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The influence of speed bumps on perceived annoyance

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Recently, several attempts to use speed bumps as a noise reduction method have been made. Objective analyses of the effect of speed bumps on noise have been shown to result in a rather small reduction of noise. In the present paper the influence of speed bumps on perceived annoyance is investigated. The annoyance rating of a situation in which a passenger car approaches with constant velocity, then decelerates, crosses the bump, accelerates, and then recedes at a constant speed was compared with a car pass-by at a constant velocity without a bump. Three different velocities were analyzed: 40, 50 and 60 km/h, and two types of driving conditions: normal, and aggressive. Listeners judged their annoyance for all the investigated scenarios using the ICBEN scale (0-10) for annoyance assessment. Objective analyses showed a significant reduction of L_{AeqT} in the bump situation for all tested velocities, and for both driving conditions. The results of this psychoacoustic experiment show no effect of the bump on annoyance rating for normal driving conditions. However, in aggressive driving conditions the bump resulted in a significant increase in annoyance. In the light of these results, speed bumps cannot be considered as a noise reduction method.

1 Introduction

Objective analyses of the effect of speed bumps on noise have already been performed in several studies [1-3] and speed bumps have been shown to result in a rather small reduction of noise. Speed reductions are a way of reducing traffic noise, providing that the necessary measures do not lead to an increase in accelerations and decelerations. On the street with speed bumps there is a situation in which a passenger car approaches with constant velocity, then decelerates, crosses the bump, accelerates and then recedes at constant speed. The effectiveness of the speed bumps can be expressed as the difference between the noise levels generated by the car in these two different situations: a car passing-by on the street, with and without bump. It is known from the literature that this difference is in the range from 0.4dB [4] to 5dB [5] for light cars and is negative for heavy trucks. On the other hand, a different driving pattern - normal versus aggressive - may lead to an increase in noise level of about 6 dB(A) [6].

In most of the cited studies, the effectiveness of speed bumps is expressed in noise reduction value, in dB. However, even in case of light cars and low speed, where reduction of noise level is the highest, there is a comment that "in spite of the measured decreases in noise levels, annoyance from traffic noise increased significantly, and many respondents to the questionnaire survey perceived increases in traffic noise when indoors at home" on page 25 [7]. This means that reduction measured objectively is not the same as noise reduction perceived by people. Is there an objective noise indicator other than L_{AeqT} or L_{AE} that better corresponds with public reaction to noise?

In the present paper the influence of speed bumps on perceived annoyance is investigated. Three different velocities are analyzed: 40, 50 and 60 km/h, and two types of driving conditions: normal, and aggressive. Listeners judged their annoyance for all the investigated scenarios using the ICBEN scale (0-10) for annoyance assessment. Objective noise characteristics calculated for car noise generated in two experimental situations – with and without a bump – are compared to the subjective assessment of noise annoyance ratings.

2 Method

2.1 Stimuli

Binaurally recorded passenger car noises were used as stimuli in an psychoacoustic experiment. The noises were recorded simultaneously with two Neumann KU100 dummy heads and a Fostex hard disc recorder, with a sampling frequency of 48 kHz and 24 bits resolution. One dummy head was placed at 1.5m over the ground in the middle of the bump – 7.5m from the center of the closer lane. A second dummy head was at the same height and distance from the road, but was displaced 200m to the left. This second head was used to record only the motion with constant speed whereas the first head was used to record motion around the bump.

The duration of each stimulus was 10 seconds. The test stimuli was a pass-by recorded on the first dummy head (in front of the bump), where the car passed the head in the middle of the stimuli (5 second). The test stimuli consisted of constant speed, deceleration, a bump crossing, acceleration and constant speed – the same as before the acceleration. The reference stimuli were recorded on a second head – and consisted of part of a car pass-by with constant speed – before the bump. The car also always passed the head in the middle of the stimulus' duration (5 second). The stimuli setup is presented in Fig. 1.

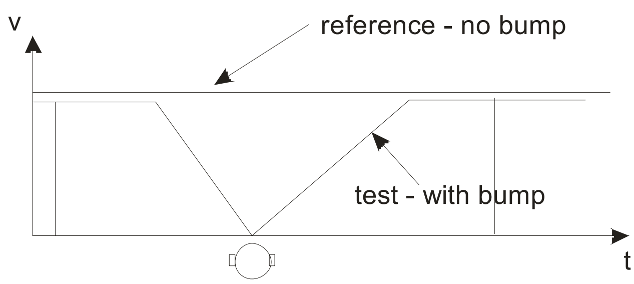

Fig.1 Experimental setup.

