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PERCEPTION OF RESIDENTS ON ACOUSTICALLY IMPROVED FAÇADE

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Since 2010, a program of projects has been undertaken to study the sound insulation offered by existing dwelling facades on more than two thousands properties subject to railway noise. These projects are part of the French government's environmental scheme. The overall aim is to provide noise mitigation measures to dwellings identified as Noise Sensitive Receivers (NSRs) due to their proximity to the railway. The objectives are to improve the acoustic comfort of the residential properties not only against the current noise environment but also against the anticipated increase of railway usage as an alternative to road transport. The treatment of these NSRs consists of upgrading the façade insulation of the buildings, including replacement of existing windows and ventilation systems. The project is fully funded by ADEME (80%) and SNCF Réseau (20%) The improvement of the insulation of each facade has been tested acoustically and the results have been previously published, but the subjective perception by the residents has not yet been quantified. This paper studies this perception and compares it with the acoustic improvement of the façade insulation. As a first step, the acoustic improvement of the façades is detailed. A noise reduction varying between 30 dB and 47 dB could be reached with these modifications. Subjective perception is then evaluated by the residents at least one year after the improvement, using a questionnaire.

Keywords: building acoustics, perception, façade insulation

1. Introduction

In the last 30 years, societal needs of mobility and commerce exchange have led to an increase of traffic movements. At the same time, traffic noise exposure has been growing and it is of interest to study noise pollution. In 2000, the European Parliament and Council adopted European Noise Directive 2002/49/EC relating to the assessment and management of environmental noise [1].

In 2001, French Departmental monitoring of noise generated by land transport infrastructures began. This work includes the identification of noise sensitive receivers (NSR), and deciding upon noise protection measures proposed by infrastructure managers. The government has made available to the Agency for Environment and Energy (ADEME) a national funding allocation for the treatment of NSRs. The "Circulaire du 25 Mai 2004" [2] addressing the funding of these measures to assess and treat NSRs (railway noise) was supplemented by an agreement signed on the 1st December 2009 between ADEME and SNCF Réseau. This agreement provides funding for insulating the façades of noise-sensitive buildings, supported 80% by ADEME and 20% by RFF/ SNCF Réseau.

A social survey realised in 1996 by Lambert et al. [3] gave guidance for noise exposure (levels of annoyance) for residents. As a result of this survey it might be possible to define noise exposure limits, and to infer appropriate timetabling for trains. In 2012, Pening et al. [4] showed that general annoyance, and the frequency of sleep disturbance, can increase significantly with the total number of trains and freight trains per night, but non-significantly with the equivalent A-weighted sound pressure level. However they explained that they had a small sample size to get clear tendencies on annoyance and sleep disturbance because of trains. In a more recent study [5], overall train noise and vibration have been taken into account and compared with other previous works. It showed that there exists a relationship between vibrations and railway noise in annoyance perception. At night, disturbance seems to be higher than during the day.

Several works highlight that all kinds of transportation may affect rest and sleep. Some studies considered that annoyance from railway noise is lower than other transportation noise. However, in a laboratory study, Kim [6] discussed this point, and suggested that more detailed investigations for various types of vehicle should be done in different environments. Road, rail, and aircraft traffic noise cause similar after-effects, but physiological sleep parameters are most severely affected by rail noise [7]. It has been confirmed too that awakenings during sleep were produced more frequently by freight trains than by passenger or automotive trains. Whatever the age, both macro- and microstructure of sleep are disturbed by such trains, compared with other trains under the same maximum level and the same patterns during the night [8]. Being permanently exposed to nocturnal railway noise leads to decreased sleep fragmentation and to cardiovascular habituation [9].

All these studies are clear evidences that inhabitants are affected by trains. Particularly, those who live close to railway lines. According to the noise maps produced in the context of these projects, over 3500 houses could take advantage of an acoustic improvement of their building to reduce railway noise pollution. Improvements in the acoustic and thermal insulation of these properties has already be published [10], but the subjective perception of the inhabitants has not yet been quantified.

