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Dwellings in harbour areas

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As the City of Helsinki is increasing its housing supply, new apartments are being planned ever closer to the shore and harbour areas. In order to fulfil Finland's requirements for noise levels in dwellings, measures need to be taken to ensure sufficient sound insulation. The characteristics and properties of the ships' auxiliary engine noise also need to be taken into account, as they create a noise very different to the typical road traffic noise, which is more commonly considered in sound insulation. This paper will elaborate on both the unique properties of the emitted noise as well as the methods to fulfil the guideline values in dwellings.

1 Introduction

Construction in Finland is bound by several legislative norms regarding noise levels in dwellings. Both new and old legislation and norms give the highest permissible sound level for low frequency and/or narrow band noise at 25 dB during night time, even if the noise were not continuous through the night [1, 2, 3].

Harbours and especially mooring ships are noise sources which emit typically low frequency noise and often narrow band noise as well. As Helsinki is expanding closer to the harbour areas it is important to consider these special characteristics of ship noise in planning.

This paper demonstrates a method with which it is recommended to calculate both the sound insulation of a building façade against ship noise as well as how to set the appropriate requirements. The method follows loosely the generally accepted methods for sound insulation calculation in Finland [4].

If one were to eliminate the narrow band and low frequency components of ship noise, ships at berth should be cold ironed (using shore-to-ship power). This would result in having to use normal regulation values without penalties and the unique characteristics which this paper covers would not be applicable and normal sound insulation methods could be considered sufficient.

2 Harbours as noise sources

Harbours contain a variety of noise sources, most of which operate during day time. During day time the ships usually make quick pit stops at the harbour and don't stay at berth for long durations. However, at night time the ships may moor for 9 hours at a time.

Passenger ferry noise can often be a cause of noise issues in the nearest dwellings. The root of the problem is that the shape of the spectrum of ship noise is rather different to regular traffic noise. Ship noise has strong low frequency components, which isn't present in road, railway of aircraft noise (figure 1).

The source for the narrow band noise is the auxiliary engine of the ship. The auxiliary engine provides the ship with power for HVAC and electricity while it's moored at berth. The engine is on for the entire time the ship is at berth. It's located in the engine room of the ship, but the main noise source is the exhaust pipe, at the top of the ship's funnel. This means that the noise source is often at a height of 30-40 m, making noise barriers futile.

Low frequency noise is especially difficult because typically used building structures have poor sound insulation against it, even if they generally have proficient sound insulation. This added to the fact that ship noise is often narrow band makes the combination especially difficult. Narrow band noise is often deemed as more disruptive than noise with a flatter spectrum. In Finland this results in a +5 dB penalty to any measured sound level [3]. The correction is made to the measured or calculated sound level before it is compared to sound level limits.

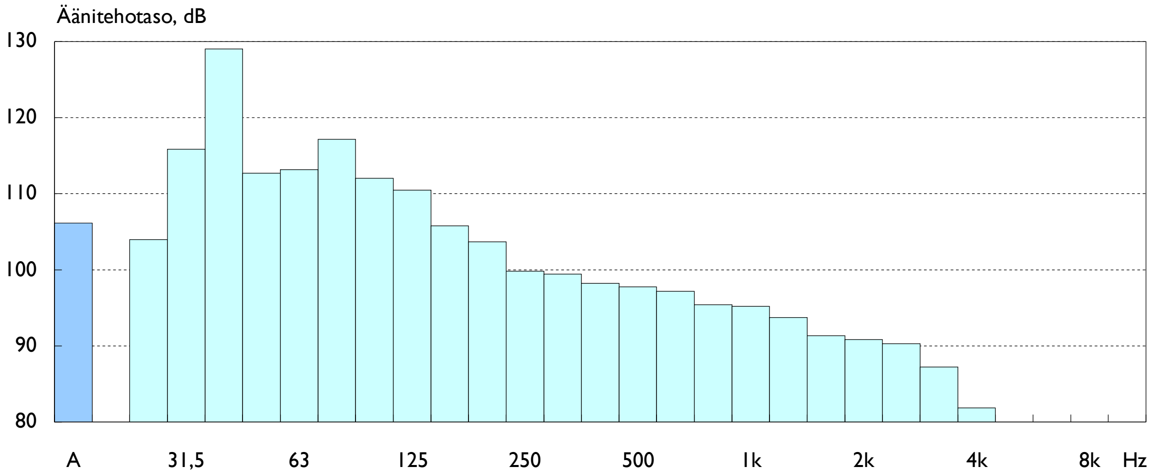

Figure 1. A typical spectrum of the sound power level L_W of a passenger ferry:
"M/S Princess Anastasia", Helsinki South Harbour, 6.5.2011.

3 Sound level difference in legislation

Finnish legislation on noise relies on the guideline values for highest permitted equivalent sound level (L_{Aeq}) during daytime and night-time. The given values are 35 dB for daytime and 30 dB for night time [1]. Since the guideline value for night time is 5 dB stricter than for daytime no special penalty is used for night time noise, like it is in L_{DEN} calculations.

