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Investigations of noise and disturbance from vehicles crossing cattle grids and examination of options for mitigation

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ABSTRACT

Cattle grids are used on roads and tracks to prevent grazing animals from leaving an open space without fencing onto a more controlled area where access to the road from surrounded land is more limited. They are widely used in the UK at the entrances to common and moorland areas where animals are free to roam, but also on private drive entrances. Typically, they consist of a series of metal bars across the road that are spaced so that an animal's legs would fall through the gaps if it attempted to cross. Below the grid is a shallow pit that is intended to further deter livestock from using that particular crossing point. The sound produced as vehicles cross these devices is a characteristic low frequency "brrrr" where the dominant frequencies relates to the bar passage frequency under the tyres. The sound can be disturbing to riders and their horses and walkers and residents living close by as evidenced by press reports and the need to consider noise aspects in planning for new installations. For this reason and due to the lack of available information on the size and nature of the problem measurements and recordings have been made at a number of sites in Yorkshire in the UK. In

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addition, questionnaire surveys of residents living close by and façade measurements have also been used to gauge impact. Results show that there is a wide variation in the maximum noise level produced by cattle grids of apparently similar design. This can be related to impact noise produced by the movement of all or part of the grid as the frame comes under impulsive loading as the vehicle crosses. It was further established that some residents living close to the cattle grids were disturbed by the noise, and in some cases vibration, and wanted them removed or suitably modified. Means of reducing the problem are proposed

Keywords: cattle grid, tyre / road noise, noise impact

1. INTRODUCTION

Cattle grids are widely used to prevent grazing animals from leaving unfenced farmland or moorland onto more controlled spaces where access to the road is prevented by walls, fences or hedges. Typically, they consist of a grid of regularly spaced metal bars with a shallow pit beneath. They are designed so that an animal's leg would fall through the grid if attempts were made to cross. There is design guidance set out in BSI 4008 2006 [1]. This gives the range of spacing and widths of the individual bars. The gaps between bars should be in the range 130 to 150 mm and the running surface of the bars should be 30 to 40 mm wide if of rectangular section.

Figure 1 shows an installation on the entrance to Baildon Moor (Site Baildon B) north of Bradford in West Yorkshire. It consists of 11 rectangular topped steel bars of width 75 mm set at right angles to the road at 200 mm centres.

Figure 1: Cattle grid installation on Baildon Moor (site Baildon B)

Noise associated with vehicles crossing these installations, which is typically a low frequency ‘brrrr’ is often the main reason why people living in the vicinity of cattle grids complain to the planning or highway authorities. Within the United Kingdom cattle grids are often located in areas of public amenity, such as the urban-rural fringe, National Parks, ancient commons and Areas of Outstanding Natural Beauty (AONB), all of which attract large numbers of visitors on a daily basis. The perceived degradation of environmental quality caused by vehicles continually crossing cattle grids in these areas was partially assessed in a controlled laboratory study carried out by the University of Bradford in 2013 [2]. The study examined the extent to which the introduction of congruent mechanical and natural soundscape components into video recordings of a range of natural environments, influenced the perception of tranquillity and wildness. Cattle grid noise was introduced into a video clip of an ancient monument located in Dartmoor National Park (Horns Cross), which when rated for tranquillity by subjects using an 11 point scale (0-10), achieved a mean tranquillity rating of 4.2 This was significantly lower than the mean tranquillity rating of 8.3 awarded when the same environment was presented in its original, i.e. unedited state. In this example the 4.2

reduction in tranquillity rating points was accompanied by an 11.9dB increase in L_{Aeq}. The L_{Aeq} values for the in-situ and edited soundscapes were 38.4dB and 50.3dB respectively.

Disturbance to peace and quiet and to the overall tranquillity of a location by the installation of a cattle grid, is a concern that is regularly reported in the press and articulated to the UK Government's Department of Transport (DoT) inspectors. In 2007 a Public Enquiry was held following objection to the proposed installation of cattle grids in the ancient Stannery town of Chagford, which is situated at the heart of Dartmoor National Park. Here local residents complained that the noise would be *"a jarring, metallic sounding disturbance in this tranquil area"* that would *"entirely change the nature and character of local heritage sites"* [3]. In 2013 similar concerns were being raised on Chailey Common in East Sussex, where locals voiced concerns that the introduction of cattle grids on ancient common land would *"blight the tranquillity of their homes"* [4].

In both of these cases noise and the associated change to the localised acoustic environments was an important issue especially when it came to sleep disturbance. In the case of Chailey Common two residents reported being awakened by noise from the cattle grid, one of which claimed that *"my sleep is now permanently disrupted because of the sound of cars clanking over cattle grids"* [4].

Further evidence of concern about the noise impacts of cattle grids can be found in Dorset County Council's 2010 Roads and Rights of Way Committee Report (Agenda Item 4), where objection to the installation of cattle grids in the Throop area was opposed by two of the local Parish Councils [5], and in written objections submitted to the Public Enquiry into the installation of cattle grids within Epping Forest, held by the Department of Transport in 2011 [6].

Evidence provided to Dorset County Council's Roads and Rights of Way Committee [5] included a statement that said *"at low speeds (about 10mph) there is no significant noise generated when travelling over a cattle grid, and it may even be less than on Tarmac (asphalt). At 20mph there is a slight increase but the noise at the nearest properties to the grid is not expected to be significantly higher than the noise of the vehicle itself".* Speed related increases in noise levels has been a concern in all of the examples discussed, however, a detailed review of the literature has not identified any scientific studies that support the claim that in terms of noise levels, passing over a cattle grid at 10mph is quieter that transiting asphalt at the same speed.

