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NOISE CONTROL FOR A BETTER ENVIRONMENT

Noise produced by lift in multi-story apartment building, case study

Torres, Jorge[1]
Brekke & Strand Akustikk AS
Hovfaret 17, Oslo. Norway

Haugen, Knut[2]
Brekke & Strand Akustikk AS
Hovfaret 17, Oslo. Norway

ABSTRACT

Norwegian building regulations requires that all buildings open for general public and work buildings with two or more storeys shall have lifts installed to meet the requirements for universal design. The most commonly used lift system is commonly called the machine room less (MRL) lift where the machinery is located on top of a dedicated lift shaft. Rotating machinery and moving parts represents potential noise and vibration annoyance when not correctly installed. This paper presents a case study where excessive noise levels were observed in a bedroom in the top floor apartment, close to the lift machinery. This paper gives a presentation of the strict requirements that apply to noise from service equipment by the Norwegian building regulations. Also, the various mitigations measures to reduce structure-borne noise and vibration are discussed.

Keywords: Lift, structure borne noise, annoyance
I-INCE Classification of Subject Number: 43

1. INTRODUCTION

The Norwegian Building act and regulations specify that all occupational buildings as well as buildings open for the general public shall have lifts installed when the building have two or more storeys. For residential buildings, all buildings with three storeys or more containing dwellings shall have lifts.

The most commonly used lift system in residential buildings is the machine room less (MRL) lift with the electric motor located in the top of a dedicated lift shaft. The lift shaft is usually made of 200 mm cast concrete walls. The main advantage of the MRL lift system is that it eliminates the need of a separate machine room in the hoistway overhead and thus saves building space. In addition, with the new generation of MRL lift is possible to save up to 50 % energy compare with traditional designs [1].

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[1] jto@brekkestrand.no
[2] khn@brekkestrand.no

Almost all MRL lifts are gearless traction machines. Many fabricants are using gearless synchronous machine because this machine has considerable low noise levels compared with gear machines. However, the noise and vibration from the lift in operation can still result in generation of noise and resulting noise annoyance for the building's occupants. The noise impact is often higher in lightweight buildings because the structure borne noise can propagate easily in to the building structure [2].

In this paper it is shown an evaluation of a MRL lift installation with the results from several noise and vibrations measurements presented. It is also shown the noise level limits which apply to the lift suppliers operating in Norway by Norwegian building regulations. At last, the different mitigation measures to reduce structure borne noise problems are assessed and evaluated.

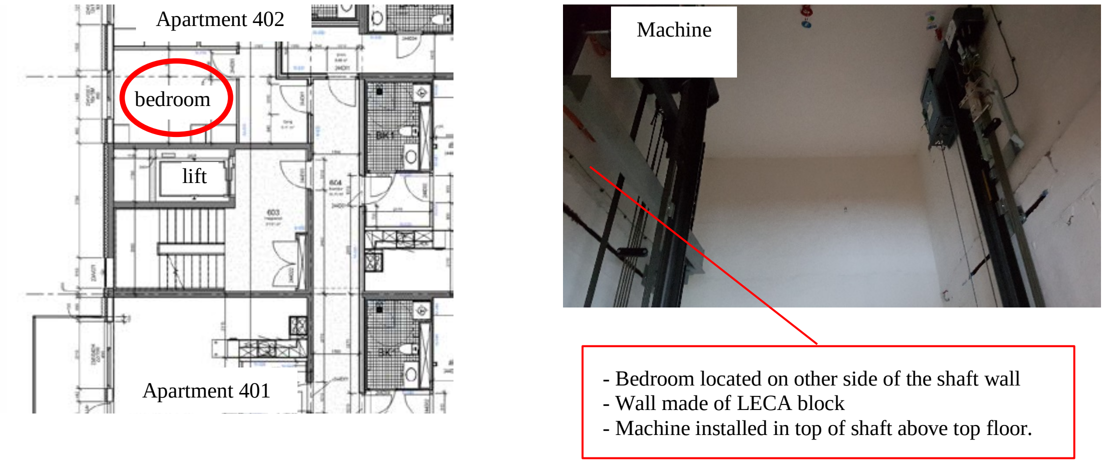
2. NOISE LEVELS REGULATIONS, LIFT FABRICANTS AND BUILDIND'S REGULATIONS

The noise control of lifts systems is governed by a series of standards and directives. The directives for lift fabricants provide limits for sound level inside the hoistway during cabin travel, sound levels in the last floor during landing, as well as for sound levels for the public address system when opening the doors. This set of directives do not provide requirements for noise levels in adjacent spaces. This is because each country has its own regulations for maximum allowable noise levels. It is important that the lift supplier knows all applicable regulations for noise in the place that the lift will be installed.