In order to ensure the fulfilment of these guidelines a sound level difference ΔL_A is given in the official plan document for each city block. This number is the difference between the A-weighted noise level incident on the façade of the building and the guideline value, the A-weighted sound level inside the dwelling. Noise levels are calculated separately for day time and night time, and the higher sound level difference is then taken into the legal plan document.

Typically, the noise source is road or railway traffic. As mentioned before, in a typical case no penalties for night time are applied. Traffic is usually heavier during daytime which in most cases results in day time noise yielding the determining sound level difference.

4 Sound insulation against ship noise

Sound level difference ΔL_{As} in itself does not explain what kind of building structures have sufficient sound insulation, since it is merely the result of outdoor noise and the structure as a whole. In order to assess structures more accurately the A-weighted sound reduction index R_A needs to be considered. These two – despite both being expressed in decibels – are different variables and nearly always their numerical values differ as well.

In Finland there is a generally accepted method used to transform the sound level difference to sound reduction index [4]. However, it is intended for regular traffic noise and has two main components which require adjusting in order to befit the demands of ship noise.

The standard method has a lower limit at 100 Hz, which isn't enough for ship noise. The available data for sound insulation for windows, balcony doors and wall structures also often starts at 100 Hz at the low end. In rare cases information may be available at 50-80 Hz bands. However, even these are too high for ship noise, where the maximum is typically at 40 Hz. At such low frequencies the room absorption and the distribution of sound in the room behave differently than with mid-frequency noise. For example, the maximum sound level is measured at the edges and corners of the room – often where the residents will be placing their bed. These factors need to be taken into account when a sound reduction index is determined for a building near harbour areas.

Another unsuitable feature of the regular method is the shape of the spectrum, which accounts for road traffic noise with the added C_{tr} correction term. The spectrum of ship noise differs vastly from the regular road traffic noise spectrum thus demanding its own correction term.

Since the usual methods are not applicable for harbour noise a new calculation method was required to ensure the sound insulation to be sufficient. The method was first proposed in 2005 and refined in 2011.

Figures 2-3 show how the sound level spectrum L_{si} for ship noise is generated. The ship-specific A-weighted sound reduction index R_{As} against ship noise is derived from this information. It is a single number index for the sound insulation properties of a building structure against ship noise and is calculated in the same way as the correction terms C and C_{tr} in the standard ISO 717-1 [5]. In simplified form the A-weighted sound reduction index is calculated with the following formula:

$$R_{\mathrm{As}} = -10\lg \sum 10^{(L_{\mathrm{As}i} - R_i)/10} \qquad (1)$$

where

i is the one-third octave band index;

$L_{\mathrm{As}i}$ is the A-weighted normalized sound level spectrum for ship noise;

R_i is the sound reduction index curve (in one-third octave bands) for a structure.

It is worth noting that the sound reduction curve should be known at least down to 40 Hz third octave band. Since the ship noise spectrum dips very soon below 40 Hz the effect of 31,5 Hz and 25 Hz bands is practically negligible. However, the low frequency and narrow band properties of ship noise means that it is necessary to take the 40 Hz band into consideration. This proves to be a problem as most building element manufacturers are not able to provide sound insulation values below 50 Hz. Such estimates require a good knowledge in acoustics and the field of sound insulation.

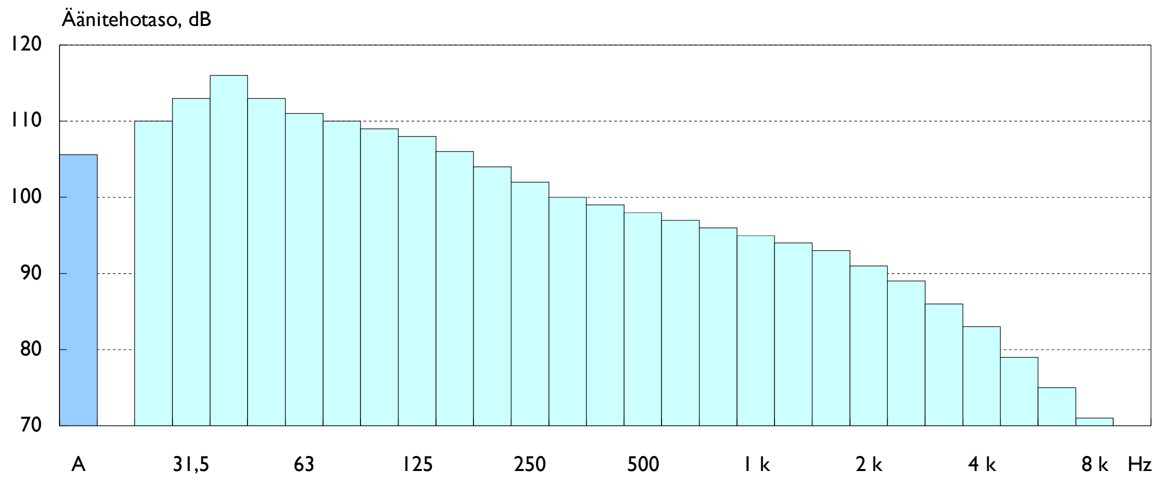

Figure 3. Unweighted average sound power level spectrum of passenger ship noise.

