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Citation: Watts GR, Amir K and Pheasant R (2017) Investigation of noise and disturbance from vehicles crossing cattle grids and examination of options for mitigation. *Acoustics Bulletin*. 42(1): 42-50.

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

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6

7 **ABSTRACT**

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

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

28

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

30 **1. INTRODUCTION**

31 Cattle grids are widely used to prevent grazing animals from leaving unfenced
32 farmland or moorland onto more controlled spaces where access to the road is prevented
33 by walls, fences or hedges. Typically, they consist of a grid of regularly spaced metal
34 bars with a shallow pit beneath. They are designed so that an animal's leg would fall
35 through the grid if attempts were made to cross. There is design guidance set out in BSI
36 4008 2006 [1]. This gives the range of spacing and widths of the individual bars. The
37 gaps between bars should be in the range 130 to 150 mm and the running surface of the
38 bars should be 30 to 40 mm wide if of rectangular section.

39 Figure 1 shows an installation on the entrance to Baildon Moor (Site Baildon B) north
40 of Bradford in West Yorkshire. It consists of 11 rectangular topped steel bars of width
41 75 mm set at right angles to the road at 200 mm centres.



42

43

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

44

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

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

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

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

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

86 Evidence provided to Dorset County Council's Roads and Rights of Way Committee
87 [5] included a statement that said "*at low speeds (about 10mph) there is no significant*
88 *noise generated when travelling over a cattle grid, and it may even be less than on*
89 *Tarmac (asphalt). At 20mph there is a slight increase but the noise at the nearest*
90 *properties to the grid is not expected to be significantly higher than the noise of the*
91 *vehicle itself*". Speed related increases in noise levels has been a concern in all of the
92 examples discussed, however, a detailed review of the literature has not identified any
93 scientific studies that support the claim that in terms of noise levels, passing over a
94 cattle grid at 10mph is quieter than transiting asphalt at the same speed.

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

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

106 **2. METHOD**

107 **2.1 Outline of approach**

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

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

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

126 **2.2 Measurement of noise selected from passing traffic**

127 The method employed was guided by the statistical pass-by standard of measurement
128 method described in ISO 11819 - 1[9]. Due to restricted level ground at the sites the
129 distance to middle of the nearside lane was fixed at 5m and not 7.5m as given in this

130 standard. At some sites far side measurements were also carried out and distance
131 corrections made to enable comparisons with nearside measurements. The microphone
132 height was 1.2m which conforms with ISO 11819 – 1. The method involved sampling
133 vehicles that were freely moving and widely separated from other vehicles so that the
134 noise of the selected vehicle was not contaminated by other vehicles on the road. The
135 approach speed to the cattle grid was measured using a radar speed meter (Bushell
136 Velocity speed gun) positioned close to the edge of the carriageway. A sample of
137 between 60 and 110 vehicles were obtained on the higher flow roads but on roads
138 carrying very little traffic it was only possible to sample between 10 and 40 vehicles and
139 in some cases the samples were too small for statistical analysis. However,
140 measurements with a test vehicle was made at all sites. All measurements were
141 conducted with a wind speed less than 2m/s and background noise levels were low <55
142 dB(A). Where possible measurements were also made on adjoining road surfaces (i.e.
143 without cattle grid) with the test vehicle.

144

145 **2.3 Measurements with a test vehicle**

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

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

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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.

