



Road humps and ground-borne vibrations

Introduction

The Driver Information and Traffic Management Division commissioned the Transport Research Laboratory (TRL) to carry out track trials to assess the effect which road humps (including speed cushions) might have in generating ground-borne vibrations when commercial vehicles are driven over them. The intention was to generate advice to local authorities, to help avoid the creation of possible nuisances. Measures of vibrations were made for a wide range of vehicle types crossing a selection of road humps, and the results were used to estimate the likely effects when placed on various soil types.

This leaflet summarises the investigations carried out and the results. More detailed information can be found in TRL Report 235, "Traffic Calming: Vehicle Generated Ground-borne Vibrations alongside Speed Control Cushions and Road Humps", which can be purchased from TRL.



Background

Vehicle generated ground-borne vibration is produced by reaction-forces imparted as a vehicle's wheels pass over discontinuities, such as

road humps, on the road surface. The highest levels of vibration are generated by heavy vehicles. Traffic vibration is a common source of nuisance; most of the nuisance results from low frequency noise emitted principally by large commercial vehicles. However, in some cases the problem has been thought to be due to ground-borne vibration, which was the subject of this study.

Ground-borne vibration diminishes as it radiates from its source. The firmer the soil in the vicinity, the more localised will be the vibration effects.

The TRL Trial

Eleven vehicle types were used, selected from three categories: light vehicle; buses and large commercial vehicles. The vehicles ranged from a passenger car, through single and double decker buses and a midi bus, to rigid and articulated goods vehicles. The two rigid vehicles had gross vehicle weights (GVW) of 7.5t and 17t, and the articulated vehicles had GVW of 32.5t and 38t. The 38t vehicle was fitted with steel leaf suspension, and the 32.5t vehicle with air suspension.

Generally the commercial vehicles were tested in both laden and unladen conditions. Special attention was to be given to whether an unladen vehicle with a steel leaf suspension axle generated more vibration than a laden one. This was thought possible, as in the unladen state the wheels can lose contact with the road surface as they run over the top of the road hump. The wheels of a laden vehicle were more likely to remain in contact with the road.

It was also considered important to establish whether ground-borne vibration was influenced by overall vehicle weight or by individual axle weight. If individual axle weight were a notable factor, a 17t two axle vehicle might cause higher levels of vibration than some multi-axle 38t vehicles.

The following types of road humps were tested:



Speed cushion installed at test site



A round top hump 65mm high



A flat top hump 75mm high



A "thump" (short hump) above the recommended height for this feature at around 75mm high, was used to examine the effect of a harsh profile on vibration generation

Objective

The objective was to determine the likely levels of vehicle generated ground-borne vibration alongside each of the road humps tested, for a range of different soil conditions. A prediction model had been developed by TRL as a result of previous studies (TRRL Report 246). With a scaling factor applied, it would enable the results from the trial to be used to predict ground vibrations for various soil types.

Results

As with previous studies, it was found that there was a tendency for vibrations to increase with increases in speed. For a given crossing speed the 74mm high "thump" generated the highest levels of vibration recorded during the study. The long flat top road hump also had high vibration levels relative to the other road hump types, though much lower than the "thump". The narrowest cushions gave results similar to each other, causing the least generation of vibration.

The side ramp gradients of the wider speed cushions also appeared to influence the level of vibration generated. The steeper the ramp, the higher the vehicles will ride over the cushion, and the greater the vibration.

In terms of commercial vehicle performance, for steel leaf suspension the vibration levels were much higher when the vehicles were unladen. However, in the case of a laden commercial vehicle with air suspension it was found that vibration levels were equivalent to, or higher than the levels measured when the vehicle was unladen. Multi-axle vehicles also tended to produce higher vibration levels than two axle vehicles, even though the axle load for the latter was greater in some cases.

Based on typical crossing speeds, for the various road hump types the longer wider cushions with the steepest side ramps (1:3) gave the highest maximum and mean vibration levels for commercial vehicles, followed by the long flap top hump. The round top hump gave the lowest maximum and mean vibration levels for commercial vehicles. Vehicles with GVW over 7.5t were found to generate the highest levels of ground-borne vibration.

For buses, the flat top road hump gave the highest maximum and mean vibration levels. The round top hump was next highest. The short (2m) length, 1.9m wide speed cushion with 1:4 side ramp gradients gave the lowest maximum and mean vibration levels.

British Standard 7385: Part 2 provides guide threshold values of vibration exposure which may give rise to minor cosmetic damage to buildings. The threshold relates to very minor damage such as the formation of hairline cracks on plaster finishes or in mortar joints and the speed of existing cracks. These values were used to calculate minimum distances which it would be desirable for road humps to be sited from dwellings, according to soil types (Table 1). Predictions have also been made of minimum distances within which sustained vibration exposure may cause superficial hairline cracks that might often go unnoticed. At lower levels of vibration exposure the table shows minimum distances required to avoid ground-borne vibration that would be perceptible or might give rise to complaint. These latter minimum distances were predicted based on a review of literature available. It can be seen that even very minor hairline cracking should not occur unless the road humps are placed less than 4m from a dwelling for even the softest soil. However, it is quite possible that the effects of a commercial vehicle crossing a road hump could, on these soft soils, be sensed up to 76m away. It is highly unlikely that any road hump will result in structural damage occurring to neighbouring buildings.

