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PROJECT REPORT 18

ROAD HUMPS FOR CONTROLLING VEHICLE SPEEDS

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CONTENTS

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EXECUTIVE SUMMARY

1. INTRODUCTION

The term 'traffic calming' has rapidly become familiar over the past few years and interest in road engineering schemes has increased greatly. Many schemes have been installed in Great Britain to improve road safety and enhance the environment, by using various road engineering measures. It is important that schemes form part of an area-wide Urban Safety Management Strategy which ensures that only suitable traffic uses each type of road. The treatment of single roads should be avoided. It is also important that access, particularly for the emergency services and public transport, is considered at an early stage, as well as the effect on the surrounding main roads of the increased traffic. Consultation with the public, particularly the residents immediately affected, is also very important.

This Report describes some of the types of vertical deflections which can be used, together with an assessment of effectiveness, to help the engineer decide which is the most appropriate measure for a given situation.

2. EARLIER RESEARCH

The Laboratory published results (Baguley, 1981) which related vehicle speed midway between humps to the hump separation. This formed the basis of the Traffic Advisory Leaflet published in 1987 (Department of Transport, 1987) and subsequently updated in 1990 (Department of Transport, 1990). This has recently been updated by Lines (Traffic Engineering and Control, Jan 1993). Local Authority engineers can use these publications as a guide when designing schemes, but should take account of their own local experiences.

3. TYPES OF VERTICAL DEFLECTIONS

The following measures are discussed together with an assessment of effectiveness, to help the engineer decide which is the most appropriate measure for a given situation.

3.1 ROAD HUMPS AND RAISED JUNCTIONS

Road humps have in the past proved to be the most effective way of controlling vehicle speeds. The Highways (Road Humps) Regulations 1990 define the dimensions, siting, signing and lighting of road humps for use on the Highway; more details are given in Traffic Advisory Leaflet 2/90. They can be flat-topped (including raised junctions) or have a circular profile and can taper short of the kerb with heights in the range 50 - 100 mm. An amendment to the Highways Act 1980, through the Road Traffic Act 1991, which commenced 1 July 1992, allows the Secretary of State to authorise road humps which do not conform to the Highways (Road Hump) Regulations 1990. Details of the authorisation procedure is given in Circular Roads 2/92, "Road Traffic Act 1991: Road Humps and Variable Speed Limits".

The spacing between humps, the hump height and the ramp gradient for flat-topped humps can be tailored to achieve the desired speed reduction.

3.2 SPEED CUSHIONS AND 'BUMPS'

The speed cushion is often regarded as a 'bus friendly' measure and has been used in Germany. Tests in UK conditions indicate that they can be more acceptable to bus operators. Short low humps 'bumps', 900 mm long by 37 mm high have been used with apparent success in the UK. Both of these measures would require authorisation (see 3.1). Further investigations including on-road trials, are being made into the design and use of both of these features and a report will be produced.

3.3 RUMBLE AREAS/JIGGLE BARS

These are generally up to 13 mm high and are used to alert drivers to hazards such as bends and at entrances to villages. These can now be authorised by procedures under the Highways Act 1980, as amended by the Traffic Calming Act 1992. Regulations are expected which will negate the need for these matters to be referred to the DOT. Examples of current practice by highway authorities are being studied and a report on this is expected later.

3.4 SPECIAL DESIGNS

Designs which can assist the vulnerable road users (cyclists and pedestrians) are considered, in addition to measures which favour the emergency vehicles and buses.

4. SPEEDS BETWEEN HUMPS

The speeds of vehicles between humps are determined primarily by the hump spacing. The spacing of measures becomes especially important if the roads are within an area that may ultimately become part of a 20 mph zone.

TRL have carried out research to investigate whether vehicle speeds attained at hump sites have risen since the 1970's. This involved gathering and analysing speed data from 30 sites where 100 mm high circular profile humps had been installed. This gave a relationship between the 85th %ile speed (V85 mph) midway between the humps, and the hump separation (S metres) of:-

$$V_{85} = 16.73 + 0.087S$$

Relationships have been derived for flat-topped tables and all of the results are given in Appendix A with the confidence limits (i.e. the anticipated range of speeds for a given spacing) indicated. It was noted that local conditions could affect the speeds to a large extent and in many cases there was no apparent reason for the variation.

5. ACCIDENTS

A preliminary analysis of the accidents at traffic calming sites with vertical deflection measures showed that the accident frequency was reduced by 71%. The sites are still being monitored and more time will be needed to achieve a more robust result covering a wider range of conditions and to determine if this reduction is maintained over a longer period.

ROAD HUMPS FOR CONTROLLING VEHICLE SPEEDS

ABSTRACT

Traffic calming schemes in Great Britain use various measures to slow the traffic. The most effective at reducing speeds usually involve some form of vertical deflection, normally in the form of a road hump or raised table. Humps and raised tables are now permitted to be 50 - 100 mm in height and can have flat-tops, in addition to the more common circular profiles as allowed under the original Regulations.

This Report describes the types of vertical deflections which can be used, together with an assessment of each, in order to assist Local Authority engineers to decide which is the most appropriate measure for a given situation.

Up to now the only estimate of the effect of hump spacing on speeds available to the local authorities (apart from their own and other known schemes) was published in 1987 (Department of Transport, 1987) and was based on work carried out before this date. This Report gives an updated speed/separation relationship which indicates that, for a given speed, the separation between humps is now less than that previously predicted.

An analysis of accidents has shown these have been substantially reduced at a selection of sites where humps or tables have been used.

1. INTRODUCTION

1.1 GENERAL

Sixty nine percent of all casualties occur in built-up areas and of these a high proportion are 'vulnerable' road users, pedestrians and cyclists, (96% of pedestrian and 90% of cyclist injury accidents occur in built-up areas). Schemes to reduce these accidents are an important element in working towards the Department of Transport's casualty target of a one third reduction by the year 2000 compared with the 1981-85 level. Many of these schemes involve installing road engineering measures in residential areas to reduce speeds and encourage through traffic onto more appropriate main roads.

Traffic Calming schemes from mainland Europe were reported by Pharoah and Russell (1989) and other significant literature has been produced by Tolley (1990), Devon County Council (Chorlton et al 1991), Hass-Klau et al (1992) and Kent County Council (1992). TRL has also published a translation of a comprehensive Dutch 30 kph zone design manual (Lines and Castelijn, 1991) describing the types of measures used in the Netherlands.

1.2 AREA-WIDE APPROACH

Various measures can be used to slow traffic, but installation on a 'single road' basis should be avoided because this often causes local diversions often on to other unsuitable roads; thus it is important that the package forms part of an overall Urban Safety Management Strategy. This is known as an area-wide approach described in RR153 (Lynam et al, 1988) and RR263 (Mackie et al, 1990) and it aims to ensure that only suitable traffic uses each type of road. This can be achieved by establishing the road hierarchy for the roads enclosed by main roads (IHT, 1990) and (DoE DTp, 1992) and installing road engineering measures to encourage appropriate traffic onto appropriate roads. Varying the type and height of the measures can be used to define the hierarchy of the area. This can be achieved by placing the most severe measures on the roads which are unsuitable for through traffic and less severe lower measures on other roads.

Experience from mainland Europe indicates that it is often beneficial to use a mix of measures. Environmental improvements can often be incorporated, such as extensive use of coloured block paving and additional street furniture, as a further means of deterring through traffic from certain routes and enhancing the pedestrian nature of the area.

1.3 CONSULTATION

It is important that the public are involved in any scheme from an early stage and also that they are kept informed of the progress through publicity, which should concentrate on the benefits that it will bring to vulnerable groups such as children, the elderly and pedestrians in general. A more detailed assessment of public acceptability was carried out for four traffic calming schemes and the results have been published by TRL (Windle and Mackie, 1992). It is a statutory requirement to consult with the police on schemes involving road humps, and notices must also be published advertising proposals regarding road humps (section 90C, Highways Act 1980). Discussion at an early stage in the design of a road hump scheme is also strongly advised with emergency services and bus operators, to avoid any subsequent problems regarding the operation of their vehicles.

1.4 REGULATIONS

A Traffic Advisory Leaflet was published in 1990 giving details of the new Highway (Road Humps) Regulations 1990, which allowed greater flexibility in both the siting and shape of humps. The Regulations allow road humps to be between 50 - 100 mm in height and can be either flat-topped or of a circular profile. These regulations were introduced to assist local Authority engineers design schemes. The design of subsequent road engineering measures can then be modified by their own scheme experiences.

DOT Circular Roads 2/92 gives details of the Road Traffic Act 1991: Road Humps and variable message signs, which amends the Highways Act 1980, through the Road Traffic Act 1991. This new legislation empowers the Secretary of State to authorise the use of non-standard road humps with dimensions which vary from those in the regulations, however it is unlikely that humps higher than 100 mm would be authorised.

Legislation was recently introduced in the Traffic Calming Act 1992 which amended the Highways Act 1980. This should encourage more innovative designs incorporating horizontal deflections in new schemes. These can, if the local authority is doubtful about it's general powers to install these features, be authorised by DOT. It is expected that regulations will be made which will negate the need for these matters to be referred to the DOT.

Regulations describing the procedure for the approval of 20 mph zones have been introduced in Circular Roads 4/90 (Department of Transport 1990b).

1.5 SPEEDS

TRL has carried out a study of the effect of humps on vehicle speed and relationships between hump spacing and speed have been developed. The effects are given in sections 2 and 3 for circular profile and flat-top humps respectively and results of the study are reported in Appendix A. It would appear that the speed data published in LR878 and LR1017 is now out of date, possibly due to the advances in vehicle suspension and increased performance. A spacing of less than 65 metres is now necessary to achieve a maximum speed of 20 mph midway between humps.

1.6 ACCIDENTS

TRL has analysed 'Before' and 'After' accident data from 25 sites, ranging from a rural village to central London, where humps had been installed. The results are given in Appendix B. The accidents were reduced by 71% on the treated roads and 8% on the surrounding untreated roads. This work is still in progress and more time will be required before the effect of the measures on accidents can be confidently predicted. However, it does give an indication as to the likely safety benefits of traffic calming schemes. Early analysis of accidents within 20 mph Zones indicates similar accident reductions. Similarly, it appears that pedestrian accidents have been substantially reduced showing that they are one of the main beneficiaries of the Traffic Calming schemes studied.

1.7 20 MPH ZONES

Humps are normally used on roads which have a 30 mph speed limit. However, Circular Roads 4/90 allowed Local Authorities to apply for a road or an area to become a 20 mph Zone where the Regulations defining the signing, lighting and positioning of road humps are considerably less rigid than for schemes which are not 20 mph Zones.

Additionally under amendments to the Highways Act 1980, through the Road Traffic Act 1991, the Secretary of State has powers to vary the requirements of the Regulations, if this is considered appropriate.

1.8 OUTLINE OF REPORT

In the following sections (2 - 7) various types of vertical deflection devices are discussed, with an assessment of each.

Sections 8 - 10 describe and discuss special designs which can be used to assist cyclists, pedestrians and the emergency services/buses.

Appendix A contains details of 'Before' and 'After' flows and speeds for a range of schemes. These 'After' speeds midway between humps of various separations were used in the analysis discussed in 1.5 above.

Appendix B contains the summary tables of the accident data from selected schemes showing the numbers of 'Before' and After' accidents which occurred on both the treated roads and the surrounding roads.

Appendix C contains brief lists of the locations in the UK of examples of circular humps, flat-topped tables and raised junctions. The lists are representative but not exhaustive as the numbers are continually increasing. Various hump heights have been included because the height can be tailored to suit the type of road where they are installed.

2. ROAD HUMP WITH CIRCULAR PROFILE

The circular profile road hump is probably the most frequently used measure for slowing traffic both on and off the public highway. TRL carried out track trials (Watts, 1973) using humps with different profiles and dimensions to determine which were most suitable for use on the highway. The results showed that circular profile humps, 4" (102 mm) high and 12' (3.66 m) long were the most appropriate to adopt as 'standard'. They also showed that higher humps were too severe and that low/short humps became less effective as the crossing speeds were increased. This led to experimental road trials where a series of standard humps were installed at nine trial sites.

These preliminary results reported in LR878 (Sumner and Baguley, 1979) and LR1017 (Baguley, 1981), showed that the speeds and accidents were reduced. Results from these trials gave a relationship between hump separation and vehicle speed midway between adjacent humps.

This research formed the basis of Regulations issued in 1983 that defined the location, lighting and signing of humps on the public highway. The Highways (Road Hump) Regulations were amended in 1986 and again in 1990 (Department of Transport, 1990a).

New relationships between speed and hump spacing have been developed and these are given in the effectiveness paragraph of this section and in more detail in the Appendix A.

DESIGN:

Material: asphalt; concrete; rubber

Typical cost: Approx. £400 - £1,000 at 1991 prices. (humps which are kerb to kerb will cost more because provision for drainage will be required)

Dimensions: Height - 50 mm (min) to 100 mm (max)

Width - Across full road width or with a gap of 200 mm between hump and kerbs. Edge ramps of 150 - 300 mm

Length - 3700 mm

Profile - Circular

See Figs. 1,2 and 3 at the end of this section.

Spacing: Humps must not be more than 150 m apart (min 20 m) and the first in the series must be 40 m or less from a low speed feature such as a junction or bend. See Fig. 4 for details. This would not apply in a 20 mph zone or if special authorisation had been sought and granted.

General: Important to assess traffic flows, vehicle speeds, vehicle types and accident records before designing a scheme.

EFFECTIVENESS:

* Determined by height and spacing.
* Good speed control device.
* Humps with the maximum height of 100 mm will give better speed reductions than the lower humps for a given spacing (See Appendix A)
* Speed/separation relationship (for 30 sites) (all 100 mm high)

$V1 = 16.73 + 0.087S$ $r = 0.80$ S.E. = 1.59

$V2 = 12.10 + 0.092S$ $r = 0.87$ S.E. = 1.28

V1 = 85% speed mph midway between humps
V2 = mean speed mph midway between humps
S = separation metres
r = Correlation Coefficient
S.E.= Standard Error mph

* Typical vehicle crossing speeds for 100 mm humps
85% tile Range 14 - 19 mph Average 18 mph
Mean Range 11 - 16 mph Average 14 mph
* Spacings of approximately 40 metres would be required at a typical site to achieve an average 85% tile speed of 20 mph mid way between humps.
* Flows were reduced on average by 14% depending on alternatives available. Full details are given in Appendix A.
* Accidents were reduced by 71% on the treated roads.

Full details are given in Appendix B.

SIGNING AND LIGHTING:

Signing and lighting are described in Regulation 4(3)(a) and 6 of the Highways (Road Humps) Regulations (SI 703), and required except when used in a 20 mph zone. Road humps should have triangular and edgeline markings. Appropriate warning signs should be erected at the start of the series and at the entry points from intermediary roads. (See Fig 5).

SUITABLE LOCATIONS:

Within the road hierarchy two possible locations are:-

a) On residential access roads where vehicle speeds are excessive and severe measures are required.

b) On distributor roads where lower speeds are required.

FOR:

* Inexpensive especially when the humps taper down short of the kerb
* effective proven speed control device
* covered by Regulations
* hump heights of 50 - 75 mm can be used on bus routes and are more acceptable to the emergency services.
* the height of the humps can be varied to suit each road within an area scheme
* traffic may avoid the measures by using more suitable roads thus reducing inappropriate flow
* the hump spacing can be set to obtain the target vehicle speeds
* no limit on the number of humps in a series
* no loss of parking spaces as vehicles can park on road humps
* narrowings can be incorporated at the hump to increase the effectiveness
* overall noise reduced between humps if 'calm' driving style adopted and less than 10% heavy vehicles (DTp, 1988)

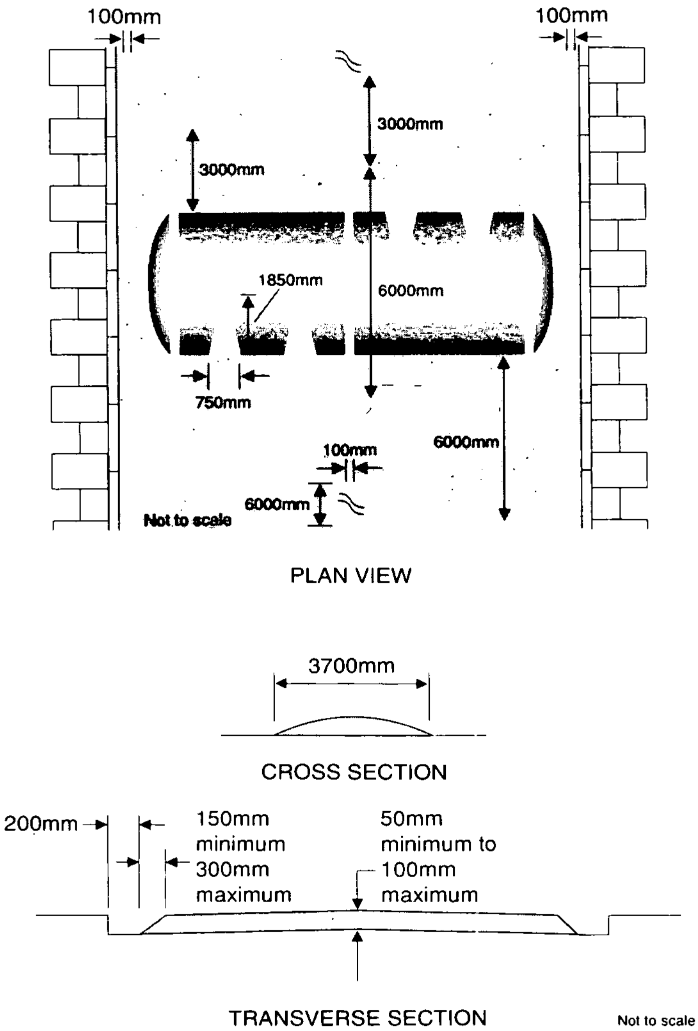

Fig.1 Circular profile hump with tapered edge

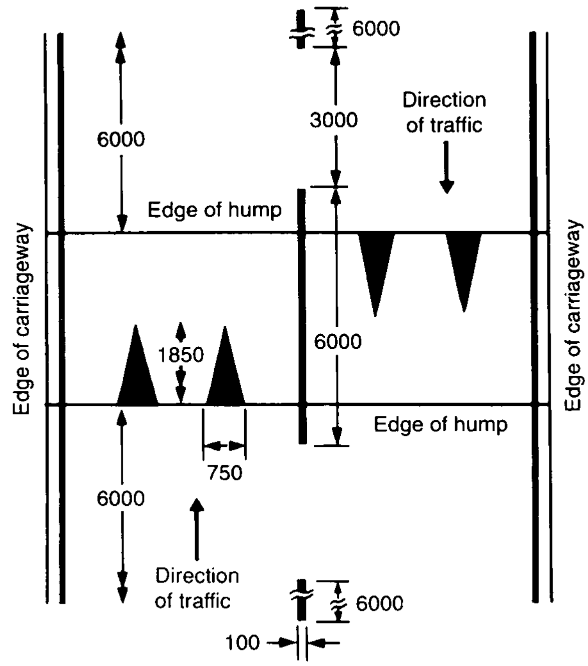

Fig.2 Circular profile hump. Full width

AGAINST:

* Increased traffic noise and vibration at the hump
* Regulations limit dimensions and locations
* can be uncomfortable for some cyclists
* even the lower humps of 50 - 75 mm may be opposed by the bus companies and the emergency services depending on the types and frequency of vehicles in use
* unpopular with some residents
* not visually attractive, particularly without environmental improvements
* may lead to an increase of traffic on other roads which may not be desirable
* a considerable number of humps in a series could be necessary on a long road
* where narrowed it can be hazardous for cyclists
* cyclists may attempt to use the taper to negotiate humps which taper down short of the kerb; the use of edgeline markings even in 20 mph zones will help to discourage this
* modifications can be made to dimensions (see section 8.3)
* certain long wheelbase, low clearance vehicles may ground

EXAMPLES:

A sample list of schemes is given in Appendix C which contains humps of 50 - 100 mm in height.

