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

29

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

## 31 **1. INTRODUCTION**

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

40 Figure 1 shows an installation on the entrance to Baildon Moor (Site Baildon B) north  
41 of Bradford in West Yorkshire. It consists of 11 rectangular topped steel bars of width  
42 75 mm set at right angles to the road at 200 mm centres.



43

44

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

45

46 Noise associated with vehicles crossing these installations, which is typically a low  
47 frequency ‘brrrr’ is often the main reason why people living in the vicinity of cattle  
48 grids complain to the planning or highway authorities. Within the United Kingdom  
49 cattle grids are often located in areas of public amenity, such as the urban-rural fringe,  
50 National Parks, ancient commons and Areas of Outstanding Natural Beauty (AONB), all  
51 of which attract large numbers of visitors on a daily basis. The perceived degradation of  
52 environmental quality caused by vehicles continually crossing cattle grids in these areas  
53 was partially assessed in a controlled laboratory study carried out by the University of  
54 Bradford in 2013 [2]. The study examined the extent to which the introduction of  
55 congruent mechanical and natural soundscape components into video recordings of a  
56 range of natural environments, influenced the perception of tranquillity and wildness. It  
57 was found that the introduction of cattle grid noise reduced tranquillity ratings  
58 significantly.

59 Disturbance to peace and quiet and to the overall tranquillity of a location by the  
60 installation of a cattle grid, is a concern that is regularly reported in the press and

61 articulated to the UK Government's Department of Transport (DoT) inspectors  
62 [3,4,5,6,7,8].

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

## 66 **2. METHOD**

### 67 **2.1 Outline of approach**

68 Roadside measurements of vehicle noise were carried out at 2 sites near Baildon, 3 sites in  
69 Ilkley (both groups near Bradford) and at 2 sites on the A684 east of Sedbergh in the  
70 Yorkshire Dales. Vehicles were selected from the traffic passing ensuring they were freely  
71 moving and not in close proximity to other vehicles. In addition, measurements were carried  
72 out using a test vehicle at these and further locations at a fixed speed for accurate comparison  
73 of noise produced across sites. Finally, façade measurements at homes where residents were  
74 affected by the noise from cattle grids were also taken.

75 The approach adopted included roadside measurements of the maximum noise produced by  
76 vehicles crossing the cattle grids in both directions, where safe and practical to do so, and  
77 recordings of the sound produced by a test vehicle for later analysis.  $L_{Amax}$  was the preferred  
78 measure as the nature of the sound was less than a second in duration. All sites were on minor  
79 single carriageway roads where average vehicle speeds were generally in the range 40 to 50  
80 km/h. For the purpose of characterising the noise produced a Bruel and Kjaer sound level  
81 meter type 2250 was used for capturing maximum A weighted levels using fast averaging and

82 additionally for recording a few seconds from a test vehicle cruise-by for post processing.

83 Measurements were confined to light vehicles i.e. cars and vans as there were very few heavy  
84 vehicles on these minor single carriageway roads and it would have taken too long to obtain a  
85 valid sample.

## 86 **2.2 Measurement of noise selected from passing traffic**

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

104

## 105 **2.3 Measurements with a test vehicle**

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

113

#### 114 **2.4 Measurement near homes of residents affected by noise**

115

116 To determine the size and nature of any noise and vibration disturbance caused by  
117 vehicles crossing cattle grids, questionnaires were posted to homes within an  
118 approximate radius of 150m from two cattle grids located near to residential areas i.e.  
119 sites Baildon A and Ilkley A. Each questionnaire was accompanied by a postage paid  
120 reply envelope and permission was sought to allow measurements at their home if it was  
121 thought appropriate. In all, measurements near the facades of four such homes were  
122 carried out. The distances from the cattle grids ranged from 7.7m to 122m. Figures 2  
123 show maps of the cattle grid sites situated close to dwellings with concentric circles  
124 centred on the cattle grids to indicate distance. The four measurement positions are  
125 indicated with asterisks.

