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RAILWAY NOISE - CALCULATION AND MEASUREMENT

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1 INTRODUCTION

The proposed channel tunnel rail link brought about renewed interest in noise from railways and the recently published Mitchell report recommends a level of rail noise thought to be equitable with the Specified Level of road traffic noise under the Noise Insulation Regulations 1975 [1]. Researchers are working on rail noise prediction methods comparable with those used for road traffic noise [2,3]. In the light of this revived interest a retrospective look has been taken at some planning cases in Somerset involving railway noise. A new look at some old data has revealed a novel way of estimating train speeds and has allowed comparisons with published empirical railway noise data. Road traffic noise measurements near the Frome by-pass incidentally provided some useful railway noise data and people living there have been asked about their subjective response to road and rail noise.

2 SITE NOISE ASSESSMENT - THE LONG WAY

In 1982 a residential development was proposed on a green field site on the outskirts of Wellington adjacent to the main Paddington to Penzance line. The local authority conducted an extensive noise monitoring programme using a data logger. Two 24 hour recordings were made at 12 measurement positions on a 3 x 4 grid pattern across the site. The data tapes were processed to give Leq(1 hr) values. The procedure was time consuming but provided a wealth of data. Noise level contours were drawn for the site, these were curved because the railway runs on a 2 metre embankment beside the site but disappears into cuttings at both ends. The attenuation rate was confirmed to be 3 dB(A) per doubling of distance up to 60m.

Various planning criteria adopted by other local authorities at the time were examined. These came mainly from the GLC and authorities in the Midlands and northwest. The Environmental Health dept. adopted what was considered a good standard and recommended that no building within 30 m of the tracks or where the Leq(24hr) exceeds 60 dB(A) or the L1 exceeds 80 dB(A).

The 60 dB(A) contour was approximately 40m from the tracks but the developers built no nearer than 55m. The intervening land now contains car parking areas and landscaped banks with trees. The measured Leq (24 hr) at the houses is 58 dB(A). Residents interviewed expressed slight disturbance (i.e. interference with TV viewing etc.) but no annoyance from train noise.

Event times were determined from some of the data tapes for comparison with train passage times. SEL values could be obtained from further analysis of the tapes but, unfortunately they were not kept.

At same time as 'good' standards were being imposed in the Borough, not far away in Frome houses were being built where the Leq(24 hr) was 70 dB(A). More of these later.

3 SITE NOISE ASSESSMENT - THE QUICK WAY

More recent applications for development of land by the railway have included house, residential caravans and gypsy caravans. Rail noise assessments have been made by the well established method of measuring SEL directly and computing Leq(24 hr) from the average SEL for trains in a particular class [4]. Comparisons with measured Leq(24 hr) have given very good agreement, calculated and measured SELs were found to be within 2 dB(A). Where the traffic volume flow is high and the number of different train types is low the calculated Leq(24 hr) is fairly insensitive to moderate errors in traffic volume estimations. Usually, 5 or 6 measurements of each train type gave a reasonably good average SEL and intercity trains and heavy freights were found to be the dominant sources. Measurements can be made at all the required locations on a site obviating the need to calculate corrections for the effects of barriers, cuttings and ground absorption. Methods do exist for estimating such effects, based partly on theory and partly on empirical results, but these can be complex [2]. Freight movements can be obtained from the pocket timetables published for railway enthusiasts. [5]

4 A NEW LOOK AT SOME OLD DATA

The Frome by-pass, opened in 1989, runs parallel to, and 50m east of, the main Paddington - Penzance railway for just over 4 km. The road and railway run around the eastern outskirts of the town and pass close to many houses (figure 1). Before the road was built an environmental noise impact assessment was made. 24 hr measurements were made at 20 locations with the environmental noise analysers programmed to produce hourly statistical levels. Single event histories were also recorded at two premises in order to find out whether train noise dominated the Leq levels. The intention was to match the recorded events with timetabled train passages and sum the SEL values. This worked well, as describe above, and gave predicted 24 hr Leq's within 1 dB(A) of those measured. Since the measurements had been made at the same time, the sets of event data were compared in an attempt to filter out other spurious events such as low flying jets. The idea then occurred that the train speeds could be estimated from the results but the clocks had not been synchronised.