This paper presents a survey which evaluates the perception of annoyance and sound comfort of the residents that benefitted from this insulation improvement. This survey was a 5-point scale questionnaire according to ISO 15666 [11]. The perception results will be compared with the previous insulation improvement.

2. Façades sound insulation improvement

Each property linked to this study has been visited by an acoustician. During this visit, a survey of the geometry (walls, roofs…) of the exposed façade has been carried out and a plan of the property has been drawn. The sources of acoustic weakness such as windows, doors and trickle vents were examined. Following this survey, a report was prepared and remedial work for improving the sound insulation of the exposed façade was detailed where necessary.

2.1 Simulation of the existing façade sound insulation

In order to evaluate the sound insulation of the existing façade, the software ISOLAC has been developed by collaboration between Edinburgh Napier University and ENSIM, University of Maine, France. This software uses the calculation methodology defined in the Standard ISO 12354-3 [12], which allows determination of the sound insulation of the façade (D_{Atr}) based on the acoustic performance of each component, on the geometry of the façade, and on the receiver room.

2.2 Measurement of the façade sound insulation after remedial work

Acoustic testing was undertaken for each NSR property following completion of the building works to verify their conformity to the regulatory targets. Acoustical testing was performed in accordance with French standard NF EN ISO 10052 [13]. The results of the measurements are shown in Figure 1.

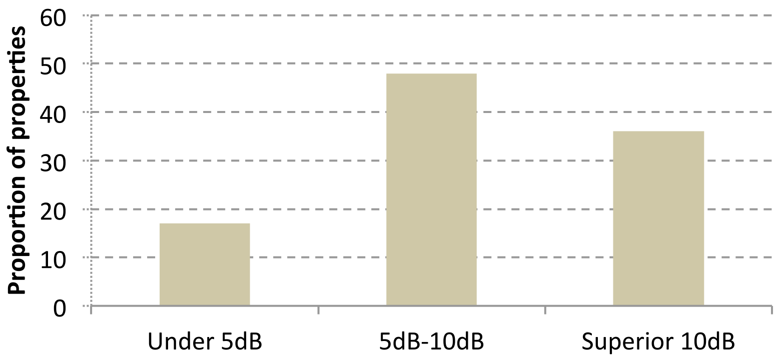

Figure 1: Proportion of properties in the study that achieved the noted sound insulation improvements (the three bars sum to 100%).

3. Survey on the improvement

3.1 Questionnaire and rating scale

A survey has been carried out in order to quantify the perception of the sound insulation improvement by the residents, one year after the upgrading work was tested and shown to meet the required standards. It was conducted by telephone with individual residents who have benefitted from an improvement in the sound insulation of their façade. The participants were first asked about their age, gender, hearing loss, and general noise sensitivity. Before being asked specifically about train annoyance, they had to inform the survey about any external sources of noise they could hear whilst at home with the windows closed. Annoyance evaluations were made with a questionnaire according to ISO 15666 [11]. A 5-point scale from “not at all” to “extremely” have been used and translated into French. Even if the acoustic improvement of the home has been done mainly to reduce train noise, the subjects had to evaluate annoyance, before and after treatment, of the following noise sources: Passenger Train, Freight Train, Road Traffic, Neighbourhood, Factories, and Street. This last item makes reference to the noise produced by people talking or walking in the street.

At first they were asked: “Thinking about the previous months before your acoustic treatment, when you were at home, how much did noise from each of these sources of noise annoy you?”. They had to evaluate in another 5-point scale the disturbance due to these sources of noise when they were: Reading, Watching the TV, Sleeping, Talking by telephone, and Interpersonal talking within the home. They had to inform the survey whether they could see the railway from their home. Then, they had to again evaluate annoyance due to noise, but now in the present day. They were asked the following question: “Thinking about the last months since you received the acoustic treatment, when you are at home, how much does noise from each of these noise sources annoy you?”. At the end of the test, participants were asked to inform the survey whether they were satisfied, overall, with the acoustic treatment, and if they considered that they had benefited from some acoustical or thermal improvement.

