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Fresh Air and Silence - Maximizing the Potentials of Sound Insulation for Opened Windows

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ABSTRACT

Noise pollution, especially in urban areas, increasingly conflicts with the requirements of healthy and comfortable dwelling. The challenge is to defuse this conflict between outside noise and the demand for natural ventilation and silence inside a building. However, common technical solutions like loggias, sound absorbing fans etc. are relatively limited in their effectiveness. "Eilenburger Fenstertechnik" – a German medium-sized enterprise – therefore has developed a product line of innovative windows, which allow to have a very high sound insulation value of up to 46 dB while being in a (partially) opened position. These types of windows are based on a box-window system and enable the natural ventilation of fresh air while sound is being absorbed between the two window levels. The system is based on the "Hafencity-window". This presentation shall help to understand the potentials and the limits of current measures for effective sound insulation in combination with natural air ventilation. Different innovative and traditional approaches will be compared in their effectiveness, their usability and costs. Backed by some real life case studies, the lecture also shows how these technical innovations can have a strong impact on urban development and trends in building regulations.

Keywords: Building, Sound-proof windows, Ventilation
I-INCE Classification of Subject Number: 51

1. INTRODUCTION

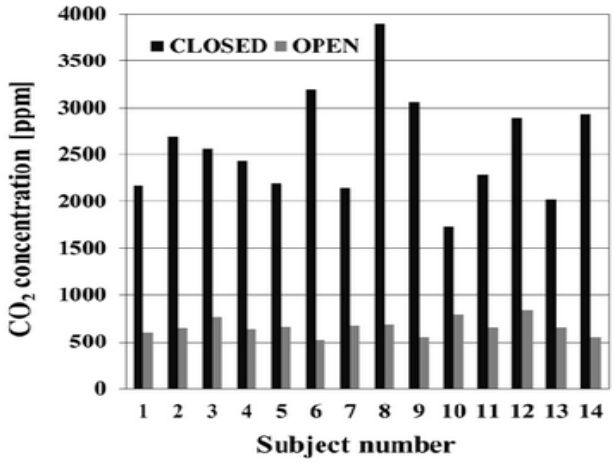
Natural ventilation of fresh air is one of many basic needs, a proper dwelling should always fulfil. Clearly, this requirement is not limited to night time, but healthy sleep is an especially delicate and important issue, demanding silence and fresh air. A vast majority of people in Europe sleep with a window at least slightly opened, and many more would do so if noise wasn't hindering them. These people mostly can only choose between two bad alternatives: noise or lack of fresh air. This health problem is more and more in the focus of planners, architects and the building standard setting community. At the same time several technical approaches – some innovative, some more traditional

– are at hand to tackle the challenge of fresh air “in” and noise “out”. HAFENCTIY windows from Eilenburg contribute to master this challenge.

2. PROBLEM SCOPING: WHY NOISE SHOULD BE OUT AND FRESH AIR IN

2.1 Effect of an open window for sleep quality and human health

The negative effects of noise on human sleep quality and health have been investigated relatively long ago. However, the issue of indoor air quality and how this factor relates to sleep quality has not been given the same level of attention. Recent comparative studies have confirmed the fact that indoor air quality is closely related to sleep quality. Research findings from Peter Strøm-Tejsen of the Technical University of Denmark have shown that the average CO2 level is up to 5 times higher when the bedroom is not ventilated by an open window 1).



Comparison of the Co2 concentration during night-time, each bar representing a 4-day average

“The intervention of opening the window had a significant positive effect on the assessed freshness of air.” There were significant and positive effects of a higher ventilation rate (open window) on the actigraph measured sleep latency and on the subjects’ assessment of the freshness of the air, their ability to fall asleep and nasal dryness. Subjects reported that they felt sleepy and could concentrate better the day after sleeping with the window open.
Similar findings were documented in a study from 2017, where Dutch researchers used high-tech methods to track the nighttime movements of 17 healthy volunteers over five nights. Asit Kumar Mishra, of Eindhoven University of Technology summarizes "Lower carbon dioxide levels [in the bedroom] implied better sleep depth, sleep efficiency, and lesser number of awakenings“

