EUROREGIO BNAM2022
Joint Acoustics Conference
9th-11th of May, Aalborg, Denmark

Solving structure borne noise problems from car wash facility

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Abstract

A car wash facility is a complex system with many noise sources. When the car wash is on the ground floor of a residential building, there are frequently reported noise complaints. The number of complaints usually increases when the car wash service is open 24 hours, and it is constantly in use during the day.

This paper shows how to predict propagation of structure borne noise and airborne noise inside a residential building. It is described different measures, not only to solve structure borne noise problems from a car wash facility, but also to reduce airborne noise. It is presented a case study were structure borne noise was the main noise source. In Norway, noise limits for car wash facility installed in the same building should not exceed a sound level of 25 dB inside the residential apartment ($L_{p,A,T} \leq 25$ dB). This limit is quite difficult to achieve in some situations.

Keywords: car wash facility, structure borne noise, air borne noise, building acoustic.

1 Introduction

A car wash is a facility used to clean the exterior of vehicles. Car washes can be self-service (where the vehicle's owner self-wash his car), full-service (with employees who wash the vehicle), and fully automated (usually connected to a gas station).

Car washes facilities are usually questioned not only for discharge of "dangerous" substances, but also for noise pollution [1]. Noise emissions associated with the car wash would not be a problem when the car washes are situated outside the populated residential areas (for instance adjacent to motorways). However, car washes are often situated in residential areas. Of course, depending on where the car wash is situated, it won't be a problem. For instance, cities that already have a great deal of noise generated by traffic in the area. On the other hand, suburban areas, could have zoning regulations regarding noise pollution. As such, a new car wash must be planned with noise reduction before their permits are approved. For example, Banayan [2] and Kierzkowski and Law [3] presents a case study where a car wash does not comply with city regulations (noise limits during daytime on outdoors residentials areas). The authors investigated several features to reduce noise from the proposed car wash.

This work deals with the noise problems generated from an automated car wash situated on the ground floor in a residential building. The car wash is located on an urban area where any noise coming from the car wash was not problematic since the street noise is already over the noise regulations for car wash facilities in Norway. However, due to car wash facility is in the building, it was found several noise sources associated with their operation. The noise measurements revealed that noise transmitted to neighbours in the same building have two components: airborne noise and structure borne noise.

2 Noise levels regulations in Norway

In Norway the noise regulations are defined according to the national standard NS 8175, *acoustic conditions in buildings* [4]. The guideline indicates limit values for indoors and outdoors that are sufficient to meet the requirements in the building technical regulations. Current noise limit values are shown in Table 1.

Table 1: Sound levels limit, indoors and outdoors, from technical installations in the same building. Excerpt from NS 8175, sound rating C.

Type of user area	Sound limit in NS 8175, sound rating C
In living rooms and bedrooms from technical installations in business and service activities in the same building	$L_{p,A,T} \leq 25$ dB $L_{p,AF,max} \leq 27$ dB
Sound level in outdoor living area and outside window from technical installations in the same building and in another building	Night, 23-07, $L_{p,AF,max} \leq 35$ dB Evening, 19-23, $L_{p,AF,max} \leq 40$ dB Day, 07-19, $L_{p,AF,max} \leq 45$ dB

3 Case study

In one urban area of Oslo city, it is installed an automated car wash in a residential building. The existing site currently has a gas station and convenience store on premises. The gas station and convenience store are opened 24 hours a day, but the car wash is to operate from 07:00 a.m. and 11:00 p.m.

Figure 1 shows a noise map from the area. During the day was not complaints from adjacent neighbours in the area, due to any noise coming from the car wash facility was masked by street noise. However, neighbours on the plan 1 complaints from noise that come from car wash facility. Initial measurements showed noise levels of $L_{p,A,T}$ = 30-36 dB, in the apartment on plan 1. During measurements, it was possible to hear/follow the washing process. Noise levels were measured for three different types of cars, and results variated 2-3 dB.