3.2 Participants

Twenty-four subjects were evaluated in this work (12 female and 12 male) from 46 to 84 years old. The mean age was 69.3 with a standard deviation of 11.9. Surprisingly, only 25% of the participants noted that they had hearing losses.

3.3 Results

Noise sensitivity of the participants follow a normal distribution using a one-sample Kolmogorov-Smirnov test as illustrated in Figure 2.

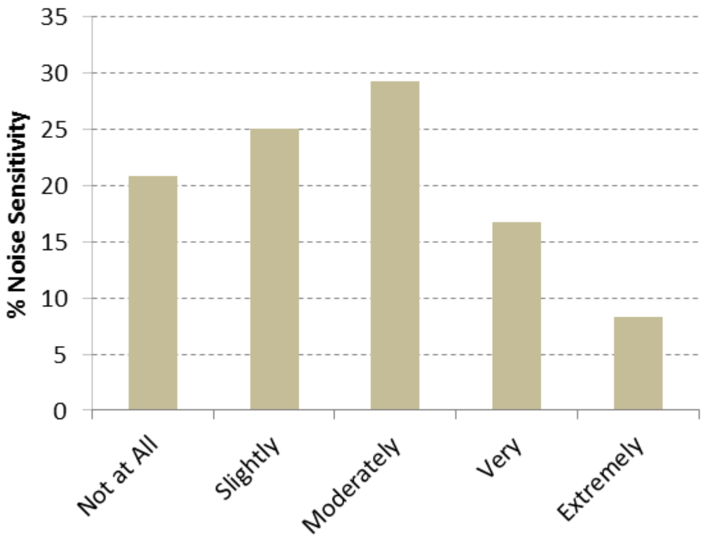

Figure 2: Percentage distribution of self assessed general sensitivity to noise of participants.

For each parameter evaluated the data were tested for normality using a one-sample Kolmogorov-Smirnov test. Annoyance from all the sources of noise follow a normal distribution between subjects showing no significant deviation from normality with $p > 0.05$. Figure 3 shows the comparison of annoyance before and after the treatment with a range of confidence of 95%. Noises from trains (passengers and freight trains) are show the greatest reduction in annoyance.

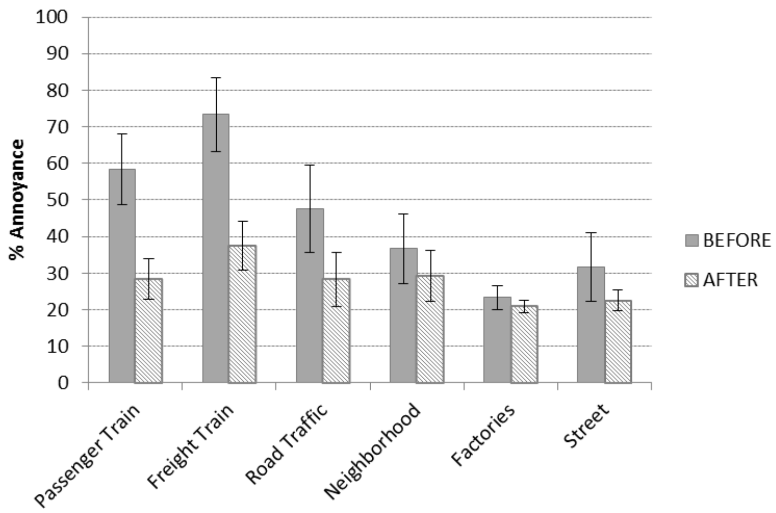

Figure 3: Percentage of the annoyance of the different sources of noise before and after treatment

For the freight train noise, the correlation between the insulation improvements evaluated in dB and the absolute difference, between the subjective evaluation before and after the treatment, were calculated. A relatively slight correlation of 0.49 with a significance level of $p < 0.05$ was obtained.