Not all of the concerns about cattle grids raised in the examples presented were upheld at either the Local or Central Government levels. However, what they show is that health and quality of life issues are an important consideration when proposing, installing or maintaining cattle grids. This is supported by the press report that was instrumental in starting the present study, where very high sound pressure levels recorded by a complainant living within 50m of a cattle grid that is used by approximately 5800 vehicles a day [7] had significantly compromised his family's right to peace and quiet and a decent night's sleep [8].

The aims of this preliminary study were to investigate the size and nature of the problem and evaluate effects on residents living nearby. It was expected that the findings would be of use in further more detailed studies leading to solutions.

2. METHOD

2.1 Outline of approach

Roadside measurements of vehicle noise were carried out at 2 sites near Baildon, 3 sites in Ilkley (both groups near Bradford) and at 2 sites on the A684 east of Sedbergh in the

Yorkshire Dales. Vehicles were selected from the traffic passing ensuring they were freely moving and not in close proximity to other vehicles. In addition, measurements were carried out using a test vehicle at these and further locations at a fixed speed for accurate comparison of noise produced across sites. Finally, façade measurements at homes where residents were affected by the noise from cattle grids were also taken.

The approach adopted included roadside measurements of the maximum noise produced by vehicles crossing the cattle grids in both directions, where safe and practical to do so, and recordings of the sound produced by a test vehicle for later analysis. L_{Amax} was the preferred measure as the nature of the sound was less than a second in duration. All sites were on minor single carriageway roads where average vehicle speeds were generally in the range 40 to 50 km/h. For the purpose of characterising the noise produced a Bruel and Kjaer sound level meter type 2250 was used for capturing maximum A weighted levels using fast averaging L_{Amax} and additionally for recording a few seconds from a test vehicle cruise-by for post processing. Measurements were confined to light vehicles i.e. cars and vans as there were very few heavy vehicles on these minor single carriageway roads and it would have taken too long to obtain a valid sample.

2.2 Measurement of noise selected from passing traffic

The method employed was guided by the statistical pass-by standard of measurement method described in ISO 11819 - 1[9]. Due to restricted level ground at the sites the distance to middle of the nearside lane was fixed at 5m and not 7.5m as given in this standard. At some sites far side measurements were also carried out and distance corrections made to enable comparisons with nearside measurements. The microphone height was 1.2m which conforms with ISO 11819 – 1. The method involved sampling vehicles that were freely moving and widely separated from other vehicles so that the noise of the selected vehicle was not contaminated by other vehicles on the road. The approach speed to the cattle grid was measured using a radar speed meter (Bushell Velocity speed gun) positioned close to the edge of the carriageway. A sample of between 60 and 110 vehicles were obtained on the higher flow roads but on roads carrying very little traffic it was only possible to sample between 10 and 40 vehicles and in some cases the samples were too small for statistical analysis. However, measurements with a test vehicle was made at all sites. All measurements were conducted with a wind speed less than 2m/s and background noise levels were low <55 dB(A). Where possible measurements were also made on adjoining road surfaces (i.e. without cattle grid) with the test vehicle.

2.3 Measurements with a test vehicle

For the purpose of making detailed comparisons of the noise produced from different installations a test vehicle was used and driven over each cattle grid at a speed of 40km/h. The test vehicle, a Toyota Yaris, was a front wheel drive compact and had a wheelbase of 2.44m and a kerb weight of 830kg. The crossing speed was chosen to be close to the average observed crossing speed across sites of vehicles in the traffic stream. Again the maximum A-weighted dB level on fast averaging was recorded on site and short recordings taken for post processing.

The effects of speed on L_{Amax} was also investigated at one site in Ilkley in order to determine if a low speed limit would produce a significant reduction in L_{Amax}.

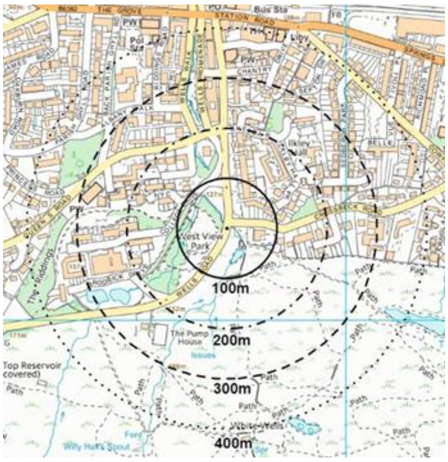
2.4 Measurement near homes of residents affected by noise

To determine the size and nature of the problem questionnaires were posted to homes within an approximate radius of 150m from two cattle grids located near to residential areas i.e. sites Baildon A and Ilkley A. The questionnaire is given in Appendix A and was provided with a postage paid reply envelope. There was an invitation to allow measurements at their homes if they thought this was appropriate. In all measurements near the facades of four such homes were carried out. The distances from the cattle grids ranged from 7.7m to 122m. Figures 2 show maps of the cattle grid sites situated close to dwellings with concentric circles centred on the cattle grids to indicate distance. The four measurement positions are marked with asterisks.