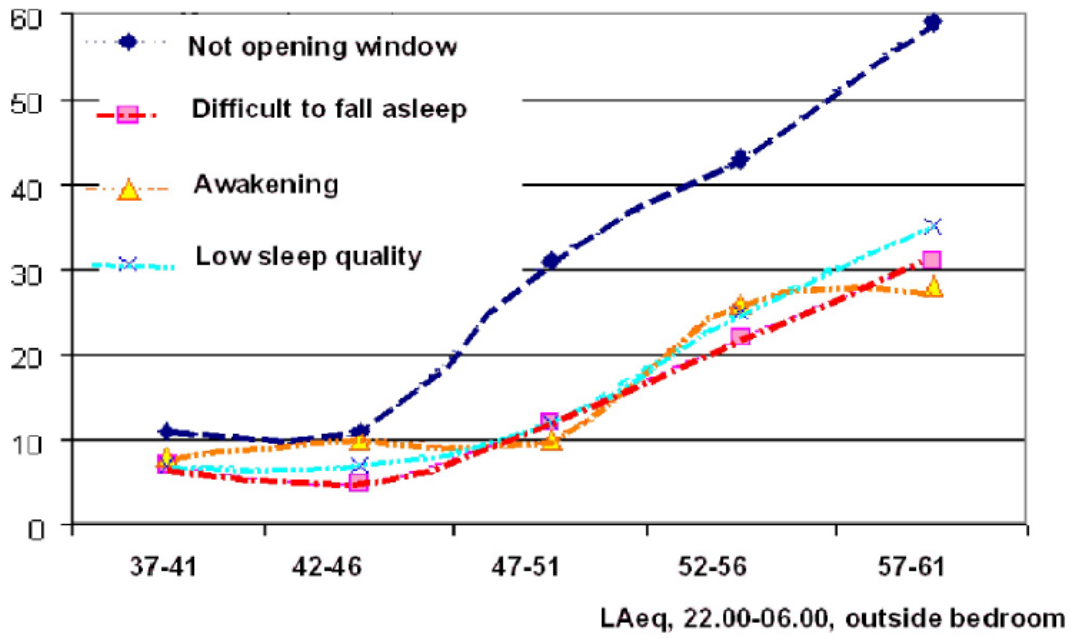
However, there is a large minority of people in Europe who – in spite of all advantages – still do not open the window.

“In order to protect residents inside their homes against noise from outside sources, attention should be focused on windows since they are generally the weakest points in the sound propagation line.”(3)

Window position	% Nights
Closed	25
Slightly open	43
Hand width	23
Half open	5
Fully Opened	4

Window positions during research period (April-November) (3)

Outside noise is *the* main reason for people to leave the window closed in spite of all the negative effects (at least this can be said outside the winter season). Outside noise levels of approx. 47 dB upwards increasingly drive people to close their windows much more than reasoning around temperature or security.



Results from Swedish Soundscape research program (4)

The above diagram shows that people feel forced to close the window in the case of outside noise. This results in indirect negative effects of outside noise: lower inside air quality and perceived acoustic encapsulation.

2.2 Effect of noise on sleep quality and human health

Noise triggers different reactions depending on the time of day (day / night). In general, averaging levels within dwellings below 25 dB (A) at night and below 35 dB (A) during

the day are not expected to cause any significant impairment. These conditions are still achieved with tilted windows if the outdoor levels are below 40 dB (A) at night and below 50 dB (A) during the day. During the day, averaging levels above 55 dB (A) outside the home will increasingly lead to impairments in mental and social well-being. To protect health, an averaging outside level of 65 dB (A) during the day and 55 dB (A) during the night should not be exceeded (5).

WHO recommends a maximum L_{night} of 40 dB (A) at a person's ear. The following indications are to be considered regarding health effects of noise exposure:

- up to 30 dB (A): No significant biological effects
- 30 to 40 dB (A): Moderate effects (e.g. body movements, wake-up reactions), effect depends on the sound characteristics
- 40 to 55 dB (A): Negative health effects, many people have to adapt their lives to the noise situation
- above 55 dB (A): Increasingly harmful to health, large parts of the population is severely bothered, risk of cardiovascular disease is increasing

In the consequence it is not surprising that the most annoying effect of outside noise is not only the noise itself, but the fact that people are forced to close their windows in reaction to that noise. This argument is strongly supported by a survey conducted by the German Environmental Agency (Umweltbundesamt) in 2011 (5), The highest direct noise annoyance comes from motorbikes. Approx. 40% of the people feel "extremely annoyed" or "very annoyed" by their sound emissions. The percentage of people being annoyed by having to close their windows, however, is much higher and adds to approx. 75% (5).