From all the home activities, watching TV was the most disturbed activity before the acoustic treatment as it is shown in Figure 4.

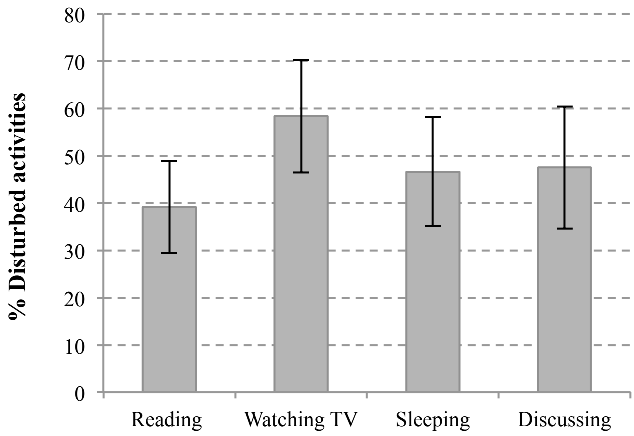

Figure 4: Percentage of the disturbance of the subjects activities.

Even if 96% of the participants can see the railway from their home, 92% of the inhabitants considered that the treatment was satisfactory. 74% of them considered that they had benefitted in some way from acoustical and thermal improvements.

4. Discussion

Improvements to the façades were carried out mostly to reduce the annoyance of freight train noise. The subjective test showed a reduction in the acoustic annoyance. A slight correlation has been obtained between the annoyance reduction and the improvement of sound insulation per resident. It is mostly due to the ordinal 5-point scale and to the relatively small number of subjects used for the subjective test.

A plot of the change in perceived annoyance before and after façade improvements versus the objective level of the sound insulation improvement measured, is shown in Figure 5.

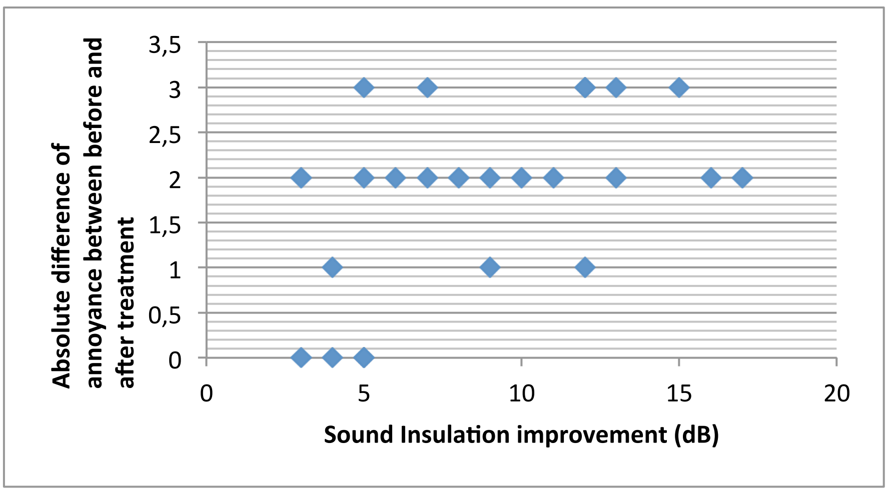

Figure 5 : Difference in level of annoyance regarding freight train noise before and after sound insulation improvement

The results from this pilot survey are not conclusive; more people need to be surveyed. We can simply highlight that the results would be influenced by the following factors. In South of France, people need to open the windows from May until September because the high heat level, which will potentially limit the positive impact of sound insulation upgrade of the façade. Also people who received a higher sound insulation improvement are much closer to the railway line and therefore can also feel the vibration.

This survey has been undertaken as a test to prepare the methodology, and many more residents will be questioned during the next few months. Finally, it is interesting to note that many of the participants do not appear to be aware of potential hearing loss from which they may be suffering. This might be considered a little surprising, due to the average age of the participants. The possible role such potential hearing loss might play in this kind of subjective survey seems worthy of further investigation.

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