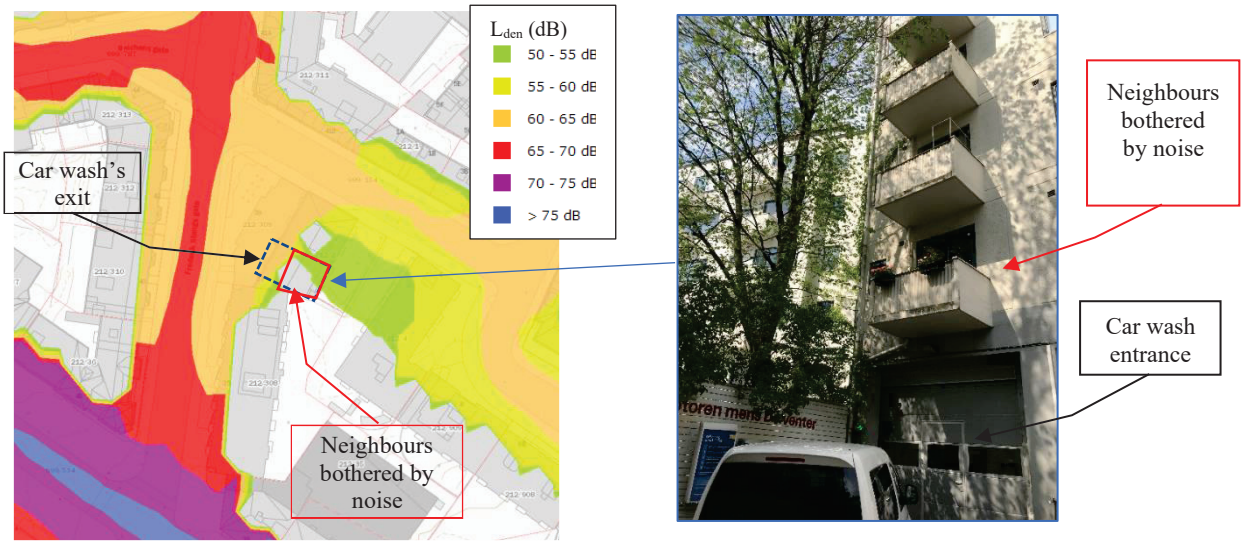


Figure 1 - Left: noise map (excerpt from https://miljoatlas.miljodirektoratet.no/). Right: picture entrance of car wash.

3.1 Construction detail

Walls and floor in the building are made of concrete and brick (thickness is unknown). The car wash is encased with sandwich element of Promisol 100 mm. The sandwich elements are embedded in the foundation plate. The apartment on the plan 2 is a small apartment. The bedroom and living room are located over the technical room which belong to car wash, see Figure 2. There are two high pressure pumps in the technical room. Those are used to remove chemical with high pressure water. The pumps run at a speed of 2930 rpm (48.8 Hz).

