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Detailed analysis of the sound field in a scale model of a street canyon

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ABSTRACT

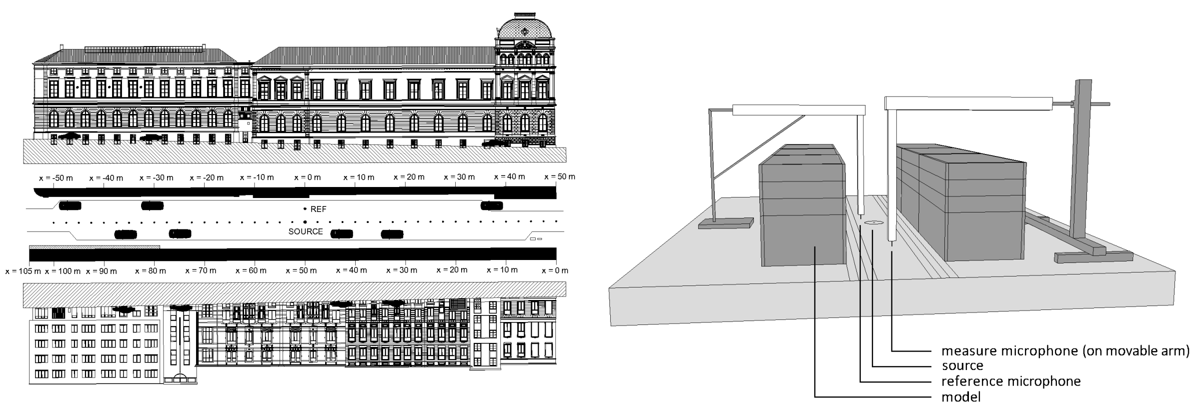
Reverberation increases sound levels in narrow street canyons and could also aversely influence perceived quality of the sound. Building facades are most often acoustically rigid, leading to high levels of reverberation, especially in long and small street canyons. Detailed city architecture has a strong influence, as diffusely reflecting facades tend to lower the reverberation. In order to optimize the sound field, knowledge of the influence of facade geometry on the sound field must be gathered. Scale models are often used for this purpose. Here, a 1/30 scale model of an existing 105m long street canyon has been constructed, including full facade details, to an extent that exceeds previous work. Measurements of the sound pressure level distribution in the detailed model and a box-model are compared and the influence of a newly designed facade is investigated.

1. INTRODUCTION

The human perception of the soundscape in the city has a large influence on the psychological well-being and behavior of city-dwellers. It is therefore important, when designing new architectural surfaces, to make an a priori estimation of their influences on the sound-field.
At the one hand, simulation software can be used. However, there are no computational techniques available that can handle the full architectural detail in three dimensions for structures as large as a street canyon. Existing approximating numerical models prove to be computational expensive and suffer from modeling assumptions and simplifications. At the other hand, scale modeling is still very useful and commonly applied for this kind of studies [1, 2]. To limit the geometrical complexity, the facades can be modeled e.g. as an arrangement of blocks [2]. However, the specific influence of facade details, such as ornaments and surface irregularities, and their exact placement is then lost.
In this research a highly detailed 1/30 scale model has been constructed to study the sound distribution in an existing street canyon. In order to investigate the influence of details on the sound-field, the sound pressure level in this detailed scale model is compared to the sound pressure level in a simple box-model of the same size, the acoustical equivalent of a modern flat facade. Based on these findings, an architectural proposal of a newly designed facade is measured and results will be discussed.

2. SOUND-FIELD COMPARISON OF A DETAILED AND BOX-MODEL

In order to estimate the influence of facade detail, a highly detailed scale model and simple box-model of a 105m long and 10m wide street canyon are created. The scale of 1/30 is large enough for the details to be modeled with high accuracy. In Fig. 1(a) a drawing of the geometry of the street canyon is depicted. The detailed model is created by laser-cutting 3.6mm thick plywood, based on these drawings. After assemblage, the model is varnished to make the material acoustically harder. The box-model, to which the detailed model is compared, consists of multiple height adjustable MDF boxes, configured in such a way that the length and width of the street canyon is preserved.