In Germany, the standard VDI 2566-2 [3] is used. According to this standard a maximum permissible A-weighted maximum sound level, L_{pAFmax}, in adjacent rooms is 30 dB. In Netherland, the building code states the same sound levels as Germany, i.e., noise levels should not exceed L_{pAeq} 30 dB. However, Kalman and Buijs [4] concluded in their research that sound levels within apartments should be lower than 25 dB ($L_{pA,eq} \leq$ 25 dB) to reduce complaints. In Norway the noise regulations are defined according to the national standard NS 8175 [5]. The limit for noise from service equipment, including lift systems, is given as both $L_{pAFmax} \leq$ 32 dB and $L_{pA,eq} \leq$ 30 dB in bedrooms and living rooms of residential buildings. In addition, the Norwegian standard points out that measured sound levels shall be corrected by adding 5 dB before they are compared with the limits values in case the noise contains distinct audible pure tone or the noise is of impulsive character. In addition, the frequency spectrum shall be analysed and evaluated for certain octave band threshold values if the noise exhibits low frequency bias. Rotating machinery and lifts systems have various elements that create tonal noise, such as the speed at which the motor rotates, interactions between pulley and the cables, etc. This means that measured sound levels in Norway should be lower than 25 dB ($L_{pA,eq} \leq$ 25 dB), measured over a full "cycle" as described in the measuring standard ISO 16032 [6].

3. STUDY CASE

Below is presented one case study for troubleshooting the excessive structure-borne noise from a lift installation. In an apartment block, a bedroom was located on the other side of the lift shaft wall, see Figure 1. The machine was placed in top of the lift shaft above the top floor on the common partition wall between the bedroom and the shaft. The walls of the lift shaft were made of Light Expanded Clay Aggregate (LECA) block with extra sound isolation with 3 gypsum boards with mineral wool and cavity. Initial measurements showed noise levels of approximately L_{pAFmax} = 40 dB in the bedroom. Similar noise levels were observed in other two buildings using the same lift system.



- Bedroom located on other side of the shaft wall
- Wall made of LECA block
- Machine installed in top of shaft above top floor.

Figure 1 Excepts from floor plan for the one case study (left). Photo from inside lift shaft (right)

4. NOISE FROM LIFT SYSTEM

Generally, noise from lifts can be caused by airborne noise or structure-borne noise or a combination of both.

Depending on the speed, synchronous machines produce high levels of airborne and structure-borne sound in the low-frequency range between 50 and 250 Hz. This is the frequency range in which first natural frequencies occur for typical concrete walls, and generally shows a clearly lower sound reduction. Figure 2 shows the measured sound reduction index (black solid line) for the case study together with the A-weighted sound pressure levels measured in the lift shaft for two modern lift machines (split / dotted lines).