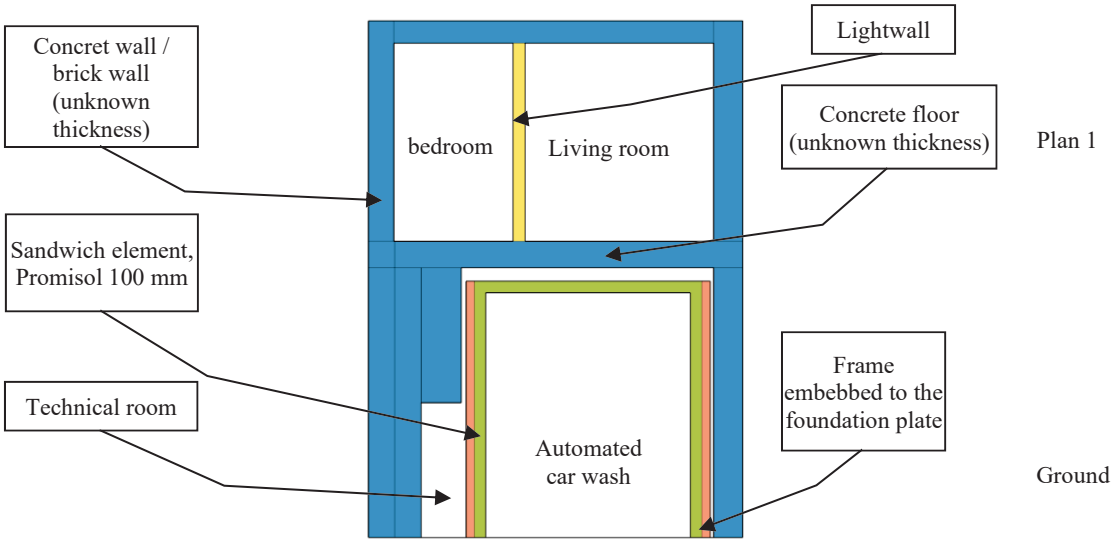


Figure 2: Sectional drawing of the car wash and the apartment which is bothered by noise.

4 Sound and vibration measurements

To map transmission paths, it was performed following measurements:

- Noise and vibration measurements in the car wash, while a car is being washed.
- Noise and vibration measurements in the apartment on plan 1, while washing a car.
- Vertical airborne sound insulation between the car wash and the apartment on plan 1.
- Horizontal airborne sound insulation of the door to the car wash.
- Horizontal airborne sound insulation of building facade.
- Noise level on the facade while washing a car.

Measurements were performed with sound level meter Nor140, with microphone Nor1225 and accelerometer Nor1270.

4.1 Noise and vibration levels

The car wash has different washing programs. Noise measurements were performed for washing program XL which has extra prewash and extra polishing. This washing program has the following processes:

1) Degreasing.
2) Wheel washing + polishing.
3) High pressure flushing.
4) Extra flushing (hood, roof, and boot, without high pressure).
5) Washing with brushes (three brushes, 2 on the side door / frame, and one on the middle) + wheel wash.
6) New round with 3 brushes + extra polishing at the same time.
7) Drying.

Noise measurements were performed in accordance with ISO 16032: 2004 [5]. Simultaneous measurements of vibration levels were also performed on the wall in the apartment and technical room / car wash.

Figures below show results from noise and vibration measurements in the car wash and in the apartment before mitigation measures. A reference line at 25 dB and 80 dB is shown in orange in all figures. Figure 3 shows noise measurements in the car wash and the apartment. The noise level in the apartment (blue curve) increases from $L_{p,A,T}$ = 22-23 dB (background noise) after the washing process started, and it is approximately constant around 35 dB through alt washing process. Lower values were registered in the last part of the washing (drying of the car), but the noise level is also above the requirement.