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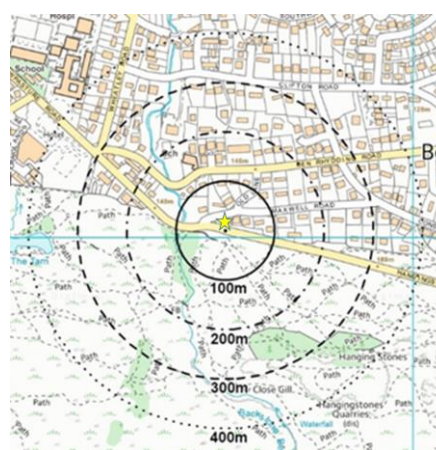
129

130

Baildon A



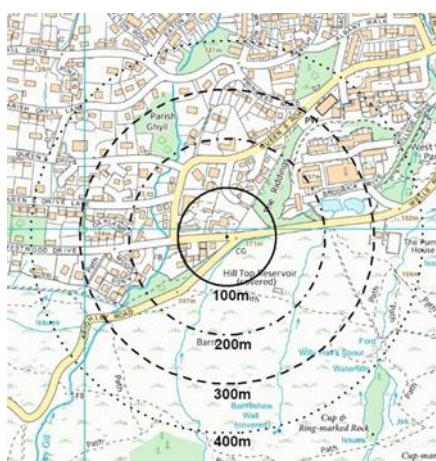
Ilkley A



Ilkley B



Ilkley C



131

132

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

### 133 3. RESULTS AND ANALYSIS

#### 134 3.1 Passing traffic

135 Plots were made of the captured  $L_{Amax}$  against crossing speed for each installation.

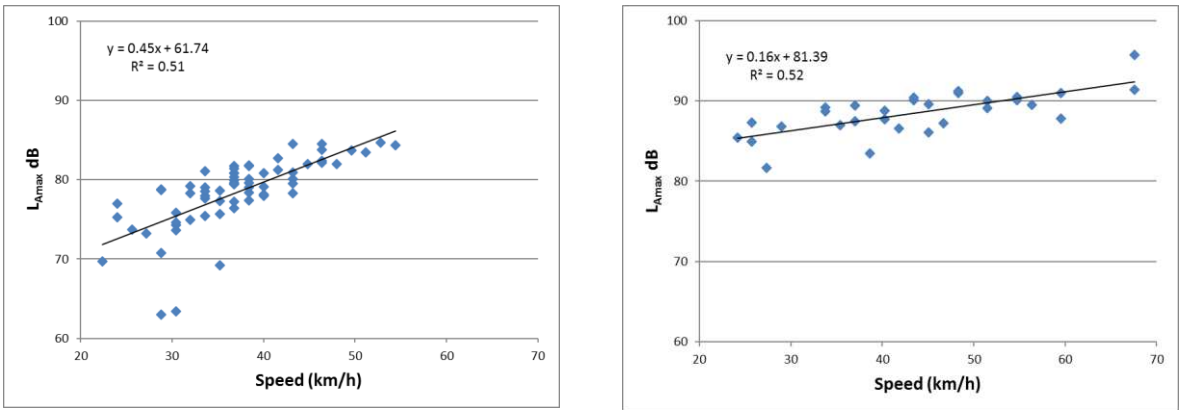
136 Measurements made to vehicles travelling in the far side lane were normalized to a

137 distance of 5m for comparison purposes. For this purpose, a simple correction based on

138 hemi-spherical spreading was used i.e.  $10 \log_{10} [(5/d)^2]$  where  $d$  is the distance to the

139 middle of the far side lane (in range 7.5 to 8m)

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



147  
148 *Figure 3:  $L_{Amax}$  against crossing speed at Baildon A and Sedbergh A*