Baildon A

Ilkley A

Ilkley B



Ilkley C

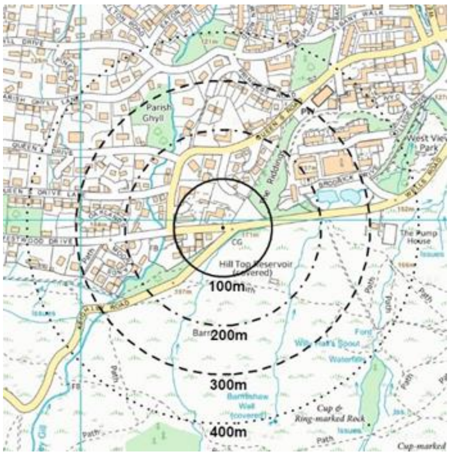


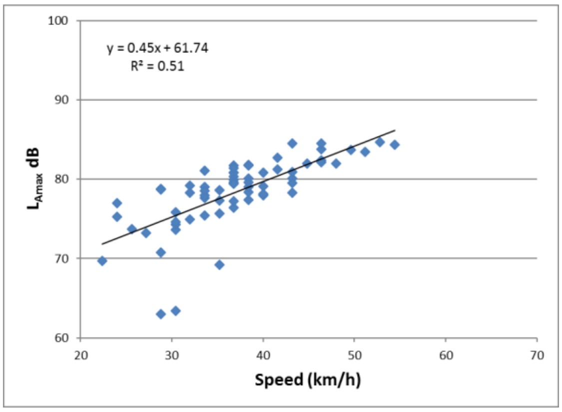
Figure 2: Site maps of cattle grids where noise disturbance is likely

3. RESULTS AND ANALYSIS

3.1 Passing traffic

Plots were made of the captured L_{Amax} against crossing speed for each installation. Measurements made to vehicles travelling in the far side lane were normalized to a distance of 5m for comparison purposes. For this purpose a simple correction based on hemi-spherical spreading was used i.e. $10 \log_{10} [(5/d)^2]$ where d is the distance to the middle of the far side lane (in range 7.5 to 8m)

Figure 3 shows a plot of L_{Amax} against speed for the cattle grid at two contrasting sites, the entrance to Baildon Moor (Baildon A) and on the A684 in North Yorkshire east of Sedbergh (Sedbergh A). In both cases measurements were made in the nearside lane. It can be observed from the fitted regression line that the predicted mean maximum levels at Sedbergh are significantly higher than is the case for the site at Baildon. Note that the correlation coefficients were similar whether the actual speed or logarithm of the measured speed were used and so it was decided to use the measured speed.



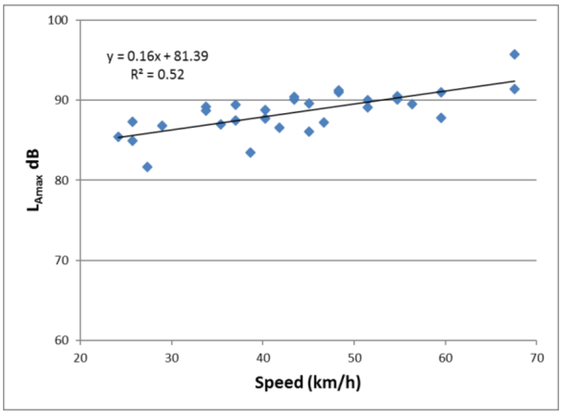


Figure 3: L_{Amax} against crossing speed at Baildon A and Sedbergh A

For comparison purposes a speed of 40 km/h (25mile/h) was chosen across all sites as it was close to the overall average crossing speed (44 km/h). Regression analyses were carried out on the data for each site and the predicted mean L_{Amax} at 40km/h. Table 1 lists these predicted means together with the 95th percentile confidence intervals for the means, number of data pairs and the R^2 value. It can be seen that 2 sites produce significantly higher noise levels i.e. Sedbergh A and Sedbergh B

3.2 Test vehicle

Test runs at 40 km/h over the cattle grids at each site were carried out with the test vehicle. For this purpose the vehicle speedometer was used. This was later checked at the test speed of 40 km/h by timing 8 runs over a measured mile (1.61 km) and it was found sufficiently accurate. The average speed was found to be 39.44 km/h with 95% confidence interval ±0.33 km/h. Using the test vehicle passing at constant indicated speed of 40 km/h it was found that the radar speed meter was reading low at an average value of 37.57 km/hr based on 23 readings (95% confidence interval of 0.65 km/h). Appropriate adjustments were therefore made when predicting the maximum L_{Amax} at 40 km/h from the data collected at each site.

At some sites it was relatively easy to find a suitable turning place close to the cattle grid to enable efficient testing in both directions but at other sites a suitable turning place could not be found close by and this delayed data collection and as a consequence the number of readings was reduced. Table 1 shows the average L_{Amax} together with confidence intervals and number of readings.