(a) Detailed geometry of the 105m long street canyon used for the scale model. The source position, reference position and different measurement positions are given by dots (•).

(b) Measurement setup in the anechoic chamber. The movable arm with microphone and reference microphone are indicated, together with the source in the center of the canyon.

Figure 1. Scale model and measurement setup.

Measurement setup

The scale models are placed on a rigid ground-plate inside an anechoic chamber. In the center of the street canyon, a source underneath the street level radiates sound through a small hole in the ground-plate. As sound source, two different tweeters are used to reproduce an exponential sweep between 500Hz-35kHz and 20kHz-96kHz. During the measurement cycle, the sweep is repeatedly recorded by two 1/8" microphones. One of these microphones is mounted on a mechanical arm, which is automatically moved to each measurement position. The other microphone is used as reference microphone, positioned nearby the source, but out-of-center (Fig. 1(b)). After measuring, each recorded signal is analyzed in octave bands and a relative sound pressure level between position dependent and reference position is calculated. Fluctuations caused by the source can be eliminated in this way.

Results and discussion

A comparison of the relative sound pressure level at selected octave bands from the detailed and box-model is plotted in Fig. 2 (at full scale). At low frequencies (63Hz and 125Hz) the introduction of details makes only little difference. This is not surprising as at these frequencies the wavelength is much larger than the size of the irregularities. Most sound is then specularly reflected. At mid frequencies the decrease in sound pressure level with distance is much higher for the detailed model than for the box-model. The introduction of facade detail clearly lowers the sound pressure level, as the sound is more diffusely reflected in the canyon. A back-diffusion effect can occur in the neighborhood of the source, as sound is scattered back, causing a small increase in sound pressure level, relative to the box-model. At the highest frequencies considered (2kHz) no significant effect is observed by the presence of the diffusely reflecting facade. This could be caused by the fact that our source was no longer omnidirectional at these frequencies, radiating sound upwards without interaction with the facades or it could be caused by poorly scaled absorption.