<u>Estimating train speeds</u>
A previous attempt to estimate the speed of a an intercity train was made during the frequency analysis of a tape recording. During the FFT analysis two tonal peaks appeared, 525 and 455 Hz, and coincided with the audible Doppler shift of the locomotive noise (figure 2). The result of a simple calculation gave a speed of 88 km/hour. However, at a distance of 40m from the track the relative velocity between train and observer is constantly changing. In fact the tonal component will shift continuously. Thus the calculation cannot be

done unless the location of the train is known at a given time (and for that you need the speed!). A rough estimate of the angle from microphone location to the locomotive gives a speed of 125 km/hour. A better estimate of the train speed from the number of coaches and the timed passage gave 170 km/hr. The use of the Doppler shift is therefore not to be recommended unless you have a very fast, high resolution analyser and can make the measurements from a bridge over the track.

For the next pair of noise measurements made at Frome the clocks were synchronised. It has thus been possible to use the single event histories to compute train speeds. A program compares the events and calculates the average speed and directions of the trains. The event durations also give a measure of the length of the trains but the error is large for fast trains because of the short durations, 4 to 6 seconds. The program compares the event durations at both locations to check that the train speed has remained fairly constant. Some things could fool the computer such as trains going opposite ways passing each other between the two sites. Intercity trains normally pass at speeds above 110 km/hr. The freight trains generally travel at less than 80 km/hr. The program can thus identify train types from their speeds and lengths.

5 RESULTS

The two measurement locations were 1,050m apart and both approximately 30m from the track, running in a 4m cutting (figure 1). The sites were chosen for their proximity to the road and, although useful for this exercise, are not ideal locations. Local trains branch into Frome station and so do not pass the southern location. Stone trains from Whatley Quarry also use that branch. Quarry trains from Merehead travel on the main line from the south.

The up line is continuous welded rail and the down line is jointed rail on wooden sleepers so allowing a useful comparison of the two tracks. Some noise level histories are shown if figure 3. The peaks on the approach noise in 3(e) occurred for all the down trains and are probably caused by 'hanging' joints. A calculation of the distance between the joints based on the estimated speeds gives 26.5 $\pm$.2m. Since a standard rail length is 18.3m the rail is either non standard or there is an error in the speed calculations.

Researchers have determined that wheel/rail noise predominates at high speeds and Lotz and Kurtzweil report that for long trains at 30m 90 percent of the data lie within $\pm$ 6 dB(A) of the relationship:

$$L_A = C + 30 \log_{10}(V/V_0) \quad dB(A)$$

where V is the speed of the train, V_0 is 60 km/hr and C is 74 for welded rail and 81 for jointed rail [6].

Taking a simplified view of the level-time history shape as a rectangle the following expression for SEL can be derived:

$$SEL = 20 \log V + K \quad dB(A)$$

where K = 49 for welded rail and 56 for jointed rail.

The measured SELs for trains identified as intercity are plotted against estimated speed in figures 4 for jointed rail and 5 for welded rail together with the curve and ± 6 dB(A) limits from the above equation. The measured values are corrected for facade reflection (2.5 dB(A)) and angle of view but not the effects of the cutting. The data generally follow the slope expected and one other datum point was obtained during a 20 mph speed restriction on the down line. The SEL recorded fitted the graph reasonably well. There is much more scatter in values for the welded rail. The southern measurement location is adjacent to a whistle sign on the up line and most of the drivers sound the horns. Maximum levels of 100 dB(A) have been recorded (fig. 3b). The horns probably increase the SEL values accounting for some of the scatter. Down trains do not whistle at this location.

Houses close to the railway have measured noise levels of 68 to 70 dB(A) Leq(24 hr). About 100 loaded stone trains travel north each week. These produce an average SEL of 100 dB(A) at 30m and because a large number travel at night the Leq(8 hr) (2300-0700) is usually only 1 or 2 dB(A) less than the Leq(24 hr).

6 THE LOCAL RESPONSE TO ROAD AND RAIL NOISE

At most of the houses west of the railway the L10(18 hr) levels, predominantly road traffic noise, rose by about 3 dB(A) from the low 50s to the mid 50s after the by-pass was opened. Leq values, being much higher and dominated by rail noise, remained the same. To the east of the by-pass the L10 levels at one house have risen by 15 dB(A) from 45 to 59 dB(A). The rise of only 3 dB(A) is deceptive; the subjective impression of the noise environment is that road traffic noise is now a foreground noise rather than a background one. The by-pass is also characterised by a high percentage of heavy vehicles especially quarry traffic operating from around 3.30 a.m.

