Sound Masking to Reduce Annoyance by Traffic Noise

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Abstract

Office building energy efficiency, especially in tropical climates, could be improved by applying natural ventilation thus reducing the period of air-conditioning. However, in general unacceptable increase of annoyance by traffic noise occurs when the façade is opened. The use of sound masking to overlap the external noise could reduce the disturbance. Clearly R'_w gets lower when the façade is opened, but this reduction is not sufficient to characterize the change in acoustic comfort. Besides the (A-weighted) level of the perceived noise also a change in the frequency content, in the temporal fluctuation and in the “character” of the noise is of important influence. It was investigated, by questionnaries and measurements, to which extend the negative acoustical effects on the subjective “well-feeling” of office users can be reduced by sound masking. Water sound was used for enhanced convenience and clearly distinct effects were observed. Careful optimization of the spectrum and sound level of the masking water noise were necessary to reach acceptance of feasible higher traffic noise levels in the office rooms.

Introduction

The weather in each area can provide different conditions for cooling an ambient just by natural ventilation. In Brazil whenever the external temperature is below 24° C and relative humidity is above 40 %, the real potential on applying natural ventilation in office building can be calculated by building energy simulation program (BESP), like DesignBuilder. Results show that in Brasília city (-15°46’) up to 40 % of the worktime (8-18 h) during all the year long is favorable for cooling by natural ventilation. The base case (worst situation), where the model is cooled just at night and the HVAC system is turned on all the worktime long, the cooling demand is about 83 [kWh/m²·a] in average for the four mean orientations (N/S/E/W). However, the cooling demand decreases when the artificial cooling system is supplemented by natural ventilation, indeed just when the set point allows the window opening. The reduction is in average 12 %. Looking for the same parameters, Curitiba city (-25°26’) presented higher potential for natural ventilation. In average 28 % of the cooling demand can be reduced by 24 [kWh/m²·a] depending of the office room orientation. The model is a quadratic room with 16,8 m² floor area and 50,4 m³ volume. The window to wall ratio (WWR) for each orientation was obtained according to [1]. By this method the Ideal Window Area (IWA) is calculated considering the energy balance between daylight infiltration and solar heat load.

Many researchers have shown the effect of water sound to improve the soundscape of urban areas where traffic noise is present. However, according to [2] water sound to mask traffic noise is not of the same kind when aiming to improve tranquility. It appears that it is the effect of distracting from the more unpleasant traffic noise to a more pleasant water sound which is responsible for improvements in tranquility.

This study is proposing the use of water sound as a masker inside office rooms. The objective is to reduce annoyance by traffic noise when the windows are open. Therefore the target noise is traffic noise inside the room, but not that in free field as studied in [2].

Inside an office room with a window of relative high noise reduction due to double pane thermal insulation as common in Europe, the frequency spectrum is changed mostly on middle and higher frequencies (>250 Hz) than in lower frequencies when the window is opened stepwise. See in Figure 1 the changes in the frequency bands when the window is open in tilted manner.

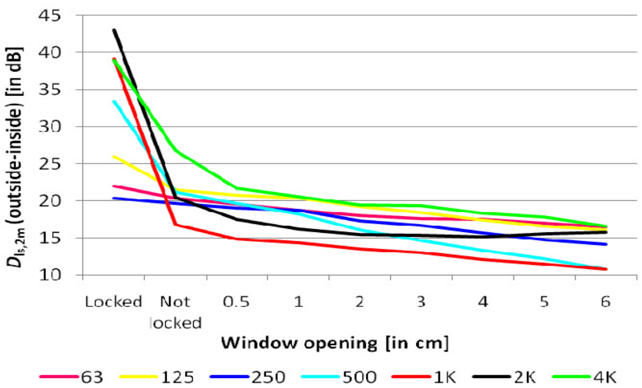

Figure 1: Sound pressure level difference for a high insulating window, when it is locked, unlocked and opened stepwise till a 6 cm slit width in tilted position.

These fact matches perfectly with a previous study [2] which says that higher frequency sounds associated with natural sound made by river or stream and rainfall are felt as pleasant sounds. It is clear that in offices, the sound masking will have a target noise and needs a masker with energy emphasis in the middle and high frequency area.

Methodology

For the first experiment fifteen water sounds were collected with a professional hand recorder from real water features. The same sequence was played on for 15 subjects who were asked to rate in a 5 points scale the pleasantness of each sound. Number 1 is pleasant, in German “angenehm” and number 5 is unpleasant “unangenehm”. The most pleasant sound sample chosen was the sound 1. Sound 1 has the lower sound pressure level $L_{Aeq,15sec} = 82$ dB and a fluctuation (L_5-L_{95}) = 6 dB. See spectrum shape in Figure 2.