3. FLAT TOP ROAD HUMPS

The Road Hump Regulations of 1983 and 1986 did not cover flat top road humps (raised tables) but these were included in the revision issued in 1990 (Department of Transport, 1990a).

Flat top road humps (raised tables) can be used in a scheme as an alternative to circular profile humps; they provide flat crossing places and are often regarded as more environmentally acceptable, particularly by pedestrians.

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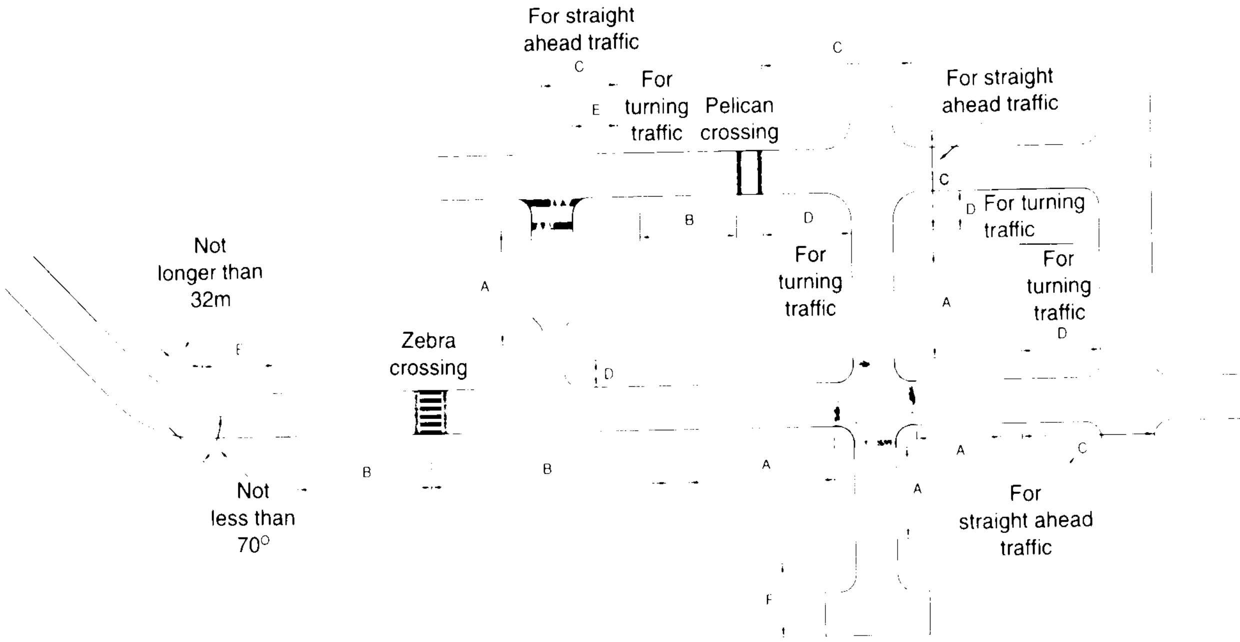
Fig.3 Examples of Circular Profile humps



A= NOT LESS THAN 20m NOR GREATER THAN 150m BETWEEN HUMPS

B= NOT LESS THAN 30m FROM A ZEBRA/PELICAN CROSSING, NOR WITHIN THE ZEBRA/PELICAN CONTROLLED AREA. NOT GREATER THAN 150m BETWEEN HUMPS

C= NOT GREATER THAN 60m FROM THE MARKINGS TO DIAGRAMS 1002.1, 1003, 1003.1, OR 1003.3

D= NOT GREATER THAN 40m FROM A JUNCTION WITH ANOTHER HIGHWAY

E= NOT GREATER THAN 40m FROM A BEND (VEHICLE TO CHANGE DIRECTION NOT LESS THAN 70 IN 32m)

F= NOT GREATER THAN 40m FROM THE END OF A CUL-DE-SAC

Fig.4 Notional road hump locations

DESIGN:

Material: asphalt; concrete; rubber; block paving

Typical cost : £500 - £3,000 (asphalt, rubber, concrete)

(1991 prices): £3,000 - £8,000 (block paving and narrowing)
Note. £500 is for tapered hump

Dimensions: Height - 50 mm (min) to 100 mm (max)

Width - Across full road width or with a gap of 200 mm between kerb and table.

Length - 3700 mm (min). No maximum table length is specified .

Profile - Flat top (min 2500 mm) with two ramps (each of min 600 mm)

See Figs. 6,7 and 8 at the end of this section.

Spacing: Humps must not be more than 150 m apart (min 20 m) and the first in the series must be 40 m or less from a low speed feature such as a junction or bend. See Fig. 4 for details. This would not apply in a 20 mph zone or if special authorisation had been sought and granted.

General: Important to assess traffic flows, vehicle speeds, vehicle types and accident records before designing a scheme. Should consider the disabled if used at crossing locations. Vertical upstands where the ramps join the carriageway surface should be minimised, as these can be a hazard for all two wheeled drivers and to a lesser extent the small numbers of drivers of three wheeled vehicles.

EFFECTIVENESS:

* Determined by height, ramp gradient and spacing between successive tables
* Good speed control device
* Tables which are the maximum height of 100 mm will give better speed reductions than the lower tables for a given spacing and ramp slope (See Appendix A)
* Speed/separation relationship

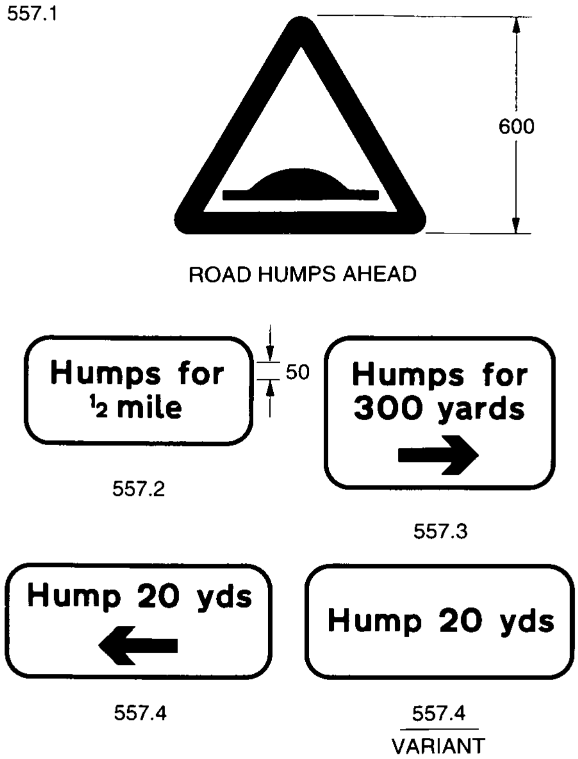


Fig.5 Road hump signs

(100 mm high, av. slope of 1:10) 24 sites

V1 = 12.95 + 0.107S r = 0.93 S.E. = 1.70

V2 = 11.06 + 0.090S r = 0.91 S.E. = 1.61

V1 = 85% speed mph midway between humps
V2 = mean speed mph midway between humps
S = separation metres
r = Correlation Coefficient
S.E.= Standard Error mph

* Typical vehicle crossing speeds for 100 mm tables with ramps of 1:10 - 1:12

  85% tile Range 13 - 19 mph Average 17 mph

  Mean Range 11 - 16 mph Average 13 mph

* Steep ramps of 1:6 will give slightly better speed reductions **AT THE HUMPS** but are likely to be less popular with drivers and residents as they are too severe and may cause grounding of low vehicles (see 'Against' section).

* Ramps of 1:10 or 1:12 have been found to be a more acceptable gradient.

* Ramps shallower than 1:20 may not be effective enough.

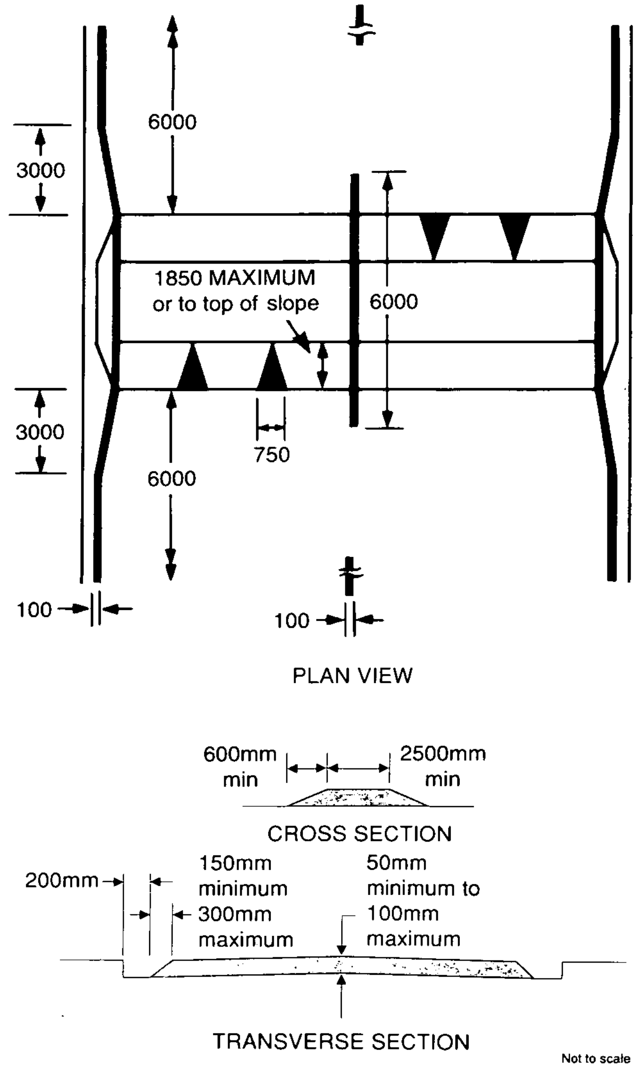


Fig.6 Flat-top tapered edge

SIGNING AND LIGHTING:

Signing and lighting are described in Regulation 4(3)(a) and 6 of the Highways (Road Humps) Regulations (SI 703), and required except when used in 20 mph zone. Road humps should have triangular and edgeline markings. Appropriate warning signs should be erected at the start of the series and at the entry points from intermediary roads. (See Fig 5).

SUITABLE LOCATIONS:

Within the road hierarchy there are many possible locations:-

a) Residential roads which may be access-only or possibly distributor roads

b) outside schools and shops

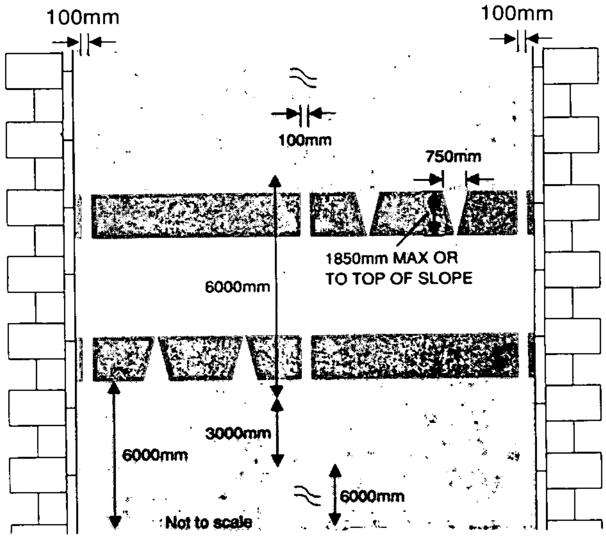


Fig.7 Flat-top full width

c) roads where a high proportion of the pedestrian crossing movements are by people who have restricted mobility including disabled and people with prams (IHT, 1991), tactile surfaces should be incorporated in accordance with Disability Unit Circular 1/91 (DOT, 1992)

d) at Zebra and Pelican crossings. (See Figs. 9,10 and 11)

e) entrances to 20 mph zones, preferably with the addition of narrowing and coloured surfaces in order to highlight the 'gateway' to the zone

FOR:

* Tapered asphalt humps can be relatively inexpensive
* rubber tables are commercially available, made from recycled vehicle tyres
* effective proven speed control device
* covered by Regulations
* the dimensions may be varied more than for round top humps to suit particular conditions
* can have pedestrian crossing incorporated as an aid to pedestrians
* one-way priority with narrowing possible if the traffic flow is lower than 6,000 vehicles/day (Bulpitt, 1990)
* can be environmentally improving if designed and built to a high standard
* some shops may benefit from enhanced pedestrian facilities
* overall noise reduced between humps if 'calm' driving style adopted and less than 10% heavy vehicles (DTp, 1988)

AGAINST:

* Noise may be increased at the table due to the surface material, engine noise (particularly buses) and lorry clatter
* uncomfortable for some cyclists
* even the lower tables of 50 - 75 mm may be opposed by the bus companies and the emergency services depending on the types and frequency of vehicles in use
* unpopular with some residents
* can be expensive compared with round top humps
* may lead to loss of parking spaces if used as crossing place
* additional drainage for kerb to kerb humps required
* Grounding. The likelihood of vehicles grounding on 100 mm humps can be minimised by using gentle ramps of 1:10 or shallower, combined with a plateau of at least 2.8 metres. Consultation may show that even 75 mm could be too high particularly if hearses/limousines, which can have very low ground clearances, are likely to frequently cross the humps.

EXAMPLES:

A sample list of schemes is given in Appendix C which contains humps of 50 - 100 mm in height.

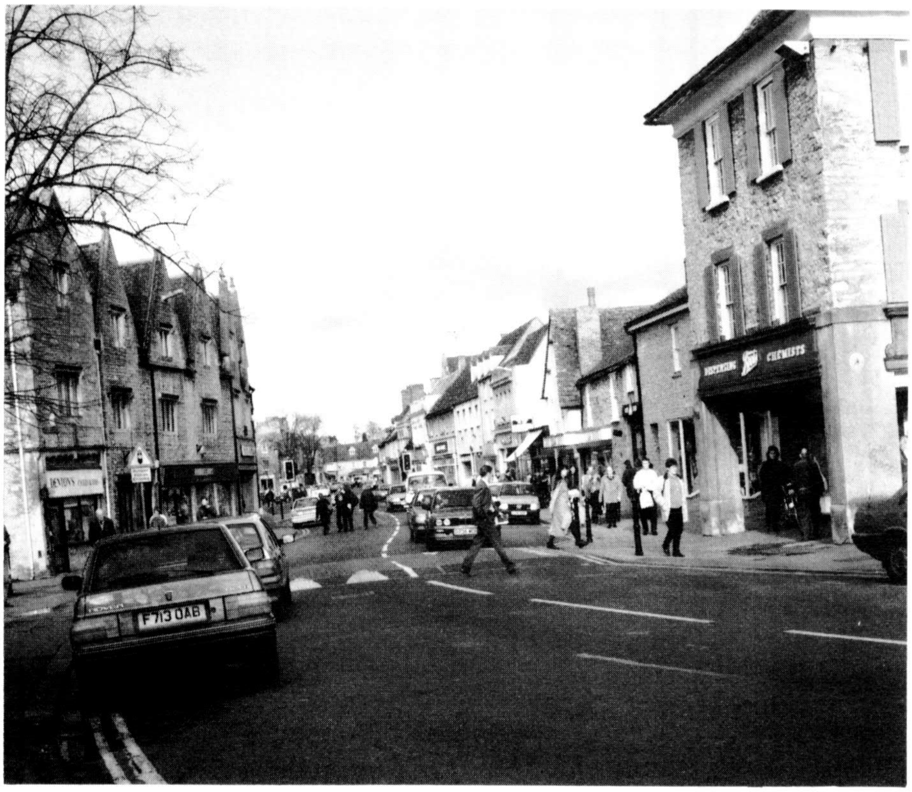
4. RAISED JUNCTIONS

Raised junctions are a development of the flat top road hump (table) discussed in section 3. They would be most useful within an area scheme at junctions which are known to be hazardous and where major reconstruction would not be justified or viable.