180

Baildon A



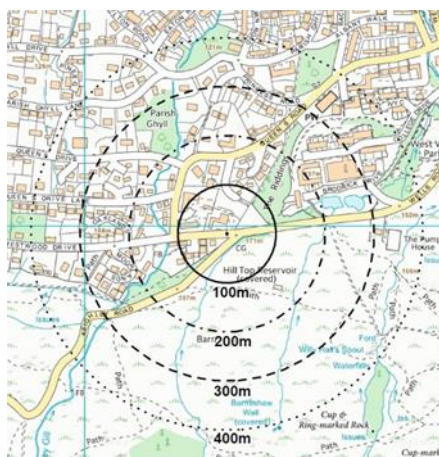
Ilkley A



Ilkley B



Ilkley C



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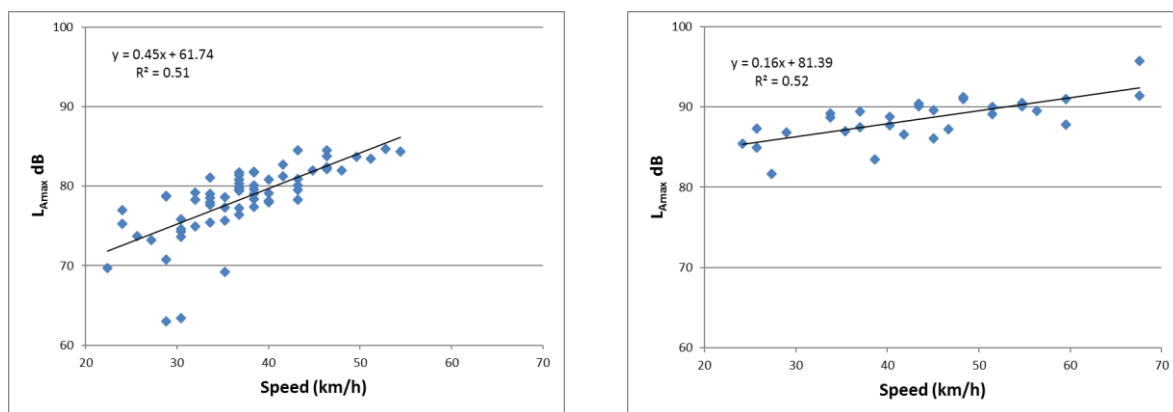
Figure 2: Site maps of cattle grids where noise disturbance is likely

183 3. RESULTS AND ANALYSIS

184 3.1 Passing traffic

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

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



197
 198 *Figure 3: L_{Amax} against crossing speed at Baildon A and Sedbergh A*

199
 200 For comparison purposes a speed of 40 km/h (25mile/h) was chosen across all sites as
 201 it was close to the overall average crossing speed (44 km/h). Regression analyses were
 202 carried out on the data for each site and the predicted mean L_{Amax} at 40km/h. Table 1
 203 lists these predicted means together with the 95th percentile confidence intervals for the
 204 means, number of data pairs and the R^2 value. It can be seen that 2 sites produce
 205 significantly higher noise levels i.e. Sedbergh A and Sedbergh B

206

207 3.2 Test vehicle

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

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

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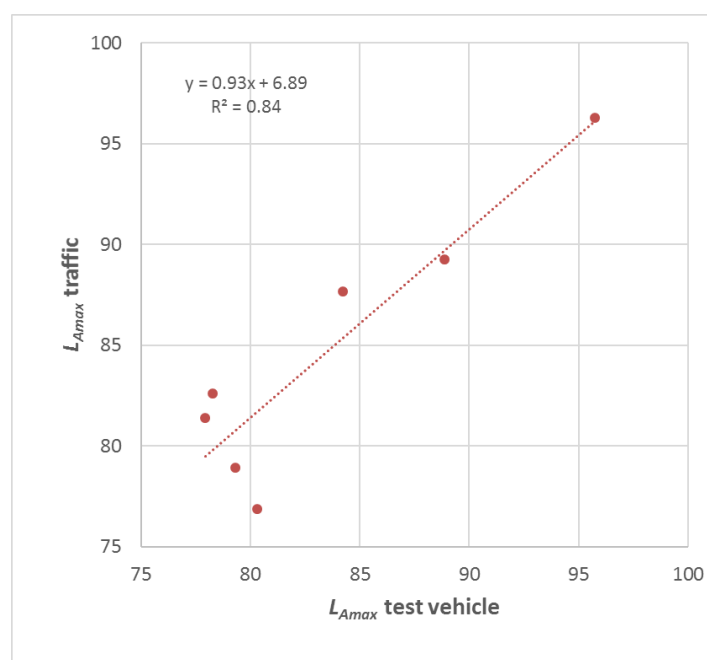
232 *Table 1: Average L_{Amax} levels at 40km/h crossing speed from passing light vehicles*
 233 *and test vehicle*

