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Music-school concert hall – flutter echo treatment

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This paper deals with acoustical planning - and treatment of flutter echoes – in a minor concert hall which was built with double-curved walls. To avoid focusing the double-curved walls was recommended having very large radius of curvature. Also diffusing coverings on the curved walls, absorbing back wall and variable acoustics using curtains was recommended. The hall has horizontal floor and under the plane ceiling is a removable grid for light. The halls acoustic is satisfactory in normal use with the stage at the one end and chairs at the floor. The reverberation time is variable from 1.1 – 1.6 sec. fulfilling the requirements. In the central part of the hall - when used without chairs – is a flutter echo created by higher order reflections between the floor and the double-curved walls when the curtains are absent. A proposal to eliminate this flutter echo will be presented supported by calculations with Billiard- and Soundwave plots as well as results of the newest calculation tools, Dietsch's echo-criteria from a room acoustical Odeon-model of the hall.

1 Introduction

In 2006 Copenhagen municipality wanted a new music school at the old meat market in Copenhagen in ”The Double Calf-hall”. The task was a little special because you had to preserve the external old look from the existing building. Internal the school should have a number of rehearsal studios and a minor concert hall. The hall was placed central in the building due to high sound insulation requirements against external noise. The architect (KANT A/S) designed the hall with a whole new shape – with double curved walls – and external covering looking a little like an armadillo – see figure 1.

Figure 1: Music School with the concert hall, exterior and internal view of covering

2 Basic acoustical planning

Among the most important acoustical tasks is to ensure an equal sound distribution, good reverberance and speech intelligibility and – natural – to avoid focussing from the double curved walls. As shown in figure 2 the double curved walls were designed with large radia of curvature (approximately 1,5-3 times the room dimensions, meaning that focus points are located outside the hall).

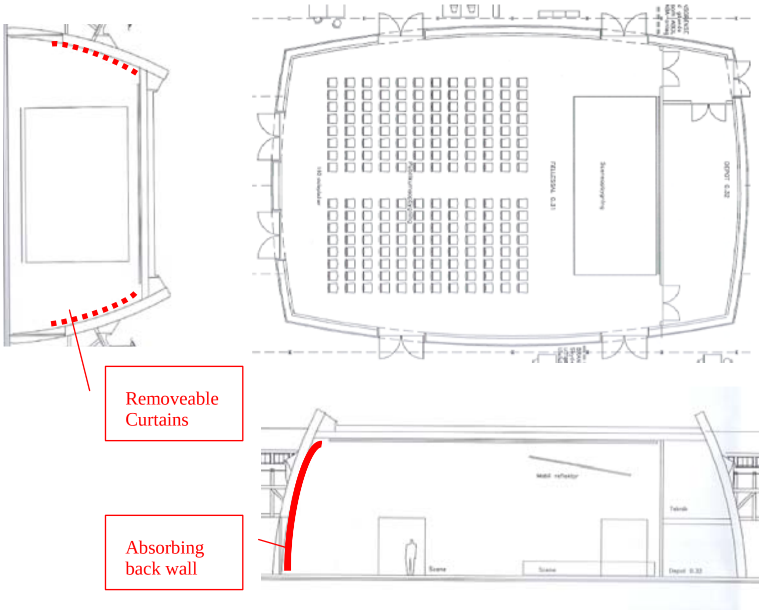

Figure 2: Project-drawings of Music School. Plane view and sections. Room dimensions: $l * w * h$ = 15 x 19,5 x 6,75 m. The stage and the original reflector are shown.

Internal in the hall in front of the long curved walls are diffusing coverings (wooden lists) at the lower parts. At the upper curved walls and behind the stage are curtains for variable acoustics. The double curved back wall is covered with an absorbing plaster. The hall has horizontal floor and under the plane ceiling is a moveable grid for light (and originally also sound reflector) above the stage. The project was cut down due to the economic realities. Thereby some of the diffusing wall covering at the upper wall parts – as can be seen at figure 3 - and the stage reflector were removed.

Figure 3: Diffusing wall coverings at lower parts and rails for curtains at upper parts of curved walls

3 Room acoustic results

The halls acoustic is satisfactory in normal use with the stage at the one end and chairs at the floor. The reverberation time is variable from 1.1 – 1.6 sec. and it fulfilled thereby the requirements.

After the hall was delivered the new users started to use the hall in a more flexible way and included larger parts of the floor to the musicians. This is in general solved satisfactory due to the many small ceiling reflectors – as shown at figure 4.

Figure 4: Ceiling reflectors.

4 Flutter echoes

But in the central part of the hall - when used without chairs – there is a flutter echo created by higher order reflections between the floor and the double-curved walls when the curtains are absent. As shown at figure 5 several flutter echo paths are possible, except no. 1 due to the small ceiling reflectors.

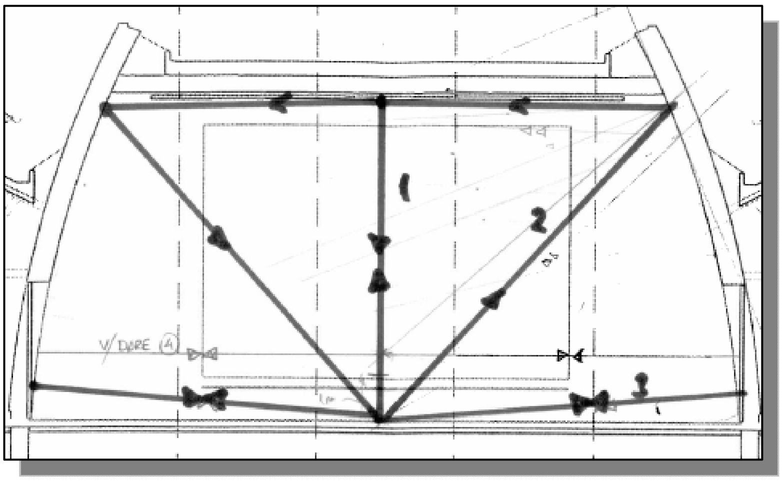

Figure 5: Possible flutter echo paths.