The key to a healthy and comfortable living standard is therefore closely connected to the technical capabilities of the windows so that they can be opened on one hand and still provide significant sound insulation.

2.3 Areas of conflict: sizing the problem and defining the challenge

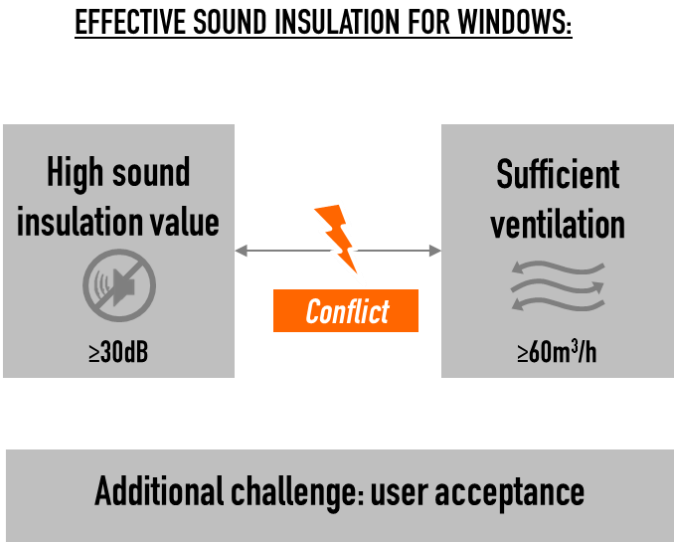
According to EU data from 2017, about 130 Million people are exposed to a noise level of $L_{den} \geq 55$ dB and approximately 90 Million people are exposed to a noise level of $L_{night} \geq 50$ dB living in EU 27 (6). These areas can be referred to as very noisy.

A tilted window can reduce noise by maximum of around 15 dB. In order to ensure a maximum noise level of 30 dB at the person's ear in an extremely noisy outside environment of e.g. 70 dB, a tilted window is by far not enough. Even to ensure the maximum inside level of 40 dB (WHO recommendation) it would be barely enough for millions of people in Europe alone.

82% of the exposed noise can be traced back to major roads, thereof ¾ to urban roads. It seems fair to say, that noise exposure is not only, but mainly an urban issue.

Since urbanization across the world is increasing and will continue to do so, this is an even more alarming fact. The aim to create highly wanted urban dwellings strongly conflicts with the aim to ensure healthy and comfortable living conditions for the urban population. This conflict – if not defused – can significantly affect the supply-side of urban housing (e.g. lack of building permits) and / or it can have a negative effect on people's health. Based on this fact, more and more communities e.g. in Germany, enforce building regulations which demand a maximum noise level of 30 dB (A) during the night time in the bedroom with a window – at least partially – opened.

A contribution helping to defuse the conflict is special innovative window constructions.



Success factors for effective sound insulation for windows

Sound insulation and ventilation are technically difficult to reconcile. Moreover, existing solutions can be ineffective due to a lack of user acceptance (7), e.g. 62% of the users of soundproof windows (to protect from aircraft noise) kept their windows in a tilted position at night, which undermines their sound insulation capacities. 48% of the owners of active soundproofing fans do not use them due to perceived disturbances (7).

The challenge with regard to windows is to enable high sound insulation values while allowing natural ventilation of air. On top of this, the window solutions has to be accepted by the users by being easy to handle and by generating a perceivable increase in living comfort.

3. EXISTING SOLUTIONS AIMING FOR SILENCE AND FRESH AIR

3.1 Passive measures for sound insulation in the context of urban management

All type of windows aiming to solve the challenge above have to be seen as a passive sound reduction measure and are as such a type of last-resort measure. The aim of urban and architectural planning and the aim of active sound reduction measures should be to avoid the necessity of passive sound reduction measures in the first place as widely as possible.

Considering the sheer amount of existing critical exposure situations, however, passive sound protection measures – especially around windows – play a critical role in reaching acceptable living standards concerning health and comfort in urban dwellings, offices and other building types.