Location	Passing traffic					Test vehicle		
	<i>N</i>	Av. speed*	R^2	Av. L_{Amax}	Conf. int.	<i>N</i>	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
<i>With distance correction</i>	-	-	-	-	-		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
<i>With distance correction</i>	-	-	-	-	-		77.28	
Ilkley A (NS)	104	39.04	0.41	75.3	± 0.57	4	80.3	± 1.44
<i>With distance correction</i>				76.88			80.3	
Ilkley A (FS)	102	47.06	0.73	78.5	± 0.41	6	74.18	± 0.82
<i>With distance correction</i>				82.59			78.27	
Ilkley B (NS)	-	-	-	-	-	6	77.38	± 0.63
Ilkley B (FS)	-	-	-	-	-	5	75.94	± 1.32
<i>With distance correction</i>							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
<i>With distance correction</i>				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
<i>With distance correction</i>				96.3			95.73	

234
 235 A comparison was made at a crossing speed of 40 km/h between the average
 236 predicted L_{Amax} values obtained from passing light traffic and those obtained from the
 237 corresponding mean value for the test vehicle as can be seen in Figure 4. The regression
 238 line indicates good agreement between the two sets of averages i.e. the difference
 239 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
 240 gives support for using the results for comparative purposes from the test vehicle at sites
 241 where it was not possible to collect sufficient data from passing traffic.

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

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

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254 3.3 Crossing speed and maximum noise levels

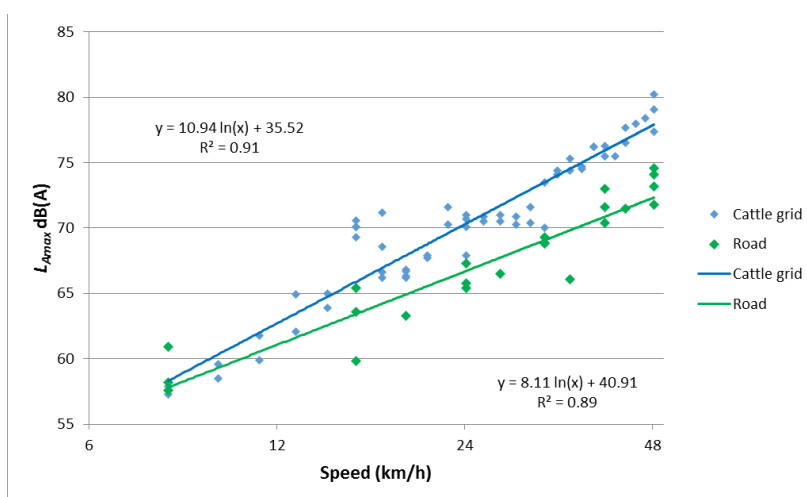
255

256 In order to investigate the effects of crossing speed on L_{Amax} in more detail a series of
 257 measurements were made with the test vehicle on a residential road, Ilkley C with little
 258 traffic. The purpose was to determine if significant speed restrictions down to as low as
 259 8km/h would have a significant effect of recorded maximum levels. It was considered

260 that such traffic calming restrictions could be an option for controlling cattle grid noise
 261 in noise sensitive areas.

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

270



271

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

273

274 Some of the scatter in values of L_{Amax} particularly at lower speeds may be due to
 275 variations in engine noise depending on the low gear selected and possibly the electric
 276 fan cutting in and out. Despite these scattered points it can be seen that the trend in the
 277 difference between maximum levels produced on this cattle grid and the control reduce

278 steadily with speed. At 48 km/h this difference is 5.1 dB(A) while at 8 km/h there is no
279 significant difference (< 1 dB(A)).