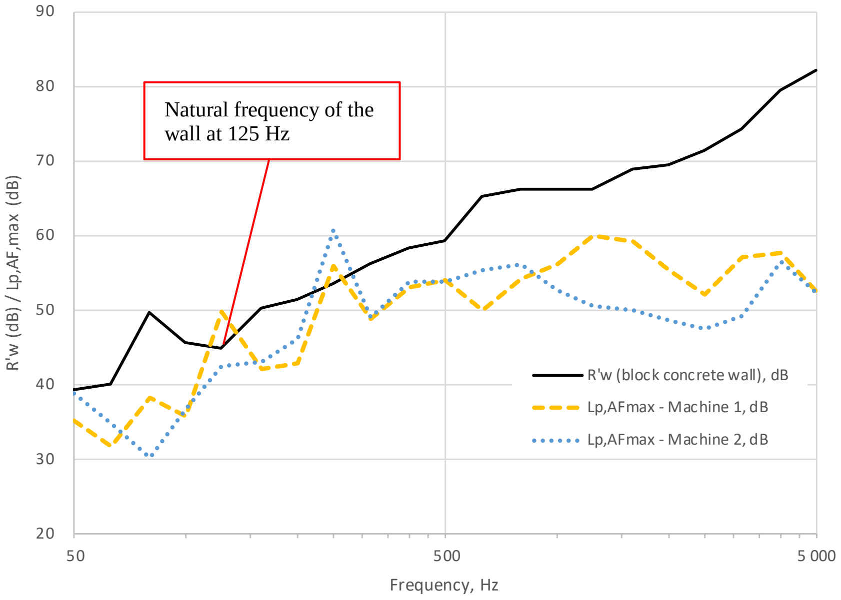


Figure 2 Apparent sound reduction index (R'w), noise levels for two lift machines

Airborne noise from lifts is rarely a problem when the lift shaft is made of concrete structures, where the airborne noise is effectively attenuated. It is observed that modern machines are quieter than older ones and for three modern lifts, the noise level in the lift shaft, close to lift machine, were measured to be in the range of 60 – 70 dB (L_{pAFmax}).

Figure 3 shows results for vibration measurements on the interaction between the lift guide rails and the building structure together with the measured spatial-average sound pressure level in the adjacent bedroom, when the lift cabin is moved between the floors. From the apparent correlation between the curves, it is evident that the noise levels measured in the bedroom are caused by structure-borne noise.

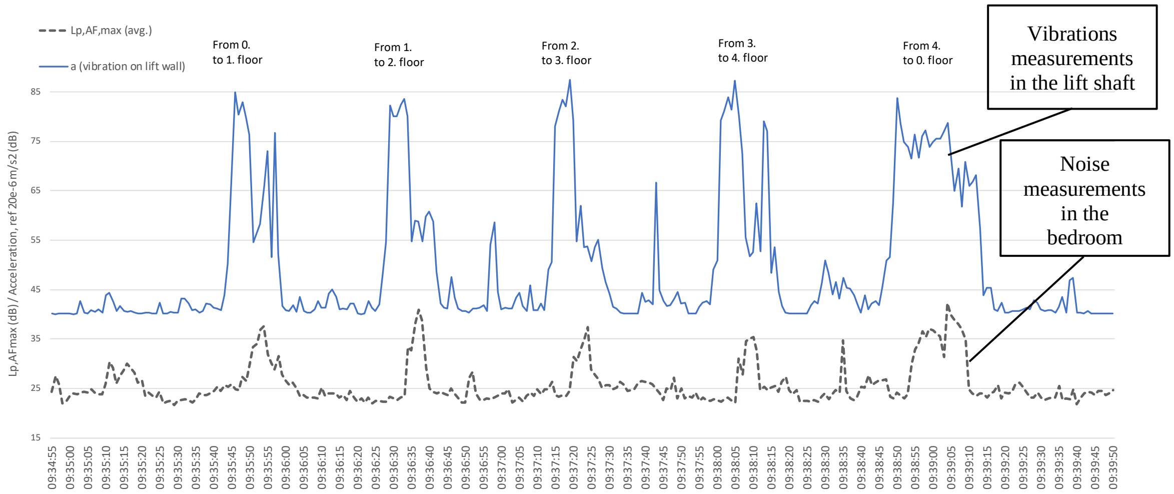


Figure 3 Noise and vibrations measurements when the lift cabin is moved between the floors

Figure 4 shows the characteristic noise level frequency distribution as measured in the bedroom, for the case presented in this paper. The frequency spectra show the highest noise levels in the frequency range from 50-200 Hz., it was found a predominant frequency around 150 Hz.