The type of speed bump used in the experiment is presented in Fig. 2.

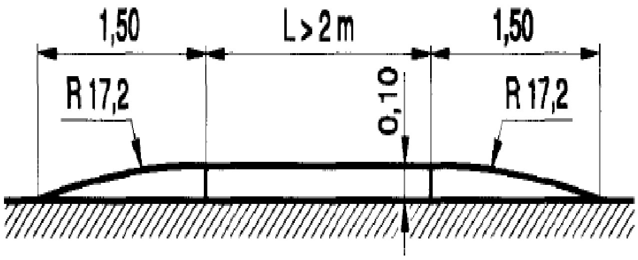

Fig.2 The size of the speed bump

The stimuli used in the experiment were recorded at three different velocities: 40, 50 and 60 km/h. Additionally, each test stimulus (for the velocities 50 and 60 km/h) appears in two versions, with respect to the driving conditions. In the first – the pass-by over the speed-bump which is designated as normal driving – consisted of typical deceleration and acceleration behaviour. The second driving conditions – designated as aggressive - consisted of dynamic deceleration and dynamic acceleration. The aggressive condition was not taken into account for the lowest velocity – since it was not possibility for dynamic deceleration and acceleration. A total of 8 different stimuli were used: 3 – reference, 3 test stimuli with normal driving conditions, and 2 test stimuli with aggressive driving conditions.

2.2 Participants

Fourteen listeners, 5 women and 9 men, participated in the pychoacoustic experiment. The listeners were 23 to 28 years old. All were students of the Faculty of Physics, Adam Mickiewicz University. All the listeners qualified as having normal hearing (normal hearing was defined as the audiometric threshold of 20 dB HL or better for the frequency range from 250 to 8000 Hz).

2.3 Procedure

The stimuli were presented in random order. The participants judged the annoyance caused by each stimulus using an 11 point (0-10) number scale that is recommended for noise surveys by ICBEN [8]. The subjects were given the following instruction: *What number from 0 to 10 shows best how much are you bothered, disturbed, or annoyed by the noise? If you are not at all annoyed, choose 0, if you are extremely annoyed, choose 10, if you are somewhere in between, choose a number from 1 to 9.*

3 Results

3.1 Objective analysis

An objective analysis of all the stimuli was performed with the help of Artemis software. Three different acoustical characteristics of these stimuli are presented in Table 1 and in Figs. 3, 4, 5. These are: the A-weighted equivalent sound pressure level, average loudness N, and a percentile value of loudness N5. As can be seen from the value of L_{AeqT}, N and N5 in Table 1, the speed bump reduces the noise expressed in sound level (Fig. 3) and in N5 (Fig. 5). When the noise is described as an average loudness there in no noise reduction for aggressive driving conditions.

v [km/h]	bump	driving condition	L [dB(A)]	N [sone]	N5 [sone]
40	no	normal	55.2	8.5	14.36
	yes	normal	52.0	8	10.5
50	no	normal	58.4	9.95	18.6
	yes	normal	54.2	9.14	13.84
		aggressive	56.4	10.5	16.72
60	no	normal	59.2	9.77	19.8
	yes	normal	54.7	9.56	12.76
		aggressive	56.3	10.5	16.11

Table 1 Acoustical characteristics of the stimuli

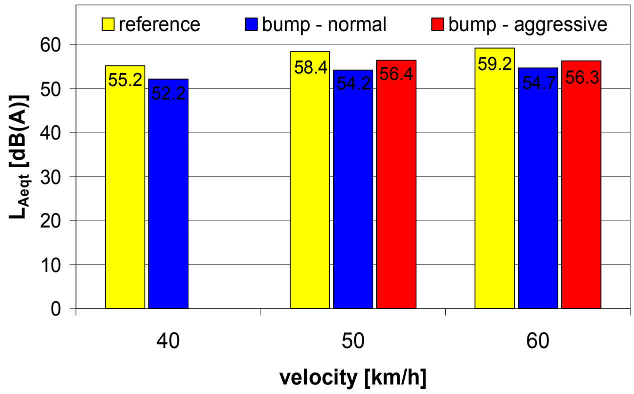

Fig. 3 L_{AeqT} calculated for 3 reference stimuli, 3 test stimuli with normal driving conditions, and 2 test stimuli with aggressive driving conditions.