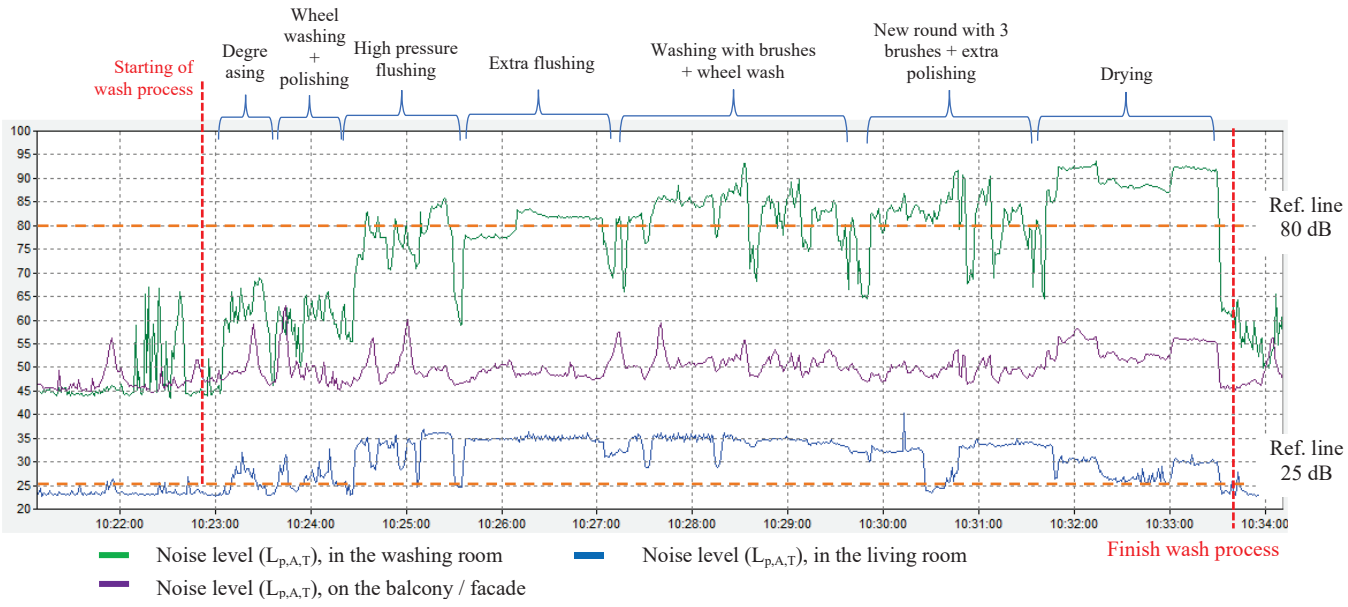


Figure 3: Noise measurements in the car wash and in the apartment, living room.

Figure 4 shows vibration and noise measurements in the apartment while a car is being washed. The vibration level in the apartment (light blue curve) increases when pumps in technical room are activated (brown curve). The measurements show that the noise is mainly transmitted as structure borne noise.

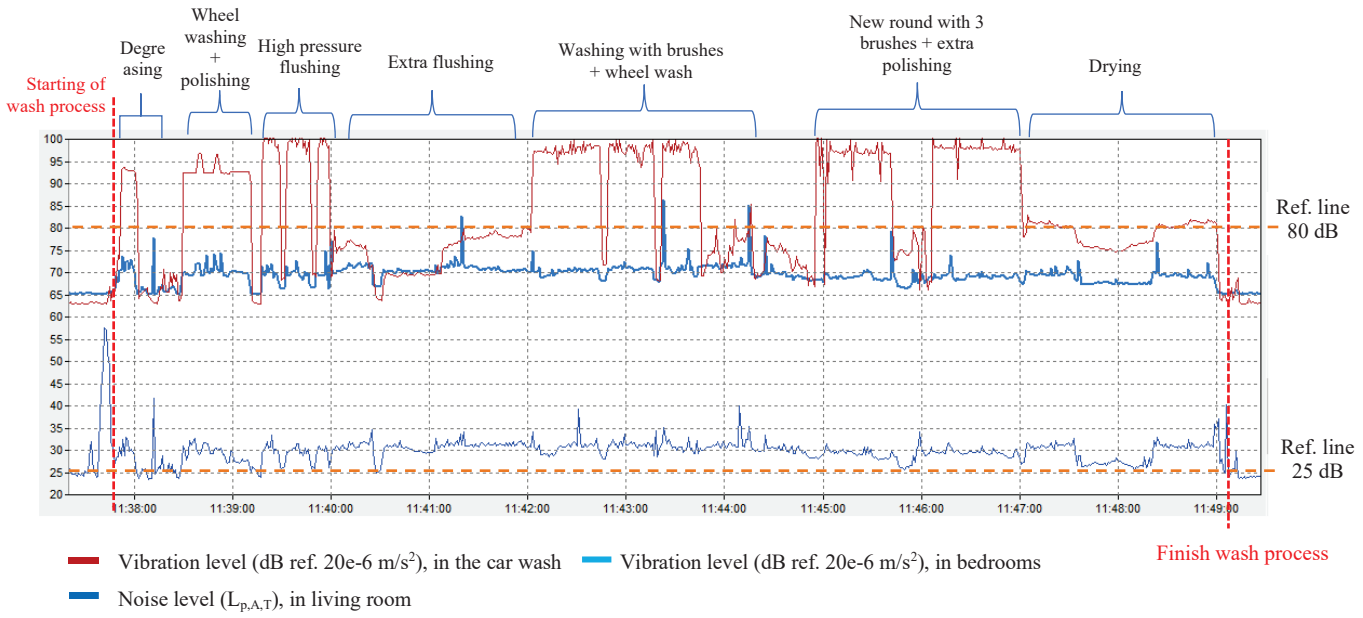


Figure 4: Noise and vibration measurements in the technical room and in the apartment, bedroom.