280

281 **3.4 Measurements near buildings with test vehicle**

282

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

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

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

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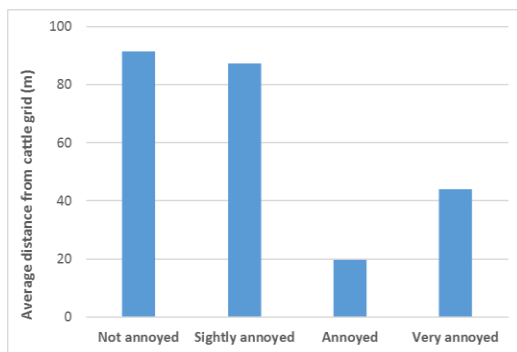
303 *Table 2: Summary of questionnaire returns at sites Baildon A and Ilkley A*

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

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

305

306



307 *Figure 6: Average distance for different levels of rated annoyance*

308

309

310 These data are summarized in Table 3 below. Where N is the number of readings and
 311 $Est. L_{Amax}$ is the estimated level based on hemi-spherical spreading over a hard surface
 312 and average measured level at 5m. In the case of prediction at the closest site there is
 313 a noise barrier 2.4m tall extending 5m in each direction from the centre of the cattle
 314 grid that clearly has contributed to the 9.2 dB(A) difference between estimate and

315 measured L_{Amax} . In the case of the site at 30.7m the property lies below the level of
 316 the road and the road shoulder provides a diffracting edge that would contribute to
 317 the observed difference of 5.6 dB(A). At the remaining two sites the estimated and
 318 measured levels are close.

319

320

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

321

322 3.5 Spectral analysis

323

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

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

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

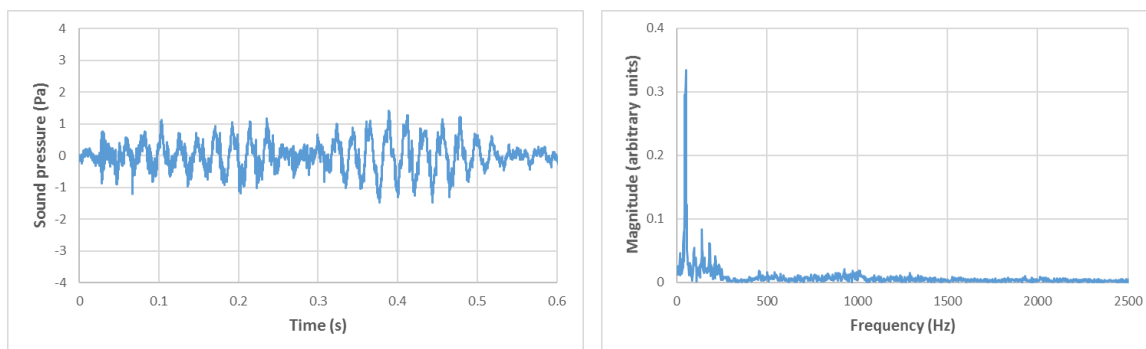
Site	No. bars	Bar width	Spacing	Gap width	Overall length	Passage time	Passage frequency
Baildon A	11	80	240	160	2800	0.479	45.5
Baildon B	11	75	200	125	2325	0.436	54.6
Ilkley A	11	83	218	135	2533	0.455	50.1
Ilkley B	11	85	219	134	2543	0.456	49.9
Ilkley C	10	80	220	140	2340	0.437	49.7
Sedbergh A	16	30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

