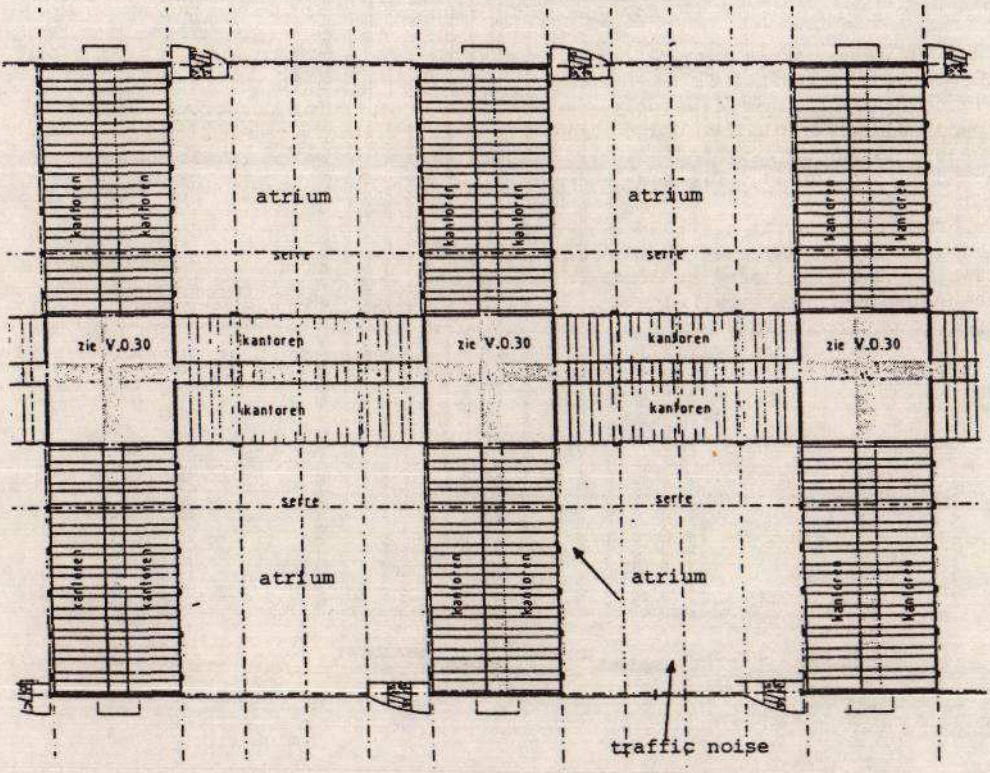

Picture 6 Part of the floor plan of the Ministery of HPPE in The Hague

As regards sound reduction, the necessity of ventilation openings in the outer facade (maximum 50 m^2) to control summer temperatures, had to be taken into account. The ratio of this open surface to the amount of sound absorption leads to a reduction of external sound levels in the atria of ca. 15 dB. With a traffic noise load of 70 dB(A) on some facades, the atria make it possible to open windows of rooms for ca. 10 cm without exceeding an indoor sound level of 40 dB(A).

The amount of sound absorption is sufficient to control the sound level of the occupants in the atria.

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6. Conclusion

In most cases atria have a building physical function, daylight access and smoothing of climate. It is important to provide an agreeable acoustical ambience as well. This can (only) be achieved by applying the proper amount of sound absorption in the right places. Especially when a great density of occupants is to be expected, control of the resulting sound levels by means of sound absorption is indicated.

In other cases atria can play a role in reducing high ambient sound levels to moderate levels at inner facades as well. Again sound absorption is an important means in realizing an adequate sound reduction.
When speech intelligibility through public address systems and music (re-) production are unimportant, the reverberation time as such plays no role. It is the amount of sound absorption that has to be guarded.