Figure 5 shows the frequency spectrum from vibration measurements. It was measured on the concrete walls in the technical room (dot red line), in the bedroom (yellow and green line) and in the living room (dash blue line). The results show that fundamental frequency from high pressure pumps (48.8 Hz) is propagated via concrete walls and radiated from the floor and walls into the apartment. The spectrum from noise measurements in the living room shows harmonics components at 100 Hz and 150 Hz when high pressure pumps are operative, it means, the sound energy is structure borne noise transmitted to the apartment.

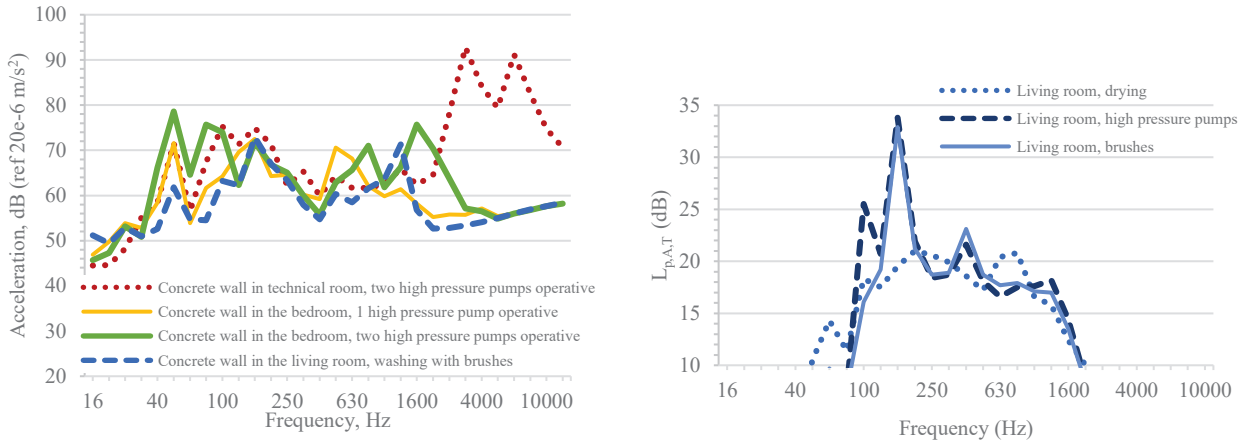


Figure 5: Spectrum from vibration (left) and noise measurements (right).

On the other hand, it was also measured the vertical airborne sound reduction from washing room to the apartment. The result from measurements was $R'_w = 65$ dB and it is not enough to reduce the airborne noise from the washing room. Noise level in the washing room was measured to $L_{p,A,T} = 83 - 93$ dB, see Figure 3. This means that part of noise measured in the apartment is airborne.

5 Recommended mitigation

5.1 Car wash gate

The car wash gate is a rolling gate, model Crawford OH 1042P. This gate is made with steel and aluminium, and it has a thickness of 42 mm filled with CFC polyurethane foam. It was done sound measurements according to standard ISO 16283-1:2014 [6]. Sound measurements show that gate has an airborne sound reduction of $R'_w = 23$ dB. This agrees with producent datasheet. A reduction of 23 dB is not enough to attenuate noise from the car wash facility. The results also show weakness over 400 Hz in the sound reduction. During the inspection, it was observed sound leaks around the gate. It was sealed spaces around the gate with elastic rubber.