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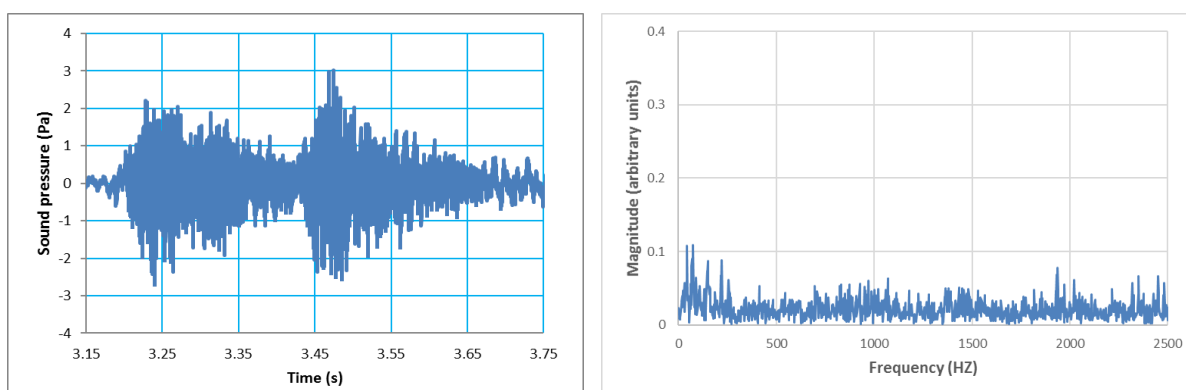
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343 The passage of front and rear wheels is also clearly visible in Figure 7. In the case of
 344 Sedbergh B site although the passage of the two tyre sets can be seen there is no
 345 dominant frequency at the bar passage frequency of 78.1 Hz although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

Ilkley C.



Sedbergh B



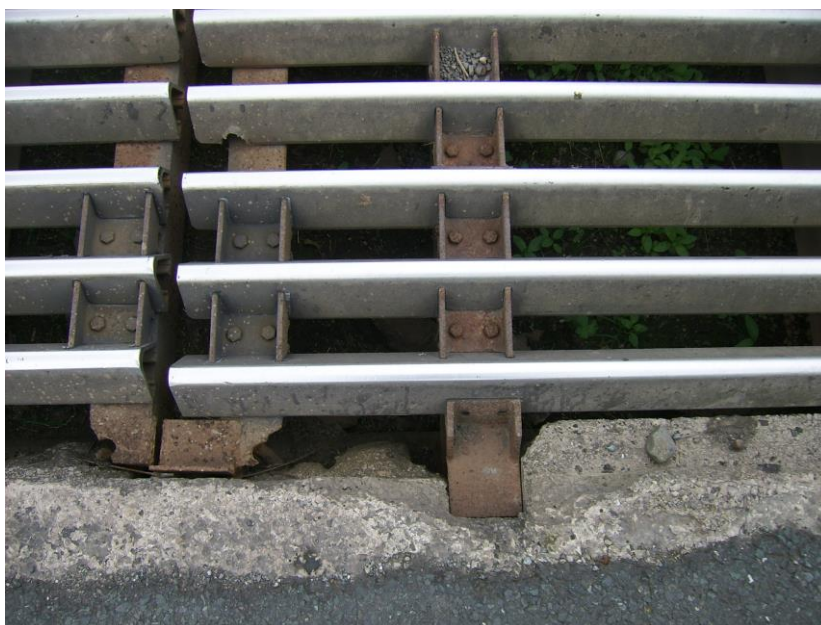
349 *Figure 7: Time histories and FFT of test vehicle crossing cattle grids at sites Ilkley C*
 350 *and Sedbergh B*

351 4. DISCUSSION AND CONCLUSIONS

352
 353 The results indicate that there is considerable variation in the noise level and
 354 characteristics of the sounds generated by passing vehicles at the cattle grid sites
 355 examined. The construction of the cattle grids was essentially the same consisting of
 356 regularly spaced metal bars placed across the road above a shallow pit. However, there
 357 was some variation in design since the number of bars varied from 10 to 16 and each bar
 358 varied in width from 20 to 85mm with gaps between bars of between 140 – 120mm. The
 359 bars had a flat running surface with rounded corners except at Baildon A and Sedbergh
 360 B sites where the running surface was convex throughout. None of the designs
 361 encountered in this study conformed to the UK British Standard BS 4008:2006 [1]. The

362 three Ilkley sites had the correct gap spacing but the bar width exceeded the standard i.e.
363 30 – 40mm. One site Sedbergh A had the correct bar width of 30mm but the gap width
364 of 156mm was wider than specified (130 – 150 mm).

