



Road humps: discomfort, noise, and ground-borne vibration

Introduction

Acceptance of road humps schemes depends in part on whether traffic speeds are reduced. However, it is also influenced by the degree of discomfort to vehicle occupants, and the effect the road humps may have on traffic noise and ground-borne vibrations. Bus operators, for example, have considerable concerns about the effects that their passengers and drivers may experience. Residents of streets where road humps are installed will wish to be assured that any traffic noise or ground-borne vibrations generated are not going to amount to a nuisance.

The Transport Research Laboratory (TRL) was commissioned by the Department of the Environment, Transport and the Regions (DETR) to investigate the effects on discomfort, noise and ground-borne vibrations of sinusoidal profile road humps, in comparison with flat-top and

round-top road humps. This was done by means of trials conducted on a test track.

This leaflet provides only a summary of the trials undertaken and the results obtained. The results, along with other details from the trials, are reported more fully in TRL Reports 416 and 417. These reports should be consulted if there is uncertainty over any matters mentioned in this leaflet.

The trials

Hump profiles. The dimensions of the profiles chosen for evaluation are shown in Table 1. The five hump profiles used in the trials included three profiles not commonly used: a 3.7m long sinusoidal profile, a 5m long round-top profile and an 8m long flat-top with sinusoidal ramps. Two standard profiles were included for comparison: a 3.7m long round-top profile and an 8m long flat-top hump with straight ramps. All the hump profiles were 75 mm high.

Table 1: Profile dimensions

TABLE 1 PROFILE DIMENSIONS					
PROFILE	LENGTH (M)	MAX. HEIGHT (MM)	PLATEAU LENGTH (M)	RAMP GRADIENT	DETAIL OF PROFILE
Sinusoidal	3.7	75	n/a	n/a	
Round-top	3.7	75	n/a	n/a	
Round-top	5.0	75	n/a	n/a	
Flat-top with sinusoidal ramps	8.0	75	6.0	n/a	
Flat-top with straight ramps	8.0	75	6.0	1:13	

Vehicles tested. A range of vehicles was used in the trials to assess discomfort, noise and ground borne vibrations. These included five different bicycle types, a small, medium and large car, five different buses, including a low floor bus, three different goods vehicles with steel or air suspension, a fire appliance and three different ambulances.