149  
150 For comparison purposes a speed of 40 km/h (25mile/h) was chosen across all sites as  
151 it was close to the overall average crossing speed (44 km/h). Regression analyses were  
152 carried out on the data for each site and the least squares fitted line was used to predict  
153 the mean  $L_{Amax}$  at 40km/h. Table 1 lists these predicted means together with the 95<sup>th</sup>  
154 percentile confidence intervals for the means, number of data pairs and the  $R^2$  value. It  
155 can be seen that two sites produce significantly higher noise levels i.e. Sedbergh A and  
156 Sedbergh B

157

### 158 3.2 Test vehicle

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

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

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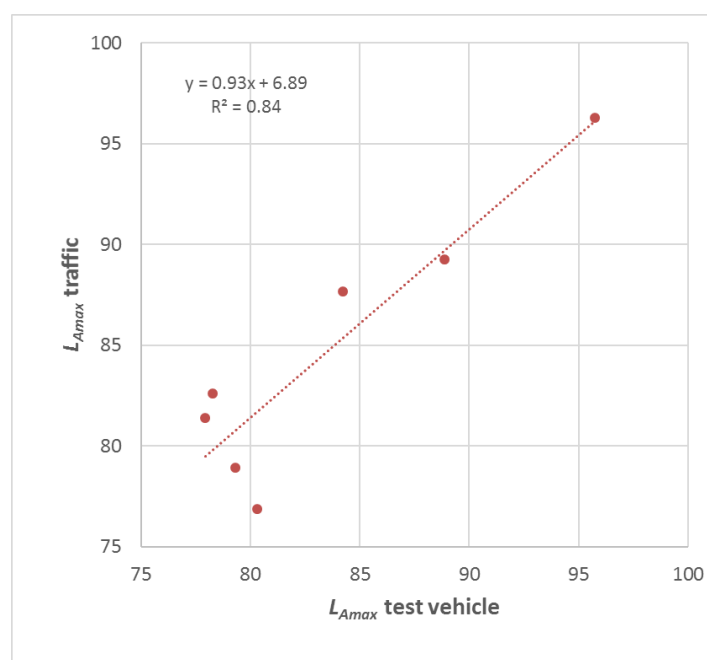
183 *Table 1: Average  $L_{Amax}$  levels at 40km/h crossing speed from passing light vehicles*  
 184 *and test vehicle*

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	

185  
 186 A comparison was made at a crossing speed of 40 km/h between the average  
 187 predicted  $L_{Amax}$  values obtained from passing light traffic and those obtained from the  
 188 corresponding mean value for the test vehicle as can be seen in Figure 4. The regression  
 189 line indicates good agreement between the two sets of averages i.e. the difference  
 190 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  
 191 gives support for using the results for comparative purposes from the test vehicle at sites  
 192 where it was not possible to collect sufficient data from passing traffic.

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

199



200

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

203

### 204 3.3 Measurements near buildings with test vehicle

205

206 A total of 13 questionnaires were received from the 26 that were delivered to the two  
 207 cattle grid installations with houses close by. Ten were received from residents living  
 208 close to Baildon A and 3 from Ilkley A. The questionnaire replies are summarized in  
 209 Table 2 below. It can be seen that there is a tendency for ratings of annoyance to

210 decrease with distance. Clearly the amount of screening of a property by other buildings  
 211 or local topography would have a significant effect on the peak noise levels and  
 212 consequently on the level of any annoyance caused so that a simple relationship was not  
 213 expected.

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

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

222 *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

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

224

225

226 to the cattle grid. These data are summarized in Table 3 below. Where  $N$  is the  
 227 number of readings and  $Est. L_{Amax}$  is the estimated level based on hemi-spherical  
 228 spreading over a hard surface and average measured level at 5m. In the case of  
 229 prediction at the closest site there is a noise barrier 2.4m tall extending 5m in each  
 230 direction from the centre of the cattle grid that clearly has contributed to the 9.2  
 231 dB(A) difference between estimate and measured  $L_{Amax}$ . In the case of the site at  
 232 30.7m the property lies below the level of the road and the road shoulder provides a  
 233 diffracting edge that would contribute to the observed difference of 5.6 dB(A). At  
 234 the remaining two sites the estimated and measured levels are close.

