7th AAAA Congress
on Sound and Vibration
22-23 September 2016, Ljubljana, Slovenia

Slovenian Acoustical Society

Effect of traffic calming measures on ground-borne vibrations in residential areas - the Slovenian experiences

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ABSTRACT

Based on the fact that no rules of design the main roads through the urban areas exist in Slovenia, such infrastructures were built on the criteria of relevant capacity (normally wide and narrow multi or single lane roads). With the goal to guarantee the quality of life and traffic safety (decrease of average speed in urban areas) traffic calming measures were needed. In most cases in urban areas speed humps and platforms were installed, which effectively slow down the speed, but on the other hand massive increase ground-borne vibrations, produced by vehicles passing over these "road irregularities".

In many countries, such devices have been the subject of careful investigations (in order to assess their effectiveness and doubtfulness) and this has resulted in a number of modifications (improvements) in the design to improve their performance. On the contrary, no systematic studies have been carried out for speed humps and platforms in residential areas in Slovenia.

The paper presents the results of measurements of ground borne vibrations caused by a variety of speed humps (various forms, sizes and materials) which are used in Slovenia. Based on the results of experiment guidance for the improvement of the existing traffic calming measures will be prepared.

1. INTRODUCTION

Road humps and platforms are commonly used by local authorities in Slovenia at sensitive road locations as a means of reducing vehicle speeds and increase traffic safety. On the other hand, this measures, massive increase ground-borne vibrations, produced by vehicles passing over and cause problems for residents living close to affected roads. Experts are facing a problem of how to design road humps and platforms to find a compromise between effective speed reductions and less ground-borne vibrations.

In this paper we have focused on and analysed two different traffic calming measures which were installed in residential areas: road humps and platforms.

2. TRAFFIC CAUSED GROUND BORNE VIBRATIONS

Ground-borne vibrations caused by traffic are a common concern of society, because they very often cause problems to individuals and structures [1]. Vibrations caused by traffic represent an external source and result from heavy traffic caused by buses and trucks. Cars and light trucks rarely cause vibrations that are discernible in buildings [2]. Road transport usually causes vibration frequency in the range between 5 and 25 Hz and a speed variation of soil from 0.05 to 25 mm/s [3]. Vibrations caused by road traffic are generated if a vehicle strikes an irregularity in the road surface, such as:

- Humps and platforms for traffic calming.
- Construction irregularities.
- Dilatations.
- Drainage covers.
- A very rough road surface.

All these are intentionally constructed to improve traffic safety and the functionality of road infrastructure. Vibrations are also caused by damaged road surfaces. Vibration characteristics depend mostly on [4]:

- A vehicles' suspension systems.
- The allowed speed and weight of vehicles.

3. EXPERIMENTAL METHOD

Test cases

A total of four cases were selected for the study and the dimensions are given in Table 1.

Table 1. Dimensions of the test cases

Case number	Type of traffic calming	Dimensions (mm)			
		Width	Length	Height	Distance of the measur. point
1	Platform trapezoid shape	6000	10000	120	700
2	Hump trapezoid shape	2500	4600	70	600
3	Hump sinusoid shape	600	3200	60	800
4	Concrete hump	600	4200	60	900

The specifications for first three cases were representative of designs which are common use on the public roads, because there are in accordance with the Slovenian technical guidelines. The fourth one is not in accordance with the guidelines, but this is a common phenomenon on local roads in Slovenia.

Figure 1. The case of road hump in sinusoid shape

Vehicle selection and operation

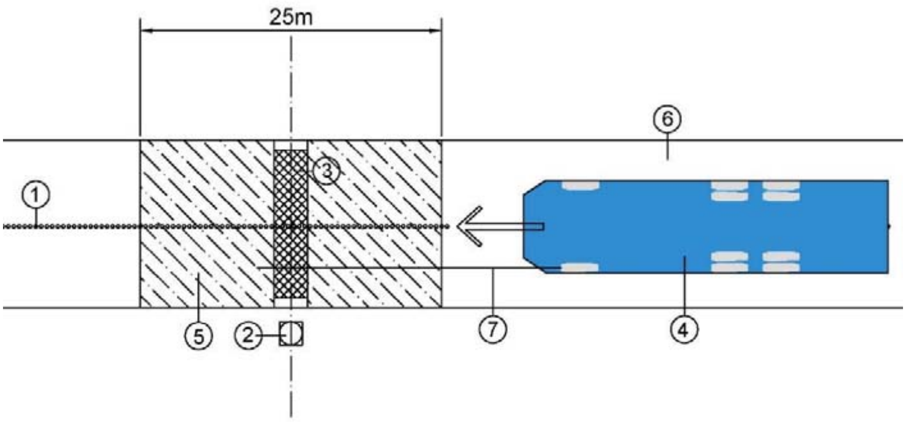
Two test heavy vehicles were selected for which we known the weight and the travel speed (30 km/h) when they pass the test cases.