Design Guidance

Table 1 can be used as an initial guide, where similar hump designs are to be installed. This has particular relevance in trying to avoid locating road humps within distances where, because of the soil type, complaints regarding ground vibrations might arise. However, soil types locally can vary

considerably. If the soil is layered, significant differences to the results in the table could occur. If there is any doubt, it is recommended that measurements should be carried out to verify the predictions. The maximum likely vibrations can be gauged by driving a heavy vehicle over a temporary profile. Any measurements should only be undertaken by persons skilled in the technique and in the interpretation of results.

Narrow cushions (1.5m - 1.6m wide) generally produce the least vibrations for a given crossing speed relative to other profiles. However, this may be counteracted by the fact that crossing speeds for narrow cushions are typically greater than crossing speeds for other road hump types.

Care should also be taken that cushions are placed so that they are likely to be straddled by the axles of heavy vehicles; when only one set of wheels encountered narrow cushions, the measured vibration levels were approximately double those when the vehicle straddled the cushion. This factor is not covered in Table 1.

The slope of the leading ramp of a road hump can also have an effect on ground vibrations. For this reason it is recommended that ramp gradients for speed cushions and flat top humps should not exceed those generally advised (see Traffic Advisory Leaflet 7/96 and Traffic Advisory Leaflet 2/96). For speed cushions this is 1:8, and for flat top road humps, 1:10. In certain cases, where for example commercial vehicles make up more than 8% of the total flow, it may be appropriate to adopt even shallower gradients. In these cases it may also be appropriate only to consider the use of the narrower cushions. Such cushions have been used on the A49 at Craven Arms in Shropshire (see TRL Report 212).

Those vehicles with the greatest GVWs tend to generate the higher levels of vibration. Therefore, if the circumstances are appropriate, consideration might be given to imposing an axle weight limit of 7.5t, in order to limit possible ground vibrations being generated.

Because of the very high level of vibrations generated by the 75mm high "thump" it is strongly recommended that if "thumps" are used for traffic calming purposes in proximity to buildings they should not be higher than 40mm. A maximum height of 50mm is already recommended for this feature in Traffic Advisory Leaflet 7/94.

TABLE 1 - PREDICTED MINIMUM DISTANCES BETWEEN ROAD HUMPS AND DWELLINGS TO AVOID VIBRATION EXPOSURE (Metres)

	Level of Perception							Complaint							Superficial cracks from sustained exposure							Minor damage (BS7385)						
Hump Type	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
Alluvium	56	40	76	41	45	57	37	12	9	17	9	10	12	8	3	2	4	2	2	3	2	<1	<1	1	<1	<1	<1	<1
Peat	16	13	19	13	14	16	12	6	5	7	5	5	6	4	2	2	3	2	2	2	2	<1	<1	1	<1	<1	<1	<1
London clay	15	11	18	12	12	15	11	5	4	6	4	4	5	3	2	1	2	1	1	2	1	<1	<1	<1	<1	<1	<1	<1
Sand/gravel	4	3	6	3	3	4	3	1	1	1	1	1	1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	
Boulder clay	2	1	3	2	1	2	1	1	<1	1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	
Chalk rock	1	<1	1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	

A=Cushion; length 2m, width 1.9m, height 0.74m, side ramp 1:4, leading ramp 1:8

B=Cushion; length 3.5m, width 1.9m, height 0.71m, side ramp 1:4, leading ramp 1:8.5

C=Cushion; length 3.5m, width 1.9m, height 0.72m, side ramp 1:3, leading ramp 1:7.7

D=Cushion; length 3.5m, width 1.6m, height 0.64m, side ramp 1:3.8, leading ramp 1:7.5

E=Cushion; length 3.5m, width 1.5m, height 0.65m, side ramp 1:3.7, leading ramp 1:7.4

F=Flat top hump; length 7.8m, height 0.73m, leading ramp 1:12

G=Round top hump; length 3.7, height 0.64m

Enquiries

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References

- TRL Report 235 - Traffic calming: Vehicle Generated Ground-borne Vibration alongside Speed Control Cushions and Road Humps
- British Standard 7385: part 2:1993. Evaluation and Measurement for Vibration in Buildings: Part 2 - Guide to Damage Levels from Ground-borne Vibration

- TRRL Research Report 246 - Traffic Induced Vibrations in Buildings
- Traffic Advisory Leaflet 7/96 - Highways (Road Humps) Regulations 1996
- Traffic Advisory Leaflet 4/94 - Speed Cushions
- Traffic Advisory Leaflet 2/96 - 75mm high road humps
- Traffic Advisory Leaflet 7/94 - "Thumps" Thermoplastic road humps
- Traffic Advisory Leaflet 3/91 - Speed Control Humps: Scotland, England & Wales
- TRL Report 180 - Traffic calming: vehicle noise emissions alongside speed control cushions and road humps
- TRL Report 212 - Traffic calming on major roads: the A49 trunk road at Craven Arms, Shropshire

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