5.2 Ventilation facade

The car wash entrance is situated in an alley, and it was built a noise wall around the entrance. After several noise measurements it was discovered that noise level is “trapped” in the alley, and it is transmitted via the facade. Noise level on the facade increases to $L_{P,A,T} = 50 - 57$ dB during drying prossces, see Figure 3.

The facade is built with concrete / brick, and it has windows 6-16-4 (Sound isolation $R_w = 37$ dB). It was measured airborne sound reduction of $R'_w = 30$ dB according to standard ISO 16283-1:2014. The measurements show weakness between 500 – 2000 Hz. It was concluded that some of the noise level measured in the apartment comes via the facade.

In this residential building, the fresh air was supplied to the bedroom with not damping air vents on the façade, it means existing vents did not attenuate the sound. Several tests were performed, and the results show that air vents on the facade contribute to noise measured in the apartment. It was recommended to replace the existing air vents with a sound-absorbing air vents, type TL80DE from Fresh ventilation.

5.3 Technical room

The high-pressure pumps were screwed to the foundation plate with neoprene vibration isolators. This method does not provide sufficient vibration isolation of low-frequency noise. In addition, some water pipe from pumps were fastened with plastic supports and other were fastened with rubber clamps, but it was rigid connected the concrete walls. Vibration transmission from water pipes to the apartment was identified.

High pressure pumps were vibration isolated with polyurethane material, type Sylomer SR220 with thickness 12.5 mm. Regarding pipes, some were fastened with anti-vibration clamps and other were changed with hosepipes and it was disconnected from the building walls.

5.4 Washing room

The car wash has two vertical washing brushes, one horizontal washing brush, and two-wheel brushes on the sides. Figure 6 shows the brushes with yellow arrows. Each brush is connected to a motor that run at 1400 rpm (23.3 Hz).

The space between sandwich element and concrete floor was approximately 20 mm. Such as, it was not possible to improve vertical sound reduction. Sound computation was done with the software for room acoustics, ODEON. As mitigation measure, the ceiling and approximately 50 % of the wall inside washing room were covered with absorber plate, sound absorption class A, type Loke^{TM} strong 40 mm.

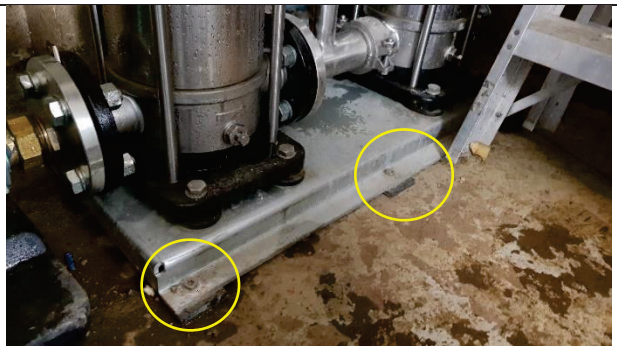
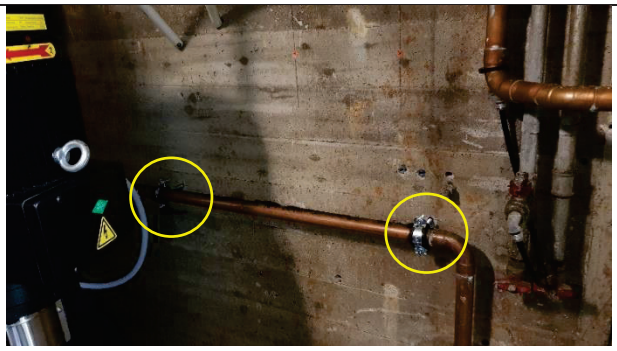
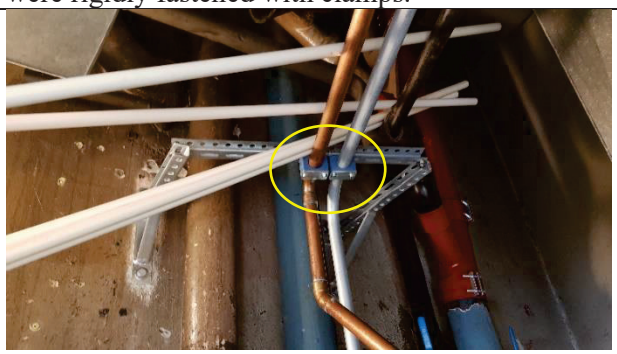
Figure 6: Washing room