All 15 spectra were compared with the reference spectrum of traffic noise measured inside an office room ($L_{eq,\ 5min}$) and with the water sound spectrum which better improves tranquillity [2]. The suitability of each spectrum to fit the reference spectrum was calculated by the sum of the deviations. The best spectrum to fit the traffic noise spectrum was sound 1 (M1) and the best to fit the water sound spectrum in [2] was sound 15 (M15). See Figure 2.

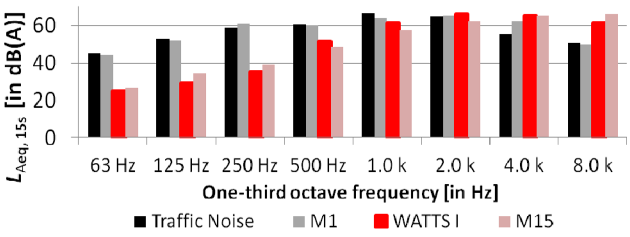

Figure 2: Comparison between spectrum sounds to fit traffic noise and that to fit water sound spectrum [2].

A model room was set in a real small office room with 20 m² for two workers, single-sided ventilated and located on the 10th floor of a high-rise building. Inside this office 66% of the subjects were not annoyed with the traffic noise when one window was open. It means that the office soundscape was not dominated by traffic noise, although the street, which the room façade is facing, is classified as a high noise level range 4 according to DIN 4109, showed in average 69,3 dB(A).

In this experiment two subjects per each section (total of 30 subjects) were asked to spend about 60 minutes working in that office and simultaneously to answer some few objective questions. The questioner aimed to assess the acoustic comfort of the room in certain conditions; when windows were open and when the sound 1 (masker) was electronically played by a professional loudspeaker in the axis of the room. The masker was played during 15 minutes for each three different sound pressure levels: low, medium and high level. The background noise in the office room without sound masking was in average $L_{95,\ 15min} = 38$ dB(A). The three levels of the sound masking were in average 1,5 dB, 3 dB and 7 dB, respectively, higher than the previous background noise. The aim was to evaluate the maximum level people can bear without being annoyed. The results show that the medium level of $L_{95,\ 15min} = 41$ dB(A) in average, was higher rated on the comfortable scale. See Figure 3.
According to R.M. Schafer, the well known creator of the soundscape term, a lo-fi soundscape features almost a constant level that is able to isolate the listener from the environment. This extreme condition could be contemplated by high level sound masking.

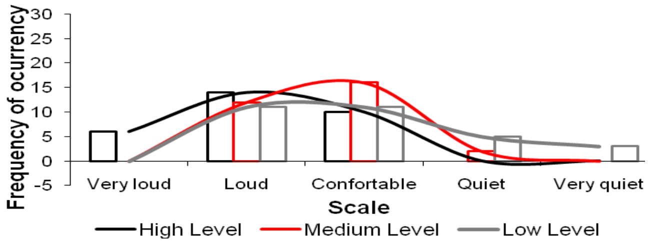

Figure 3: Votes for the noise assessment in the workspace.

When analyzing the temporal fluctuation during the measured period ($L_{eq,\ 15min}$) it occurred that the higher the sound pressure level of the masking, the lower is the fluctuation. High and medium level sound masking was able to reduce the fluctuation up to 10 dB, see Figure 4.

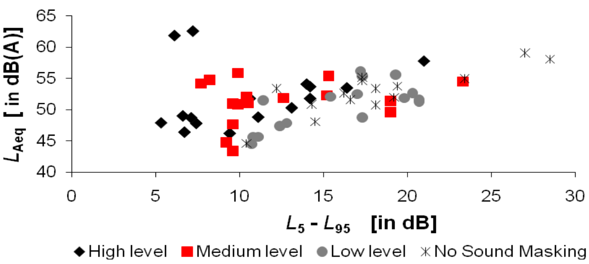

Figure 4: Influence of sound pressure level on the temporal fluctuation.

As Figure 4 shows the variation between sound pressure levels in the same range of fluctuation is high. A chi-square analysis indicated that the difference in three different ranges of fluctuation (<10; 10-15; >15) by different sound pressure level (high, medium and low level) is significant at 95% level (chi-square = 44,2; df = 6; p<0,001). The values on the fluctuation range depend on the sound pressure level.

Discussion

Using the most pleasant water sound chosen as a masker, the sound pressure level of the office room was increased up to 3 dB. However, 60 % of subjects labelled the office soundscape as comfortable or quiet when the sound masking was played at medium level, in average $L_{A,\ eq} = 52$ dB(A) and $L_{AF,\ 95\%} = 41$ dB(A). The values fit well to the recommended overall sound level adequate for office activity like in VDI 2058 (1999-2), where the maximum of 55 dB(A) is allowed. The use of real water features seems to be an economic and effective strategy to improve energy efficiency and acoustic comfort in office buildings. Further studies will better focus on the effect of the masker sound for offices soundscape with extreme dominant traffic noise.

References

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