Table 1: Average L_{Amax} levels at 40km/h crossing speed from passing light vehicles and test vehicle

	Passing traffic					Test vehicle		
Location	*N*	Av. speed*	R^2	Av. L_{Amax}	Conf. int.	*N*	Av. L_{Amax}	Conf. int.
Baildon A (NS)	67	38.81	0.51	78.93	± 0.81	8	79.33	± 1.48
Baildon A (FS)	-	-	-	-	-	6	76.28	± 1.25
With distance correction	-	-	-	-	-		*80.37*	
Baildon B (NS)	110	55.39	0.67	81.41	± 0.57	4	77.93	± 0.65
Baildon B (FS)	-	-	-	-	-	3	73.2	±1.49
With distance correction	-	-	-	-	-		*77.28*	
Ilkley A (NS)	104	39.04	0.41	75.3	± 0.57	4	80.3	± 1.44
With distance correction				*76.88*			*80.3*	
Ilkley A (FS)	102	47.06	0.73	78.5	± 0.41	6	74.18	± 0.82
With distance correction				*82.59*			*78.27*	
Ilkley B (NS)	-	-	-	-	-	*6*	77.38	± 0.63
Ilkley B (FS)	-	-	-	-	-	*5*	75.94	± 1.32
With distance correction							*80.02*	
Ilkley C (NS)	-	-	-	-	-	14	79.29	±0.74
Sedbergh A (NS)	30	45.48	0.52	87.65	± 0.75	9	84.22	± 1.48
Sedbergh A (FS)	42	43.24	0.44	85.61	± 0.54	5	85.23	± 0.39
With distance correction				*89.24*			*88.86*	
Sedbergh B (NS)	-	-	-	-	-	*7*	85.43	± 1.64
Sedbergh B (FS)	10	41.95	0.32	92.67	± 1.58	9	92.09	± 1.50
With distance correction				*96.3*			*95.73*	

A comparison was made at a crossing speed of 40 km/h between the average predicted L_{Amax} values obtained from passing light traffic and those obtained from the corresponding mean value for the test vehicle as can be seen in Figure 4. The regression line indicates good agreement between the two sets of averages i.e. the difference ranged from 0.5 dB(A) at 95 dB(A) to 1.5 at 80 dB(A)with high R^2 value (0.84). This gives support for using the results for comparative purposes from the test vehicle at sites where it was not possible to collect sufficient data from passing traffic.

The control measurements were only possible at three sites due to the problem of finding suitable measurement sites on narrow roadside verges. However, at the sites where measurements were possible the test vehicle driven at 40 km/h on surfaces before or after the cattle grids showed a narrow range of recorded L_{Amax} from 69.5 to 72.7 with average 70.8 dB(A). From Table 1 this indicates an increase in noise of at least 6.6 dB(A) and at Sedbergh B site an increase of 24.9 dB(A).

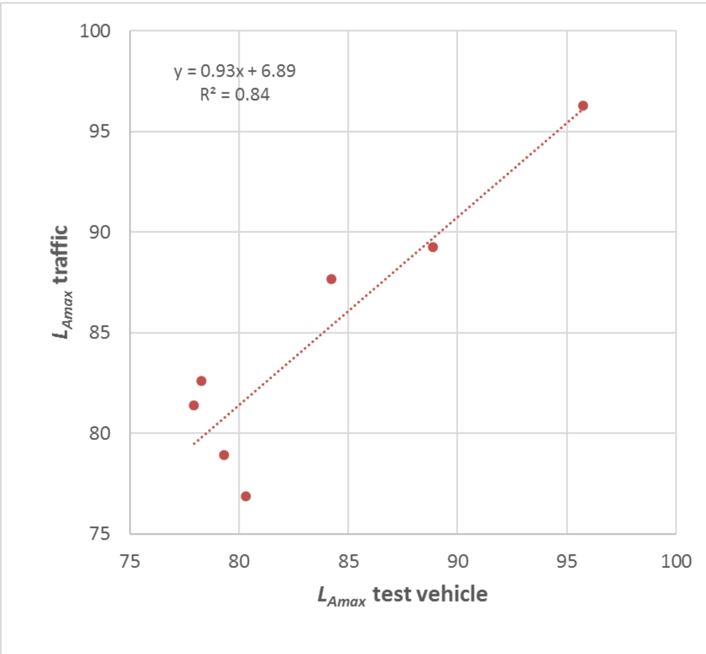


Figure 4: Correlation between average L_{Amax} at 40 km/h produced by test vehicle and the average predicted from sampled passing light vehicles

3.3 Crossing speed and maximum noise levels

In order to investigate the effects of crossing speed on L_{Amax} in more detail a series of measurements were made with the test vehicle on a residential road, Ilkley C with little traffic. The purpose was to determine if significant speed restrictions down to as low as 8km/h would have a significant effect of recorded maximum levels. It was considered that such traffic calming restrictions could be an option for controlling cattle grid noise in noise sensitive areas.

Measurements were conducted at crossing speeds between 8 km/h and 48 km/h (the maximum speed limit for this road) in 1.6 km/h (1 mile/h) increments. As a control measurements were also made on the road surface approximately 50m from the cattle grid. Due to the wide speed range it was found that a logarithmic speed scale gave a slightly better fit with recorded L_{Amax} than did a linear scale. Figure 5 shows this relationship with speed for both the cattle grid and control measurement sites. The relationships are close with R^2 values of 0.91 and 0.89 for the cattle grid and control datasets.