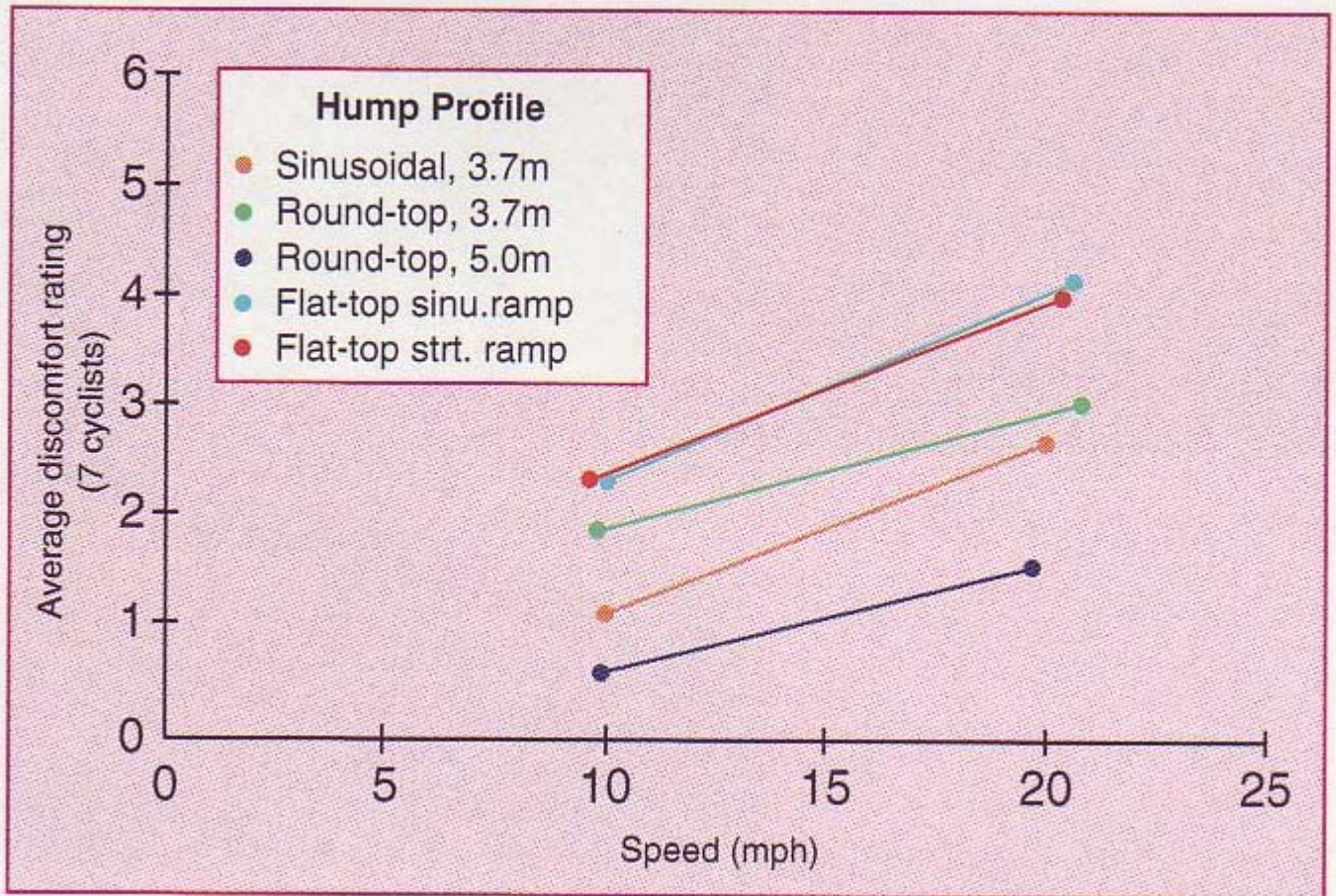


Figure 1 Unladen cyclists

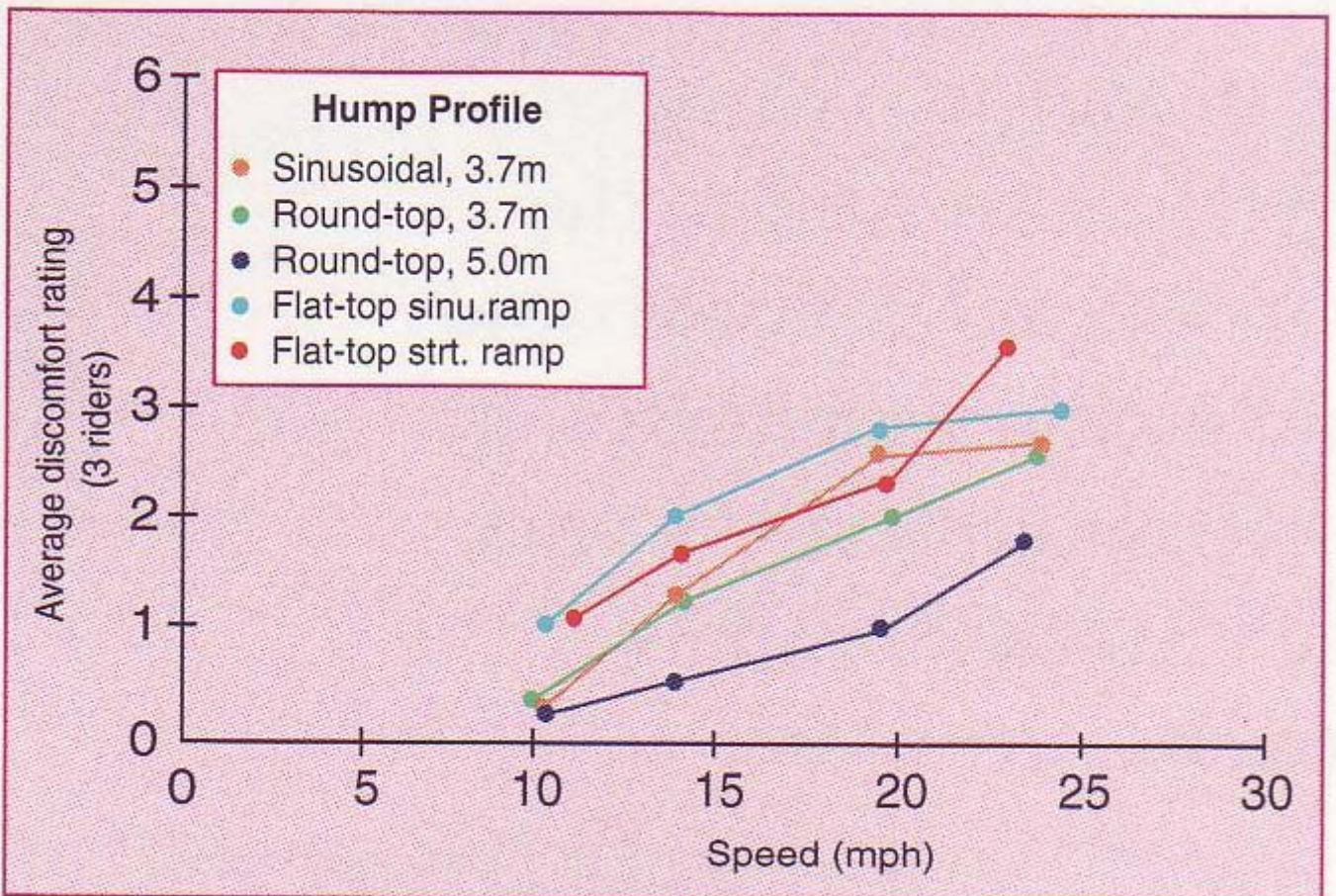


Figure 2 Motorcycles - combined results from small, medium and large motor cycles