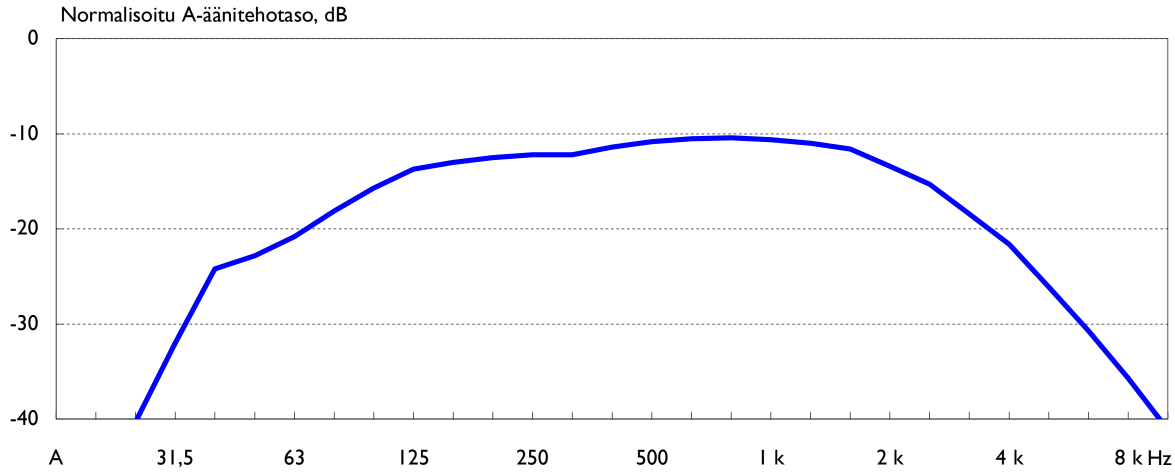

Figure 4. A-weighted and normalised sound level spectrum for ship noise L_{Asi}.

In order to fully functionalise the method it is necessary to formulate a method to connect the sound level difference ΔL_{As} to the A-weighted sound reduction index R_{As}, as described above. The method to calculate the requirements for a structure's sound reduction index is of the form:

$$R_A \geq \Delta L_A + 10 \lg \frac{S}{A} + K \qquad (2)$$

where S is the surface area of the façade, A is the room absorption area and K is a constant.

The determination of a sufficient sound reduction index follows the standard procedure in Ref. [4] and starts with the sound level difference requirement ΔL_A (or ΔL_{As} in this case). The sound level difference is corrected using the area term [= 10 lg (S/A) + 3 dB], which represents the sound power level propagating into the room and the room absorption, as well as an additional correction term of 4 dB. The latter takes into account possible errors in construction as well as uncertainties in spectra and method where the spectral index is forced to be presented as a single number. Therefore in the regularly used and accepted method $K = 3 + 4 = 7$ dB.

The standard method assumes the room absorption area to be 80 % [4] of the room's floor area. This is suitable for regular, mid-frequency noise. However, since ship noise lies lower in the spectrum and thus has a notably larger wavelength, the effective room absorption is much less. It is recommended to use an absorption area of 40 % of the room's floor area S_H:

$$A = 0{,}4\ S_H \qquad (3)$$

The method can be combined into the following equation:

$$R_{As} \geq \Delta L_{As} + 10 \lg \frac{S}{0{,}4 \cdot S_H} + 7 \qquad (4)$$

Since the sound reduction index for a given building structure is defined using equation (1), a sufficient sound insulation is ensured when the calculated R_{As} fulfils equation (4).

5 Sound abatement at the source

It is worth noting that the most effective noise abatement is always done at the source. If the ships are able to switch off their auxiliary engines and use cold ironing, the above process would not be necessary. The ships HVAC would remain a noise source (and a fairly notable one still), but the low frequency narrow band properties of the noise would cease to exist for the duration of berthing. Nonetheless, cold ironing is not an option for ships that don't moor for the entire night and therefore it is important to consider the option of vessels berthing for a short period of night time, during which the auxiliary engines will remain running. This is why the above method remains relevant.

6 Conclusion

Sound insulation against ship noise is not sufficient if generally acceptable methods are used. Instead the method needs to be adjusted to entail the unique properties of ship noise as well as the structures' sound insulation properties at atypically low frequencies.

Using cold ironing reduces the need for extreme sound insulation, but only if the ships berth at the port for most hours of) the night. Any use of auxiliary engines at night time means that the above measures should be considered when choosing the building elements for dwellings near harbour areas.

References

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[2] Ympäristöministeriön asetus rakennuksen ääniympäristöstä **796/2017**, Helsinki 2017. [Decree of the Ministry of the Environment on acoustic environment in buildings]

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