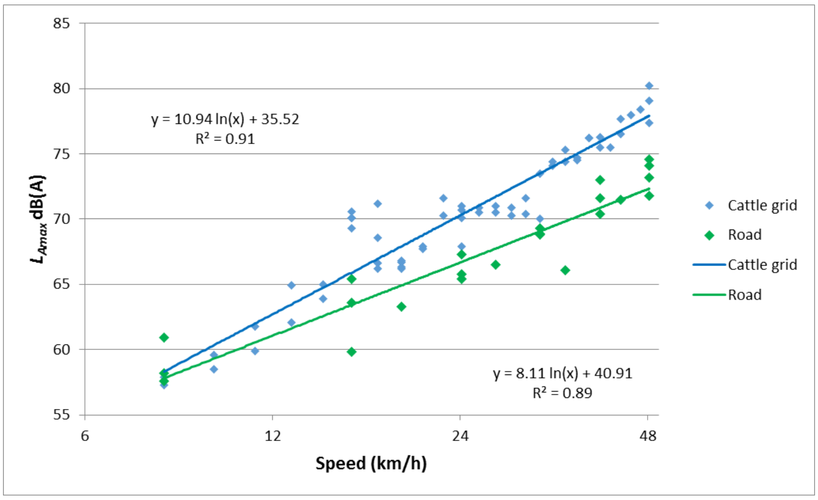


Figure 5: Variation of L_{Amax} with speed on cattle grid and control road surface

Some of the scatter in values of L_{Amax} particularly at lower speeds may be due to variations in engine noise depending on the low gear selected and possibly the electric fan cutting in and out. Despite these scattered points it can be seen that the trend in the difference between maximum levels produced on this cattle grid and the control reduce steadily with speed. At 48 km/h this difference is 5.1 dB(A) while at 8 km/h there is no significant difference (< 1 dB(A)).

3.4 Measurements near buildings with test vehicle

A total of 13 questionnaires were received from the 26 that were delivered to the two cattle grid installations with houses close by. Ten were received from residents living close to Baildon A and 3 from Ilkley A. The questionnaire replies are summarized in Table 2 below. It can be seen that there is a tendency for ratings of annoyance to decrease with distance. Clearly the amount of screening of a property by other buildings or local topography would have a significant effect on the peak noise levels and consequently on the level of any annoyance caused so that a simple relationship was not expected. This is more easily seen in Figure 6 where for each level of annoyance on a scale 1 to 4 the average distance from home to cattle grid is given.

It is also shown in Table 2 that at 2 sites vibration was also felt in addition to noise. This can be seen to be associated with the highest rating of annoyance as would be expected.

A small number of residents allowed measurements to be taken close to the façade of their homes facing the cattle grid. There were 3 sites near site Baildon A and one site near Ilkley A. These measurements involved driving the test vehicles over the cattle grids at 40 km/h and recording the level L_{Amax} at a microphone set up at a height of 1.2m and at a distance of 1m from the nearest façade to the cattle grid.

Table 2: Summary of questionnaire returns at sites Baildon A and Ilkley A

Distance (m?)	Notice noise	Notice vib.	Rating
7.7*	✓	✓	4
19.7*	✓	×	3
30.7	×	×	1
32.5	✓	✓	4
59.5*	✓	×	2
67	✓	×	2
91.7	✓	×	4
94.7	✓	×	1
102	✓	×	1
107	×	×	1
108	✓	×	2
115	✓	×	2
122	×	×	1

Annoyance rating: Not annoyed:1, slightly annoyed: 2, annoyed: 3, very annoyed: 4. *Cattle grid Ilkley A

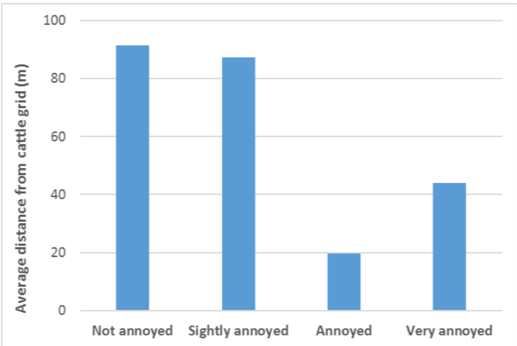


Figure 6: Average distance for different levels of rated annoyance

These data are summarized in Table 3 below. Where *N* is the number of readings and *Est.* L_{Amax} is the estimated level based on hemi-spherical spreading over a hard surface and average measured level at 5m. In the case of prediction at the closest site there is a noise barrier 2.4m tall extending 5m in each direction from the centre of the cattle grid that clearly has contributed to the 9.2 dB(A) difference between estimate and measured L_{Amax}. In the case of the site at 30.7m the property lies below the level of the road and the road shoulder provides a diffracting edge that would contribute to the observed difference of 5.6 dB(A). At the remaining two sites the estimated and measured levels are close.

Table 3: Measured and estimated L_{Amax} near building facades

Distance (m)	*N*	*Av.* L_{Amax}	*Conf. int.*	*Est.* L_{Amax}
7.7	7	65.4	± 1.05	74.6
30.7	6	57.9	± 0.81	63.5
32.5	5	66.1	± 1.83	62.9
91.7	8	53.9	± 1.01	54.0

3.5 Spectral analysis

To understand the differences between the maximum noise levels observed at the noisiest cattle-grid and one of the quietest, short segments of sound recordings were analysed i.e. the portion when the test vehicle was on the cattle grid.