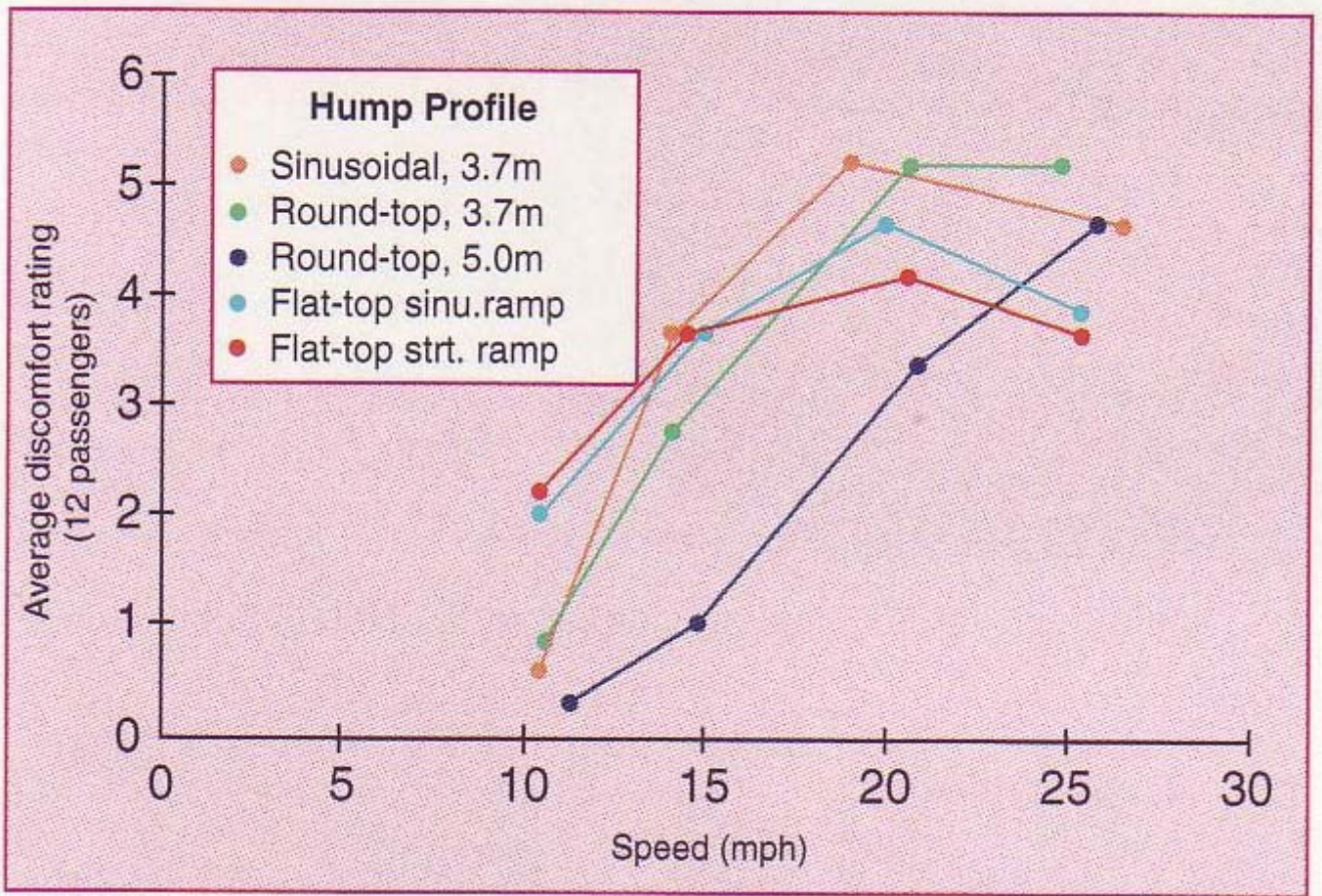


Figure 3 Minibus (Optare City Pacer all passengers sitting)