In a limited survey 52 people were interviewed about the noise. This sample is too small to produce any meaningful statistics but the responses can be summarised. Facade Leq(24 hr) levels are in three classes: 55-59, 60-64, and 65-70 dB(A) called for convenience here low, medium and high. The majority of people in low group reported rail noise disturbance as slight, the medium group said moderate and in the high group the majority claimed moderate or severe disturbance. Most people said disturbance was worse during the day even though a large number reported being woken up at night. Quarry trains, track maintenance vehicles and train horns were frequently cited as being particularly annoying. Nearly three quarters of those interviewed said they could feel vibration from trains. More than half those questioned found the road traffic noise annoying or disturbing and motorcycles and lorries were the most common source of annoyance. All but one person in the low group found the road noise more annoying than the railway. In the medium group most people said disturbance from the road and railway were about the same. In the high group nearly everyone was more disturbed by the railway noise.

REFERENCES

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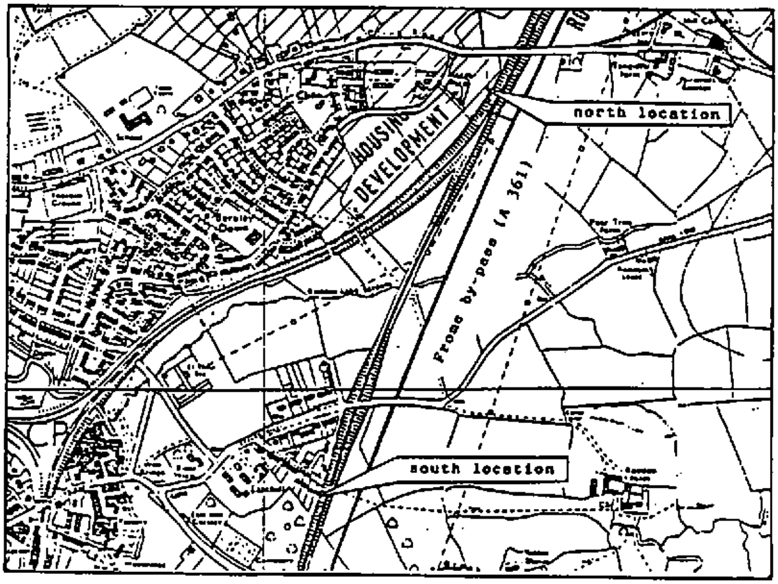


Figure 1. Plan showing the noise measurement sites used to estimate train speeds

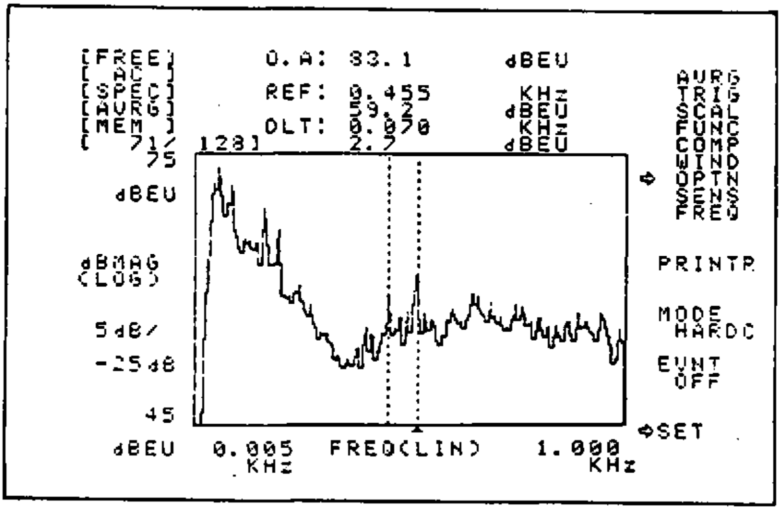
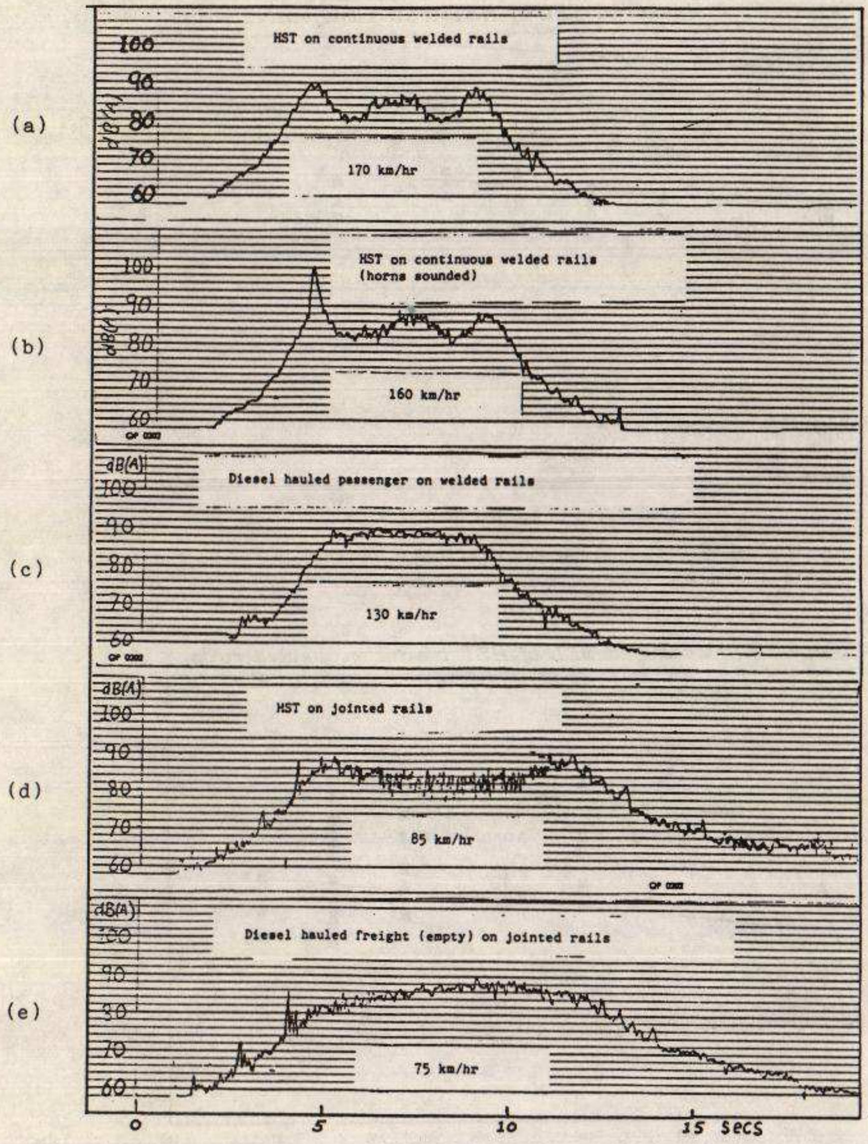