DESIGN:

Material:	asphalt; concrete block paving	
Typical cost:	£10,000 Approx. (1991 prices)	
Dimensions:	Height -	50 mm (min) to 100 mm (max)
	Width -	Across full road width.
	Length -	No maximum table length is specified.
	Profile -	Flat top (min 2500 mm) with two ramps (each of at least 600 mm)

See Figs. 6, 7 , 8, 12 and 13



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Neg.No.CR824/92/11

Fig.8(a) Examples of flat-top raised tables

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Fig.8(b) Examples of flat-top raised tables

Note. Triangular markings are not a requirement for zebra crossings and may be omitted.

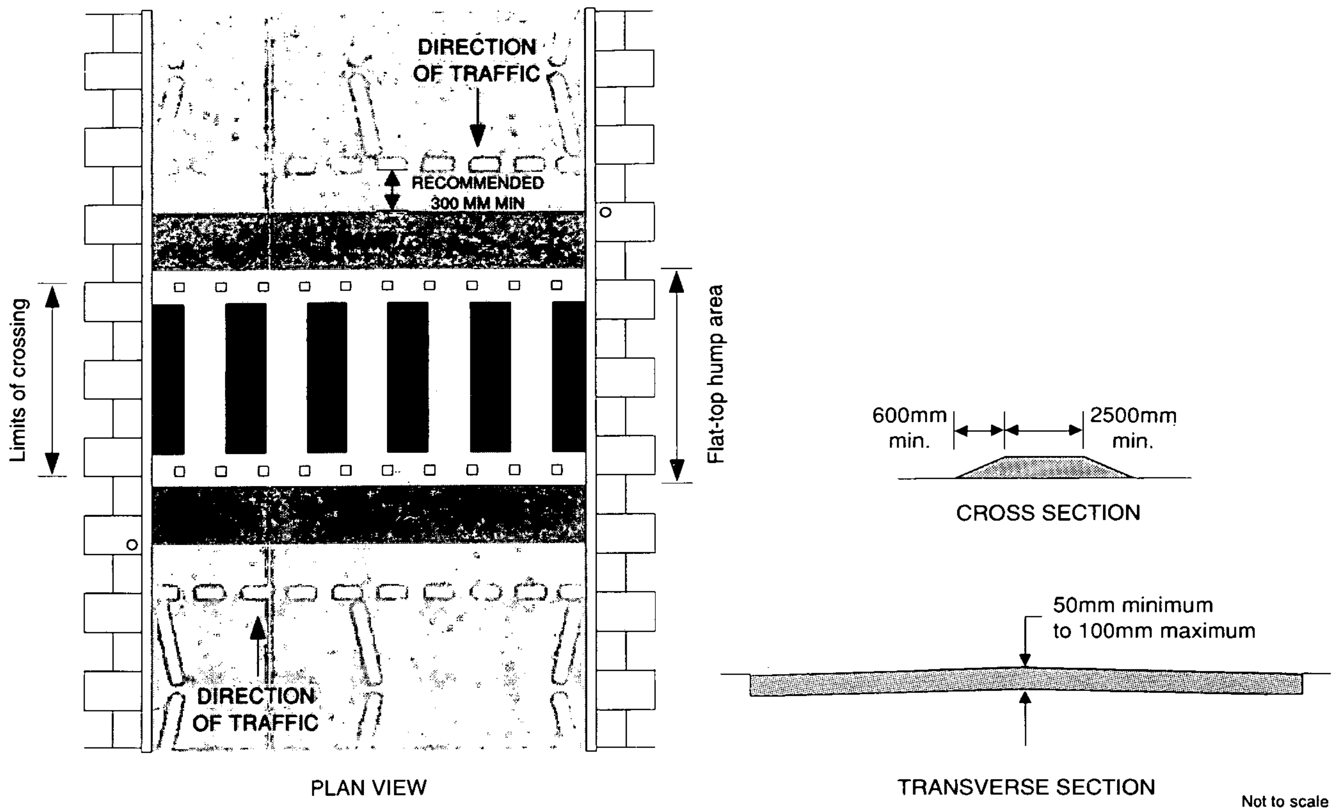


Fig.9 Humped zebra crossing

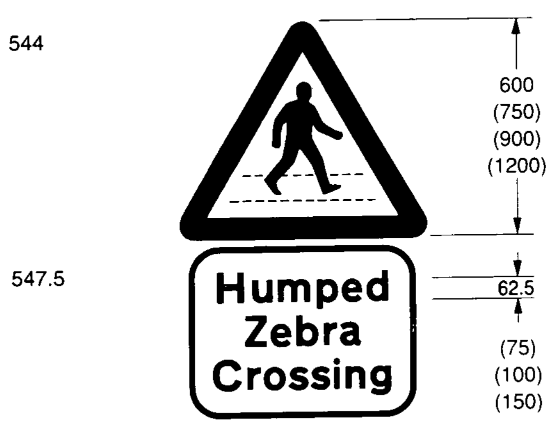


Fig.10 Zebra crossing sign

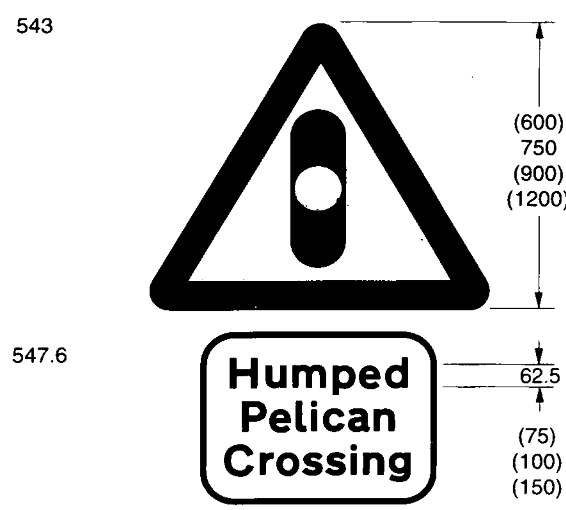


Fig.11 Pelican crossing sign

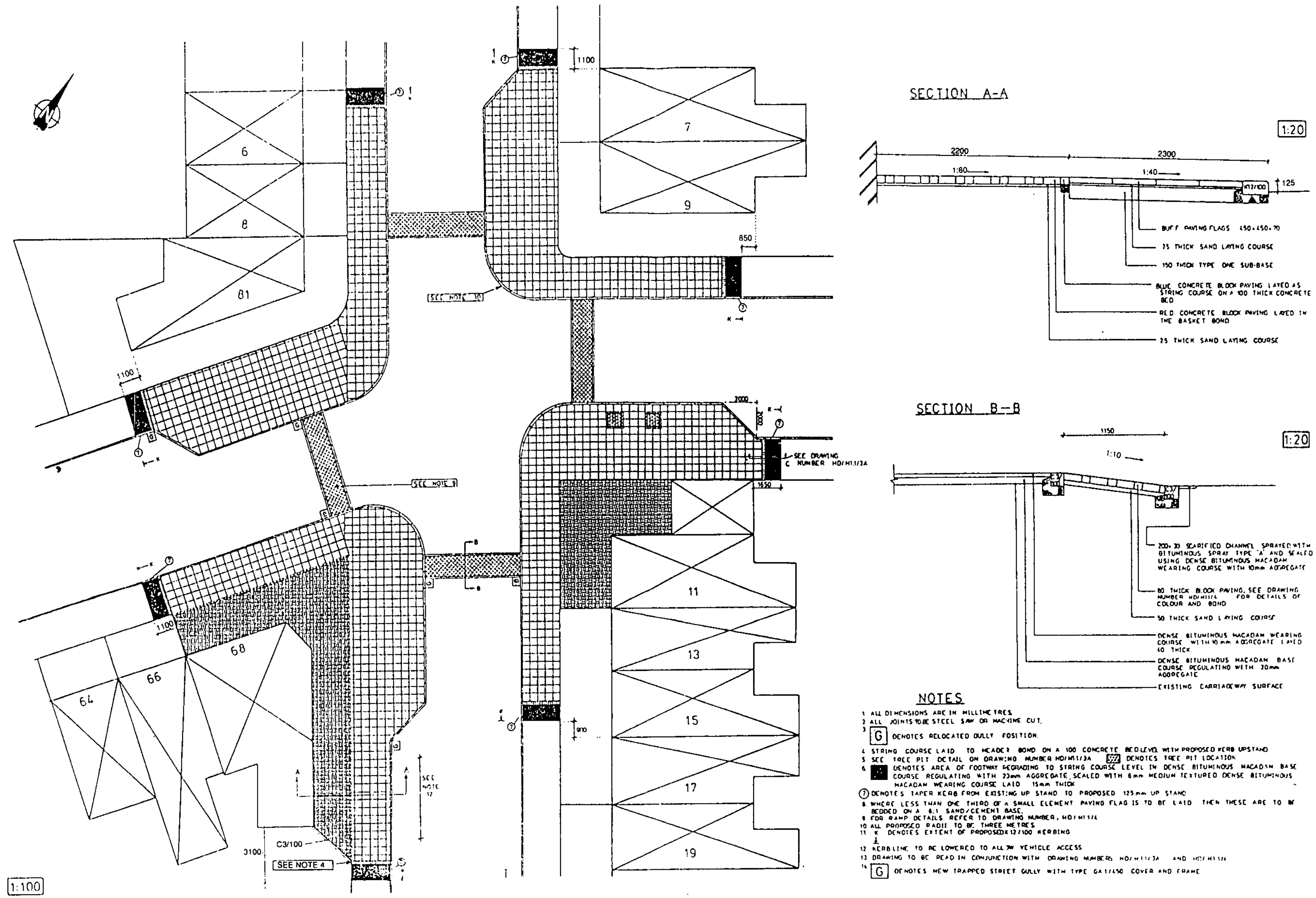


Fig.12 An example of a raised junction

Neg.No.TS304/92/19

Neg.No.TS304/92/20

Fig.13 Examples of raised junctions

Locations: The extent to which a raised junction is extended into the side roads will depend on a number of factors. However it is suggested that the raised area extend at least 6 metres so that the leading car can be level on the immediate approach to the junction. This also enables 'give way' markings, as shown in Fig 4, to be placed in the conventional position. Speed reducing features must be located on each approach arm to the junction in accordance with the Road Humps Regulations. If the feature is a road hump then it should be no closer than 20 m or further away than 150 m. Some highway authorities consider raising the carriageway on the side roads over a long length using powers under Section 77 of the Highways Act 1980, so that only a gentle gradient, not a hump, is formed. It is, of course, for each authority to satisfy themselves as to the appropriate legality of this.

General: Important to assess traffic flows, vehicle speeds, vehicle types and accident records before starting scheme design. Vertical upstands where the ramps join the carriageway surface should be minimised, as these can be a hazard for all two and any three- wheeled drivers.

EFFECTIVENESS:

* Good speed control device

  Generally they are as effective as flat-top tables from which they are a development and therefore the anticipated crossing speeds would be 14 - 19 mph provided the length is not excessive.

  Ramps of 1:10 or 1:12 have been found to be an acceptable gradient.

SIGNING AND LIGHTING:

Signing and lighting are described in Regulation 4(3)(a) and 6 of the Highways (Road Humps) Regulations (SI 703), and required except when used in 20 mph zone. Road humps should have triangular and edgeline markings. Appropriate warning signs should be erected at the start of the series and at the entry points from intermediary roads. (See Fig 5).

SUITABLE LOCATIONS:

a) 20 Zones

b) crossroads, T junctions and staggered junctions.

FOR:

* Effective speed control device
* dimensions not restrictive, table length tailored to the situation
* can be made attractive if environmental improvements are incorporated into the design
* can be made from recycled vehicle tyres
* footway enhancement, planting and high quality workmanship improve the visual impact
* can assist pedestrians to cross the roads safely using the slowing effect of the measure
* narrowing can be used if sufficient space available
* benefit two wheel riders because they negotiate the bend on a level surface

AGAINST:

* Can be very expensive to install
* illegal parking on the footway may occur if footway extensions are incorporated
* statutory undertakings must be considered and costs may influence the dimensions of the measure

EXAMPLES:

A sample list of schemes is given in Appendix C which contains various types of raised junctions.

5. SPEED CUSHIONS

Speed cushions have been used in other parts of Europe for a number of years to assist buses, cyclists and emergency vehicles. The cushions are a derivative of the flat-topped hump but their width is considerably smaller. This allows vehicles with a wide track to straddle the cushion whereas vehicles with a narrower track have to put at least one wheel on the cushion.

In July 1992 new legislation in the United Kingdom allowed the Department of Transport to authorise experimental schemes submitted by Local Authorities. Details are given in Circular Roads 2/92 (1992).

The following is based on the best information currently available; track and on-road trials, however, are being carried out and more comprehensive information is expected in the near future.

DESIGN:

Material: asphalt; concrete; block paving; rubber

Typical cost: £200 - £700 (1991 prices)

Dimensions: Fig 14 shows the optimum dimensions derived from the track trials held at TRL. Figs 16 and 17 are examples of speed cushions featured in the DOT's on-road trials in Sheffield and York.

Height 75mm		Grounding problems if higher, some low vehicles may ground even at this height particularly with shorter cushions
Overall length	2000 - 3700mm	
Overall width	2000mm	Wider would cause problems for buses
Platform width	1400mm	If smaller, likely to have reduced affect
Approach ramp	1 : 8	Steeper gives too severe discomfort
Side ramp	1 : 4	Steeper, dangerous for two wheelers