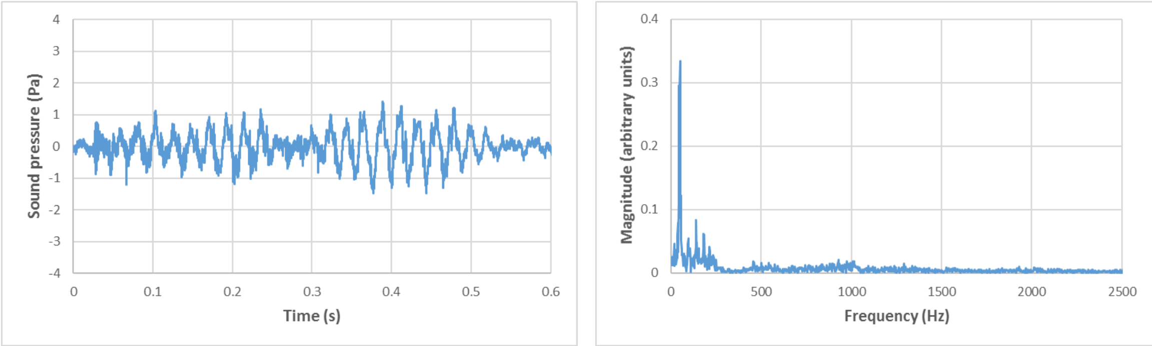
Figure 7 shows the time histories and FFT for two contrasting sites Ilkley C and Sedbergh B where average peak noise levels from several runs with the test vehicle were very different i.e. average L_{Amax} of 79.3 and 95.7 dB(A) respectively. It can be seen from Fig 7 that at Ilkley C there is a very pronounced dominant frequency at 49.2 Hz close to the calculated bar passing frequency under the tyres at 40 km/h of 49.7 Hz based on the measured separation of the bars of 1400 mm. Several harmonics of the fundamental can also be observed. Table 4 gives details of bar geometry at each site and expected passage frequency at each site.

Table 4: Cattle grid dimensions (mm), passage time (s) and bar passage frequency at crossing speed of 40 km/h (Hz)

Site	No. bars	Bar width	Spacing	Gap width	Overal length	Passage time	Passage frequency
Baildon A	11	80	240	160	2800	0.479	45.5
Baildon B	11	75	200	125	2325	0.436	54.6
Ilkley A	11	83	218	135	2533	0.455	50.1
Ilkley B	11	85	219	134	2543	0.456	49.9
Ilkley C	10	80	220	140	2340	0.437	49.7
Sedbergh A	16	30	156	126	2622	0.463	70.1
Sedbergh B	16	20	140	120	2360	0.439	78.1

The passage of front and rear wheels is also clearly visible in Figure 7. In the case of Sedbergh B site although the passage of the two tyre sets can be seen there is no dominant frequency at the bar passage frequency of 78.1 Hz although the maximum in the FFT occurs at 75.0 Hz there is in fact a wide range of frequencies present. This is consistent with impact sounds as each tyre set loaded the grid. This also agrees with the subjective impression of a pronounced crash as the test vehicle reached the cattle grid.

Ilkley C.



Sedbergh B

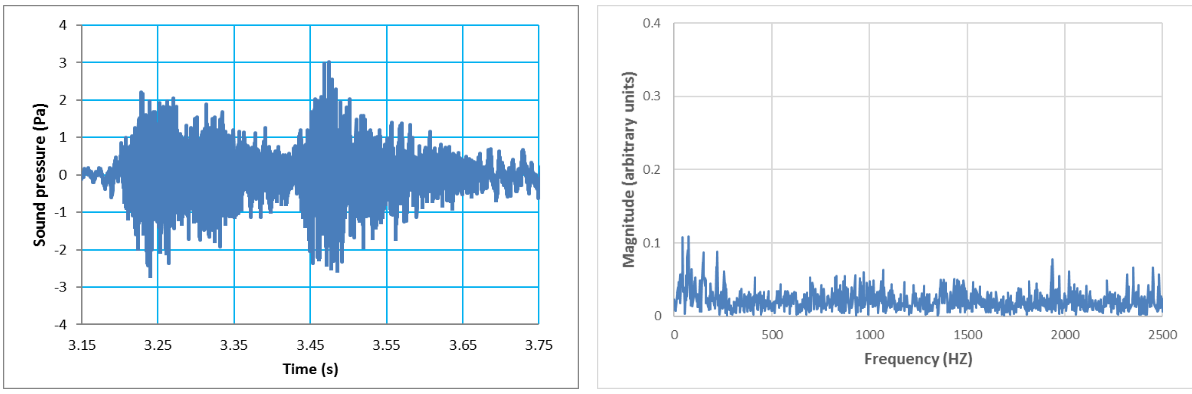


Figure 7: Time histories and FFT of test vehicle crossing cattle grids at sites Ilkley C and Sedbergh B

4. DISCUSSION AND CONCLUSIONS

The results indicate that there is considerable variation in the noise level and characteristics of the sounds generated by passing vehicles at the cattle grid sites examined. The construction of the cattle grids was essentially the same consisting of regularly spaced metal bars placed across the road above a shallow pit. However, there was some variation in design since the number of bars varied from 10 to 16 and each bar varied in width from 20 to 85mm with gaps between bars of between 140 – 120mm. The bars had a flat running surface with rounded corners except at Baildon A and Sedbergh B sites where the running surface was convex throughout. None of the designs encountered in this study conformed to the UK British Standard BS 4008:2006 [1]. The three Ilkley sites had the correct gap spacing but the bar width exceeded the standard i.e. 30 – 40mm. One site Sedbergh A had the correct bar width of 30mm but the gap width of 156mm was wider than specified (130 – 150 mm).