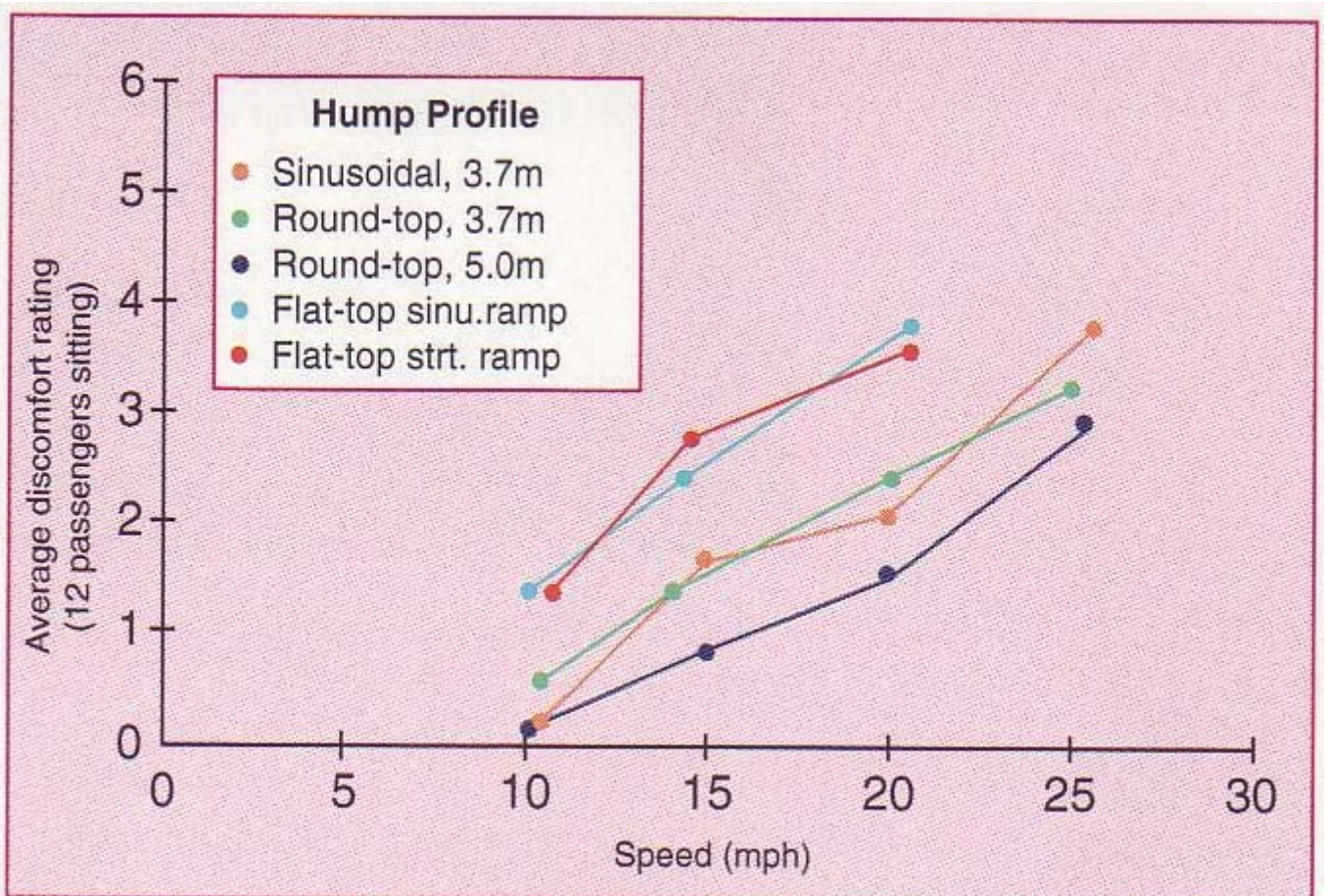


Figure 4 Large single-deck bus (Optare Low Rider - Low floor bus)

