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Impact of Building Façade Properties on Noise Levels in Street Canyons

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Summary
This article discusses the influence of the sound absorbing properties of building façades on noise levels in general and on noise levels in street canyons in particular. The effect of multiple sound reflections from building façades on the increase of the sound pressure level along the whole building façade and thus not only at ground level is shown.
Simulations were performed for a large number of variants, which were created by combining several parameters, such as the sound absorption properties of the wall claddings, the sound absorption of road surface and the width of the street.

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1. Introduction

Sound propagation in urban areas has been already investigated by many authors. However, the emerging use of new building materials, such as tensile structures, different types of structural skins, green façades and installation of kinetic shading elements on building façades is opening new questions in relation to their impact on noise conditions outdoors and indoors.
Most research in relation to building façades is focused on their thermal and moisture behaviour, daylight, and fire control [1,2]. Acoustics is often only associated with comfort issues and it is often forgotten that noise influences people's well-being and human health as well. Also when considering the acoustic properties of building façades, most attention is given to their sound insulation properties, as these are directly connected with the indoor acoustic comfort of the residents. The impact of sound absorbing properties of building façades on urban sound has been investigated less often and research on outdoor noise was limited to aspects of street width, shape and meteorological factors.
Research performed during the past years on sound propagation in urban areas has confirmed the feasibility of image source and ray-based methods for fast and adequate prediction of noise in urban contexts, provided the considered road and façade surfaces are smooth [3,4]. In case of irregular surfaces, diffuse reflections were treated by assignment of scattering coefficient to surfaces, or by modeling of sound reflections in physical way using boundary element method, finite difference method or similar approaches [5,6].
In this article we focus on the assessment of the impact of novel structural skins and shading elements placed on building façades on the noise level in street canyons with different width and different road surface properties.

2. Simulations

Simulations were performed in Odeon®. Since this software is typically used for room acoustics predictions, meteorological factors, such as wind or temperature gradients were not taken into account.

Two street canyons of 500 m long; 12 m and 24 m wide and both 50 m high (Fig.1), were considered. Simulations were performed in several variants, with different façade and road surface properties. The car sound was modelled as being generated by a linear source along the whole street canyon at the height of 1m (red line in Fig.2), representing a road with heavy traffic (corresponding to 80 dB/m).

Receivers were distributed in a plane perpendicular to the source, showing the sound pressure level distribution in a cross-section of the street.

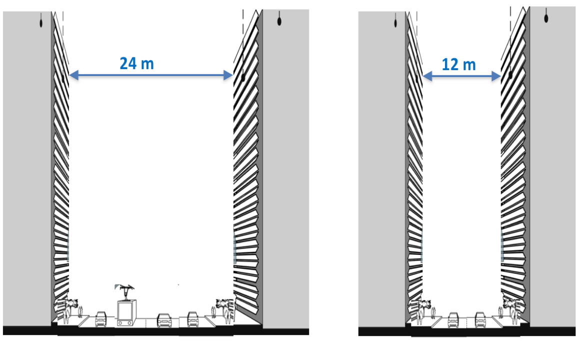

Figure 1. Two simulated street canyons

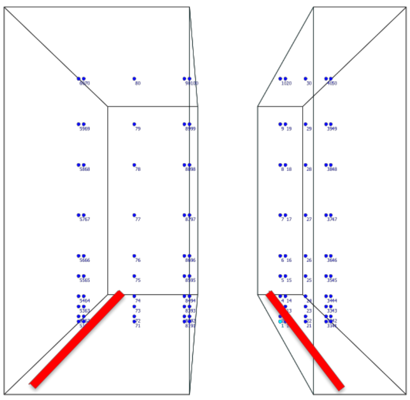

Figure 2. Acoustic models (wide and narrow street cannyon), with indication of linear sound source (red line) and sound source receivers (blue dots)

Five variants were simulated in each of the two street canyons (e.g. 12 m and 24 m wide). Variant 1 expressed a "free field" situation without buildings, equivalent with buildings with 100 % absorptive façades. Variant 2 presumed traditional wall claddings made out of bricks, simulated as flat surfaces. Variant 3 was also based on a brick façade, but large irregularities (balconies etc) were presumed. Variant 4 represented a transparent glass façade without shading elements, and Variant 5 modelled a situation in which ETFE cushions were used as façade finishing. Each Variant was simulated for two kinds of street surface: asphalt and porous asphalt.

Results and Discussions

Data were analysed in terms of different aspects and for different frequencies. In the following we show and discuss the distribution of the sound pressure level L_P (dB) in a vertical plane (cross section of a street canyon model) in the middle of the street. In Fig.3 and Fig.4, values are displayed for low frequencies represented by an octave band around 125 Hz and for middle frequencies at the 1 kHz octave band respectively.