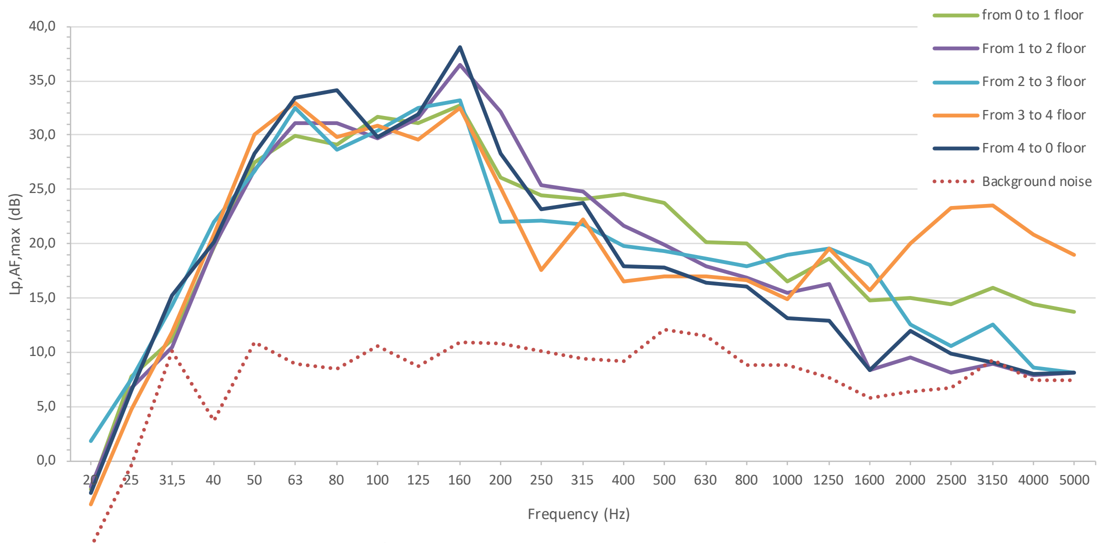


Figure 4 Frequency distribution of measured noise levels in the adjacent bedroom.

Similarly, to the noise levels, the spectrum analysis for the vibrations measurements also reveals the predominant frequency of 150 Hz, see Figure 5. This further confirms that the noise observed in the bedroom is transmitted as structure-borne noise.

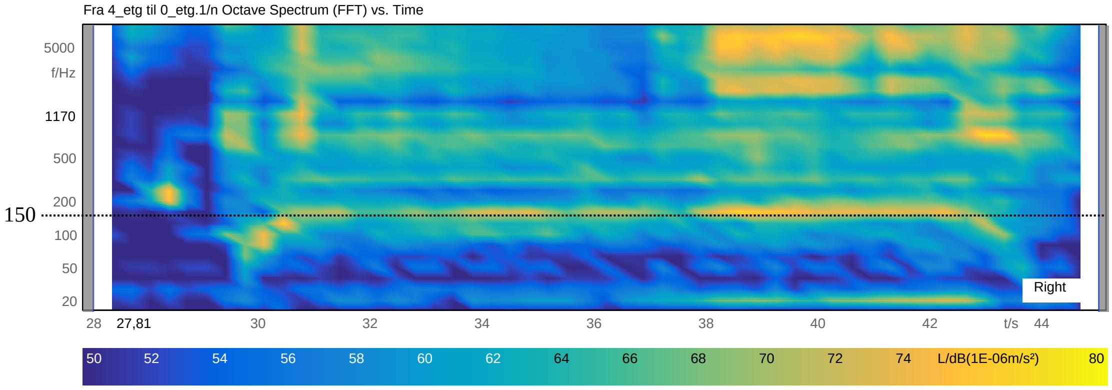


Figure 5 Spectrum analysis for vibrations measurements on interaction between rail's support and buildings structure.

5. MITIGATIONS MEASURE

5.1 Lift machine

In a conventional MRL lift the machine is mounted on a horizontal beam in the top section of the lift shaft. The rail guides for the car extend from top of shaft all the way to the bottom of shaft. The rails are rigidly mounted to the building structure. Typically, lift suppliers use anti-vibration mounts (AVMs) between machine and support. The design of the AVMs is not a simple task in these situations where you need both vibration isolation as well as damping. There is a considerable variation in the load that apply on the AVMs when the cabin is empty as compared to a fully loaded cabin. For safety and comfort, there are strict demands for high precision of the lift cabin travel and landing. For this reason, lift suppliers usually choose AVMs with smaller to moderate static deflections of just 1 to 2 mm. These AVMs typically show too low efficiency in reducing the vibrations and structure-borne noise transmitted to the building structure. AVMs with higher elasticity may however cause operational problems, for example a wire can jump out of the wire reel. Due to this, the AVMs underneath the machine have limited effect for reduction of structure-borne noise, especially at lower frequencies. However, there are some measures that can be implemented.

To achieve a better performance of the AVMs, the difference in load between an empty cabin and full load cabin could be reduced. This will however, require a more powerful drive. One alternative could be increasing the weight of the machinery itself or by adding an inertia mass. For our case, the solution to the noise problem were to substitute the troublesome machine with a heavier one and the new machine was mounted on a heavy steel plate to increase the mass above the AVM.