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



376

377

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

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

384 The survey of local residents living close to the cattle grids at Baildon and Ilkley sites
385 was limited due to the poor response rate (50%) but for those who did reply it did
386 indicate a significant problem due to noise and in some cases vibration. As expected
387 those living further from the cattle grids tended to be less annoyed but individual
388 sensitivities did mean that one resident living at a distance of 92m was very annoyed by
389 the noise. The problem in this case appeared to be night-time disturbance. In this context
390 the WHO guidelines for community noise exposure are relevant [10]. For outside
391 bedroom windows the L_{Amax} limit is set at 60 dB(A). From Table 3 it can be seen that
392 properties at 7.7m and 32.5m had average L_{Amax} levels > 5 dB(A) above this limit and
393 one property at 30.7m was just over 2 dB(A) below the limit. The fourth property at 91.7
394 dB(A) was just over 6 dB(A) below. However, these levels were obtained from the test
395 vehicle travelling at a constant speed of 40 km/h and so at greater speeds and with
396 different vehicles greater maximum values are possible. As we have seen at the Baildon
397 A site an increase of L_{Amax} with speed is on average 0.45 dB(A) per km/h increase. So
398 with a crossing speed of 54 km/h on average we would expect the L_{Amax} to increase by
399 over 6 dB(A) and sufficient to exceed the recommended guide value at night. A further
400 consideration is that the sound produced is tonal in nature and this can add significantly
401 to the disturbance caused. For example, in BS 4142 [11] in the case of industrial noise
402 with tonal character affecting residential properties, a penalty of up to 6 dB(A) has been
403 specified while for impulsive noise a 9dB(A) adjustment is possible. However, it is

404 unclear to what extent these corrections apply to short duration sounds where L_{Amax}
405 levels are being recorded. There were two cases in the small sample of 13 where both
406 noise and vibration produced by vehicles crossing the cattle grid was noticed. In these
407 cases the assessed annoyance was at the highest i.e. rated as “very annoyed”. However,
408 more generally it has been showed that where both noise and vibration are experienced
409 both additive and interaction effects can occur, so there is the potential for these higher
410 levels of annoyance [12].

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

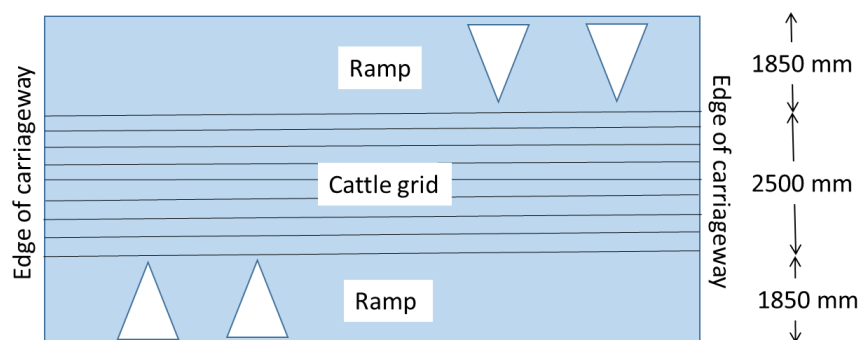
422 A number of solutions were suggested including reducing the speed of traffic by
423 means of speed control humps on the approaches and redesign of the cattle grid itself.
424 Reducing the speed of traffic would be expected to have some effect as can be seen from
425 the scatterplots in Figure 2. For the Baildon site the slope of the regression line is 0.45
426 dB(A) per km/h. For this installation a reduction by 20 km/h in average speed might
427 reasonably be expected to result in a 9 dB(A) reduction in noise. Subjectively this would
428 be almost a halving of the apparent loudness of the noise. However, at the Sedbergh site