3.2 Technical approaches for effective ventilated sound insulating windows

Technical approaches for windows allowing fresh air ventilation and sound reduction are various. The following list is not complete and it is based mainly on the practical experience gained in Germany.

The following solutions are rather established. They have sound reduction values Rw typically clearly below 30 dB but relatively good ventilation properties

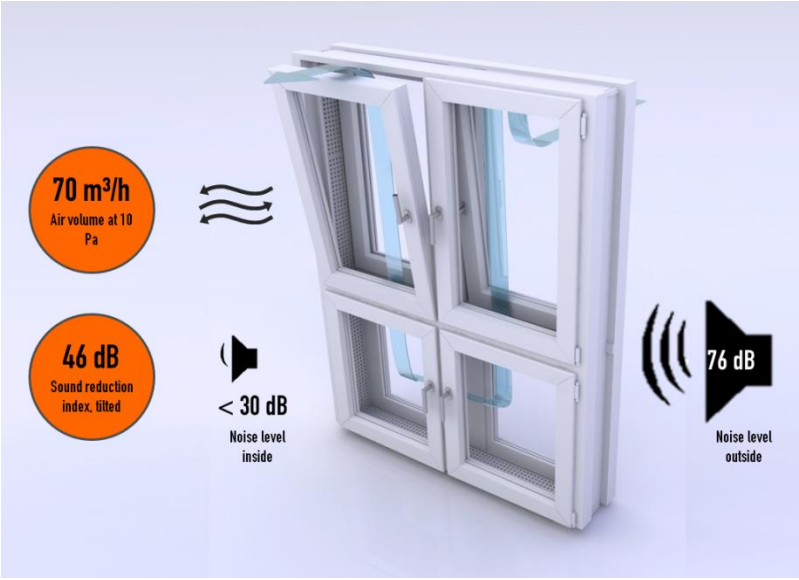
- Windows in combination with an external loggia
- Parallel opening windows
- Windows with exterior impact pane
- Tilted window with sound absorbing window reveals
- Tilted windows

Other common solutions are rather weak on the criterion of ventilation capacity. These are for example:

- Sound-proof windows with flap ventilators integrated in the frame (e.g. RegelAir®)
- Sound-proof windows with Top attachment ventilator

Most effective in terms of ventilation AND sound reduction are

- Most established sound-proof windows with electrical wall-fan
- Innovative HAFENCITY windows from Eilenburg (product line)



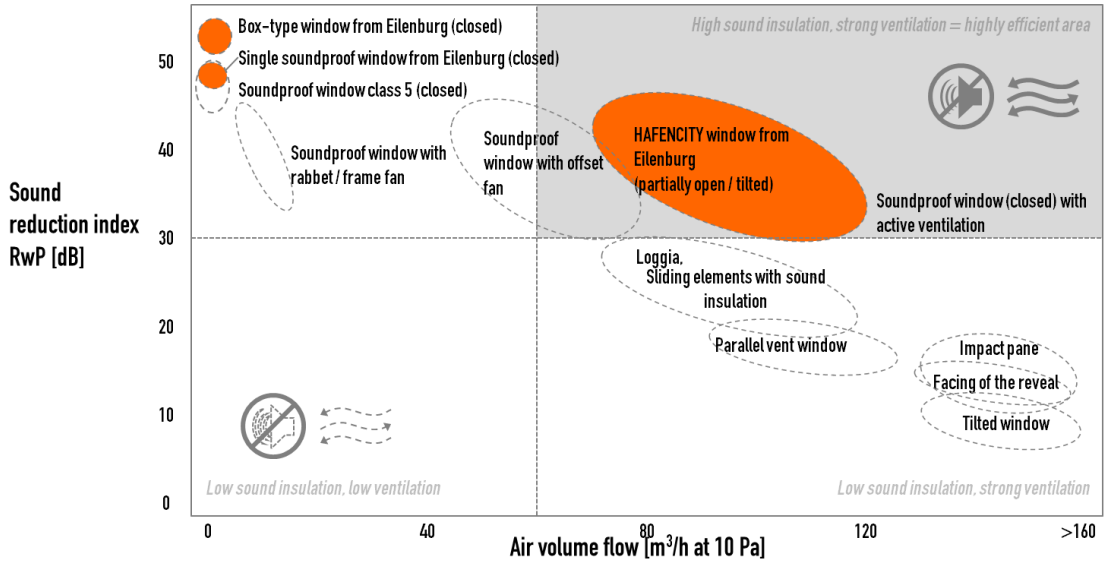
Example of HAFENCITY window from Eilenburg

Alongside these solutions, there are various individual and hybrid approaches, which mostly have the disadvantage of a medium performance and a high effort for certification of the sound reduction properties.