There was some variation in average peak levels obtained from passing traffic between sites at Baildon and Ilkley but differences were small. Some of this variation will be due to sampling errors as the variation observed with the test vehicle was much smaller as can be seen in Figure 3. Detailed differences in design would also have contributed but no conclusions can be drawn without further investigations. However. at the Sedbergh sites, levels were considerably higher and the character of the sound indicated considerable rattle noise from multiple impacts. Observations at this site revealed that the whole grid moved as the grid came under load from passing vehicles and it is likely that multiple impacts of the loose grid with supporting structures produced the observed high maximum levels. Figure 8 shows damage to the concrete frame supporting the grid that allowed significant movement during loading.

Figure 8: Damage to concrete support frame at Sedbergh B site

This was confirmed by an analysis of the sounds produced at two contrasting sites. There was a very clear dominant frequency at the quieter Ilkley site where the much lower L_{Amax} recorded was consistent with the bar passage frequency of approximately 50 Hz. At the contrasting site with much higher L_{Amax} the FFT revealed a much broader range of frequencies consistent with multiple impacts.

The survey of local residents living close to the cattle grids at Baildon and Ilkley sites was limited due to the poor response rate (50%) but for those who did reply it did indicate a significant problem due to noise and in some cases vibration. As expected those living further from the cattle grids tended to be less annoyed but individual sensitivities did mean that one resident living at a distance of 92m was very annoyed by the noise. The problem in this case appeared to be night-time disturbance. In this context the WHO guidelines for community noise exposure are relevant [10]. For outside bedroom windows the L_{Amax} limit is set at 60 dB(A). From Table 3 it can be seen that properties at 7.7m and 32.5m had average L_{Amax} levels > 5 dB(A) above this limit and one property at 30.7m was just over 2 dB(A) below the limit. The fourth property at 91.7 dB(A) was just over 6 dB(A) below. However, these levels were obtained from the test vehicle travelling at a constant speed of 40 km/h and so at greater speeds and with different vehicles greater maximum values are possible. As we have seen at the Baildon A site an increase of L_{Amax} with speed is on average 0.45 dB(A) per km/h increase. So with a crossing speed of 54 km/h on average we would expect the L_{Amax} to increase by over 6 dB(A) and sufficient to exceed the recommended guide value at night. A further consideration is that the sound produced is tonal in nature and this can add significantly to the disturbance caused. For example, in BS 4142 [11] in the case of industrial noise with tonal character affecting residential properties, a penalty of up to 6 dB(A) has been specified while for impulsive noise a 9dB(A) adjustment is possible. However, it is unclear to what extent these corrections apply to short duration sounds where L_{Amax} levels are being recorded. There were two cases in the small sample of 13 where both noise and vibration produced by vehicles crossing the cattle grid was noticed. In these cases the assessed annoyance was at the highest i.e. rated as “very annoyed”. However, more generally it has been showed that where both noise and vibration are experienced both additive and interaction effects can occur, so there is the potential for these higher levels of annoyance [12].

Using an average value of L_{Amax} of 80 dB(A) near the cattle grid and applying the distance attenuation relationship in section 3.1 it can be shown that at 50m the L_{Amax} reaches the 60 dB(A) WHO guideline value. However, if crossing speeds were higher, levels may occasionally reach 90 dB(A) at the cattle grid and in that case properties located 150m away may experience the guideline value. Figure 2 shows a distance scale superimposed on maps of relevant sites and indicates the number of houses that might be affected in this way. For example, at Baildon A site it is likely that over 20 properties with line of sight of the cattle grid would experience this level of noise at a bedroom window. From Table 2 we have evidence of reported disturbance out to 115m from this cattle grid. Factoring in the disturbing quality of the generated noise, both impulsive and tonal, may further extend the zone of possible disturbance.

A number of solutions were suggested including reducing the speed of traffic by means of speed control humps on the approaches and redesign of the cattle grid itself. Reducing the speed of traffic would be expected to have some effect as can be seen from the scatterplots in Figure 2. For the Baildon site the slope of the regression line is 0.45 dB(A) per km/h. For this installation a reduction by 20 km/h in average speed might reasonably be expected to result in a 9 dB(A) reduction in noise. Subjectively this would be almost a halving of the apparent loudness of the noise. However, at the Sedbergh site the slope is much lower at 0.16dB(A) per km/h such that a 20 km/h reduction might yield a reduction of only 3 dB(A) which may be barely noticeable. The difference may result from the different mechanisms involved for dominant noise generation as explained above. Averaged over 7 sites the average increase on L_{Amax} with speed was 0.25 dB(A)/ km/h.

One solution proposed to the Dorset County Council Roads and Rights of Way commission was to limit crossing speeds to just 10 mile/hr (16.1 km/h) where it was claimed noise levels would be similar to the maximum noise levels observed without the presence of the cattle grid [5]. There is some evidence that this could be broadly correct at some sites since at 40 km/h the average recorded L_{Amax} at three sites before the test vehicle crossed the cattle grids was 70.8 dB(A). Using the regression equations in Figure 2 and entering a crossing speed of 16.1 km/h it was found that resulting L_{Amax} values at Baildon A and Sedbergh A sites were 69.0 dB(A) and 84.0 dB(A) respectively. So at Baildon A and ignoring the possibility that freely moving traffic without the cattle grid may be moving more quickly, there appears to be similar levels under these two conditions. However, at the Sedbergh site this is clearly not the case since there is over a 13 dB(A) increase compared with the control situation.