Table 2. Test heavy vehicles

Picture	Model	Gross vehicle weight - GVW [kg]	No. of axles
	MAN TGS 33.440	16.000	3
	MAN TGA 26.430	15.000	3

Measurement instrumentation

For measurements of ground vibration velocity has been used measuring equipment manufacturer Instantel. Figure 2 shows the layout of one test site.



1 - Middle of the test site

2 - Triaxle geophone

3 - Road hump

4 - Test vehicle

5 - Measurement range

6 - Test case

7 - Tyre movement direction

Figure 2. Layout of one test site

Vibrations were measured with geophones at two locations. One was placed close to the road hump and the second one on the basic wall of the closest building.

4. ACQUIRED DATA

With the described measurement equipment ground borne vibrations near the road hump and at the basic wall of the building were measured. We measured Peak Particle Velocity (PPV) in all three orthogonal directions including maximum frequency.

Typical peak vibration levels in the radial and transversal direction were small in comparison with vertical levels. Consequently, only the PPV in the vertical direction were considered for further analysis.

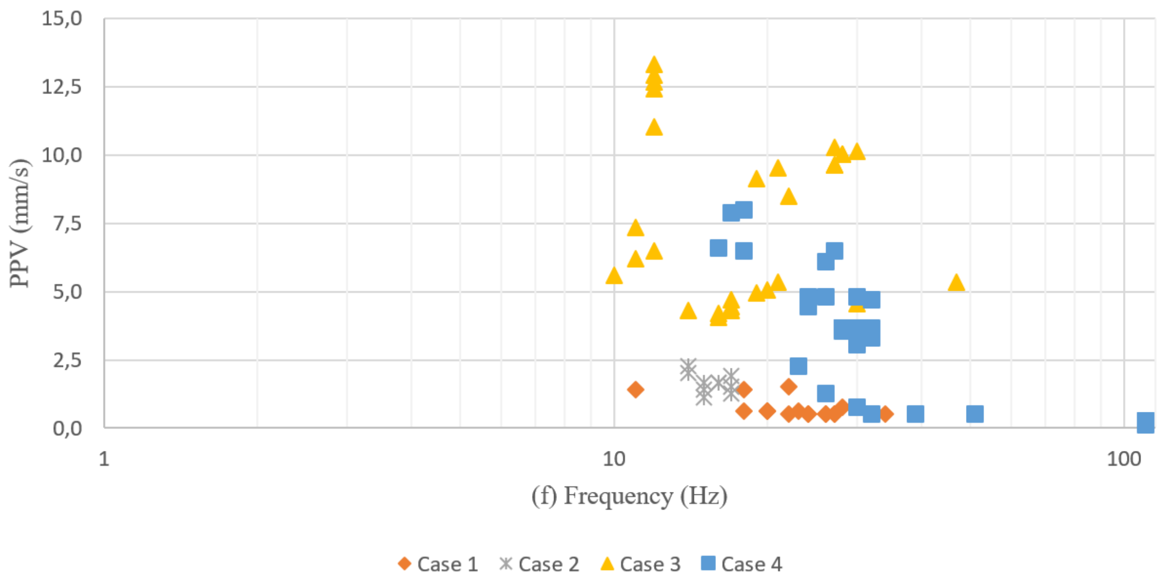


Figure 3. Results of vibration measurements near the traffic calming cases

Generally the highest level of vibrations were measured at the case 3 (hump sinusoid shape). Values of PPV ranged from 4 to 13 mm/s, with frequencies from 10 to 47 Hz. The second highest level of vibrations were measured at the case 4 (concrete hump) with values from 0.1 to 8 mm/s and frequencies from 17 to 110 Hz. The third highest PPV were measured at the case 2 (hump trapezoid shape) with values from 0.2 to 2.2 mm/hand frequency from 14 to 110 Hz. The smallest vibrations were caused from the case 1 (platform trapezoid shape) with values from 0.5 to 1.5 mm/s and frequencies from 11 to 34 Hz.

5. ASSESSMENT OF GROUND –BORNE VIBRATIONS

The measurements carried out in presented paper are compared with values obtained by a predicting model proposed by Watts [5]. The model takes into account the maximus height or depth of localized surface defect over which the vehicle passes, the speed of the vehicle and the distance between the moving vehicle and the measuring point. The model is expressed as:

$$PPV = 0.028 \cdot a \cdot (v/48) \cdot t \cdot p \cdot (r/6)^{x}. \quad (1)$$

where PPV = the peak particle velocity (mm/s), a = the maximum height or depth of a localized surface defect (mm), v = the measured speed of a vehicle (km/h), t = the coefficient of soil supporting a roadway structure, p = the wheel index, which is over 0.75 for heavy vehicles when one wheel crosses a damaged spot, or 1 in other cases, r = the distance between the measuring point and the moving vehicle. The value of the exponent x determines damping of vibrations and it depends on the site and the distance. Both values (t and x) are presented in the table. The results of the effect of vibrations caused by heavy trucks are given with the graph in Figure 4.