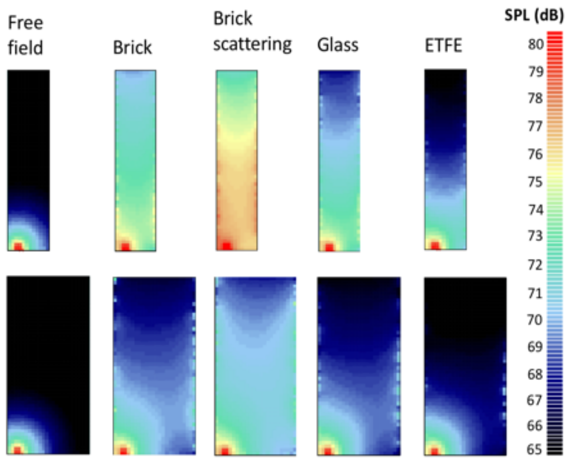

Figure 3. Distribution of Sound pressure level at 125 Hz in a cross section of two street canyons

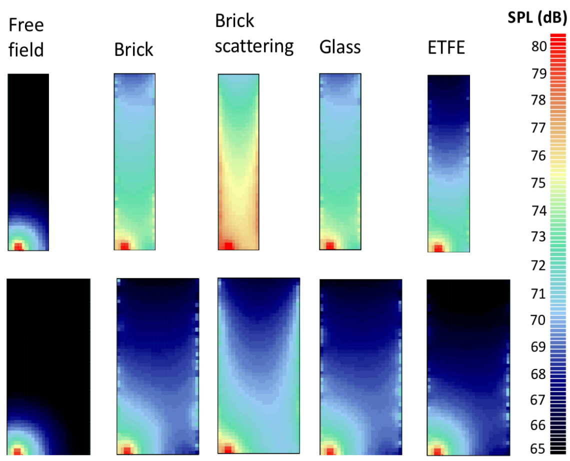

Figure 4. Distribution of Sound pressure level at 1 kHz in a cross section of two street canyons

The results show that the decreasing effect of added sound absorption on the building façade on the noise level is most prominent at the higher floors, where the dominance of the direct sound and ground reflections is less pronounced. Also, the width of the street influences the efficiency of a sound absorbing façade and thus plays an important role in the L_P distribution. In case of a street canyon with a width of 24 m, the effect of sound absorption is less pronounced in comparison with a relatively narrow street of 12 m wide. Increased sound scattering caused by irregularities on the façade increases the overall noise at the floors. This is likely to be caused by the occurrence of multiple sound reflections in case of higher scattering values. In case of flat surfaces, sound waves (rays) have a smaller probability to hit protruding surfaces and "skip" the street canyon model easier and faster in comparison with a geometry containing scattering surfaces, where the sound is "kept" longer in the canyon by model irregularities.

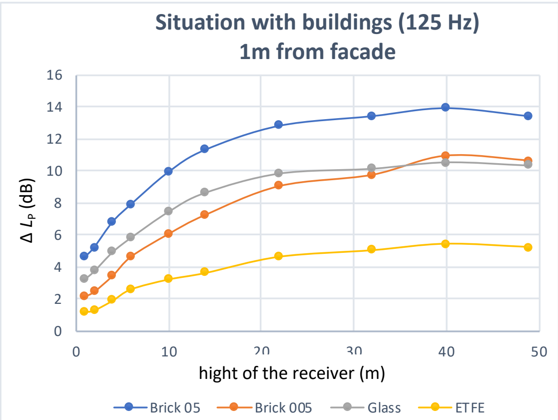

Figure 5. L_P increase in dB at 125 Hz ("y" axes) for a narrow street canyon relative to a free field situation, versus the immission height

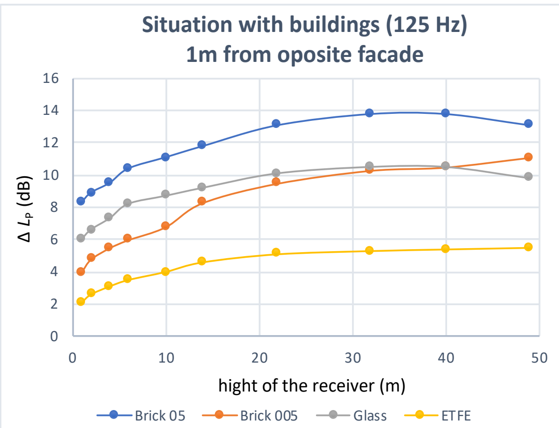

Figure 6. L_P increase in dB at 125 Hz for narrow street canyon relative to a free field situation, versus the immission height.

A more detailed analysis is shown in Fig.5 and Fig.6, which depict the relative increase of the sound pressure level due to façade reflections with respect to a free field situation (or a case in which the wall claddings would be 100 % absorptive).

The sound pressure level differences in Fig.5 and Fig.6 were calculated at point receivers (Fig.1) situated at a distance of 1 m in front of the façades. In all cases the multiple reflection induced increase of noise in upper floors is much higher than in lower floors. In case of narrow street (12 m wide) and façades made out of bricks, the increase of L_P at 125 Hz amounts up to 10 - 14 dB at 40 m height (depending on scattering properties).

3. Conclusions

Ray-based simulations of two street canyons indicate, that by reducing multiple sound reflections from building façades, by making them sound absorbing, has a positive impact on the noise situation outdoors, mainly significant at higher floor levels.

Acknowledgement

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