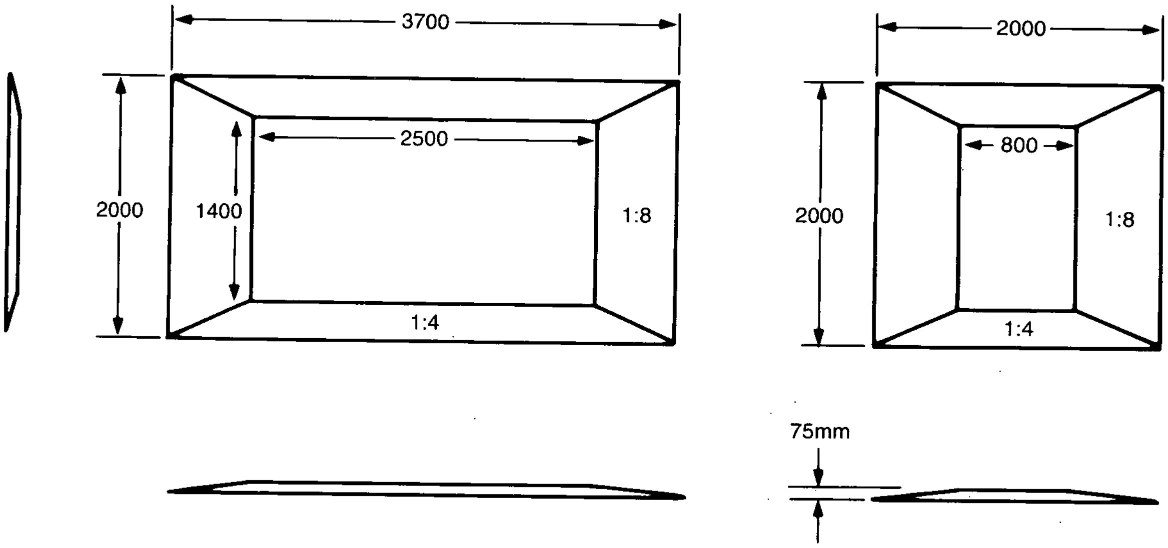


Fig.14 Dimensions of cushions from TRL track trial

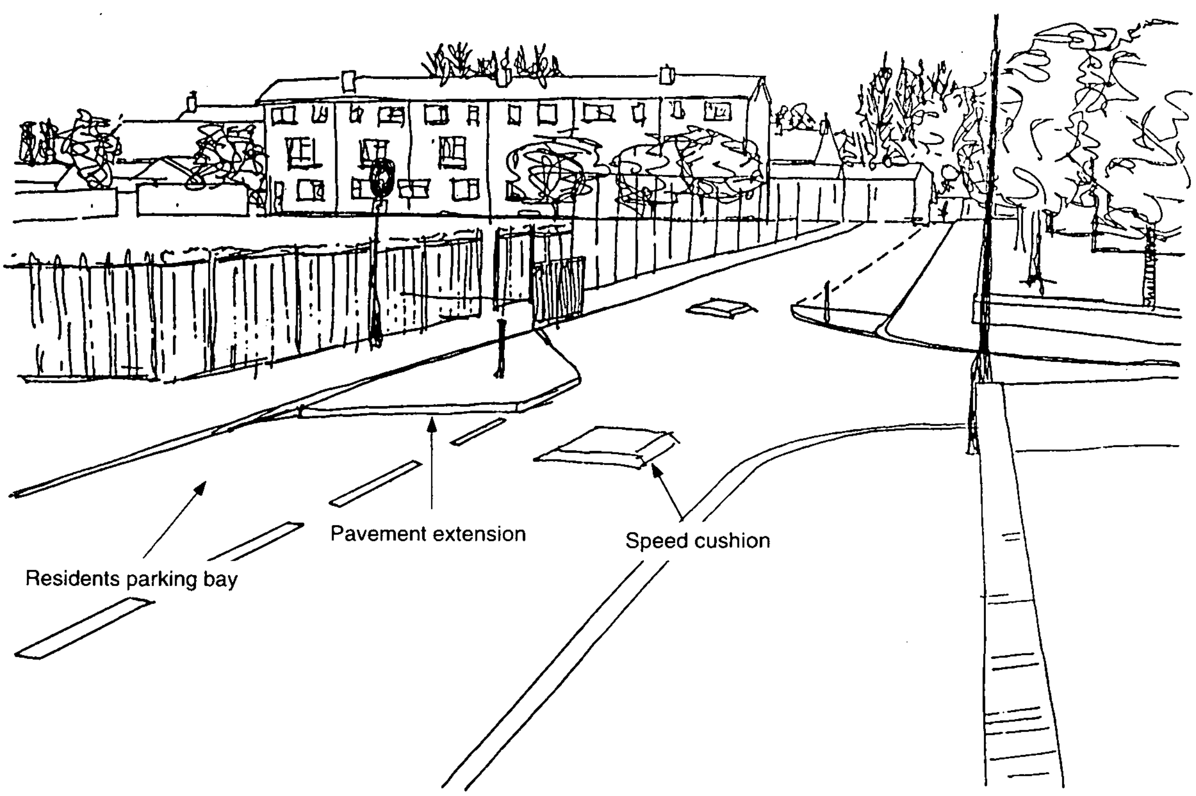


Fig.15 Diagrammatic view of an experimental one-way scheme

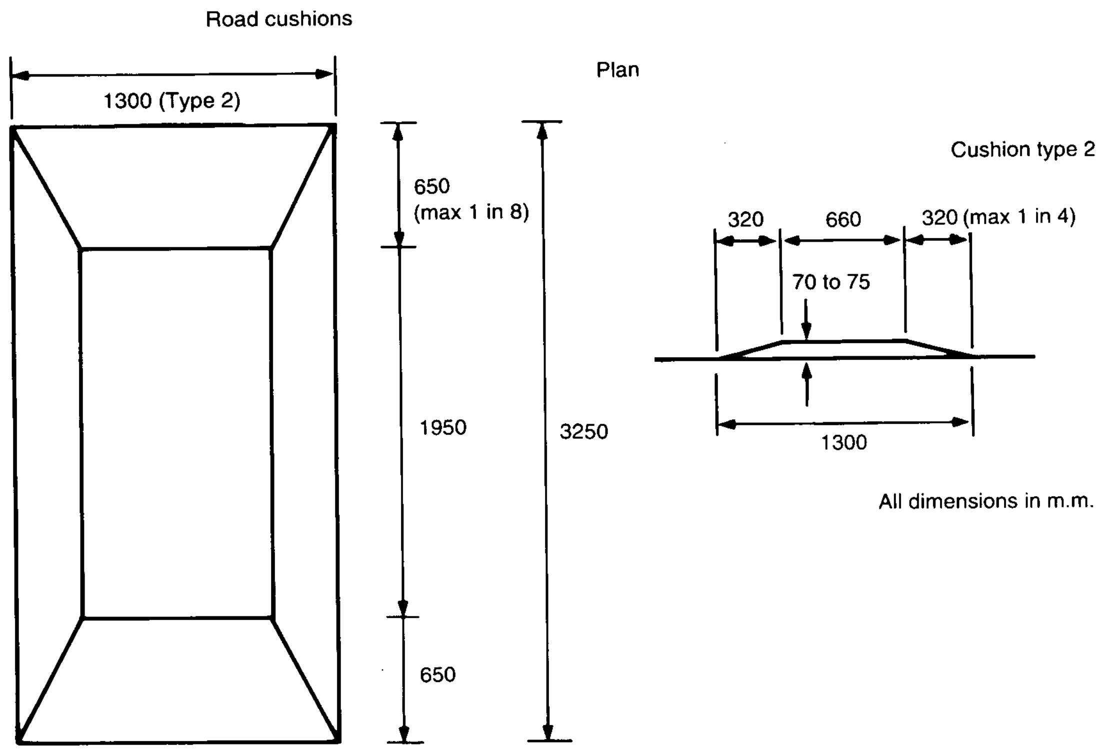


Fig.16 An example of one of the cushions on trial in Sheffield

Height - Should generally conform to the Road Humps Regulations (50 mm - 100 mm). Existing evidence suggests heights above 80 mm lead to the possibility of vehicles grounding.

Width - Overall widths presently vary from 1.3 to 2.0 m. The distance between the kerb should preferably be not less than 1 m and never less than 0.75 m.

Length - Optimum dimensions are still being investigated, but would appear to range between 2 m and 4 m.

Profile - Flat top.
Approach ramp. Max gradient 1:8.
Side ramp. Max gradient 1:4.

Spacing: Follow hump Regulations as far as possible

Construction: See Figs 15 - 18.

EFFECTIVENESS:

* Reputedly good speed reductions obtained where cushions have been used in conjunction with chicanes and other supporting measures as part of an integrated design.
* In the Berlin Moabit Area-Wide project, the 85th percentile speeds dropped from 31 mph to 15 mph due to cushions, horizontal carriageway changes and planting.
* At an experimental site in England, two cushions (1.3 m wide x 75 mm high) and a chicane were installed and the 85th percentile speeds were reduced from 28 to 17 mph.
* Steep (1:8) ramps will give slightly better speed reductions but may cause more complaints from drivers.
* Designed specifically to benefit buses and emergency service vehicles in German 20 mph zones Fig 17 and 18 where the buses could straddle the cushion. (This design may not be suitable for UK.)
* Bus operators and emergency services have expressed considerable interest in speed cushions as an alternative to road humps.

SIGNING AND LIGHTING:

Not covered explicitly by Regulations at present but must be clear to drivers in all conditions. The signing of the cushions may require special authorisation.

PROBABLE LOCATIONS:

a) Residential roads and car parks.

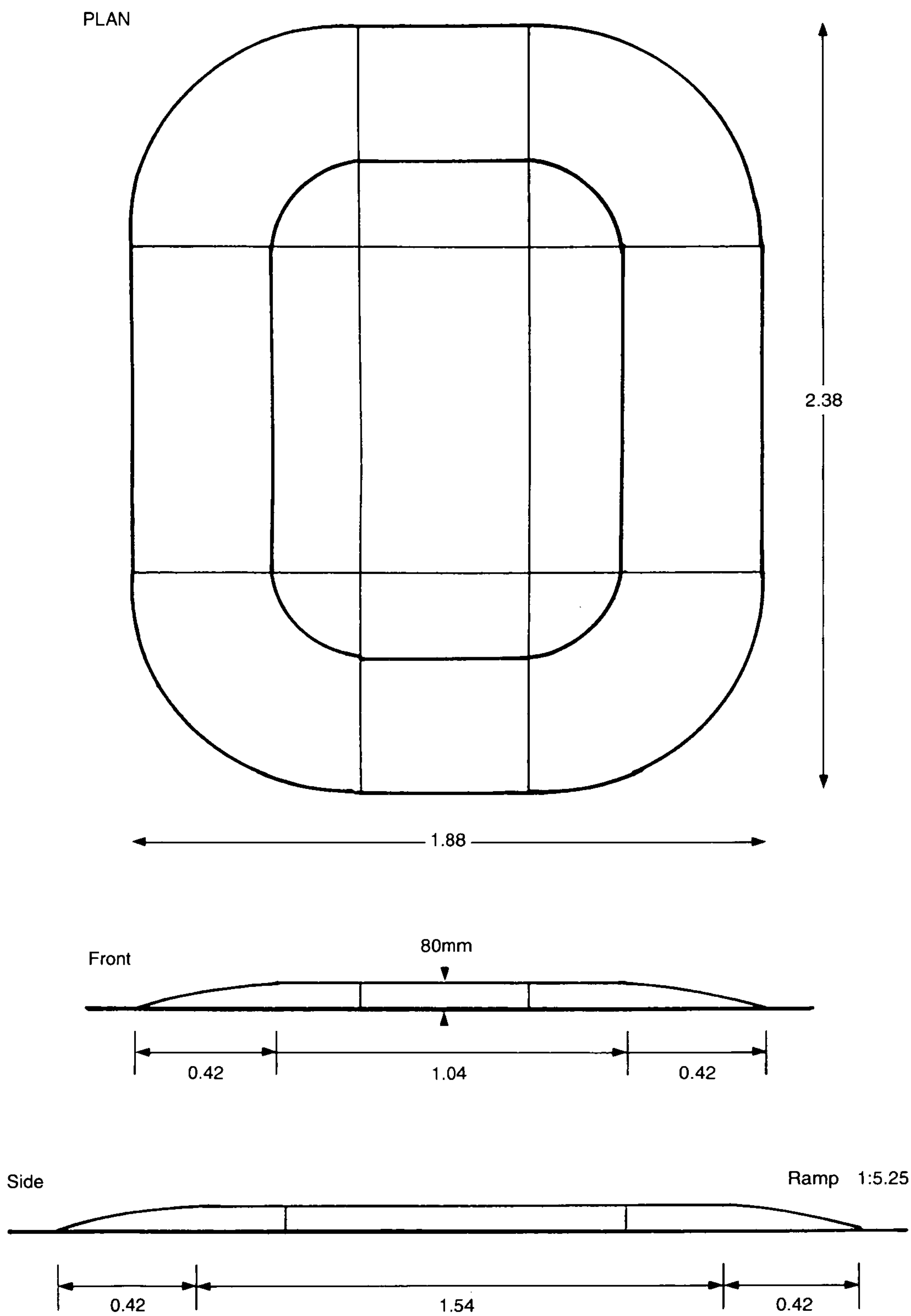
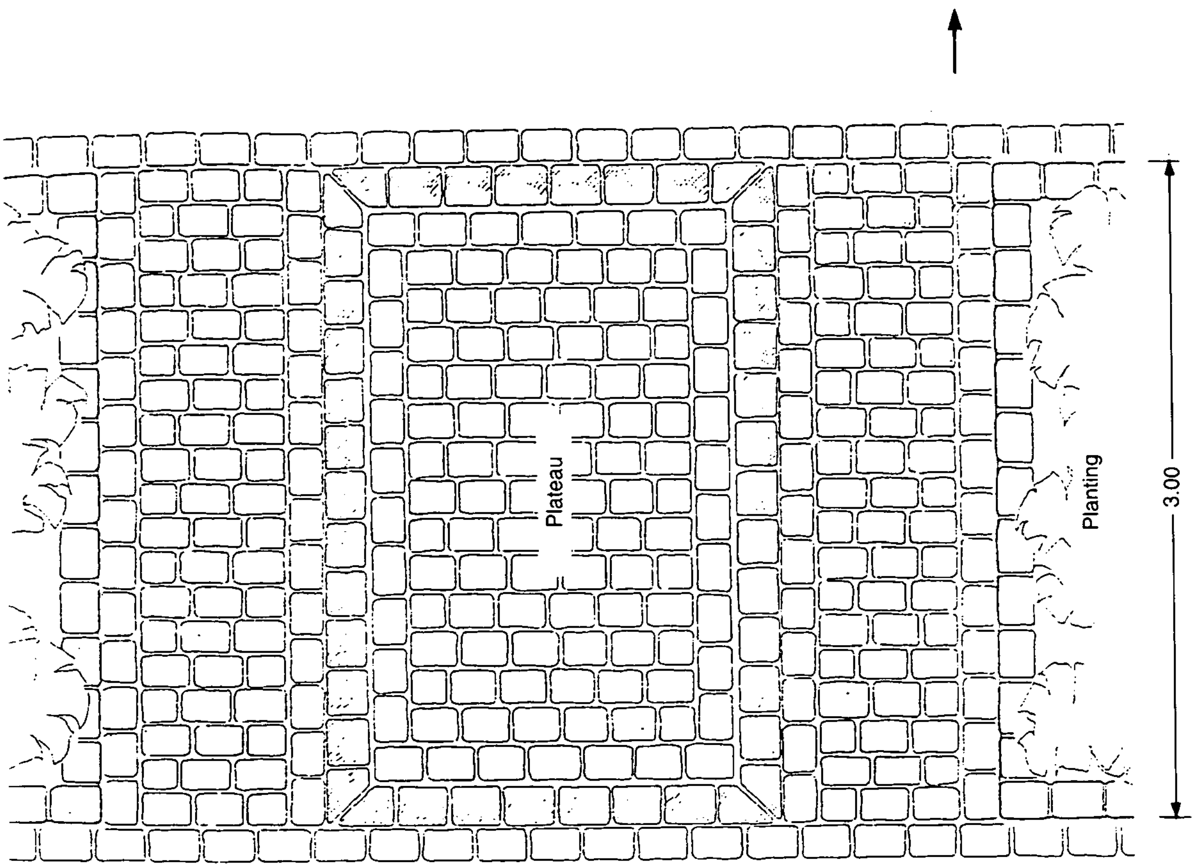
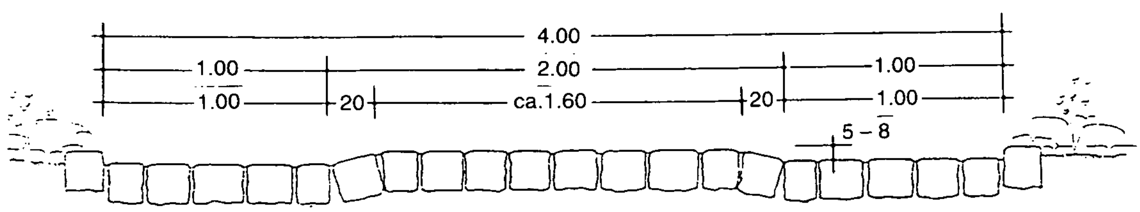


Fig.17 An example of one of the cushions on trial in York



Plan view



Cross section

Fig.18 Dimensions of speed cushions used in Berlin-Moabit

b) local distributors where traffic volumes are low and speeding is not a problem.

c) 20 mph zones.

d) bus routes or on roads used frequently by emergency vehicles particularly ambulances where full width higher humps would be undesirable and other measures ineffective.

e) roads where a high proportion of the vehicles are HGV's.

FOR:

* Generally inexpensive

* appear to be an effective speed control device for cars if used as part of an integrated design with supporting measures

* may not affect emergency vehicles/buses to same extent as smaller vehicles due to wider track (distance between wheels on a given axle), thus only the inner rear wheels pass over the cushion

* bicycles should have room to pass to the left of the cushion (at least 800 mm) depending on the actual design and road width

* drainage is not a problem

* can be used in conjunction with chicanes and kerb build- outs to further slow traffic

* materials can be used which blend in with the surroundings

* can be regarded as less obtrusive than standard humps or tables due to their smaller size

* size of cushion can be varied (e.g. up to 2.0 m wide)

AGAINST:

* Traffic noise for residents close to measure

* not suitable for reducing two-wheeled motor vehicle speeds

* not covered by Regulations at present but since July 1992 may be authorised on application to DOT

* some large cars may straddle the cushion depending upon the design

* buses and emergency vehicles may still be affected depending on the types of vehicles in use, particularly if they do not have single rear wheels

* vehicles need cross with only one wheel on the cushion, which may reduce the effectiveness

* high sided vans may tilt sideways excessively when passing with one wheel on the cushion, causing concern to pedestrians and may lead to some street furniture being damaged

* extra stress on inner rear wheels of large vehicles while crossing a cushion may cause undue wear, particularly to buses

EXAMPLES:

A sample list of schemes is given in Appendix C which contains various sites where cushions have been used.

6. SHORT/LOW BUMPS

In earlier TRL trials (Watts, 1973) it was found that short humps became less effective as speeds rose. Notwithstanding this, Wakefield MDC have experimented with short/low bumps because they felt that 'Standard' humps, conforming to the 1983 regulations were expensive to install and maintain. Thermoplastic bumps were chosen and experiments were carried out to determine a suitable design. A circular profile bump of 900 mm long and 37 mm high was found to be acceptable for a mini-bus route on Manygates Lane. 50 mm high bumps were included in the test track trials at TRL and further road trials are being carried out in Wakefield with the 37 mm high version.

NOTE. These require authorisation from DOT at present (see section 1.4)

DESIGN:

Material: Thermoplastic, rubber

Typical cost: £400 - £700 (1991 prices)

Dimensions: Height - 35 mm (min) to 60 mm (max)

Width - Across full road width or with a gap of 200 mm between measure and kerb.

Length - 900 mm (35 mm high) to 1000 mm (60 mm)

Profile - Circular (see Figs 19 and 20)

Spacing: Follow hump Regulations as far as possible.

Construction: See Fig 21

EFFECTIVENESS:

Speeds (85%ile) have been reduced from 39 mph to 28 mph in Wakefield (Broadbent and Salmon, 1991) when using 900 mm long by 37 mm high bumps. The use of colour is thought to be important (yellow used).

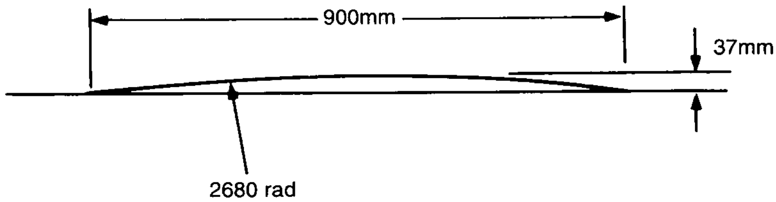


Fig.19 Dimensions of bump at Wakefield

Series of four spaced at 25 metres.

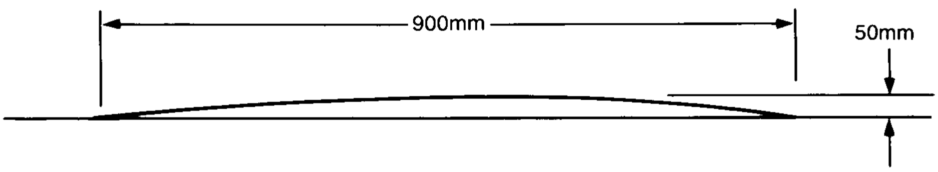


Fig.20 Dimensions of bumps used at TRL

Preliminary results of track trials at TRL using four 900 mm long by 50 mm high bumps spaced at 25 metres gave comparable discomforts (mid range) for both cars and buses at the design speed of 30 mph.

Detailed results will be published in a separate report.

SIGNING AND LIGHTING:

The signing and lighting described in Regulation 4(3)(a) and 6 of the Highways (Road Humps) Regulations (SI 703), should be followed. Should be clear to drivers in all conditions. Road markings should not be necessary but signs should be as given in Fig 5.

SUITABLE LOCATIONS:

a) May be appropriate along bus routes as an alternative to standard humps, though the effect on buses or emergency vehicles and their general acceptability is the subject of further research.

b) May be suitable on low flow distributor roads.