235

236

*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	$\pm 1.05$	74.6
30.7	6	57.9	$\pm 0.81$	63.5
32.5	5	66.1	$\pm 1.83$	62.9
91.7	8	53.9	$\pm 1.01$	54.0

237

### 238 3.4 Spectral analysis

239

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

243 Figure 5 shows the time histories and FFT for two contrasting sites Ilkley C and  
 244 Sedbergh B where average peak noise levels from several runs with the test vehicle were  
 245 very different i.e. average  $L_{Amax}$  of 79.3 and 95.7 dB(A) respectively. It can be seen  
 246 from Fig 5a that at Ilkley C there is a very pronounced dominant frequency at 49.2 Hz  
 247 close to the calculated bar passing frequency under the tyres at 40 km/h of 49.7 Hz  
 248 based on the measured separation of the bars of 1400 mm. Several harmonics of the

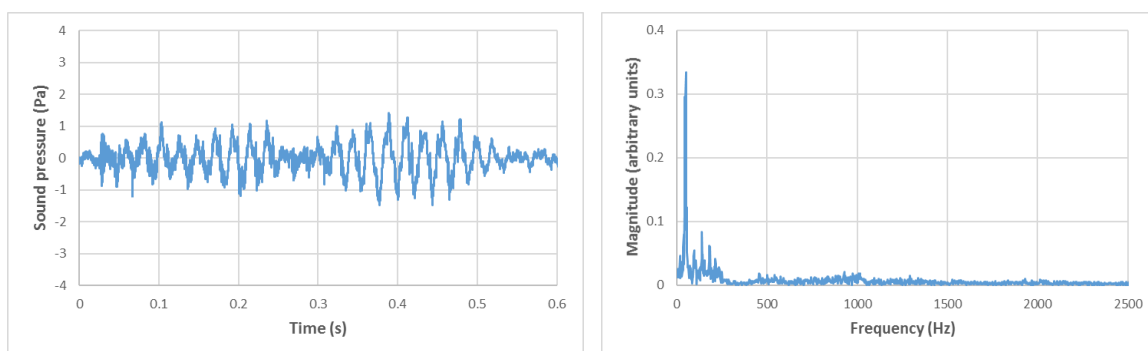
249 fundamental can also be observed. Table 4 gives details of bar geometry at each site and  
 250 expected passage frequency at each site.

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

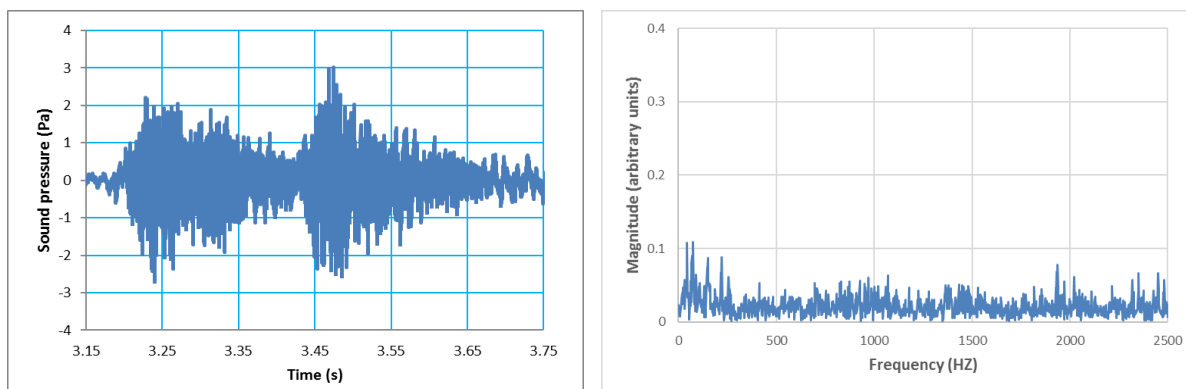
Site	No. bars	Bar width	Spacing	Gap width	Overall length	Passage time	Passage frequency
Baildon A	11	80	240	160	2800	0.479	45.5
Baildon B	11	75	200	125	2325	0.436	54.6
Ilkley A	11	83	218	135	2533	0.455	50.1
Ilkley B	11	85	219	134	2543	0.456	49.9
Ilkley C	10	80	220	140	2340	0.437	49.7
Sedbergh A	16	30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