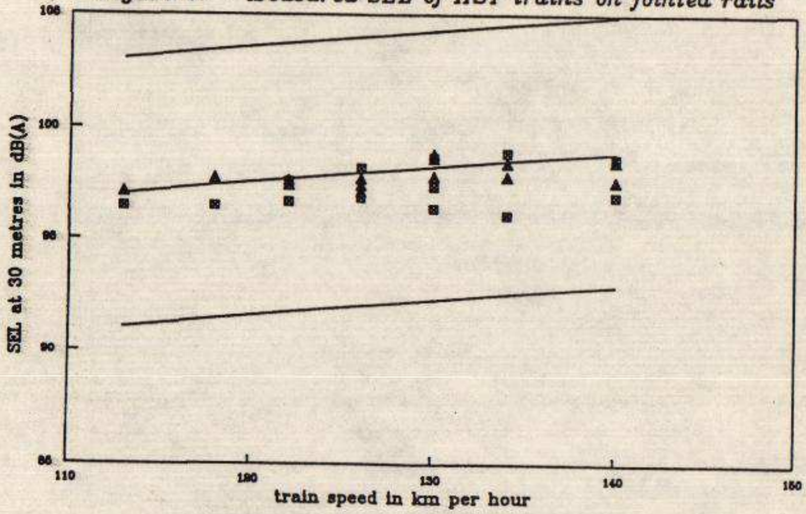
Figure 2. Spectrum of noise from an HST train at 40m showing
the Doppler shift in a tonal component from 525 to 455 Hz



Measured SEL (a) 90.3 (b) 91.5 (c) 91.8 (d) 93.2 (e) 94.0 dB(A)

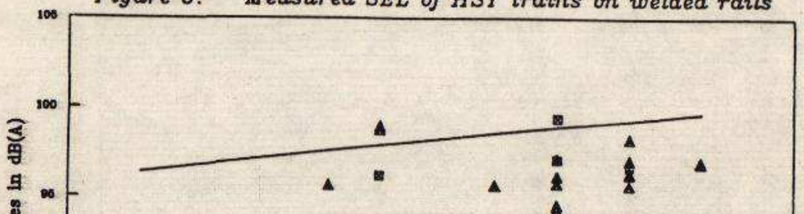
Figure 3. Train noise level histories at 25m

Figure 4. Measured SEL of HST trains on jointed rails



■ location south
▲ location north
—— from Lotz & Kurtzwell 1979

Figure 5. Measured SEL of HST trains on welded rails



■ location - south
▲ location - north
—— from Lotz & Kurtzwell 1979