429 the slope is much lower at 0.16dB(A) per km/h such that a 20 km/h reduction might
430 yield a reduction of only 3 dB(A) which may be barely noticeable. The difference may
431 result from the different mechanisms involved for dominant noise generation as
432 explained above. Averaged over 7 sites the average increase on L_{Amax} with speed was
433 0.25 dB(A)/ km/h.

434 One solution proposed to the Dorset County Council Roads and Rights of Way
435 commission was to limit crossing speeds to just 10 mile/hr (16.1 km/h) where it was
436 claimed noise levels would be similar to the maximum noise levels observed without the
437 presence of the cattle grid [5]. There is some evidence that this could be broadly correct
438 at some sites since at 40 km/h the average recorded L_{Amax} at three sites before the test
439 vehicle crossed the cattle grids was 70.8 dB(A). Using the regression equations in
440 Figure 2 and entering a crossing speed of 16.1 km/h it was found that resulting L_{Amax}
441 values at Baildon A and Sedbergh A sites were 69.0 dB(A) and 84.0 dB(A) respectively.
442 So at Baildon A and ignoring the possibility that freely moving traffic without the cattle
443 grid may be moving more quickly, there appears to be similar levels under these two
444 conditions. However, at the Sedbergh site this is clearly not the case since there is over a
445 13 dB(A) increase compared with the control situation.

446
447 Further evidence for the benefits of reducing speed over the cattle grid comes from
448 the speed versus level study carried out with the test vehicle at Ilkley C. Figure 5 shows
449 that at a cattle grid crossing speed of 24 km/h the average level recorded is very similar
450 to that found at a pass-by speed of 40 km/h on the road surface just before the cattle
451 grid. For this site it appears that this more modest reductions in speed is all that is
452 required. A solution to the noise problem that suggests itself would be to incorporate the
453 cattle grid into a traffic calming hump widely used in urban areas [13]. If the cattle grid

454 were raised 75mm above the road surface with ramps 1850mm long on either side then
455 the profile would be similar to that recommended for a regular flat top speed control
456 hump used in the UK. Such a hump produces an expected crossing speed for light
457 vehicles in the region of 24 km/h. Figure 9 shows a suggested design in plan view.
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Figure 9: Plan view of proposed cattle grid hump

461

462 In summary, the study has shown that:

463

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

474 • Noise barriers erected adjacent to the cattle grid to screen residential
475 properties can be effective in reducing noise at some sites but the height,
476 length and siting of such barriers would be crucial in producing a significant
477 reduction. From a practical point of view it is unlikely that all properties
478 could be protected in this way

479 • It was not possible in a study of this nature to come to any conclusions
480 concerning the importance of differences in detailed design of the cattle grid
481 to the noise generated. Controlled trials would be required with a range of
482 vehicles and crossing speeds before firm conclusions could be reached
483

484 **ACKNOWLEDGEMENTS**

485 The assistance of residents in Baildon and Ilkley in West Yorkshire in completing the
486 questionnaires, and in some cases allowing measurements on their property, is gratefully
487 acknowledged. The work was funded by the Bradford Centre for Sustainable
488 Environments, University of Bradford.
489

490 **APPENDIX A**

491

492 **Cattle grid questionnaire**

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

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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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582 **Table legends**

583

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

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

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

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

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591 **Figure legends**

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

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

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

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

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

599 Figure 6: Average distance for different levels of rated annoyance

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

601 and Sedbergh B

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

603 Figure 9: Plan view of proposed cattle grid hump

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