253  
 254  
 255 The passage of front and rear wheels is also clearly visible in Figure 5a. In the case of  
 256 Sedbergh B site although the passage of the two tyre sets can be seen there is no  
 257 dominant frequency at the bar passage frequency of 78.1 Hz although the maximum in  
 258 the FFT occurs at 75.0 Hz there is in fact a wide range of frequencies present. This is  
 259 consistent with impact sounds as each tyre set loaded the grid. This also agrees with the  
 260 subjective impression of a pronounced crash as the test vehicle reached the cattle grid.

Ilkley C



Sedbergh B



261 *Figure 5: Time histories and FFT of test vehicle crossing cattle grids at sites Ilkley C*  
 262 *and Sedbergh B*

#### 263 4. DISCUSSION AND CONCLUSIONS

264 The results indicate that there is considerable variation in the noise level and  
 265 characteristics of the sounds generated by passing vehicles at the cattle grid sites  
 266 examined. The construction of the cattle grids was essentially the same consisting of  
 267 regularly spaced metal bars placed across the road above a shallow pit. However, there  
 268 was some variation in design since the number of bars varied from 10 to 16 and each bar  
 269 varied in width from 20 to 85mm with gaps between bars of between 140 – 120mm. The  
 270 bars had a flat running surface with rounded corners except at Baildon A and Sedbergh  
 271 B sites where the running surface was convex throughout. None of the designs  
 272 encountered in this study conformed to the UK British Standard BS 4008:2006 [1]. The  
 273 three Ilkley sites had the correct gap spacing but the bar width exceeded the standard i.e.  
 274 30 – 40mm. One site Sedbergh A had the correct bar width of 30mm but the gap width  
 275 of 156mm was wider than specified (130 – 150 mm).

276 There was some variation in average peak levels obtained from passing traffic  
 277 between sites at Baildon and Ilkley but the outlying points were for the Sedbergh sites.  
 278 Some of this variation will be due to sampling errors as the variation observed with the  
 279 test vehicle was much smaller as can be seen in Figure 3. Detailed differences in design

280 would also have contributed but no conclusions can be drawn without further  
281 investigations. At the Sedbergh sites levels were considerably higher and the character  
282 of the sound indicated considerable rattle noise from multiple impacts. Observations at  
283 this site revealed that the whole grid moved as the grid came under load from passing  
284 vehicles and it is likely that multiple impacts of the loose grid with supporting structures  
285 produced the observed high maximum levels. It was observed that there was damage to  
286 the concrete frame supporting the grid that allowed some movement during loading.

287

288

289 This was confirmed by an analysis of the sounds produced at two contrasting sites.  
290 There was a very clear dominant frequency at the quieter Ilkley site where the much  
291 lower  $L_{Amax}$  recorded was consistent with the bar passage frequency of approximately 50  
292 Hz. At the contrasting site with much higher  $L_{Amax}$  the FFT revealed a much broader  
293 range of frequencies consistent with multiple impacts. Such impacts and resulting  
294 disturbance have also been reported in close proximity to surface defects such as bridge  
295 expansion joints [10,].