Eilenburger Fenstertechnik has developed a family of innovative windows, which allow having a very high sound insulation value of up to 46 dB while being in a (partially) opened position. These types of windows are based on a box-window system and enable the natural ventilation of fresh air while sound is being absorbed between the two window levels.

3.3 Evaluating the effectiveness of ventilated sound insulation windows

A variety of research has been conducted by Eilenburger Fenstertechnik and existing data was combined by the author to get a rough overview of the solutions' performance in comparison to each other. Obviously, a primary evaluation is done along the two criteria of sound reduction capacity (measured in Rw dB) on one hand and the ventilation capacity (measured in exchanged m³ air volume per hour).



Quantitative evaluation of typical solutions for sound reducing windows with ventilation (8)

The comparative chart above, shows that the HAFENCITY window from Eilenburg has the most effective combination of high sound reduction and high air exchange rates. The sound reduction index RwP in a tilted position is up to 46 dB, while the air exchange rate lies between 75 and 126 m3/h, which is more than sufficient for two people.

Outside noise level can be as high as 76 dB and the tilted window results in a maximum internal noise level of 30 dB, which is often a planning requirement for bedrooms.

The HAFENCITY window from Eilenburg has further advantages. For example it avoids the feeling of isolation or acoustic encapsulation, is easy to handle, produces no inherent noise and has excellent thermal insulation values.

	HAFENCITY window from Eilenburg	Soundproof window with outlet ventilator	Soundproof window and active ventilation device
Approval	+ Planning requirements easily fulfilled	- Planning requirements often not fulfilled	- Planning requirements often not fulfilled
Installation	+ Simple assembly just as usual box-type window	+ assembly as normal window - Wall breakthrough might be necessary	
Operation	+ High acoustic insulation with tilted window + Natural air exchange + Handling / cleaning as usual tilt/turn window	- Permanent ventilation / unusual airing regualtion - Low air exchange - When tilted: noise	- Inherent noise >30dB - Unfamiliar ventilation flap - Power consumption - Maintenance & service - When tilted: noise
	INNOVATION	LIMITED ACCEPTANCE	

Qualitative evaluation of highly efficient soundproofing solutions for windows

3.4 Real Life Example Projects of HAFENCITY windows from Eilenburg

So far, Eilenburger Fenstertechnik has realized more than 700 HAFENCITY windows, mostly for projects in urban dwelling situations. In numerous cases these innovative windows were a key factor in getting a building permit for dwellings in spite of a very noisy surrounding. These advantages and the flexibility it gives to planners and developers clearly offset the higher costs per window.

For a building site in Kassel, which is subject to external noise from 2 sides, 64 windows for bedrooms have been designed as HAFENCITY windows. The sound reduction value at a tilted position is at about 46 dB (picture: MDR)

For a residential development surrounded by noise from 3 sides, 214 floor-to-ceiling HAFENCITY windows were used in order to reduce the external noise level from 66 dB to 30 dB indoor noise level at tilted window positions.

135 HAFENCITY windows with 39 dB sound reduction value (partially open) have been installed in a residential area located on a multi-track railway system in Frankfurt.

105 room-high HAFENCITY windows with two wings and 39 dB sound reduction value (partially open)

4. CONCLUSIONS

Innovative window solutions like HAFENCITY windows from Eilenburg strongly contribute to defusing the conflict of air "in" and noise "out". Thus, they facilitate the production of healthy and comfortable dwelling. Urban development potentials in noisy areas can be used while meeting high standards for healthy living. This gives more flexibility to developers and planners while municipal government's plans to provide living space can be met more easily. In comparison to other passive sound reduction solutions, HAFENCITY windows from Eilenburg show the highest effectiveness regarding noise reduction at a tilted window position. Many examples in Germany prove the high acceptance of this solution not only by developers and owners, but also by the users, who confirm to be enjoying a healthy sleep with fresh air and no noise.

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