Vibration isolation of lift machinery is limited when using "hard" damping material AVMs. To solve this problem one additional measure could be to isolate the support at the place where the beam is fixed to the building's structure. This is however difficult due to safety and comfort regulations.

The predominant frequency for structure-borne noise, is related to the rotational speed of the machine, which is related to magnetic field rotating at 120f/p revolutions per minute for a frequency of "f" in Hertz and for "p" poles. For study case, it was changed the machine for a machine with less tonal rotation that performs a "smooth" rotation.

It is important to note that cabins lift travel at a constant speed, typically is 1 m/s. However, in the transition from stop position to nominal acceleration could lower vibrations frequencies be excited. After several measurements, it was found that a reduction of travel speed, could help to reduce noise levels. For the case study, the cabin travel speed was reduced to 0,8 m/s, as a compromise between the noise reduction obtained and the demands for higher travel speed.

When designing the AVMs, special attention must be given to the configuration of machine and pulley. Figure 6 shows two alternative machine configurations. The figure to the left shows a typical configuration where the pulley is located at one side of the drive. This mean that the selected AVMs must have good vibration isolation and damping properties for all directions. In addition, the loads on each AVM are different. For the lift in the case study, the AVMs were changed and optimized with regard to the actual force applied at each position. The figure to the right shows a machine configuration where the pulley is located on the centre of the machine. Vibrations measurements conducted on one of these machine configurations showed lower values than the asymmetric one.

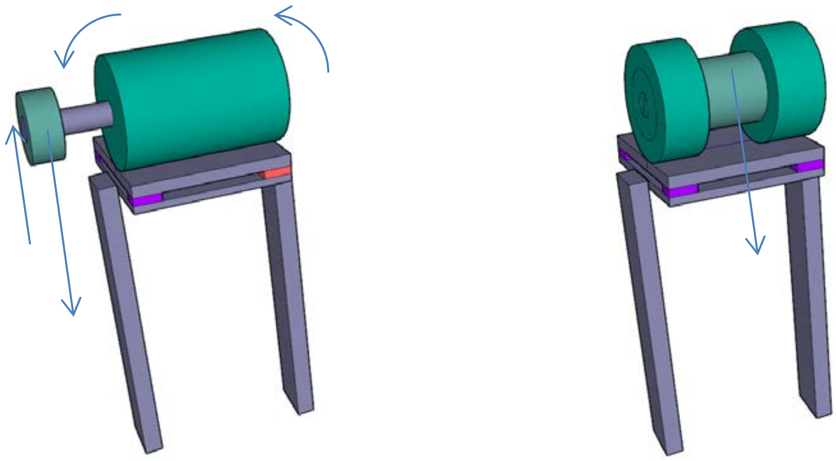


Figure 6 Illustration for two machine's configurations

5.2 Building design

For residentials buildings, noise complains are more common when bedrooms are located next to the lift shaft. A separate free-standing lightweight wall is normally recommended to reduce noise emitted from the wall to the lift shaft.

The lift car guide rails must be fixed to the building structure. Some tests showed that structure-borne noise could be lower when the guide rails were supported to the buildings' columns instead of beams /floor slab in each floor.

Lift producers must advice about minimum requirement for sound reduction of the walls around lift shaft, thus noise limits for adjacent spaces around the shaft. In this way, lift producers can choose a machine according to the building.

6. CONCLUSIONS

Noise levels observed from modern lift machinery can be as low as 60-70 dB (L_{pAFmax}). This noise is easily attenuated by concrete walls. Lift producers incorporate vibration isolation pads (AVMs) underneath the machine. Due to the strict regulations for lift systems, the AVMs are usually too stiff, which result in excessive structure-borne noise and noise complaints from building's residents. In the case investigated in this paper, the measured noise levels were around $L_{pAFmax} = 38 – 40$ dB in rooms located next to the lift shaft in the top floor apartment. For the case study, the lift was retro-fitted in an older existing building. The main focus to reduce noise was to increase the performance of the machine AVMs. Changing the machine to a heavier machine with smoother travel and new set of optimized AVMs, resulted in a substantial improvement of structure-borne noise in adjacent spaces.

7. REFERENCES

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