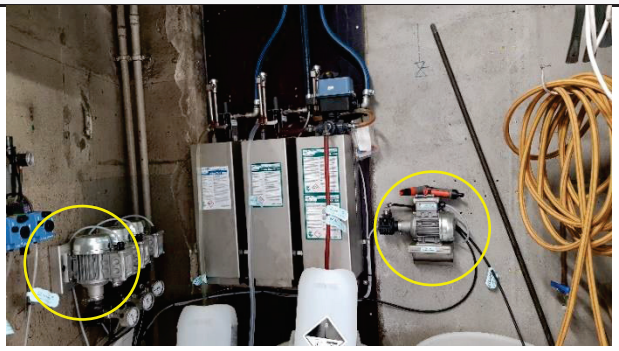
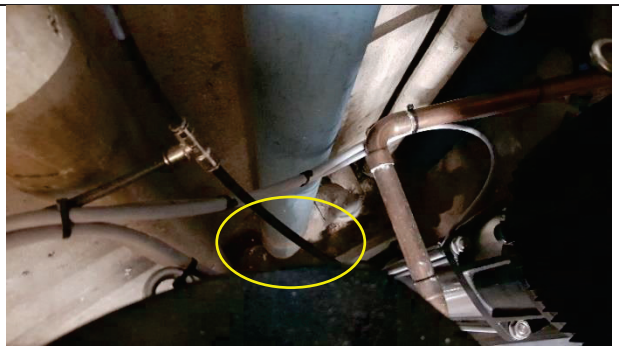
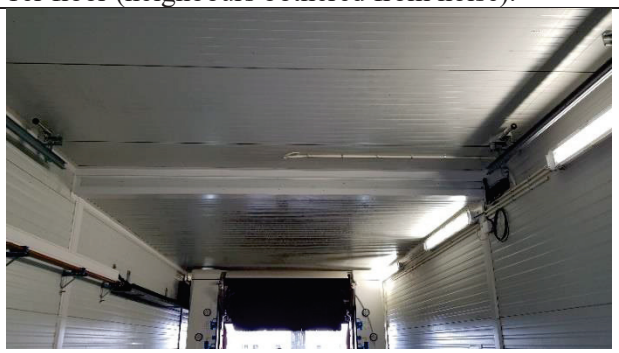
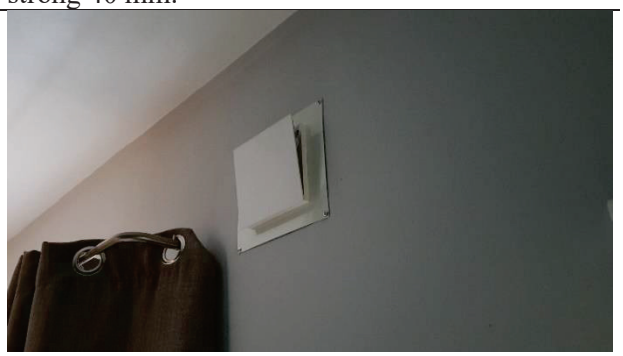
5.5 Exhaust ventilation duct

There was an exhaust ventilation duct located close to the sandwich elements in the technical room. This was used to extract air in the ground before the car wash was installed. It was checked whether the duct was connected to the vents in the bedroom in plan 1. After some studies, it was found that the air extraction in the building was changed to mechanical from the roof. Thus, the ventilation duct was cut and sealed with acoustic panels.

Table 2 shows a resume of mitigation measures.