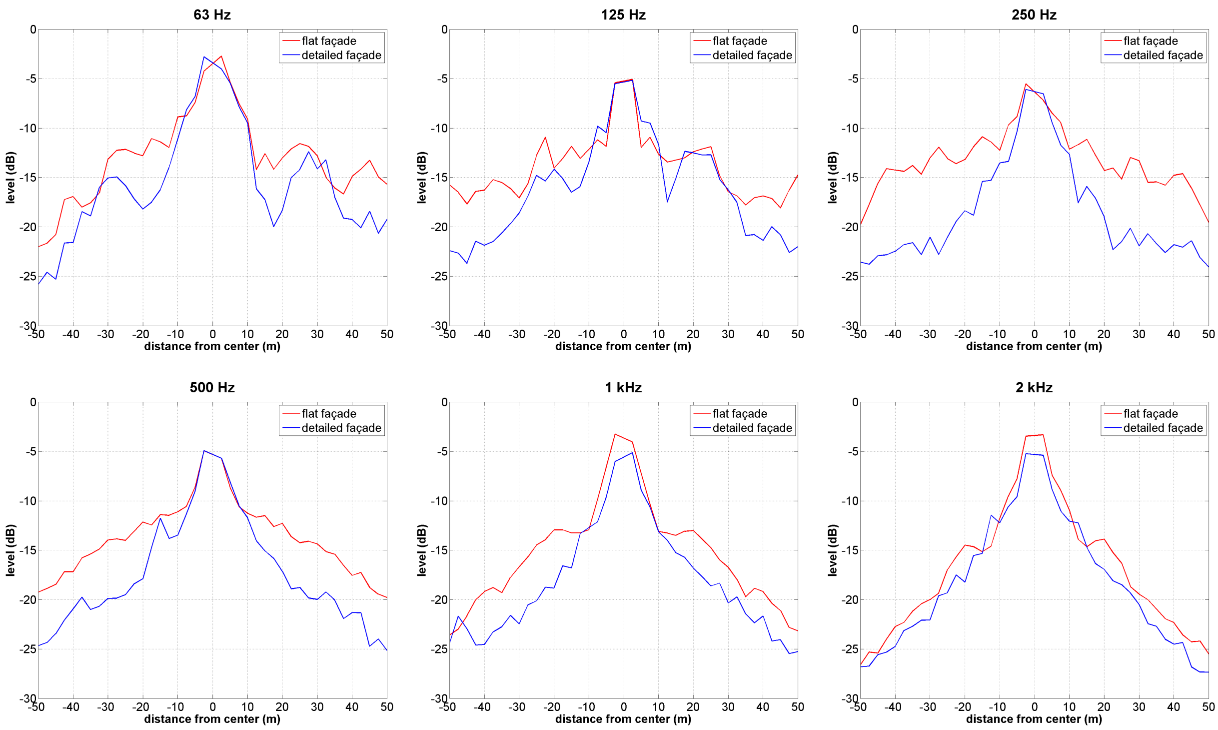


Figure 2. Comparison of the relative sound pressure level in the box-model (red) and detailed scale model (blue), in function of the distance from the center of the street.

3. A NEWLY DESIGNED FACADE

For the improvement of the sound-field, a grid-like texture is proposed as a transparent skin for the facades. This structure has an architectural pureness, compatible with modern facades. The grid proves to be highly dynamical as well, as the changing light provides a different shadow pattern during the day. The design was inspired on different types of diffusors [3], and it is predicted that the size of the grid openings play an important role. In our design, the grid opening was 36cm and depth 30cm (full scale).

Influence on the sound-field

The influence of the grid on the sound-field in both the detailed and box-model is shown in Fig. 3. Generally, it is seen that the influence of the grid is most pronounced when used in front of the box-model. As the detailed facade already contains many diffusing facade objects, the introduction of the grid improves this diffusor-effect only little, compared to its application at the flat facades of the box-model. Furthermore, it can be seen that the effect of the grid is most visible in the 250Hz - 500Hz octave band, where the sound pressure level in the box-model decreases significantly with distance from the source. In the 1kHz octave band a small level increase is seen close to the source, caused by back-diffusion of the grid-diffusor.

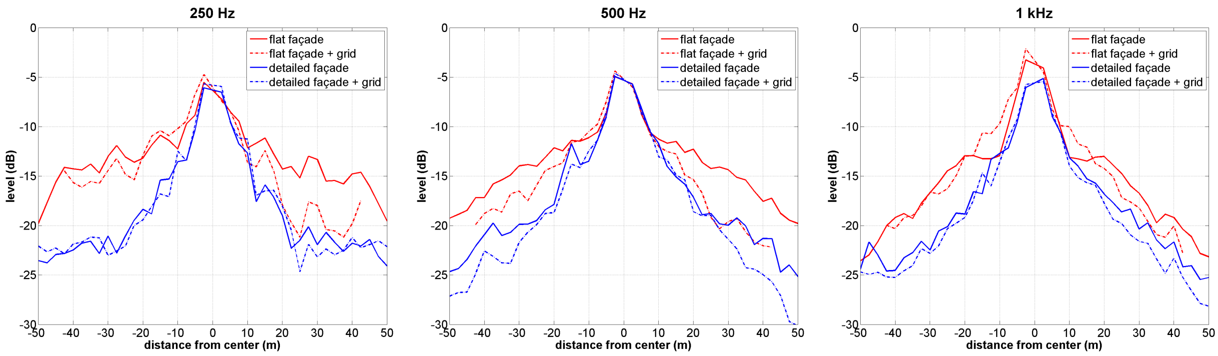


Figure 3. Comparison of the relative sound pressure level in the box-model (red) and detailed scale model (blue), with (dotted line) and without grid (full line). The relative sound pressure level is plotted in function of the distance from the center of the street.

4. CONCLUSIONS

In this work the importance to include facade detail in scale models is shown. The particular facade details in the scale model increase the scattering of sound and lead to a stronger decrease of the sound pressure level with distance from the source, compared to fully flat facades.
The presence of a grid-like structure placed in front of flat facades was shown to be a good solution to increase the diffusivity of the sound-field in a street at certain frequencies.

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