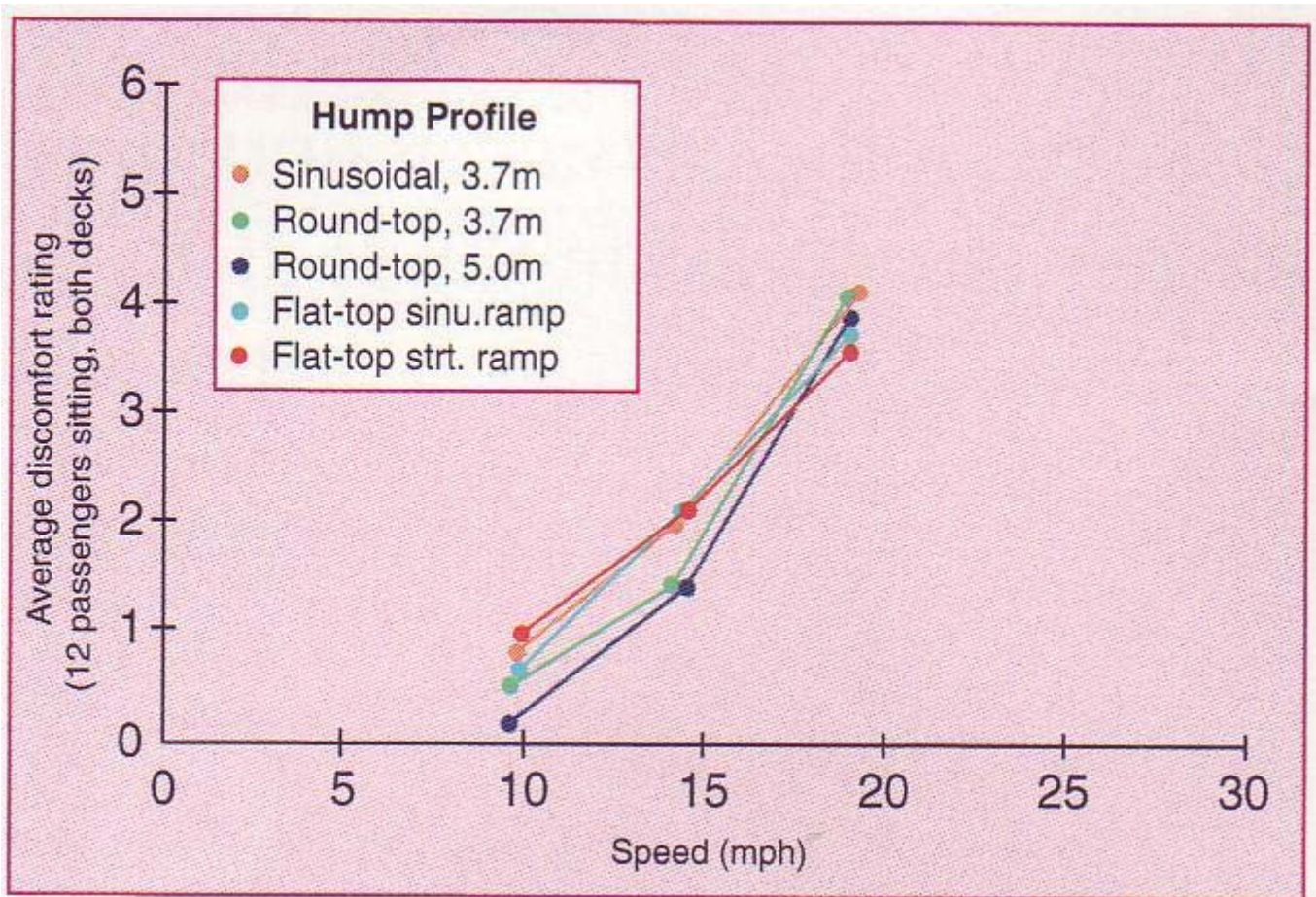


Figure 5 Double-deck bus (Optare Spectra)

Assessment of discomfort

For cyclists, motor cyclists and all occupants of cars, buses, goods vehicles and emergency service vehicles, a subjective assessment of discomfort (DR) was made on a scale 0 to 6. A discomfort rating of "0" means comfortable, and "6" very uncomfortable. Additionally, for all but cyclists and motor cyclists, an accelerometer was used. For each of the tests, this measured the vertical acceleration experienced by one occupant in every vehicle.

Cyclists. In promoting an increase in cycling it is important that, as far as possible, cyclists are offered a comfortable ride. Figure 1 shows the average discomfort ratings for unladen cyclists crossing the various hump profiles at 10 mph and 20 mph. Similar results were found for laden cyclists (5kg load).

It can be seen from Figure 1 that cyclists experienced the most discomfort when crossing the flat-top humps and that the 5m long round-top profile gave the least discomfort. This profile also gave the least discomfort to the car occupants but its use would be likely to result in higher car speeds than with the other hump profiles. For humps of a similar length (3.7m), the sinusoidal hump was more comfortable for the cyclists than the round-top profile (but see also the Summary)

Motor cyclists. Stability and comfort are important to motorcyclists, but where motorcyclists report discomfort crossing road humps, this may be due to inappropriate speeds. The tests were made using carefully controlled speeds, judged to be appropriate to the circumstances. Average discomfort ratings (DR) for motorcyclists are shown in Figure 2.

For motor cyclists, there was less difference in the discomfort experienced between the hump profiles than for the cyclists. However, the 5m round-top hump was clearly the most comfortable and the flat-top humps were the most uncomfortable.

Buses. The average discomfort rating experienced by passengers sitting in a minibus, a low floor single deck bus and a double-deck bus is shown in Figures 3, 4 and 5. These illustrate how a small change in speed can lead to a large increase in discomfort, particularly in minibuses and double-deck buses. There

was less variation in the discomfort experienced when crossing the different profiles in the double-deck bus than for other bus types. For all three bus types at speeds of 15 mph or less, passengers generally experienced less discomfort with the round-top and sinusoidal profiles than with the flat-top profiles. At speeds above 15 mph, general levels of discomfort were unacceptable for all the profiles tested.

Low floor buses are of particular interest, as it has been claimed that these vehicles are more susceptible to grounding when passing over road humps. In fact, the clearance of low floor buses above the carriageway was found to be very similar to that for other buses. The main problem would seem to occur where there is a greater overhang at the front and/or rear of the vehicle. With the bus used (Optare lowrider) the track trials did not reveal any grounding problems with the 75mm height humps used, although the driver declined to cross the flat-top profiles at 25 mph because of concern about possible damage. As pointed out above, this speed would generally be considered unsuitable in terms of the discomfort likely to be experienced.

Noise

Traffic Advisory Leaflet 6/96 describes the method of measurement used and is not repeated here.

Light vehicles. For the passenger cars tested, the differences in the maximum A-weighted noise levels generated alongside the different profiles were relatively small, and were not likely to be of practical significance. Noise levels when crossing humps generally increased as the speed increased, and tended to be slightly less than that measured on a level surface. For light vehicles, maximum noise levels would not be expected to increase as a result of installing any of the profiles tested.