Further evidence for the benefits of reducing speed over the cattle grid comes from the speed versus level study carried out with the test vehicle at Ilkley C. Figure 5 shows that at a cattle grid crossing speed of 24 km/h the average level recorded is very similar to that found at a pass-by speed of 40 km/h on the road surface just before the cattle grid. For this site it appears that this more modest reductions in speed is all that is required. A solution to the noise problem that suggests itself would be to incorporate the cattle grid into a traffic calming hump widely used in urban areas [13]. If the cattle grid were raised 75mm above the road surface with ramps 1850mm long on either side then the profile would be similar to that recommended for a regular flat top speed control hump used in the UK. Such a hump produces an expected crossing speed for light vehicles in the region of 24 km/h. Figure 9 shows a suggested design in plan view.

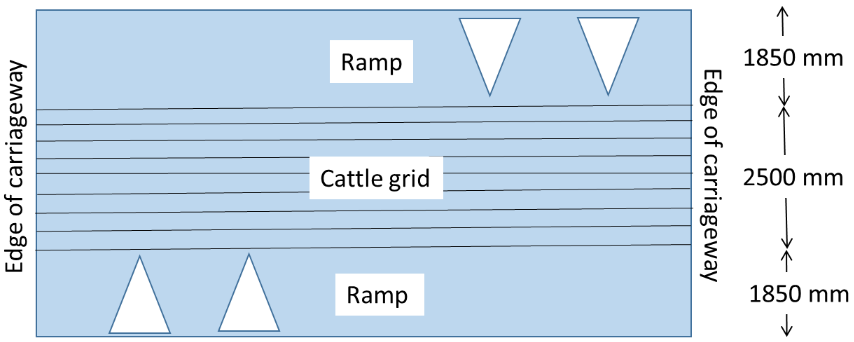


Figure 9: Plan view of proposed cattle grid hump

In summary, the study has shown that:

- Noise and vibration from cattle grids can be a serious problem within 100m of the device and in some cases some annoyance can be created beyond this distance.
- Maximum noise levels reduce with crossing speed and a suggested noise mitigation measure is to incorporate the cattle grid into a flat top speed control hump similar in profile to that recommended for traffic calming on UK roads
- Poorly secured cattle grids can produce very high noise levels as vehicles impact the loose grid. Regular maintenance may be necessary especially at heavily trafficked sites where deterioration in fixings can be expected

- Noise barriers erected adjacent to the cattle grid to screen residential properties can be effective in reducing noise at some sites but the height, length and siting of such barriers would be crucial in producing a significant reduction. From a practical point of view it is unlikely that all properties could be protected in this way
- It was not possible in a study of this nature to come to any conclusions concerning the importance of differences in detailed design of the cattle grid to the noise generated. Controlled trials would be required with a range of vehicles and crossing speeds before firm conclusions could be reached

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APPENDIX A

<u>Cattle grid questionnaire</u>

- Your assessments are most important to us and we do not want you to be influenced in any way by others. Therefore, please do not discuss any aspects with others during completion
- Where appropriate please circle the most appropriate reply
- Please return completed questionnaire in stamped addressed envelope provided

1. **Estimate approximate direct distance to cattle grid: ______ yards**
2. **How long have you lived at this address? _____ years**
3. **In this house do you hear any significant noise when vehicles cross the cattle grid? "Yes"/"No"**
4. **In this house do you feel any significant vibration when vehicles cross the cattle grid? "Yes"/"No"**
5. **If you answered "yes" to either question 3. or 4. (or both) then please rate any annoyance caused by this noise/vibration by circling the most appropriate descriptor on the rating scale below:**

- ***not annoyed***
- ***slightly annoyed***
- ***annoyed***
- ***very annoyed***

6. **If you answered "yes" to either question 3. or 4. (or both) then please describe the nature of any significant noise or vibration you experience:_________________________________**
____
____
____

7. **If you are "slightly annoyed"," annoyed" or "very annoyed" what do you feel should be done about the situation? Please ring the appropriate reply : *Do nothing, remove the cattle grid and fence off grazing animals, redesign cattle grid to reduce noise/vibration, other (please state below):* ____**
____
____
____
8. **Would you be prepared for measurements to be taken at your house? Yes/no**

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Table legends

Table 1: Average L_{Amax} levels at 40km/h crossing speed from passing light vehicles and test vehicle

Table 2: Summary of questionnaire returns at sites Baildon A and IlkleyA

Table 3: Measured and estimated L_{Amax} near building facades

Table 4: Cattle grid dimensions (mm), passage time (s) and bar passage frequency (Hz)

Figure legends

Figure 1: Cattle grid installation on Baildon Moor (site Baildon B)

Figure 2: Site maps of cattle grids where noise disturbance is likely

Figure 3: L_{Amax} against crossing speed at Baildon A and Sedbergh A

Figure 4: Correlation between average L_{Amax} at 40 km/h produced by test vehicle and the average predicted from sampled passing light vehicles

Figure 5: Variation of L_{Amax} with speed on cattle grid and control road surface

Figure 6: Average distance for different levels of rated annoyance

Figure 7: Time histories and FFT of test vehicle crossing cattle grids at sites Ilkley C and Sedbergh B

Figure 8: Damage to concrete support frame at Sedbergh B site

Figure 9: Plan view of proposed cattle grid hump