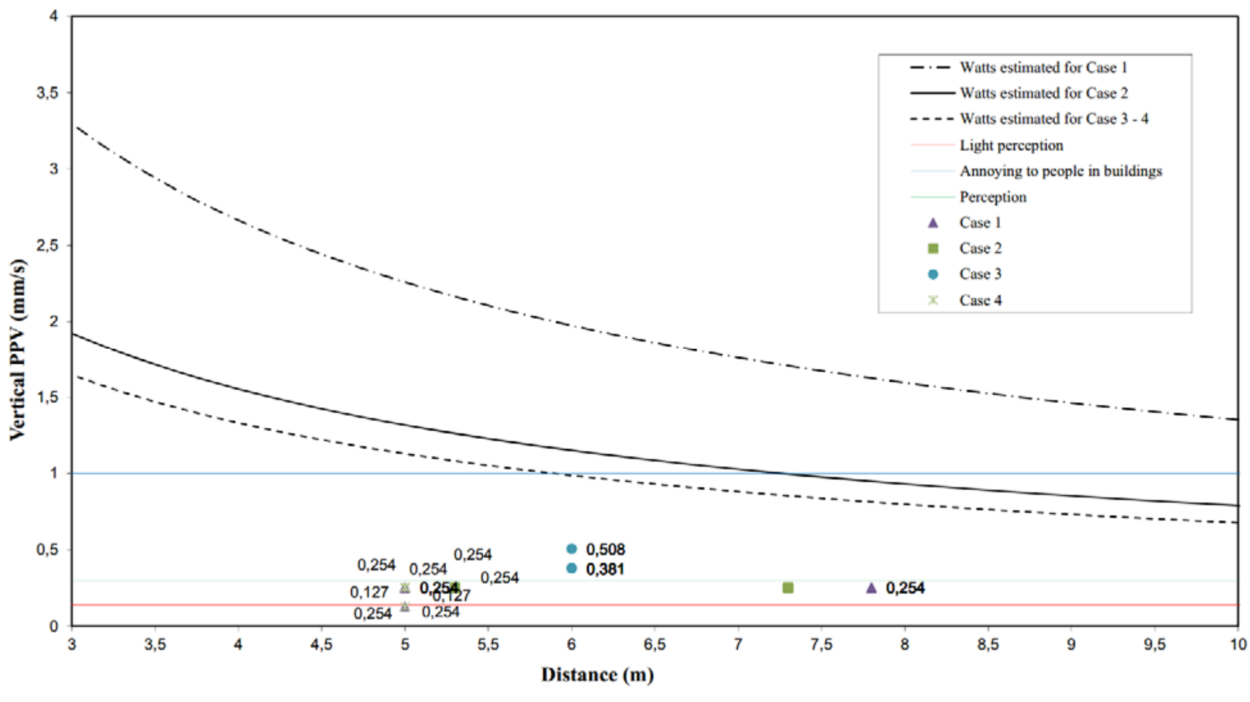


Figure 4. Measured and estimated values of PPV (for all cases)

The ground-borne vibrations caused by heavy trucks passed the speed hump sinusoid shape (case 3) are inside the values of human possibility of perception.

The ground-borne vibrations caused by heavy trucks passed the speed hump trapezoid shape and speed platform (case 2 and 1) and concrete hump (case 4) are above the limit value of human possibility of perception [6].

All measured values of vibration velocity are not above the prediction model.

6. CONCLUSIONS

The results of this study show that traffic calming measures like speed humps and platforms can produce perceptible levels of ground-borne vibration.

In urban areas this can lead to complaints from residents who live near these measures.

The study showed the nature and scale of the problem and highlights the need to careful investigations of traffic calming measures for residential areas in Slovenia.

7. REFERENCES

[1] Crispino, M., D'Apuzzo, M., Measurement and prediction of traffic induced vibrations in a heritage building, *Journal of Sound and Vibration*, 246 (2), 319-335, (2001).

[2] Watts, G. R., Case studies of the effects of traffic induced vibrations on heritage building, *TRL Reports & Publications,* (1988).

[3] Hunaidi, O. (2000). Traffic Vibration in Buildings, *Construction Technology Update*, 39, National Research Council of Canada. [Online.] available: https://www.nrc-cnrc.gc.ca/ctu-sc/files/doc/ctu-sc/ctu-n39_eng.pdf

[4] Lubej, S., Ivanič, A., Toplak, S., Lep, M., Ivanovski, I., Heritage masonry buildings and impact of heavy freight vehicle traffic via motorway and highway, *Proceedings of the 8th International Conference on Logistics & Sustainable Transport,* Celje, Slovenia, 14-16 June (2011).

[5] Watts, G.R., Krylov V.V., Ground-borne vibration generated by vehicles crossing road humps and speed control cushions, *Applied Acoustics*, 59, 221-236, (2000).

6] DIN 4150-2, Structural vibrations – Part 2: Human exposure to vibration in buildings, *German Standard*, (1999).