FOR:

* Inexpensive
* short installation time
* low maintenance costs
* effective speed reducer
* could be acceptable to the emergency services if standard humps have been rejected but there is a need for some speed-reducing measure
* shorter than standard humps
* highly visible when made of coloured reflective material

AGAINST:

* Research (Watts, 1973) showed that short/low humps are less effective at higher speeds. (Note. Humps which were 50 mm high and 1220 mm long were tested, as reported by Watts (1973) in LR597
* not covered by Regulations at present but since July 1992 may be authorised by DOT
* monitoring of new schemes important because design not widely used at present
* little practical experience is available; however research is being carried out and a further scheme in Wakefield is being monitored.
* can be visually intrusive

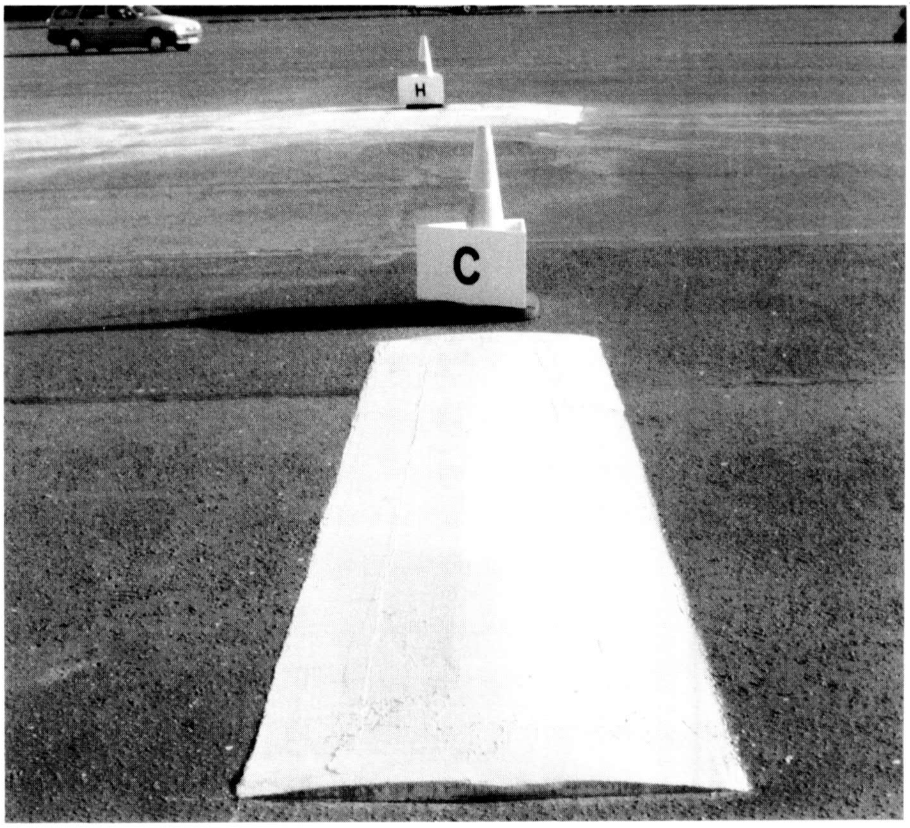


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Fig.21 Examples of bumps used at TRL track trial

7. RUMBLE DEVICES

Rumble devices (rumble strips/areas and jiggle bars) are small raised areas across the whole carriageway which are designed primarily to alert drivers to slow down for particular hazards. The devices have the effect of sending severe vibrations through the vehicle to the driver and passengers, making the ride very uncomfortable. Considerable noise can also be generated.

The amendments to the Highways Act 1980 through the draft Traffic Calming Act 1992, enables rumble strips to be authorised if the local authority has doubts as to their general powers to construct these devices. The Traffic Calming Regulations, which are expected to be made in 1993, will propose allowing the construction of rumble strips/areas up to 13 mm in height providing no vertical face is greater than 6 mm.

DESIGN:

Material:	asphalt; concrete; thermoplastic; granite setts; blocks
Typical cost:	up to £5,000 per site depending on length of road treated (1991 prices)
Dimensions:	Usually less than 13 mm high with a gap of 1 metre provided for cyclists use
Spacing:	Strips and bars are often installed in groups with clear road in between each group. Generally accepted that the spacing between strips/bars within a group should be decreased as the distance to the hazard decreases. Further information on present practices and optimum spacings is being collected
Construction:	See Figs 22, 23 and 24.

EFFECTIVENESS:

* Speed reductions of up to 10% were reported in LR800 and SR292, however they were highly dependent on the site conditions. Further research is being carried out.
* Initial speed reductions are often not sustained in the long term.
* Generally used to warn drivers of hazards and have lead to accident reductions at Hawley and Dorket Head crossroads.

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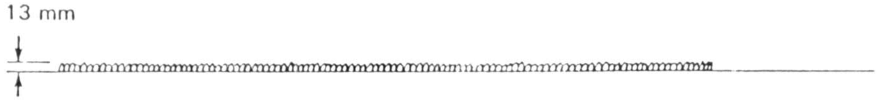
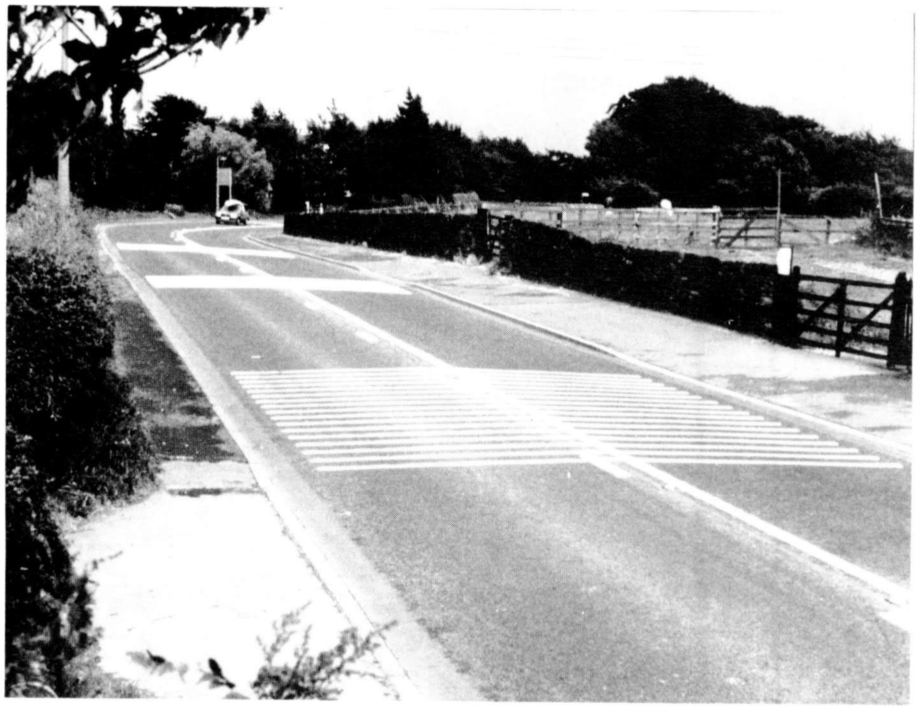
13 mm



NB. Vertical scale slightly exaggerated

Fig.22 Rumble areas (example and diagrammatic)



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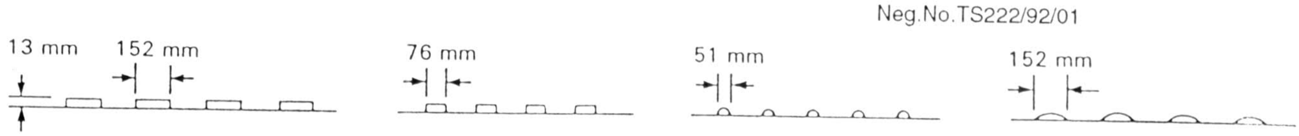

NB. Vertical scale slightly exaggerated

Fig.23 Jiggle bars (example and diagrammatic)

SIGNING AND LIGHTING:

Not covered explicitly by Regulations, however, it would often be appropriate for 'slow' markings to be used in association with a sign . Must be clear to drivers in all conditions.

SUITABLE LOCATIONS:

a) Have been used on approaches to rural junctions and hazardous bends where speed related accidents have occurred. There should be no residential properties including hospitals or similar establishments close to the site due to the problem of noise. Many highway authorities do not consider rumble devices within 200 metres of residential properties, because of the noise nuisance that can arise.

b) To form a 'Gateway' to a village to encourage speed-limit compliance through the village.

FOR:

* Inexpensive
* alert drivers to hazards
* dimensions not too restrictive
* can be made highly visible to drivers
* can lead to reduced numbers of accidents

AGAINST:

* substantial traffic noise for residents close to measure
* not popular with cyclists/motorcyclists
* special authorisation required
* any initial speed reductions may not be maintained in the long term
* effect of measure is site specific and may be quite variable for similar schemes
* consultation important because modifications can be expensive if alterations have to be made after installation
* some drivers may increase their speed to lessen the vibratory effect of the rumble device
* if not used across full carriageway, vehicles may drive around the devices

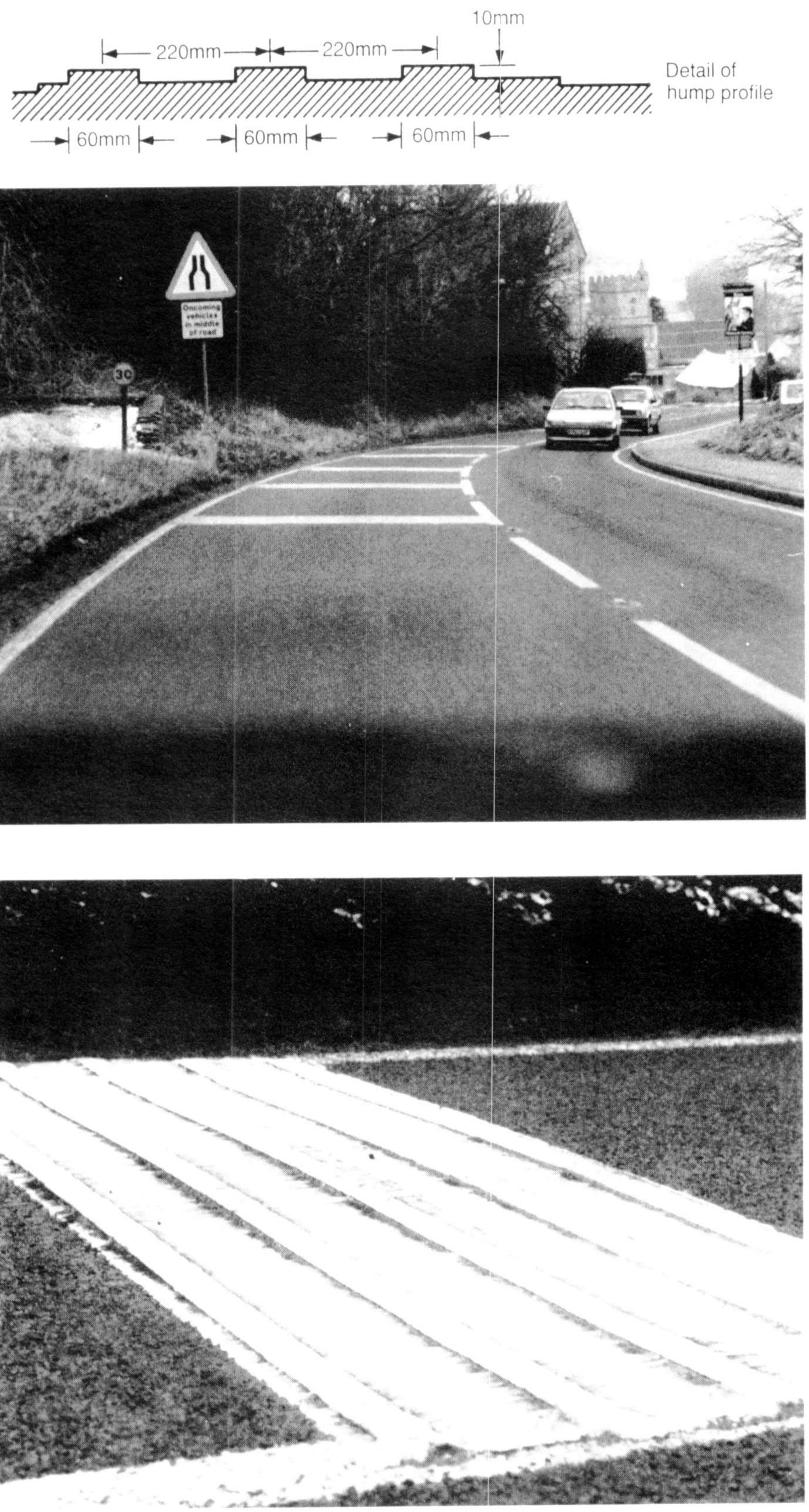

Fig.24(a) Rumble strips (examples and diagrammatic)

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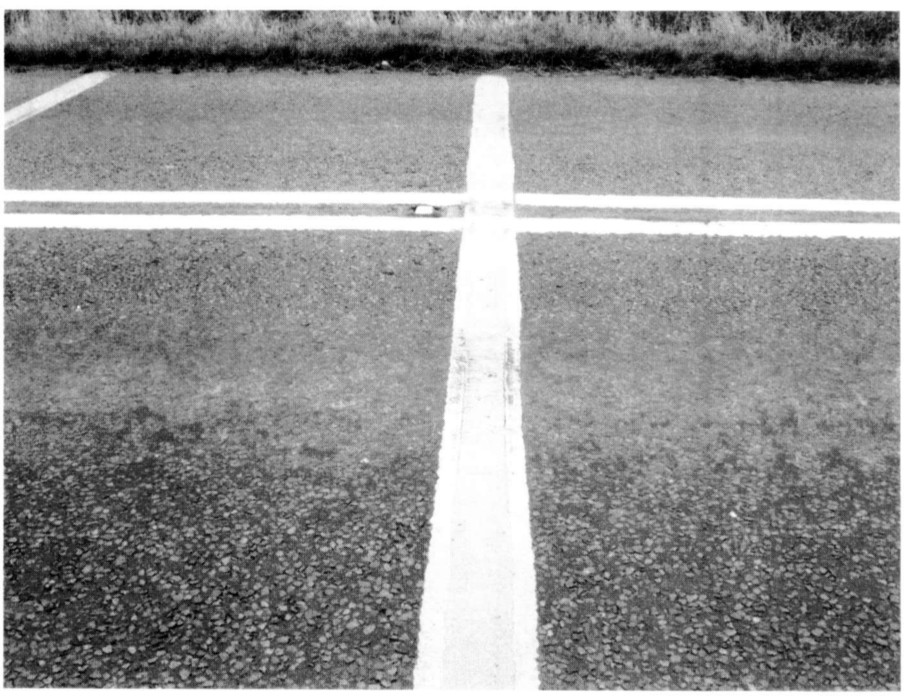


Neg.No.CR111/93/6

Fig.24(b) Rumble strips (examples and diagrammatic)

EXAMPLES:

A sample list of schemes is given in Appendix C which contains various sites where rumble strips-areas/jiggle bars have been used.

8. SPECIAL DESIGNS FOR CYCLISTS

Some Traffic Calming features incorporating vertical deflections can be uncomfortable for cyclists and if measures are being installed to assist this road user group it is important that their views are sought prior to finalising any designs.

The lower height humps of 75 mm and 50 mm are less severe for cyclists but this has to be balanced against the increased motor- vehicle speeds. Materials creating an irregular surface or designs which feature vertical upstands are uncomfortable and perceived as potentially dangerous by pedal cyclists. These materials and designs should therefore be avoided. If these types of materials are required, for visual appearance in historical areas, consideration should be given to the construction of a cycle lane bypass at the edge of the carriageway as described in section 8.1. This type of hump arrangement would require authorisation from DOT.

8.1 COMBINED HUMPS AND CYCLE LANES

8.1.1 Hump by-pass (Type 1)

This involves a standard road hump with a minimum of 700mm between the kerb and the hump allowing cyclists to pass to the left hand side of each hump. A mandatory cycle lane along the length of the scheme would be preferable to avoid encroachment by motor vehicles into the cycle lane (see Fig 25). At present the hump Regulations only have 200 mm between the kerb and the hump and so this design would require authorisation from DOT. The 200 mm design was adopted to deter cyclists and motorcyclists from trying to avoid the humps and also to discourage car and van drivers from travelling with their nearside wheels in the 200 mm channel.

8.1.2 Hump by-pass (Type 2)

Cyclists are given the option of crossing the hump, or going to the left of the hump to travel unhindered past the measure. There would be little conflict on rejoining the road after the hump had been passed because the entrance and exit of the measure could be made as shallow as required. A Dutch example (Cleary 1991), which would need authorisation under the Traffic Calming Act, is given in Fig. 26.

8.1.3 Separate raised cycle track

This would appear to be the safest type of scheme because the cycle track is combined with the footway thus keeping the cyclist separate from the motor vehicles. This solution would be suitable at sites where:-

a) the road width was not at a premium,

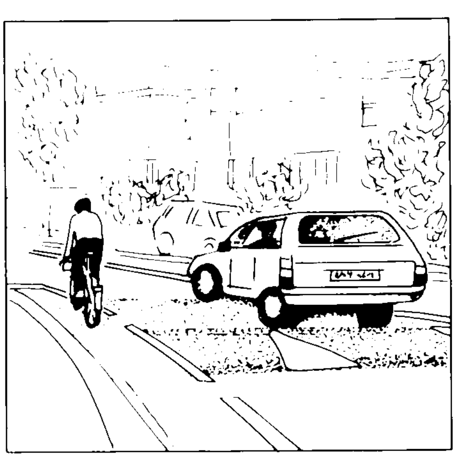
b) the numbers of pedestrians using the footway could be accommodated safely with the cyclists

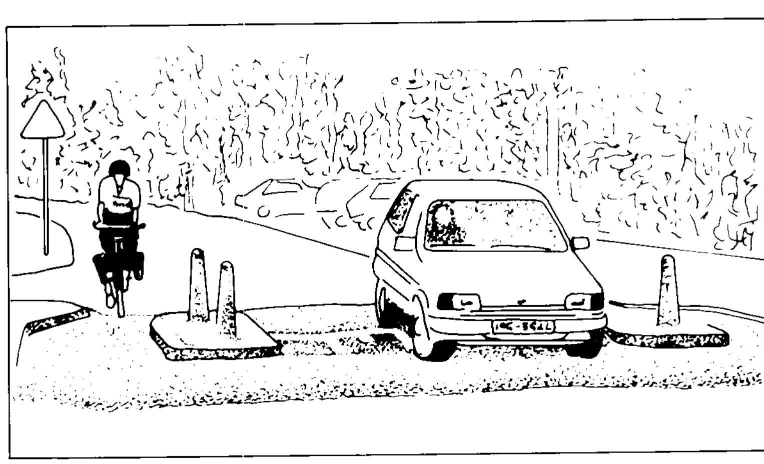
c) there were a minimal number of side roads.