Table 2: Resume of mitigation measures

#	Situation BEFORE measures	Situation AFTER measures
1		
	The car wash gate had sound leaks around.	Sound leaks were sealed with elastic rubber, but there is still a small leak on the corner.
2		
	High-pressure pumps were screwed to the foundation plate with neoprene vibration isolators.	High pressure pumps were vibration isolated with polyurethane material, type Sylomer SR 220, thickness 12.5 mm.
3		
	Water pipes connected to high-pressure pumps were rigidly fastened with clamps.	The copper tubing was remplaced with hosepipes and it was disconnected from the building walls.
4		
	Water pipes connected to high-pressure pumps were attached with plastic.	The copper tubing was vibration-insulated with rubber.

#	Situation BEFORE measures	Situation AFTER measures
5	 Small pumps for flushing chemicals were not vibration insulated.	 Small pumps for flushing chemicals were vibration-insulated with rubber material.
6	 Several drainpipes from the building were embedded to the technical room and go up to the 1er floor (neighbours bothered from noise).	No measures were taken on drainage pipes due to high-pressure pumps and their pipes were isolated.
7	 The car wash is built with sandwich element of Promisol 100 mm.	 Ceiling and walls in the washing room and technical room were covered with sound absorbing plate, sound absorption class A, type Loke™ strong 40 mm.
8	 Two fresh air vents in the bedroom on the façade were not soundproofed.	 It was changed ventilation air vents with soundproofed vents, type FRESH TL80DE.

#	Situation BEFORE measures	Situation AFTER measures
9	 There was a ventilation duct in the technical room which was connected to exhaust air system in the bedroom (plan 1).	 The ventilation duct was cut and sealed with acoustic panels.
10	There was also a duct for the heat exchanger in the technical room. This was not in use.	 The heat exchanger was cut and sealed with acoustic panels.

6 Results - noise levels

The results from the sound measurements are summarized in Table 3. The table presents the noise level for different washing prosses. The results in the table are corrected for background noise according to measurement standard ISO 16032:2004. The background noise level was measured to $L_{p,A,T}$ = 23-24 dB.

Table 3: Results for measurements in the apartment, plan 1 (corrected for background noise according to ISO 16032).

Washing prosses	Sound limit, $L_{p,A,T}$	Initial noise levels $L_{p,A,T}$	Noise levels, $L_{p,A,T}$, after mitigation measures	Comments
Degreasing	≤ 25 dB	29 dB	25 dB	The noise level for five washing processes satisfies the sound requirement after mitigation measure. The noise from drying and wheel washing is barely audible, and it has a deviation of 2 dB.
Wheel washing + polishing		28 dB	27 dB	
High pressure flushing		30 dB	25 dB	
Extra flushing		31 dB	24 dB	
Washing with brushes + wheel wash		31 dB	24 dB	
New round with 3 brushes + extra polishing		28 dB	25 dB	
Drying		30 dB	27 dB	

Before mitigation measures, the noise level in the washing room was measured to $L_{p,A,T}$ = 83–93 dB, and after measures it was measure to $L_{p,A,T}$ = 80–85 dB.

7 Conclusions

Measurement results show that implemented measures had a good effect. Noise level in apartment on plan 1 was reduced 1-7 dB.

Noise level for almost all washing processes is below the noise requirement now. There are still sound leaks on the corner of the gate, and this may be the reason why the noise level is 2 dB above the requirement.

The noise levels were compared with the relevant Room Criteria curves (RC curves) [7] to detect any interfering components. The measurement results show that the noise from the car wash does not contain disturbing sound components after mitigation measures.

Before measures, noise was measured when washing two cars, a small car, and a van. The noise level for the van was somewhat lower for several washing processes.

Acknowledgements

Acknowledgements to Brekke Strand Akustikk to support in this work.

References

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[6] Technical Committee ISO/TC 43. *Acoustic- Field measurement of sound insulation in buildings and of building elements, part 1: Airborne sound isolation*. European Standard ISO 16283-1, February 2014.

[7] ANSI S12.2:1995. *Criteria for evaluating room noise.* Acoustical Society of America.