Double deck bus. The double deck bus also showed a general increase in the maximum noise level with increasing speed. There were differences, with the sinusoidal profile giving lower noise levels than the non-sinusoidal profiles.

The highest noise levels were measured alongside the flat-top (straight ramp) profile. All the profiles gave lower noise levels at typical crossing speeds than measurements taken next to the level surface, where speeds were higher.

Large Goods vehicles. At typical crossing speeds, the noise levels for goods vehicles tested were highest alongside the flat-top profiles. The noise levels for sinusoidal profiles were slightly lower than their non-sinusoidal equivalents. The 5m long round-top profile was similar to the 3.7m round-top profile with respect to noise generation.

Large goods vehicles may have either air or steel spring suspension. The maximum noise levels generated along the hump profiles by the 38t articulated tipper vehicle with steel spring suspension were higher than the equivalent vehicle with air suspension.

For air suspension vehicles, the unladen state generated higher noise levels than the laden state, for all the profiles tested. For steel spring suspension vehicles, the difference between the laden and unladen states was less distinct: the sinusoidal profiles generated higher noise levels for the laden vehicle, and the 5m round-top profile and the flat-top profiles resulted in higher noise levels for the unladen vehicle.

Ground-borne vibration

Levels of ground-borne vibration generated by light vehicles showed no distinct difference alongside the different profiles. For the double-deck bus, the highest vibration level obtained at typical crossing speeds was for the flat-top (straight ramp) profile. For heavy goods vehicles, the highest mean and maximum ground-borne vibration levels at typical crossing speeds were also at the flat-top (straight ramp) profile. The flat-top (sinusoidal ramps) was slightly less, and the round-top and sinusoidal profiles had significantly lower levels. Higher levels of vibration were noted for the heavy goods vehicles running unladen, than when loaded.

Guidance as to the predicted minimum distances that road humps could be placed to avoid occupants of residential properties being exposed to vibration is given in TA Leaflet 8/96. Table 2 is an update of the

previous advice, adding information relating to minimum distances for sinusoidal humps, 5m long round-top humps and flat-top humps with sinusoidal ramps.

Table 2: Predicted minimum (m) distance between road humps and dwellings to avoid vibration exposure

TABLE 2 PREDICTED MINIMUM (m) DISTANCE BETWEEN ROAD HUMPS AND DWELLINGS TO AVOID VIBRATION EXPOSURE																				
Hump type	LEVEL OF PERCEPTION					COMPLAINT					SUPERFICIAL CRACKS FROM SUSTAINED EXPOSURE					MINOR DAMAGE (BS7385)				
	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e
Alluvium	31	32	34	46	53	7	7	7	10	12	2	2	2	2	3	<1	<1	<1	<1	<1
Peat	12	12	13	16	17	4	4	5	6	6	2	2	2	2	2	<1	<1	<1	<1	<1
London clay	10	10	11	14	15	3	3	4	4	5	1	1	1	2	2	<1	<1	<1	<1	<1
Sand/gravel	2	2	2	3	4	<1	<1	<1	1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Boulder clay	1	1	1	2	2	<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

(In Table 2, all humps are 75mm high: a = sinusoidal 3.7m long hump; b = round-top 3.7m long hump; c = round-top 5m long hump; d = flat-top (sinusoidal ramps) 8m long hump; and e = flat-top (straight ramps, 1:13) 8m long hump)

Analysis

Sinusoidal hump

This profile gave less discomfort to cyclists than the standard round top hump, though the difference was not large. There was also a slight benefit in reduced discomfort to car passengers, but little, if any, to motor cyclists, bus passengers, and commercial vehicle and emergency service vehicle occupants. Speed reductions are likely to be similar to those for 3.7m long round-top humps. At typical crossing speeds, the maximum noise and ground-borne vibration levels generated by commercial vehicles are likely to be slightly less than for round-top humps. For buses there may be higher ground-borne vibration than with round-top humps, though lower maximum noise levels. Whilst the sinusoidal profile offers an advantage to cyclists, the additional difficulty and cost in achieving the correct shape needs to be taken into account. Another factor in alleviating discomfort to cyclists is to avoid having any vertical upstand or other discontinuities, regardless of profile type.