Care is needed where the cyclists join the main carriageway and integrate with the main traffic stream.

8.2 SPEED CUSHIONS

These were discussed earlier in section 5 of this report. These are ideal measures for cyclists because they slow traffic down when combined with other traffic calming measures but they can be negotiated easily by cyclists. Sufficient space between the cushion and the kerb, at least 700 mm, should be provided to allow cyclists to





Figs.25 and 26 Examples of Type 1 and 2 hump by-passes for cyclists

pass to the left of the cushion avoiding the possibility of them being forced onto the side ramp. Gullies between the cushion and the kerb should be avoided and the position of others in the vicinity should be considered.

8.3 ROAD HUMP WITH SINUSOIDAL PROFILE

Humps with sinusoidal profiles have been used in the Netherlands, Lines and Castelijn, (1991) because they are supposedly better for cyclists, but in the UK they fall outside the current hump Regulations. From July 1992, however, the various designs may be authorised by applying to DOT (see Circular Roads 2/92). In practice, many circular profile humps may gradually become sinusoidal as they become trafficked, particularly if there is a high proportion of heavy vehicles. An example of a 4.8 metre long 120 mm high sinusoidal hump profile as used in the Netherlands is given in Fig 27.

9. SPECIAL DESIGNS FOR PEDESTRIANS

Schemes which use road humps can be tailored to aid pedestrians. It is important that all pedestrian groups are taken into account, particularly children, the elderly, pedestrians with prams and those who have a mobility handicap (IHT, 1991). Children may require additional training so that they understand how to use the measures safely.

9.1 PEDESTRIAN CROSSINGS

Under the latest Regulations, it is possible to have a pedestrian crossing point sited on a raised table or at a hump as discussed in section 1.2. Pelican and zebra crossings (see Fig. 28) can only be used on kerb to kerb humps. Normally these should be flat top raised tables because round top humps are not recommended for use as crossing points. Schemes which contain a number of flat top tables where some (but not all) are crossings, appear to cause no problems for the pedestrians or the other road users. Further investigations are being made into the apparent priority assumed by some pedestrians at these crossing places.

9.2 BUILD OUTS AT HUMPS

It is important for pedestrians that time spent in the road on the hump is kept to a minimum. This can be achieved by narrowing the road at the crossing by increasing the width of the footway. An example of this type of measure can be seen in Fig. 8 (two-way) and Fig. 29 (one-way priority). The shorter crossing distance gives the pedestrians a greater sense of safety but increases the cost.

9.3 FOOTWAY CROSSOVERS AT PAVEMENT LEVEL

The continuation of footways across side road junctions, to provide a 'Gateway', should give benefit to pedestrians because car drivers will have to slow down and be more careful at the junction. Crossovers are of most use on roads which have had accidents or are known to be potentially dangerous based on observations of pedestrian movements. Highway authorities need to be satisfied that either the crossover conforms to the Highways (Road Humps) Regulations, or is permitted by the general powers of the Highways Act 1980. Tactile surfaces should be incorporated when appropriate at the edge of the pavement to help pedestrians with mobility handicaps (IHT 1991) and Disability Unit Circular 1/91 (DOT, 1992). An example of a typical footway crossover is given in Fig. 30.

9.4 HUMPS/TABLES WITH CENTRAL RESERVES

Humps and tables are often constructed from kerb to kerb which means that they can be very wide. The appearance of long roads containing many humps could be enhanced by adding central illuminated bollards which may encourage pedestrians to cross the road at the hump where the vehicles would usually be travelling more slowly (tactile surfaces should be used). The conspicuity of the humps would be improved by the narrowing effect which would reduce the straight ahead sight lines for drivers. An example of a table with a central reserve is given in Fig. 31.

9.5 HUMPS AND SHARED SURFACES

The road between successive humps can be turned into a shared surface by raising the vertical alignment of the

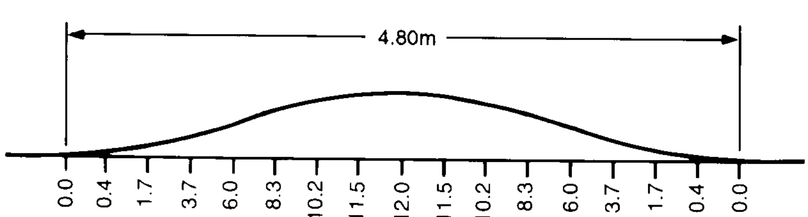


Fig.27 Example of Dutch hump with sinusoidal profile

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Fig.28 Humped pelican crossing

road so that it is level with the original kerb. This can then be combined with environmental enhancements such as planters, seats, chicanes etc. which should deter through traffic particularly if the design limits speeds to a walking pace as in continental schemes. An example of a British scheme is given in Fig. 32.

10. SPECIAL DESIGNS FOR BUSES/EMERGENCY VEHICLES

This section is primarilly concerned with buses and emergency vehicles but many of the principles apply to other vehicles such as limousines and hearses which have long wheelbases and can have ground clearances lower than 75 mm when fully laden. (See section 3)

10.1 LOW PROFILE ROAD HUMPS AND RAISED TABLES

Bus routes require special consideration. The medium height humps of 75 mm are suitable when the frequency of buses is low or the number of emergency vehicles, particularly ambulances, is likely to be small.

The lowest height humps of 50 mm are much less effective than the higher humps at reducing car speeds (See appendix A), but on bus routes they provide a low-cost compromise between reducing speeds and discomfort for bus passengers.

For flat-top road humps, bus companies tend to prefer a plateau length of at least 6.0 metres (See Fig. 33) which can accommodate the wheel-base of most buses in service in the UK. These are considered to be less uncomfortable for bus passengers because the induced pitching motion while crossing the hump is minimised. Ramp gradients of 1:10 are generally acceptable but slightly reduced gradients (1:20) are desirable if double-decker buses make up a high proportion of the vehicle fleet to minimise the upper deck pitching.

10.2 SPEED CUSHIONS

Research is still in progress into the use of cushions but early indications suggest that they may be more acceptable to bus operators. Cushions can be combined with other traffic calming measures such as narrowings and planting where materials suitable for the area can be used to improve the visual impact.

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Fig.29 One-way priority at hump

Note. Traffic Signs Regulations and General Directions do not at present allow give way markings

Neg.No.CR175/91/9

Fig.30 Example of a typical footway crossover

Neg.No.TS304/92/15

Fig.31 Example of a table with a central reserve

Neg.No.TS222/92/03

Fig.32 Residential road with shared road space

Neg.No.TS222/92/04

Fig.33 Flat-topped table for buses

10.3 COMBINED HUMPS AND EMERGENCY SERVICES/BUS LANES

The use of bus lanes requires a wide carriageway and is therefore not a practical solution on many roads. On some wide roads, however, it may be possible to have bus lanes around humps. A diagrammatic representation of a scheme is given in Fig. 34. It can be seen that the scheme is similar to having lay-by style bus stops at a hump which would be the preferred option. For use in the UK, Authorisation from DOT would be required and special priority signing may also need to be authorised to avoid any conflicts when a bus rejoins the main traffic.

For restricted width roads, it may be possible to have a bus lane running down the centre of the road with humps in the vehicle lanes (See Fig. 35).

This arrangement would also require DOT authorisation, and may also require a priority system for the bus lane, especially if there were a lot of mini-buses. Bus drivers would have to take special care when rejoining the main traffic flow. These measures would not be advisable in areas where the police consider that the degree of non compliance would be a serious problem because this would defeat the purpose of the measure.

10.4 ROAD HUMP WITH SINUSOIDAL PROFILE

These humps (See section 9.3) are not covered by the hump Regulations but could be authorised by DOT. It is possible that this design would not affect bus passengers as much as a standard hump but would still deter car drivers from travelling at excessive speeds.

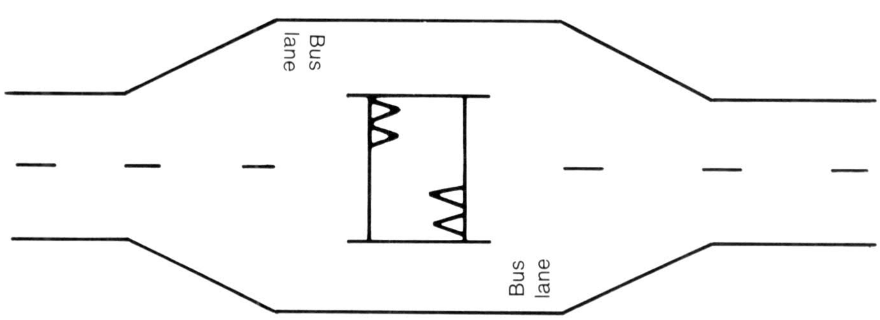

Fig.34 Bus lanes by-passing hump

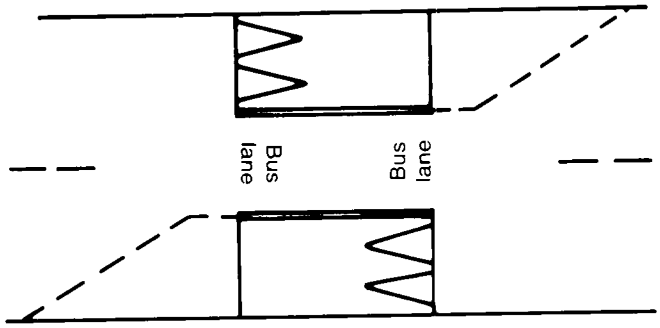

Fig.35 Single lane for buses by-passing hump

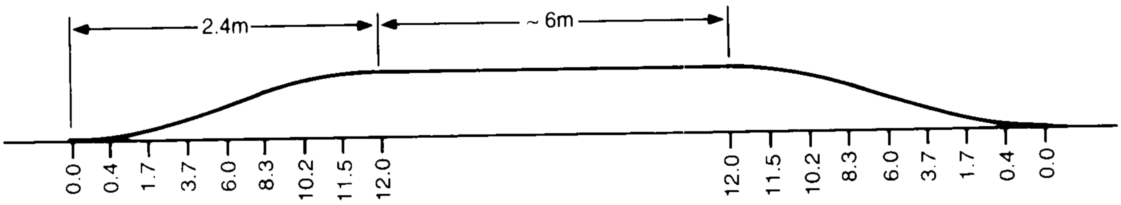

Fig.36 Example of flat-top raised table with sinusoidal ramp

Note. For 60 and 75 mm high tables the corresponding height values would be:

0.	2.0,	8.5,	18.5,	30.0,	41.5,	51.0,	57.5	and	60.0 mm.
0.	2.5,	10.6,	23.1,	37.5,	51.9,	63.8,	71.9	and	75.0 mm.

The sinusoidal profile could be used for the ramp section of a flat-top raised table if it was found that the normal linear gradient of the table was too severe and generating an undue number of complaints from the general public. An example is given in Fig. 36.

11. CONCLUSIONS

1) Vertical deflections can be used to control vehicle speeds.

2) Measures can be tailored to suit the surrounding area and need not be confined to residential roads.

3) Measures are available which are more acceptable to bus operators and the emergency services.

4) Measures can be designed specifically to aid pedestrians and/or cyclists.

5) Accident reductions appear to result from the lower speeds and are not just due to the lower flows.

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13. REFERENCES

BAGULEY, C J (1981). Speed control humps - Further public road trials. *Department of Transport, TRRL Report LR1017*, Transport and Road Research Laboratory, Crowthorne.

BROADBENT, K and A M SALMON (1991). An experiment with road humps. Highways and Transportation, November 1991.

BULPITT, M A (1990). Traffic Calming, A Code Of Practice. Paper presented at Urban Safety Management Seminar held at TRRL on 27th November 1990. (See reference Kent County Council 1992)

CHORLTON ET AL (1991). Traffic Calming Guidelines. Devon County Council, Exeter, 1991.

CLEARY, J (1991). Cyclists and Traffic Calming. A CTC Technical Note compiled by Johanna Cleary. Cyclists' Touring Club (CTC), 69 Meadrow, Godalming, Surrey GU7 3HS.

CLEMENT J P (1983). 'Sleeping policemen' work without pay. American City and County. February 1983.

COOPER D R C, P G JORDAN and J C YOUNG (1980). The effect on traffic speeds of resurfacing a road. *Department of the Environment, Department of Transport, TRRL Supplementary Report SR571*, Transport and Road Research Laboratory, Crowthorne.

DEPARTMENT OF THE ENVIRONMENT, DEPARTMENT OF TRANSPORT (1992). Residential roads and footpaths. Layout considerations. *Design bulletin 32*, Second edition. HMSO, London.

DEPARTMENT OF TRANSPORT (1987). Speed control humps. *Traffic Advisory Leaflet 3/87*, Traffic Advisory Unit, London.

DEPARTMENT OF TRANSPORT (1988). Calculation of Road Traffic Noise. HMSO, London.

DEPARTMENT OF TRANSPORT (1990a). Speed control humps. *Traffic Advisory Leaflet 2/90*. Traffic Advisory Unit, London.

DEPARTMENT OF TRANSPORT (1990b). 20 mph speed zones. *Circular roads 4/90.*

DEPARTMENT OF TRANSPORT (1992). The use of dropped kerbs and tactile surfaces at pedestrian crossing points. *Disability Unit Circular 1/91* (Final). Disability Unit, London.

DEPARTMENT OF TRANSPORT (1992). Road Traffic Act 1991: Road humps and variable speed limits. *Circular roads 2/92.*

HASS-KLAU et al (1992). Civilised Streets: A guide to Traffic Calming. Environmental and Transport Planning, 10 Clermont Terrace, Brighton BN1 6SH.

INSTITUTION OF HIGHWAYS AND TRANSPORTATION (1990). Urban Safety Management Guidelines. IHT, 3 Lygon Place, London.

INSTITUTION OF HIGHWAYS AND TRANSPORTATION (1991). Revised guidelines for: Reducing Mobility Handicaps. Towards a barrier-free enviroment. IHT, 3 Lygon Place, London.

JONES, S (1986). Driving issue: rumbling the downhill racers. Surveyor 4 December 1986.

KENT COUNTY COUNCIL (1992). Traffic Calming. A code of practice. Kent County Council, Maidstone.

KJEMTRUP K (1990). Speed reducing measures. Conference paper, Copenhagen. April 1990.

LINES, C J and H A CASTELIJN (1991). Translation of Dutch 30 kph Zone design manual. Department of Transport, *TRRL Paper PA 2046/91*, Transport and Road Research Laboratory, Crowthorne.

LYNAM D A, A M MACKIE and C H DAVIES (1988). Urban safety project. 1. Design and implementation of schemes. *Department of Transport, TRRL Report RR153*, Transport and Road Research Laboratory, Crowthorne.

MACKIE A M, H WARD and R T WALKER (1990). Urban safety project. 3. Overall evaluation of area wide schemes. *Department of Transport, TRRL Report RR263*, Transport and Road Research Laboratory, Crowthorne.

PHAROAH, T and J RUSSELL (1989). Traffic Calming: Policy and Evaluations in Three European Countries. South Bank Polytechnic, London. *Occasional Paper 2/1989*, Department of Planning, Housing and Development.

SUMNER, R and J SHIPPEY (1977). The use of rumble areas to alert drivers. *Department of Transport, TRRL Report LR800*, Transport and Road Research Laboratory, Crowthorne.

SUMNER, R and C BAGULEY (1979). Speed control humps on residential roads. *Department of Transport, TRRL Report LR878*, Transport and Road Research Laboratory, Crowthorne.

THOMPSON, S J, P GOW and G COILES (1990). Nottinghamshire's road ramps scheme. Traffic Engineering + Control (October 1990).

TOLLEY, R (1990). Calming traffic in residential areas. Brefi Press, P.O. Box 103, Tregaron, Dyfed SY25 6BR.

WATTS, G R (1973). Road humps for the control of vehicle speeds. *Department of Transport, TRRL Report LR597*, Transport and Road Research Laboratory, Crowthorne.

WATTS, G R (1978). Results from three trial installations of rumble areas. *Department of Transport, TRRL Report SR292*, Transport and Road Research Laboratory, Crowthorne.

WINDLE R and A M MACKIE (1992). Survey on public acceptability of traffic calming schemes. *Department of Transport, TRRL Contractor Report CR298*, Transport and Road Research Laboratory, Crowthorne.

APPENDIX A: EFFECT OF ROAD HUMP SCHEMES ON FLOWS AND SPEEDS

A.1 EFFECT ON TRAFFIC FLOWS

The sites were chosen so as to give a cross-section of situations ranging from a rural village (Gamlingay) to central London (Westminster) as well as several 20 mph zones (Sheffield and Kingston). Vehicle flows are included because one of the aims of a scheme may be to remove inappropriate rat running traffic. The data given in Table A1 was obtained from the local authority concerned with each scheme.