Based on experiments the path no. 3 was found to be responsible for the flutter echo at the centre of the hall - when the acoustic curtains at the upper walls were in use. Thereby it could also be concluded that the diffusing wall covering (the open wooden panels in front of the lower wall parts) was not able to avoid the flutter echo. The flutter echo and its repeated reflection patterns (paths no. 3) could be avoided either by using some sort of Schröeder diffusors or by using specific directive sound reflectors. The last type was proposed – as shown at figure 6 - and this solution included one more upside: It was invisible behind the diffusing coverings.

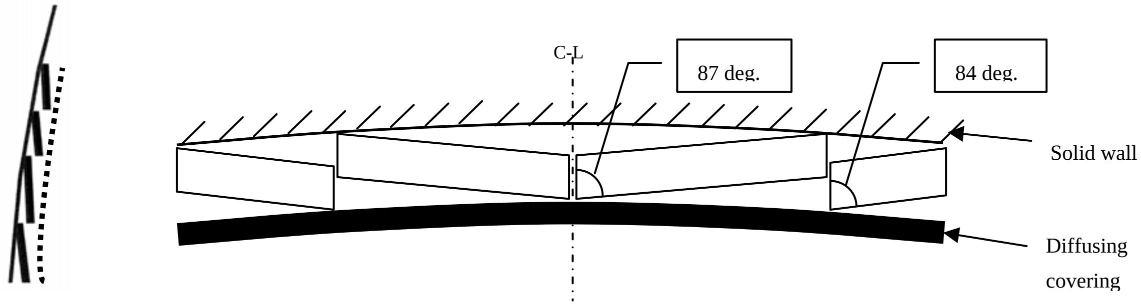

Figure 6: Proposed reflectors to eliminate flutter echo by directing the sound away from the central part of the hall.
Left: Vertical section - small scale – reflector angles re. vertical varying from 2,5 – 6 deg. Right: plane view.

In the presentation the effect of this proposal will be supported by calculations with Billiard- and Soundwave plots from a room acoustical Odeon-model of the hall. The effect of the proposal is also verified by results of the newest calculation tools implemented in the latest version (11), Dietsch’s echo-criteria. These are shown in figure 7 and the effect is clear – due to both absorbing upper walls and reflectors in front of lower walls.

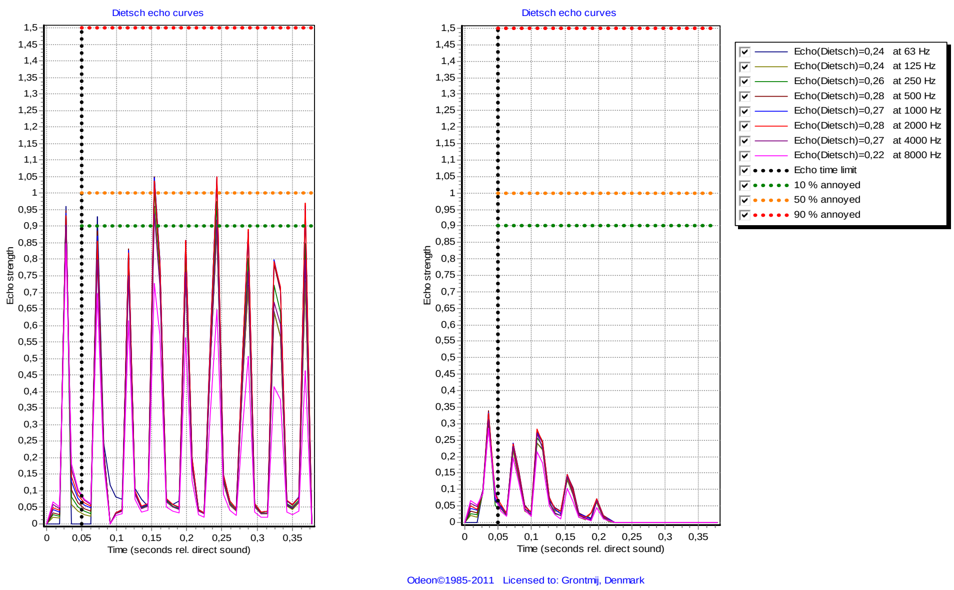

Figure 7: Dietsch echo curves calculated with source/receiver in the central part of the hall.
Left: Hard upper walls (clear audible echoes). Right: Absorbing at upper and sound reflectors at lower walls (no echoes)

5 Conclusion

Double curved surfaces can imply acoustic challenges due to higher order reflections. Based on acoustical calculations and Odeon simulations it can be concluded that the proposed reflectors – together with the existing curtains – will eliminate the flutter echo in the central part of the hall. At present the reflectors is not built and the users of the music school have arranged it by placing the musicians outside the central focus area.

References

[1] Odeon manual version 11 http://www.odeon.dk/pdf/ODEONManual11.pdf .

[2] Dietsch, L., & Kraak, W. Ein objektives Kriterium zur Erfassung von Echostörungen bei Musik- und Sprachdarbietungen (in German). *Acustica 60*, 1986, 205-216.