Flat-top hump with sinusoidal ramps

There was little, if any, benefit in terms of discomfort to any of the vehicle occupants in the use of the flat-top hump with sinusoidal ramps, when compared to the flat-top hump with straight ramps. However, the maximum noise and ground-borne vibration levels generated by buses and heavy goods vehicles are likely to be less than with the flat-top hump with straight ramps. Both flat-top hump designs gave the most discomfort to cyclists and therefore neither is recommended along routes used by a substantial number of cyclists. If raised crossings need to be included along such routes, then consideration should be given to the use of H or S humps that have shallower outer ramps (TAL 9/98).

Round-top hump, 5m long

This profile generally gave the lowest values of discomfort for motor cyclists and car occupants. At speeds of 10 to 15 mph it gave the lowest values of discomfort for bus passengers and occupants of fire appliances and ambulances. The speed at which the humps are crossed will determine the level of discomfort. Because the discomfort that can be experienced crossing this type of hump is less, it is likely that mean car crossing speeds would be higher (about 20 to 25mph) than those at round-top humps, 3.7m long (about 15 mph). Round-top humps 5m long might be appropriate where maximum speeds of around 30 mph, rather than 20 mph, were desirable. Maximum noise and ground-borne vibrations generated by buses and heavy goods vehicles will be similar to those for round top humps 3.7m long.

Round-top hump, 3.7m long.

This round-top profile, when compared to the flat-top hump with straight ramps, gave lower values of discomfort for cyclists, motor cyclists and car passengers. Between 10 mph and 15 mph, the round-top profile also gave lower values of discomfort for occupants of motor cycle/side car combinations, bus passengers, goods vehicle drivers, and fire crew and ambulance occupants. At speeds between 15 mph and 20 mph, the round top profile gave similar or higher values of discomfort.

Flat-top road hump with straight ramps

Above 20 mph the discomfort experienced by car occupants increased more rapidly for the flat top-hump than for the round-top hump. It may be of benefit to use flat-top humps where significant numbers of car drivers adopt excessive speeds. However, a general use of this type of flat-top hump to control car speeds to below 20 mph would increase discomfort to cyclists and, at speeds below 15 mph would increase discomfort to bus passengers and occupants of ambulances. The use of this type of flat-top hump instead of round-top humps would also increase noise and ground-borne vibrations generated by buses and goods vehicles. On bus routes, therefore, it would be more appropriate to use speed cushions or perhaps H or S humps, as these would give less delay and discomfort.

All road humps tested

The track trials have shown that when buses are crossing road humps, the discomfort experienced by bus passengers can increase substantially as speeds increase from 15 mph towards 20 mph. To minimise discomfort, bus operators should consider adopting an operational speed of 15 mph or less when crossing road humps.

Advice & technical enquiries

TM Division, Department of Transport, 2/06 Great Minster House, 76 Marsham Street, London SW1P 4DR. Tel: 020 7944 2974

References

TRL Report 417: Traffic Calming: Passenger and rider discomfort at sinusoidal, round-top and flat-top road humps - track trial at TRL

TRL Report 416: Traffic Calming: Vehicle generated noise and ground-born vibration alongside sinusoidal, round-top and flat-top humps.

TRL Report 32: Speed Control Humps - A trial at TRL

TRL Report 180: Traffic Calming: vehicle noise emissions alongside speed control cushions and road humps

TRL Report 235: Traffic Calming: Vehicle generated ground-borne vibration alongside speed control cushions and road humps.

Traffic Advisory Leaflet 3/94 Fire and ambulance services traffic calming: A code of practice.

Traffic advisory Leaflet 6/96 Traffic calming: traffic and vehicle noise

Traffic Advisory Leaflet 1/98 Speed cushion schemes

Traffic Advisory Leaflet 9/98 Sinusoidal, H and S road humps

Highways (Road Humps) Regulations 1999, SI 1999
No 1025

The Road Humps and Traffic Calming (Scotland)
Regulations 1999, SI 1999 No 1000 (S.70)

The Road Humps (Scotland) Regulations 1998, SI
1998 No 1448 (S.74)

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