TABLE A1

Description of site and approx. 2-way daily flows

TOWN/road	Hump type	Separation (metres)	Flow/day after*	% Diff (after)
BARNSLEY	RT	59	1,000	-28
	RT	48	1,800	+13
BATLEY	RT	100	2,000	-10
BRIDGWATER 1:10#	FT	20	4,000	-11
BRISTOL				
Longway Avenue	RT	128	1,800	-28
Callicroft Road	RT	95	1,700	-38
Lanercost Road	RT	125	1,400	0
CAMBRIDGE	RT	60	2,000	0
COVENTRY	RT	120	1,500	-25
CROYDON	RT	90	2,000	0
EXETER 1:10	FT	85	5,000	-12
FOLKESTONE 1:10	FT	150	4,000	0
GAMLINGAY	RT	80	1,500	-14
HARINGEY	RT	75	8,000	-27
KENS'TON/CHELSEA				
St Leonards Terr	RT	70	10,000	0
Abbotsbury Road	RT	70	10,000	-23
Elsham Road	RT	85	2,000	0
KINGSTON				
Beconsfield Road	RT	60	1,000	0
Lime Grove	RT	60	2,000	-5
Chestnut Grove	RT	60	2,000	-17
Sycamore Grove	RT	75	2,000	+11
Acacia Grove	RT	70	2,000	+11
LIGHTWATER	RT	143	3,500	-3
	RT	112	3,000	+7
MAIDSTONE 1:10	FT	150	5,000	-36
MILTON K'NES 1:12	FT	0	10,000+	0
OXFORD C.C. all	RT	<135	variable	-20
READING				
Grange Av	RT	56	2,700	NA
Granville Road	RT	50	400	-35
Hamilton Road	RT	58	1,200	-25
Wilson Road	RT	40	365	-44
RICHMOND				
Cumberland Road	RT	88	1,800	-5
Leyborne Park	RT	54	1,000	NA

Table A1 continued **Description of site and approx. 2-way daily flows**

TOWN/road	Hump type	Separation (metres)	Flow/day after*	% Diff (after)
ROCHESTER 1:10	FT	150	4,500	-40
SHEFFIELD				
All FT 1:8 ramps				
Dundas Road(E)	FT	75	220	-16
Dundas Road(W)	FT	75	220	-42
Hatherley Road	FT	47	240	-36
Lifford Street	FT	60	120	-59
Raby Street	FT	37	230	-50
Oversley Street	FT	43	120	-40
Earl Marshall Rd	RT	65	545	-54
Earl Marshall Rd	RT	130	1,912	-13
SITTINGB'NE 1:10	FT	100	7,500	0
SUTTON				
Washington Road	RT	80	500	0
Clarkes Avenue	RT	73	5,000	-17
Dorchester Road	RT	111	6,000	+13
Langley Avenue	RT	105	1,000	-39
Boscombe Avenue	RT	85	1,500	-17
WESTMINSTER				
Vincent Square	RT	110	3,500	-24
Vincent Square	RT	85	2,500	-44
YORK				
Salisbury Road	RT	113	9,000	NA
Garfield Terrace	RT	80	4,000	NA
			Range of flows + 13 % to - 59%	

Notes.
* Some flows are estimated.
\# 1:10 first hump, all others 1:6 RT = Round Top hump. FT = Flat Top table NA = Not available

A.2 EFFECT ON VEHICLE SPEEDS

The primary objective of the study was to determine:-

1) If the speed/separation-between-humps relationship had altered since LR1017 which was published in 1981.

2) The appropriate spacings for a given target speed using the new relationship.

The speeds (measured approximately midway between humps) obtained at the sites studied are given in Table A2.

Exponential and logarithmic relationships were established which gave correlation coefficients which were similar to the linear relationship and therefore only the linear relationships have subsequently been calculated because these are preferred for practical purposes.

The ongoing study of speeds between humps and hump separation has given the following results:-

For 100 mm **CIRCULAR PROFILE** humps

$V85 = 16.73 + 0.087S$ $r = 0.80$ S.E. = 1.59

$Vm = 12.10 + 0.092S$ $r = 0.87$ S.E. = 1.28

TABLE A2

Description of site and speeds measured.

TOWN Road	Type of hump	Vehicle speeds (mph) 85% tile Before	After	Mean Before	After	Reduction 85%	Mean
ASHFORD	FT80	41	29	36	25	12	11
BARNSLEY	RT	26	20	22	16	6	6
	RT	26	18	20	15	8	5
BATLEY	RT	30	16	-	13	14	-
BERINSFIELD Oxon							
Fane Drive	RT75	37	29	29	23	8	6
Wimblestraw Road	RT75	36	25	29	21	11	8
BICESTER (OXON)	RT85	34	25	27	18	9	9
BRIDGWATER 1:10& 1:6	FT	33	14	28	11	19	17
BRIGHTON							
Hampden Road	RT	34	22	26	18	12	8
Islingword Road	RT	30	19	24	15	11	9
BRISTOL							
Longway Avenue	RT	32	21	-	-	11	-
Callicroft Road	RT	37	24	-	-	13	-
Lanercost Road	RT	33	26	-	-	7	-
CAMBRIDGE	RT	35	22	31	18	13	13
COVENTRY	RT	23	20	20	16	3	4
CROYDON	RT	41	27	-	-	14	-
DIDCOT Wessex Rd	RT75	29	23	22	15	6	7
EARLEY Beech Ln.	RT75	43	24	36	21	19	15
EXETER 1:10							
Burnthouse Lane	FT	34	24	28	22	10	6
Dryden Road	FT	28	22	22	18	6	4
Rifford Road	FT	-	26	-	22	-	-
Rifford Road	FT	-	26	-	22	-	-
Wonford Road	FT	-	22	-	18	-	-
FOLKESTONE 1:10	FT	35	31	28	26	4	2
GAMLINGAY	RT	37	27	32	23	10	9
GUILDFORD	RT75	38	26	34	22	12	12
HARINGEY	RT	39	28	34	26	11	8
HENLEY							
Deanfield Road	RT85	38	26	29	18	12	11
Deanfield Av.	RT85	31	23	24	17	8	7

Table A2 continued **Description of site and speeds measured**

TOWN Road	Type of hump	Vehicle speeds (mph) 85% tile Before	85% tile After	Mean Before	Mean After	Reduction 85%	Reduction Mean
KENNINGTON	RT	35	28	31	22	7	9
KENS'TON/CHELSEA							
St Leonards Terr	RT	34	22	-	-	12	-
Abbotsbury Road	RT	39	22	-	-	17	-
Elsham Road	RT	39	28	-	-	11	-
KIDLINGTON	RT75	36	26	28	19	10	9
KINGSTON							
Beconsfield Road	RT	28	23	-	18	5	-
Lime Grove	RT	31	23	-	18	8	-
Chestnut Grove	RT	34	24	-	18	10	-
Sycamore Grove	RT	32	23	-	18	9	-
Acacia Grove	RT	34	24	-	18	10	-
LEICESTER 1:8							
Melbourne Road	FT	28	19	-	17	9	-
Derwent Street	FT	29	24	-	21	5	-
Mere Road (1)	FT	35	24	-	21	11	-
Mere Road (2)	FT	32	19	-	17	13	-
Park Vale Road	FT	33	24	-	20	9	-
St.Stephens Road	FT	28	22	-	19	6	-
LIGHTWATER							
Macdonald Road	RT	43	25	-	-	18	-
Macdonald Road	RT	46	28	-	-	18	-
MAIDSTONE 1:10							
Plains Avenue	FT	39	32	31	25	7	6
South Park Road	FT	30	25	24	19	5	5
MILTON KEYNES	FT	-	14	- 11	-	-	
OXFORD CITY							
Cornwallis Road	RT75	31	24	25	19	7	6
Florence Park Rd	RT75	31	24	24	18	7	6
Cuddesdon Way	RT75	34	24	27	20	10	7
Pegasus Road	RT75	37	29	30	23	8	7
Sandy Lane	RT75	33	25	22	18	8	4
Margaret Road	RT75	33	22	26	17	11	9
Quarry High St.	None	25	26	20	21	-	-
Quarry Hollow	RT75	31	25	25	20	6	5
READING							
Culver Lane	RT	38	25	32	21	13	11
Grange Av	RT	26	20	-	16	6	-
Granville Road	RT	32	23	26	18	9	8
Hamilton Road	RT	34	20	29	16	14	13
Palmer Park Av	RT	36	24	28	19	12	9
Wilson Road	RT	28	19	22	15	9	7
Canterbury Road	RT75	36	25	30	20	11	10
Long Barn Lane	RT75	40	30	34	22	10	12
New Lane Hill	RT50	45	34	38	27	11	11
Honey End Lane	RT50	35	30	30	25	5	5

Table A2 continued **Description of site and speeds measured**

TOWN Road	Type of hump	Vehicle speeds (mph) 85% tile Before	After	Mean Before	After	Reduction 85%	Mean
RICHMOND L B							
Hertford Avenue	RT	28	25	24	21	3	3
Cumberland Road	RT	30	24	-	19	6	-
Leyborne Park	RT	30	21	-	17	9	-
Connaught Road	RT	39	21	-	-	18	-
Princes Road	RT	33	19	-	-	14	-
Fairfax Road	RT	37	18	-	-	19	-
Fife Road	RT	36	24	31	20	12	11
Orford Gardens	RT	31	19	-	-	12	-
Radnor Road	RT	31	20	-	-	11	-
Christchurch Rd	RT75	41	22	29	-	19	-
Burtons Road	RT	37	26	30	21	11	9
Ormond Avenue	RT50	37	27	-	22	10	-
ROCHESTER 1:10	FT	35	29	27	22	6	5
SHEFFIELD							
All FT 1:8 ramps							
Dundas Road(E)	FT	29	19	24	16	10	8
Dundas Road(W)	FT	24	19	20	15	5	5
Hatherley Road	FT	25	17	20	14	8	6
Lifford Street	FT	25	20	21	18	5	3
Raby Street	FT	28	18	23	14	10	9
Oversley Street	FT	25	17	19	15	8	4
Earl Marshall Rd	RT	37	24	29	19	13	10
Earl Marshall Rd	RT	40	30	33	24	10	9
SITTINGB'NE 1:10							
Chiltern Avenue	FT	35	29	28	22	6	6
South Avenue	FT	37	31	28	23	6	5
Stanhope Avenue	FT	36	31	28	23	5	5
SLOUGH							
Essex Avenue	RT75	-	26	-	21	-	-
Furnival Avenue	RT75	-	28	-	23	-	-
Whittaker Road	RT75	43	31	36	26	12	10
Long Furlong Dr.	RT50	44	30	37	25	14	12
Long Furlong Dr.	RT50	44	31	37	26	13	11
SUTTON							
Washington Road	RT	32	24	27	20	8	7
Clarkes Avenue	RT	43	24	37	21	19	16
Dorchester Road	RT	32	27	29	23	5	6
Langley Avenue	RT	36	25	31	22	11	9
Boscombe Road	RT	30	24	26	21	6	5
WESTMINSTER							
Vincent Square	RT	27	24	22	20	3	2
Vincent Square	RT	28	21	23	17	7	6
WOODHAM	RTFT	36	26	-	23	10	-
YORK							
Salisbury Road	RT	31	27	28	24	4	4
Garfield Terrace	RT	26	21	23	19	5	4
				Average speed Reductions		9.8	7.8

For 100 mm **FLAT-TOPPED** humps (Nominal slopes of 1:8 to 1:10)

$V85 = 12.95 + 0.107S$ $r = 0.93$ S.E. = 1.70

$Vm = 11.06 + 0.090S$ $r = 0.91$ S.E. = 1.61

N.B. These formulae give mid range values of expected speeds and will vary from site to site.

Where V85 = Between hump 85% speed (mph)
Vm = Between hump mean speed (mph)
S = Hump separation in metres
r = Correlation coefficient
S.E. = Standard Error

These relationships are illustrated in Figs 37 - 40.

Thus the typical hump separation required to obtain a given target speed for circular profile humps can be estimated for the new linear equations. The values are given in Table A3.

The relationship given in LR1017 gives hump separations of 45, 80, 115 and 150 metres corresponding to the speed values in Table A3. It would appear to give higher speeds for a given hump spacing compared with the latest research and therefore the latest target speed data given in Table A3. should now be used in conjunction with Figs. 37 and 38 which contain the upper and lower 95% confidence limits representing the range of values which may be exceeded 1 in 20 times. In engineering terms this can be regarded as the practical range.

It should be appreciated that some sites may not attain the target speed expected due to the tolerances in the height/profile of the hump, parked vehicles, gradient, width, curvature of the road and other local considerations. For these reasons, it is important that speed measurements are taken before the measures are installed because this will indicate the percentage of drivers above the speed limit.

The typical hump separation required to obtain a given target speed for flat-topped humps are slightly different to the circular profile humps using the above linear equations. The values are given in Table A4.

Hump crossing speeds for a number of sites are given in Table A5.

These results give mean crossing speeds of 13.8 mph and 13.0 mph for humps and tables respectively which can be compared with the calculated crossing speeds (i.e. for separation S = 0) using the separation relationships given earlier (see Figs 38 and 40).

In the USA mean hump crossing speeds of 19 mph and 23 mph have been reported (Clement, 1983) for 100 mm and 75 mm high humps respectively which is probably due to the softer suspension systems on American automobiles. This does indicate that vehicle suspension and wheel design could easily be improved so that humps alone may not be enough to slow vehicles on some roads and additional measures would be required.

TABLE A3

Speed vs hump separation relationship
(100 mm circular profile humps)

Target speed midway between humps (mph) V85	Vm	Approx. hump separation required (metres)
20	16	40
22	18	60
24	20	85
26	22	105

TABLE A4

Speed vs hump separation relationship
(100 mm flat- topped humps)

Target speed midway between humps (mph) V85	Vm	Approx. hump separation required (metres)
20	16	60
22	18	80
24	20	100
26	22	120

A.3 LOWER HEIGHT HUMPS

Relationships for lower (80 mm and 50 mm) humps will be possible when more schemes have been installed. Early results (Table A2) for the typical 85th percentile and mean speed/ hump-separation relationships for 80 mm humps indicate that the expected speeds are 5 and 2 mph higher for S = 0 metres respectively and approximately the same when S = 150 metres compared with 100 mm high humps.

At present there are very few sites with 50 mm humps which have been monitored but the results so far indicate that the 85% tile speeds are 20 - 35 mph for separations up to 140 metres.

It should be noted that hump heights may vary within a tolerance of +/-12 mm and this may well account for some of the variation as discussed earlier. This will clearly be more important for humps which are nominally 50 mm high because the possible percentage variation is higher and minimum height of 38 mm may have a negligible effect on speeds.