296 The survey of local residents living close to the cattle grids was limited due to the  
297 poor response rate (50%) but for those who did reply it did indicate a significant  
298 problem due to noise and in some cases vibration. As expected those living further from  
299 the cattle grids tended to be less annoyed but individual sensitivities did mean that one  
300 resident living at a distance of 92m was very annoyed by the noise. The problem in this  
301 case appeared to be night-time disturbance. In this context the WHO guidelines for  
302 community noise exposure are relevant [11]. For outside bedroom windows the  $L_{Amax}$   
303 limit is set at 60 dB(A). From Table 3 it can be seen that properties at 7.7m and 32.5m  
304 had average  $L_{Amax}$  levels  $> 5$  dB(A) above this limit and one property at 30.7m was just

305 over 2 dB(A) below the limit. The fourth property at 91.7 dB(A) was just over 6 dB(A)  
306 below. However, these levels were obtained from the test vehicle travelling at a constant  
307 speed of 40 km/h and so at greater speeds and with different vehicles greater maximum  
308 values are possible. As we have seen at the Baildon A site an increase of  $L_{Amax}$  with  
309 speed is on average 0.45 dB(A) per km/h increase. So with a crossing speed of 54 km/h  
310 on average we would expect the  $L_{Amax}$  to increase by over 6 dB(A) and sufficient to  
311 exceed the recommended guide value at night. A further consideration is that the sound  
312 produced is tonal in nature and this can add significantly to the disturbance caused. For  
313 example in BS 4142 [12] in the case of industrial noise with tonal character affecting  
314 residential properties, a penalty of up to 6 dB(A) has been specified while for impulsive  
315 noise a 9dB(A) adjustment is possible. However, it is not clear to what extent these  
316 corrections apply to short duration sounds where  $L_{Amax}$  levels are being recorded. There  
317 were two cases in the small sample of 13 where both noise and vibration produced by  
318 vehicles crossing the cattle grid was noticed. In these cases the assessed annoyance was  
319 at the highest i.e. rated as “very annoyed”. However, more generally it has been showed  
320 that where both noise and vibration are experienced both additive and interaction effects  
321 can occur, so there is the potential for these higher levels of annoyance [13].

322 Using an average value of  $L_{Amax}$  of 80 dB(A) near the cattle grid and applying the  
323 distance attenuation relationship in section 3.1 it can be shown that at 50m the  $L_{Amax}$   
324 reaches the 60 dB(A) WHO guideline value. However, if crossing speeds were higher,  
325 levels may occasionally reach 90 dB(A) at the cattle grid and in that case properties  
326 located 150m away may experience the guideline value. Figure 2 shows a distance scale  
327 superimposed on maps of relevant sites and indicates the number of houses that might be  
328 affected in this way. For example, at Baildon A site it is likely that over 20 properties  
329 with line of sight of the cattle grid would experience this level of noise at a bedroom

330 window. From Table 2 we have evidence of reported disturbance out to 115m from this  
331 cattle grid. Factoring in the disturbing quality of the generated noise, both impulsive and  
332 tonal, may further extend the zone of possible disturbance.

333 A number of solutions were suggested including reducing the speed of traffic by  
334 means of speed control humps on the approaches and redesign of the cattle grid itself.  
335 Reducing the speed of traffic would be expected to have some effect as can be seen from  
336 the scatterplots in Figure 2.

337 The study has shown that noise barriers at the roadside can be effective in reducing  
338 noise (estimated at 8 dB(A) in the case of Ilkley A) and clearly proper fastening of the  
339 grid so that it is not free to move upon loading would be expected to reduce the high  
340 levels measured at the Sedbergh sites.

341 A more detailed examination of speed effects especially at the lowest practical  
342 crossing speeds will be undertaken as it is clear that there are substantial gains to be had  
343 at sites where the cattle grids are securely fastened.

344

345

## 346 **ACKNOWLEDGEMENTS**

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## 412 **Table legends**

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

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

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

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

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421 **Figure legends**

422

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

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

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

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

428 Figure 5: Average distance for different levels of rated annoyance

429 Figure 6: Time histories and FFT of test vehicle crossing cattle grids at sites Ilkley C  
430 and Sedbergh B

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