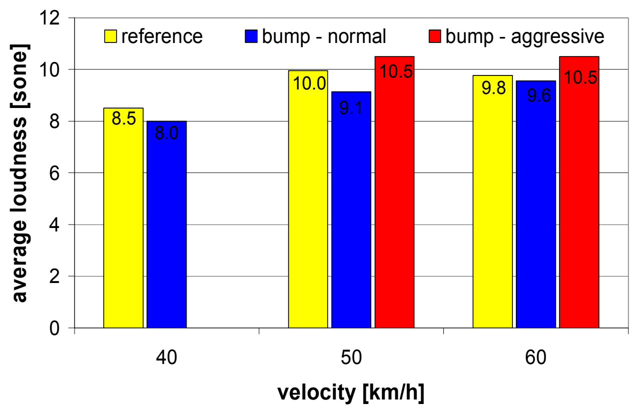

Fig. 4 An averaged loudness, N, calculated for 3 reference stimuli, 3 test stimuli with normal driving conditions, and 2 test stimuli with aggressive driving conditions.

Both noise indexes - L_{AeqT} and an averaged loudness - are “averaged over time” indexes. However, there is a difference between them. L_{AeqT} is an approximated measure of loudness (because of the A-curve correction) while the loudness N is the correctly calculated averaged loudness (according to the Zwicker’s model of loudness). One could say that in the N index all frequency components are taken into account in the computation model while in the L_{AeqT}

index the low frequency components are underestimated (by the A curve correction). In contrast, the percentile loudness N5 is related to the peak value of the noise signal.

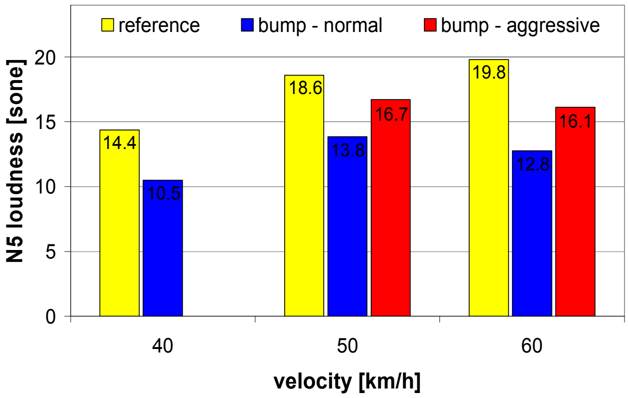

Fig. 5 The percentile loudness, N5, calculated for 3 reference stimuli, 3 test stimuli with normal driving conditions, and 2 test stimuli with aggressive driving conditions.

3.2 Subjective analysis

The data from the 30 measurements for each stimulus were averaged for each listener. The annoyance ratings averaged over all participants are plotted in Figure 6.

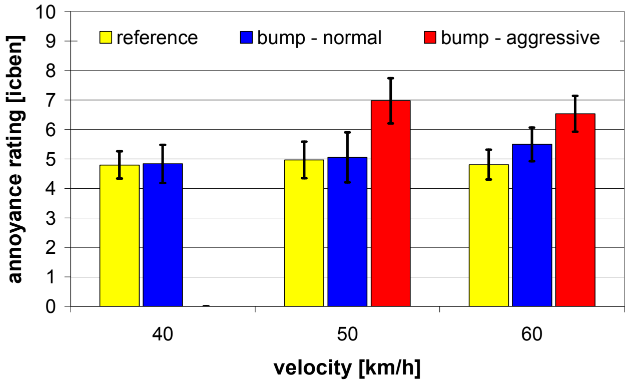

Fig. 6 Averaged over 14 subjects annoyance ratings calculated for 3 reference stimuli, 3 test stimuli with normal driving conditions, and 2 test stimuli with aggressive driving conditions.

It is clear from Fig.6 that there is no difference in the annoyance ratings between the situation where a car is passing-by on a street with a bump or without a bump, while driving in normal conditions. In aggressive driving conditions the speed bump generates a noise that is perceived as more annoying than the noise generated without a speed bump. This means that noise reduction expressed as the difference in noise level is not perceived by the subjects as a reduction in the level of noise annoyance .
Comparing the results of the objective and subjective analysis one could say that among the three tested noise indexes: the average loudness N, the percentile loudness N5 and the A- weighted sound pressure level, the average loudness best resembles the results of the subjective analysis. Moreover L_{AeqT} is not a good measure of noise annoyance.
If there is a need to predict the possible reaction of people to a given noise it is much better to consider the averaged loudness than L_{Aeqt} as a noise index.

4 Conclusion

In the light of these results, speed bumps cannot be considered as a noise reduction method. The averaged loudness, N, better corresponds with public reaction to noise than L_{AeqT} and N5.

Acknowledgments

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