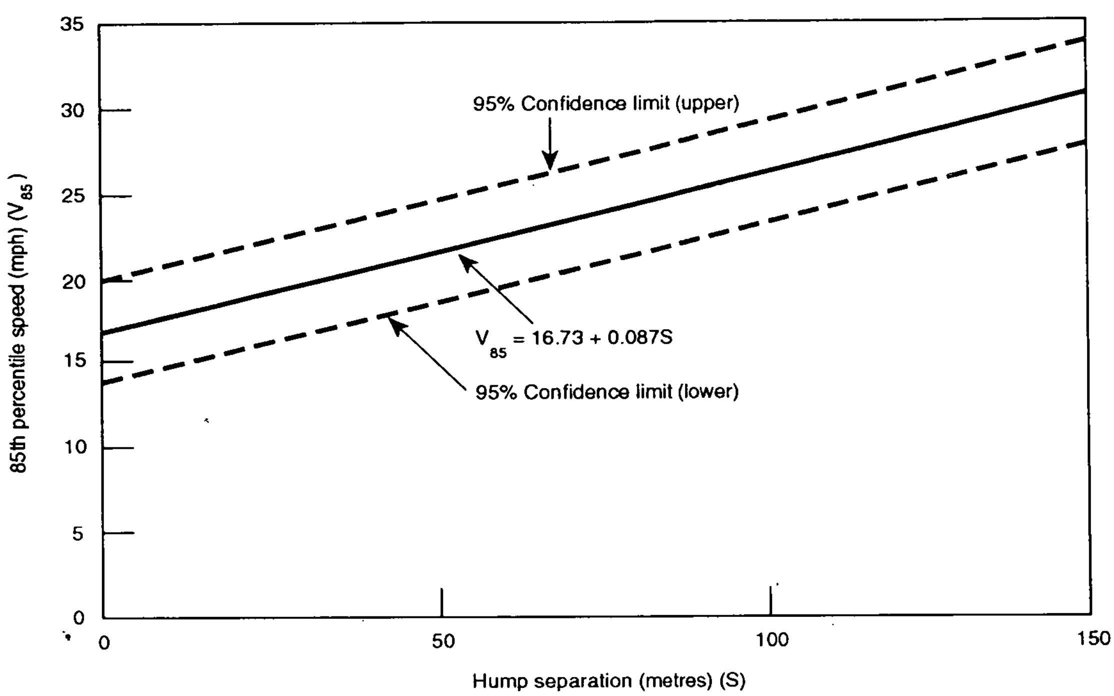

Fig.37 Hump separation/speed relationship for 100mm circular profile humps

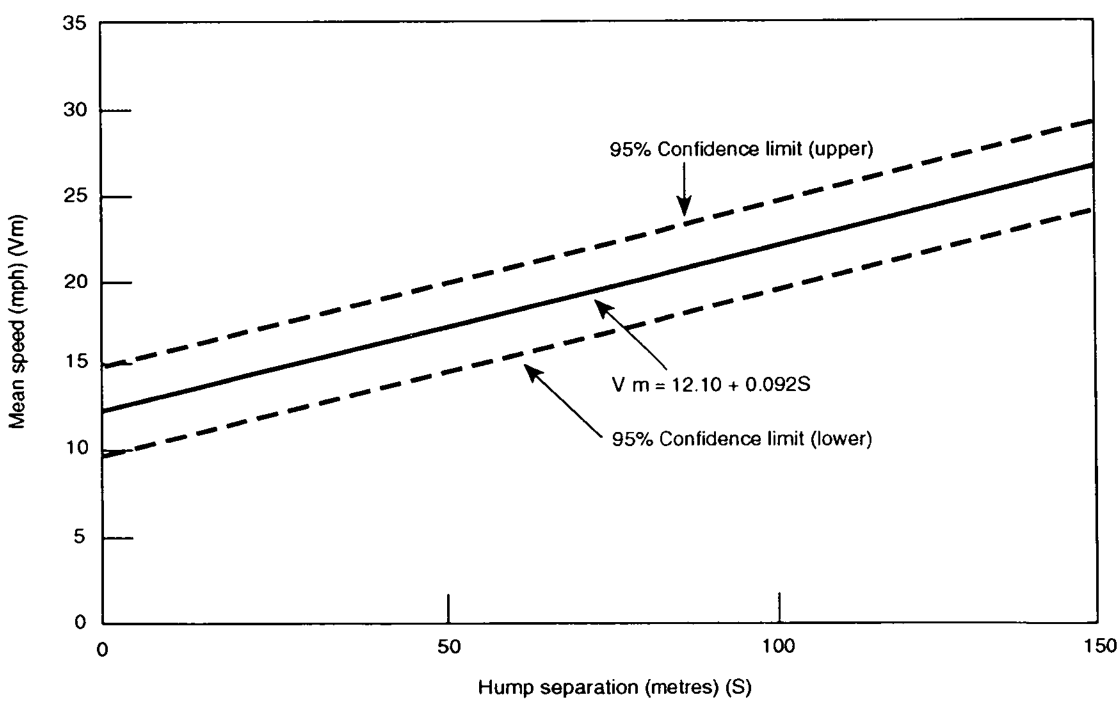

Fig.38 Hump separation/speed relationship for 100mm circular profile humps

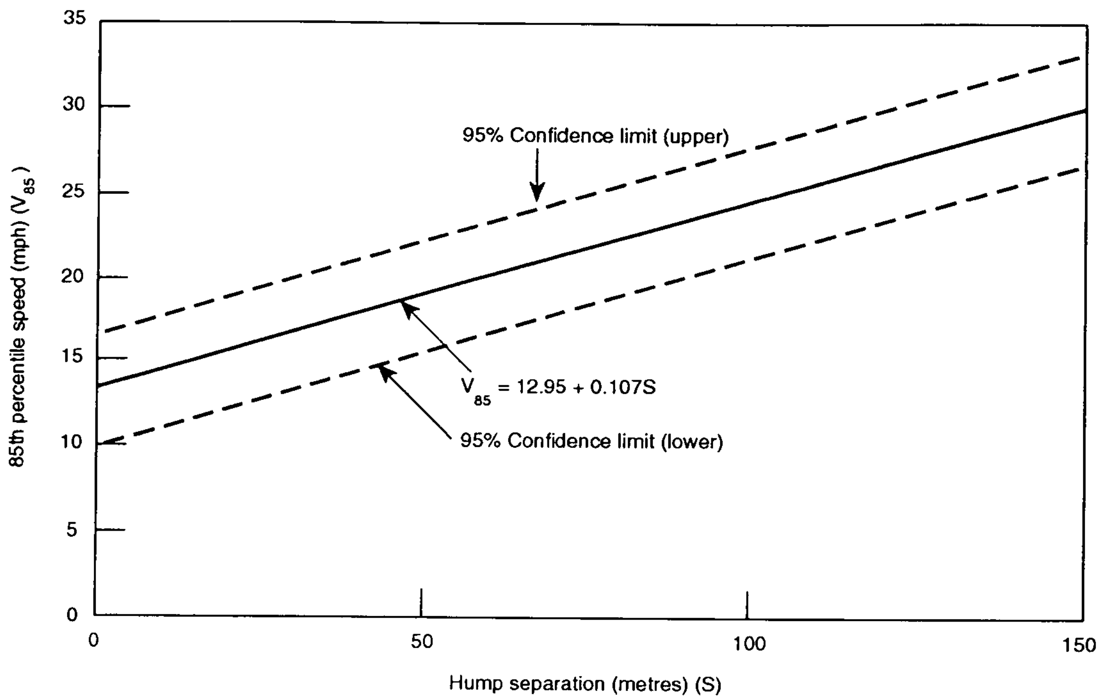

Fig.39 Hump separation/speed relationship for 100mm flat-topped humps

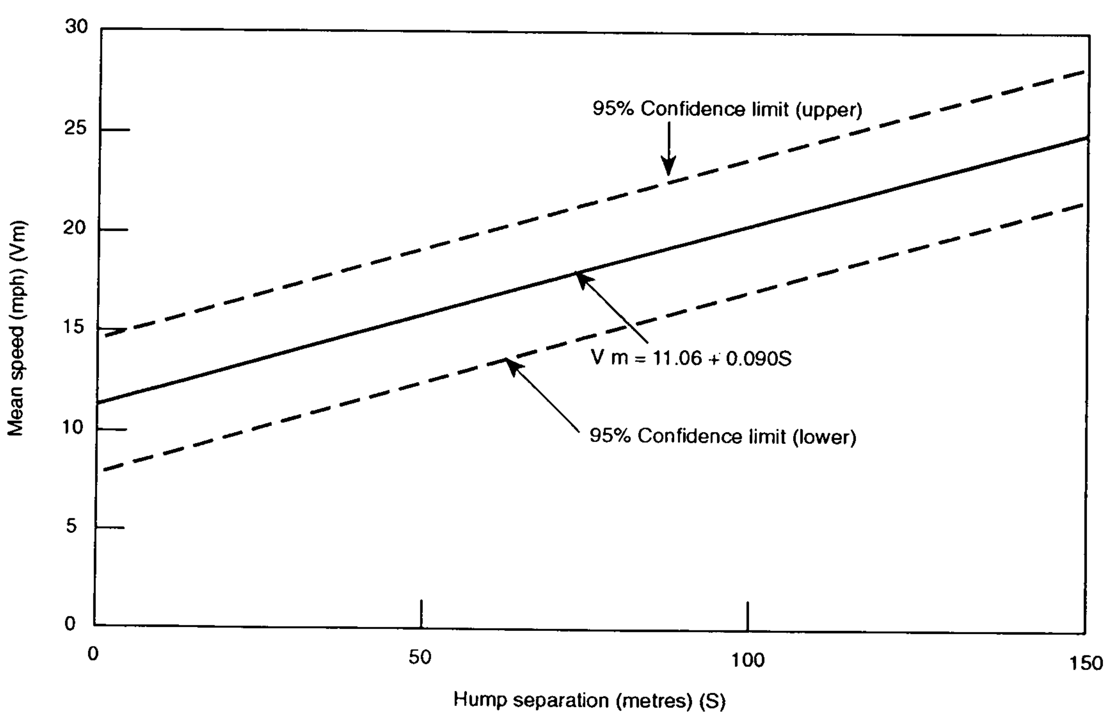

Fig.40 Hump separation/speed relationship for 100mm flat-topped humps

TABLE A5

Speeds at humps/speed tables

Site	Ramp gradient	Vehicle speed (mph) mean	Vehicle speed (mph) 85%ile	Time period hours	Readings taken No.	Readings taken Method
Ashford	1:15	15	20	-	222	Radar
Bradford 1	1:12	16	19	2	186	Radar
Bradford 2	1:12	15	18	2	84	Radar
Bradford 3	1:12	15	18	2	129	Radar
Exeter 1	1:10	14	18	1	320	Video
Exeter 2	1:16	14	16	1	90	Radar
Exeter 3	1:8	13	15	3	29	Radar
Exeter 4	1:10	11	13	2	25	Radar
Exeter 5	1:10	12	14	1	93	Radar
Exeter 6	1:10	13	-	-	40	Radar
Exeter 7	1:10	11	-	-	40	Radar
Milton* 1a	1:6 cars	10	13	1	100	Timed
Keynes 1a	1:6 buses	7	9	1	25	Timed
Milton* 1b	1:12 cars	11	14	2	100	Timed
Keynes 1b	1:12 buses	8	10	2	25	Timed
Woodham	1:20	14	17	-	206	Radar
York 1	1:6	12	14	-	100	Radar
York 2	1:10	14	16	-	100	Radar
Kingston 1	RT100	14			100	Radar
Kingston 2	RT100	14			100	Radar
Kingston 3	RT100	12			100	Radar
Kingston 4	RT100	14			100	Radar
Kingston 5	RT100	15			100	Radar
Richmond 1	RT100	15	19	24	1844	Auto
Richmond 2	RT100	16	19	1	54	Radar
Richmond 3	RT100	16	20	2x24	1565	Auto
Richmond 4	RT95	14	18	24	2061	Auto
York 3	RT80	13	17	-	100	Radar
York 4	RT100	12	16	-	100	Radar
York 5	RT100	11	14	-	100	Radar
Overall means	Tables	13.0	16.3			
	Humps	13.8	17.6			

Note. All flat top tables nominally 80 - 100 mm high.
* Single hump across dual carriageway with high pedestrian flow

A.4 GRADIENTS OF RAMPS

Ramp gradients of 1:8 to 1:12 have commonly been used on schemes and it appears that these are the most acceptable. At most sites were the maximum gradient of 1:6 has been used, it has resulted in considerable numbers of complaints and the authorities have been obliged to reduce the gradient. Gradients shallower than 1:20 have not generally been installed because the speed reducing effect would be very low unless it was combined with other features such as chicanes or narrowings. More data will be required before the speed/separation relationships for various ramp gradients and plateaux lengths can be established to supplement the relationship given in Section 3 of the main report for 1:10 gradient slopes.

TRL is currently involved in trials which are under way to design shallow gradient humps which could be used on higher speed (40 mph) roads where some kind of measures would be desirable to moderate traffic speeds.

Grounding of long wheelbase and low ground clearance vehicles can be minimised by avoiding ramps steeper than 1:10 for 100 mm high flat top humps.

APPENDIX B: EFFECT OF SCHEMES ON SAFETY

B.1 ACCIDENTS

It is obviously important when justifying traffic calming schemes to know the likely effect they will have on accidents. For this reason an analysis of the before and after accidents on all of the following treated roads has been carried out to obtain an estimate of the likely overall effect on accidents of installing measures. The results are given in Table B1.

B.2 DISCUSSION

These results indicate that a considerable (statistically highly significant) overall accident reduction of 71% has occurred so far on the treated roads but more time will be required to determine if this can be sustained.

The surrounding roads which may have had extra traffic, due to drivers avoiding the measures (see Table A1), could show an increase in accidents and so a wider analysis was carried out on data from randomly selected schemes.

The results given in Table B2 show that there was an overall 8% reduction in accidents (statistically significant) in the surrounding areas (excluding the treated roads). Kensington and Chelsea have now adopted the area wide approach which relies on considering reasonably large areas rather than single roads so that the road hierarchy can be clearly defined. Worcester Park had measures introduced in phases over a period of time which, together with local factors such as other road-works, may account for some of the increase.

TABLE B1

Before and after accident data

SITE DESCRIPTION	BEFORE (B)			AFTER (A)			FREQ Diff
	ACCS	YRS†	FREQ	ACCS	YRS†	FREQ	B - A
BATLEY	6	3	2.0	0	3	0	2.0
BRIDGWATER	7	6	1.2	1	19m	0.6	0.6
BRISTOL							
Longway Avenue	2	3	0.7	0	6m	0	0.7
Callicroft Road	4	3	1.3	0	3	0	1.3
Lanercost Road	3	3	1.0	0	3	0	1.0
CAMBRIDGE	10	4	2.5	0	17m	0	2.5
COVENTRY	2	4	0.5	1	30m	0.4	0.1
CROYDON							
Norbury Hill	9	4	2.3	2	4	0.5	1.8
EXETER	37	63m	7.0	11	3	3.7	3.3
FOLKESTONE	7	3	2.3	3	33m	1.1	1.2
GAMLINGAY	9	45m	2.4	0	17m	0	2.4
HARINGEY	13	3	4.3	0	1	0	4.3
KENS'TON/CHELSEA							
St Leonards Terr	7	3	2.3	1	3	0.3	2.0
Abbotsbury Road	2	3	0.7	1	3	0.3	0.4
Elsham Road	3	3	1.0	1	3	0.3	0.7
LIGHTWATER	8	5	1.6	0	21m	0	1.6
MAIDSTONE	9	3	3.0	3	1	3.0	0.0
MILTON KEYNES	54	3	18	8	31m	3.1	14.9

Table B1 continued **Before and after accident data**

SITE DESCRIPTION	BEFORE (B)			AFTER (A)			FREQ Diff
	ACCS	YRS†	FREQ	ACCS	YRS†	FREQ	B - A
OXFORD C C (all)	178	67m	31.7	22	20m	13.0	18.7
READING							
Canterbury Rd & Long Barn Lane	5	4	1.3	0	16m	0	1.3
Grange Av	2	4	0.5	0	15m	0	0.5
Granville Road	1	4	0.3	0	16m	0	0.3
Hamilton Road	0	4	0.0	0	15m	0	0.0
Wilson Road	0	3	0.0	0	3	0	0.0
Honey End L. area	9	3	3.0	0	5m	0	3.0
RICHMOND	42	3	14.0	5	13m	4.5	9.5
ROCHESTER	6	3	2.0	0	1	0	2.0
SHEFFIELD Earl Marshall Rd	8	5	1.6	1	3	0.3	1.3
SITTINGBOURNE	12	3	4.0	2	33m	0.7	3.3
SLOUGH	28	4	7.0	3	2	1.5	5.5
SUTTON Worcester Park	49	53m	11.1	10	23m	5.2	5.9
TWYDALL GREEN	4	3	1.3	3	3	1.0	0.3
WESTMINSTER Vincent Square	7	5	1.4	1	2	0.5	0.9
YORK Leeman Rd area	8	5	1.6	0	1	0	1.6
All sites Total			134.9			40.0	96.5
All sites Mean			4.0			1.2	2.8
				Overall accident frequency/year			-71%

Note. † Data given in months (m) when not in complete years.

TABLE B2

Before and after accident data in the surrounding area

SITE DESCRIPTION	BEFORE (B)			AFTER (A)			FREQ Diff
	ACCS	YRS†	FREQ	ACCS	YRS†	FREQ	B - A
BRIDGWATER	112	6	19	22	19m	14	5
CROYDON							
Norbury Hill	135	4	34	95	4	24	10
EXETER	88	63m	17	36	3	12	5
FOLKESTONE	324	69m	56	118	33m	43	13
KENS'TON/CHELSEA							
St Leonards Terr	187	3	62	180	3	60	2
Abbotsbury Road	144	3	48	159	3	53	-5
LIGHTWATER	78	5	16	25	21m	14	2
READING							
Canterbury Road	106	4	27	35	16m	26	1
Grange Av	56	4	14	17	15m	14	0
Granville Road	43	4	11	8	16m	6	5
Hamilton Road	75	4	19	18	15m	14	5
Wilson Road	92	3	31	79	3	26	5
RICHMOND SITES	521	3	174	232	16m	169	5
SITTINGBOURNE	134	5	27	57	33m	21	6
SLOUGH	103	4	26	45	2	23	3
SUTTON							
Worcester Park	203	53m	46	107	23m	56	-10
WESTMINSTER	622	5	124	207	2	104	20
YORK	38	5	8	7	1	7	1
All areas Total			759			686	73
All areas Mean			42			38	4
				Overall accident frequency/year			-10%*

† Data given in months (m) when not in complete years.
* Comparable overall accident frequency/year for the treated roads is -70% (Similar to all sites -71% See Table B1)

APPENDIX C

C.1 EXAMPLES OF CIRCULAR PROFILE HUMPS

The following list is representative only and the dimensions given are the nominal hump heights.

100 mm humps:- Barnsley, Queens Road
Batley, Warwick Road
Cambridge, Chesterton area
Coventry, St. Paul's Road
Croydon, Norbury Hill
Gamlingay, Cambridgeshire
Haringey, Mount Pleasant Road *
Kettering, St Mary's scheme
Kingston, The Groves 20 mph zone
Lightwater (Surrey), Macdonald Road
Richmond LB, Burtons Road
Sutton, Worcester Park area
York, Leeman Road area
York, Park Grove

85 mm humps:- Bicester, Kingsclere Road, West Street*
Henley, Deanfield Road

80 mm humps:- Sutton, Worcester Park area *
York, Lowther Street *

75 mm humps:- Croydon, Spring Park area
Didcot, Wessex Road
Kidlington, Service Roads (A423)
Reading, Canterbury Road
Richmond LB, Broom Road,
Teddington Sandhurst, Wellington Road
Slough, Essex Avenue
Westminster, Westbourne Park Road

50 mm humps:- Cambridge, Green End Road, Chesterton
Gamlingay, Cambridgeshire
Reading, Honey End Lane
Reading, New Lane Hill
Richmond LB, Ormond Avenue, Hampton
Sandhurst, College Town area
Slough, Long Furlong Drive
Westminster, Westbourne Park Villas

Note * Sites where some humps are combined with significant narrowing

C.2 EXAMPLES OF FLAT-TOPPED RAISED TABLES

The following list is representative only and the dimensions given are the nominal hump heights.

100 mm tables:- Bradford, Scotchman Road *
Bridgwater, Parkway, Somerset
Cambridge, Green End Road, Chesterton
Exeter, Burnthouse Lane *
Folkestone, Park Farm Road *
Gamlingay, Cambridge
Kettering, St Mary's scheme *
Maidstone, Shepway Estate *
Milton Keynes, Midsummer Boulevard
Plymouth, Clitterford Rd
Plymouth, Millar Way
Sheffield, Tinsley 20 mph zone
Sittingbourne, Stanhope Avenue *
York, Park Grove *

80 mm tables:- Sutton, Green Lane, Worcester Park, *
York, Lowther Street *

75 mm tables:- Bradford, Jesmond Avenue, *
Cambridge, Green End Road, Chesterton
Crowthorne, High Street *
Crowthorne, TRL 20 mph Zone #
Northampton, Broadmead Avenue #
Oxford, Westgate Car Park #

Notes * Sites where some humps are combined with significant narrowing

Rubber tables

C.3 EXAMPLES OF RAISED JUNCTIONS

The following list of examples is representative only.

Ashford, Feltham Hill Road
Bradford, Jesmond Avenue/Scotchman Road
Bristol, Argyle Road/Chester Park Road
Cambridge, Stretten Avenue/Akeman Street
Guildford, Westborough
Kettering, St Mary's scheme
Kingston, The Groves 20 mph zone
Sheffield, Tinsley 20 mph zone
Sittingbourne, Chilton Avenue/South Avenue
Westminster, Millbank
York, The Groves area

C.4 EXAMPLES OF CUSHIONS

The following list of examples are sites where cushions have been used.

Berlin,Germany
Lowther Road, York (one way road)
Poplar, Tower Hamlets

C5. EXAMPLES OF RUMBLE STRIPS-AREAS/JIGGLE BARS

The following list of examples is representative only.

Billinge, St Helens
Bourton-on-the-Hill, Gloucestershire
Cribbs Causeway, Bristol
Dorket Head crossroads, Nottingham
Hawley, Hampshire
Linton, Cambridgeshire
Nordley, Shropshire
Sanford, Avon
Sheffield, Yorks
Stagsden, Bedfordshire
West Haddon, Northants

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