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A STUDY OF THE NOISE OF SHEFFIELD SUPERTRAM

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1. INTRODUCTION

As the pressure on the transport networks in and around cities increase with the number of vehicles on the road, so does the concern that surrounds the harmful emissions that these vehicles produce This has prompted some city authorities to severely restrict accessibility to their city centres and led to the resurgence of the use of light rail transit systems in a number of major city in Britain. It is seen as a complement to other systems and has a passenger capacity that falls between that of buses and conventional railways and is therefore well suited to improve the public transport systems of the larger cities.

Typical rapid transit systems are light in construction with station spaced over close distances, a capacity of up to 20,000 passengers per hour and an average speed around 15-20 mph. In most cases they are mainly segregated from other systems, in some sections following the road but also with sections of tunnel, elevated track and may make use of existing rail infrastructure.

This paper reports in brief on some noise studies carried out on the South Yorkshire Supertram system in an ongoing study of noise of rail-based transport in and around the Sheffield and wider Yorkshire area. Previous papers have reported on the noise and vibration of rail based vehicles, Heng [1], and acceptable rail noise levels at nearby residences, Heng [2].

2. SOURCES OF NOISE AND VIBRATIONS

Studies of noise of rail based vehicles have been reported by researchers such as Munjal and Heckl [3] and Lang [4], as being mainly produced by the interaction of the wheel and rail but with some significant additions such as exhaust noise as well as other sources of wayside noise.

The mechanism that is generally regarded to be the primary source of wheel/rail noise is the excitation of the wheel and rail by small scale roughness on the surfaces of the wheels and rails which are sufficient to generate the observed levels of wheel rail noise. Studies into the production of rolling noise have produced conflicting results centred primarily on whether the wheel or the rail is the primary source. However, other potential sources include rail vertical and horizontal vibration, complex rail vibration (torsion, relative motion between head and foot, etc.), wheel tread axial vibration, wheel tread radial vibration, wheel web axial vibration, tie vibration, bogie frame vibration and rail car body vibration.

It has in general been found that from 315 Hz to 630 Hz all sources tend to contribute to sound radiation, from 800 Hz to 2500 Hz the sound radiation from the vertical vibration of the rail dominates, and above 2500 Hz sound from the radial vibration of the wheel begins to dominate.

Impact noise produced by rail and wheel discontinuities is generally regarded to be a major source of noise. It is a product of rail joints produced by the sectional nature of railway track and the need to allow for thermal expansion, wheel flats which are produced during normal service, created through the action of heavy braking, and railway points to allow for the directing of rail traffic. These are the origin of the rhythmic sounds normally associated with rail operations. They are however not associated with the operation of the tram system in Sheffield due in the main to the predominant use of continuous welded rail, where the sections of rail are permanently joined and the fish plates (the sections of metal plate used to secure lengths of rail together) dispensed with. In addition the rolling stock used is relatively new and much effort is made to keep the wheel/rail contact in good condition.

However there are also other important sources of noise. Rolling noise is the noise generated by the vehicle on a straight track in the absence of impact noise. The moving load reaction at the rail wheel interface acts on different parts of the wheel periphery producing a deflection in the wheel that may induce wheel/rail vibration. Local impedance changes along the length of the track often are a source of noise generation, for example, if the track bed stiffness varies along the length of the rail. As the wheel rolls along the rail, the force between the wheel and rail will vary with time, thereby exciting the wheel and rail. These tend to affect the low noise frequencies and would probably be felt as vibration.

Other less important sources of noise are those produced by the horns and buzzers, and the electric motors used by trams. Flange squeal is generally only a problem on tight curves and is thought to be caused by lateral creep of the wheel on the rail. Noise is also generated by the infrastructure created in the running of a railway such as noisy disembarking passengers and that produced during maintenance work.

Vibration, like much of the audible noise is generated by the interaction of steel wheels rolling on steel rails, and is influenced by a number of similar factors. The vibration generated is transmitted through the rail fasteners to the track structure where it propagates through the soil to the foundations of adjacent buildings. Perceptible vibration usually occurs at the low frequency range of 10 to 30 Hz. The ground borne vibrations caused by trams in streets within cities are a special problem because the vibrations propagating to these buildings may be felt by the inhabitants and may be heard via the structure borne sound radiated to the adjacent rooms.

3. EFFECTS OF RAIL NOISE

Rail noise has been found to be one of the least offensive forms of transportation noise and one that is subjective in nature by researchers such as Fields and Walker [5], but as cities grow and rail transit systems are introduced to ease urban congestion, more and more people are being exposed to it. The noise from rail operations can be broadly divided into annoyance (general vexation) and disturbance (specific instances of disturbance). A review of surveys into community response to rail noise by Moehler [6] found that the order of annoyance tends to be firstly, interference with communication, secondly, disturbance of rest and relaxation, and lastly, disturbance of sleep. Noise interference with communication and conversation, as well as vibration, which may cause low frequency rumble and windows and crockery to rattle, may serve as a trigger for annoyance

4. MONITORING AND ANALYSIS

As far as was practicable, all monitoring was carried out following the recommendations of BS7445, Description and Measurement of Environmental Noise, using a precision digital sound level meter with third octave filter and DAT tape recorder. The recordings were subsequently analysed back in the laboratory with a high resolution signal analyser attached to a desktop personal computer and computer software package. Monitoring sites were chosen at six random locations along the route, of which two were chosen at likely problem areas. The weather conditions during the recordings were mainly dry with the temperature around 5°C and as far as possible with little or no wind. The monitoring equipment was set up approximately one meter from the facade of the nearest building about one meter above the ground level. Before each set of recordings were made, a reference sound from a calibrator was made on the tape so the signal analyser could be calibrated and used as a reference upon subsequent laboratory analysis. Each time a tram or train passed, a recording was made of the event. This was repeated on a number of occasions in order to obtain a suitable average.

5. RESULTS

Noise measurements were carried out as described in the above. Typical results are shown in Figure 1 showing one of the possible problem location at Hillsborough Park, the map location, as well as the average spectrum of noise measured. Figure 2 shows another location at a point on the route near Holme Lane, a map location and a spectrum of the noise measured.

6. CONCLUSION

As part of an overall study of railway noise in and around the Sheffield area, a study into the noise of the Sheffield Supertram has been carried out. Preliminary results show that at four of the random locations, noise levels were very low and much below existing noise levels of other forms of transport and other roadside noise sources. At the two locations where noise problems were expected, the levels were found to be likely sources of complaint. Further studies are being carried out to determine acceptable noise levels and methods to minimise noise levels where applicable. A study is also being undertaken to apply newly established methods of predicting railway noise to determine its applicability to urban tram noise.

Acknowledgements

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References

1. R.B.W. Heng, Some aspects on Noise and Vibration, International Mass Rapid Transit Conference, Singapore 1982.
2. R.B.W. Heng, A Study of Rail Noise Affecting Nearby Residences, Institute of Acoustics, Vol 13, Pt 5, 1991.
3. M.L. Munjal and M. Heckl, Some mechanisms of excitation of a railway wheel. Journal of Sound and Vibration, Vol 81, 1982.
4. J. Lang, Ground borne vibrations caused by trams and control measures. Journal of Sound and Vibration, Vol 120, 1988.
5. J.M. Fields and J.G. Walker, The response to railway noise in residential areas in Great Britain. Journal of Sound and Vibration, Vol 85, 1982.
6. U. Moehler, Community response to railway noise: a review of social surveys. Journal of Sound and Vibration, Vol 120, 1988.
7. Dept of Transport, Calculation of Railway Noise, HMSO, London, 1995.

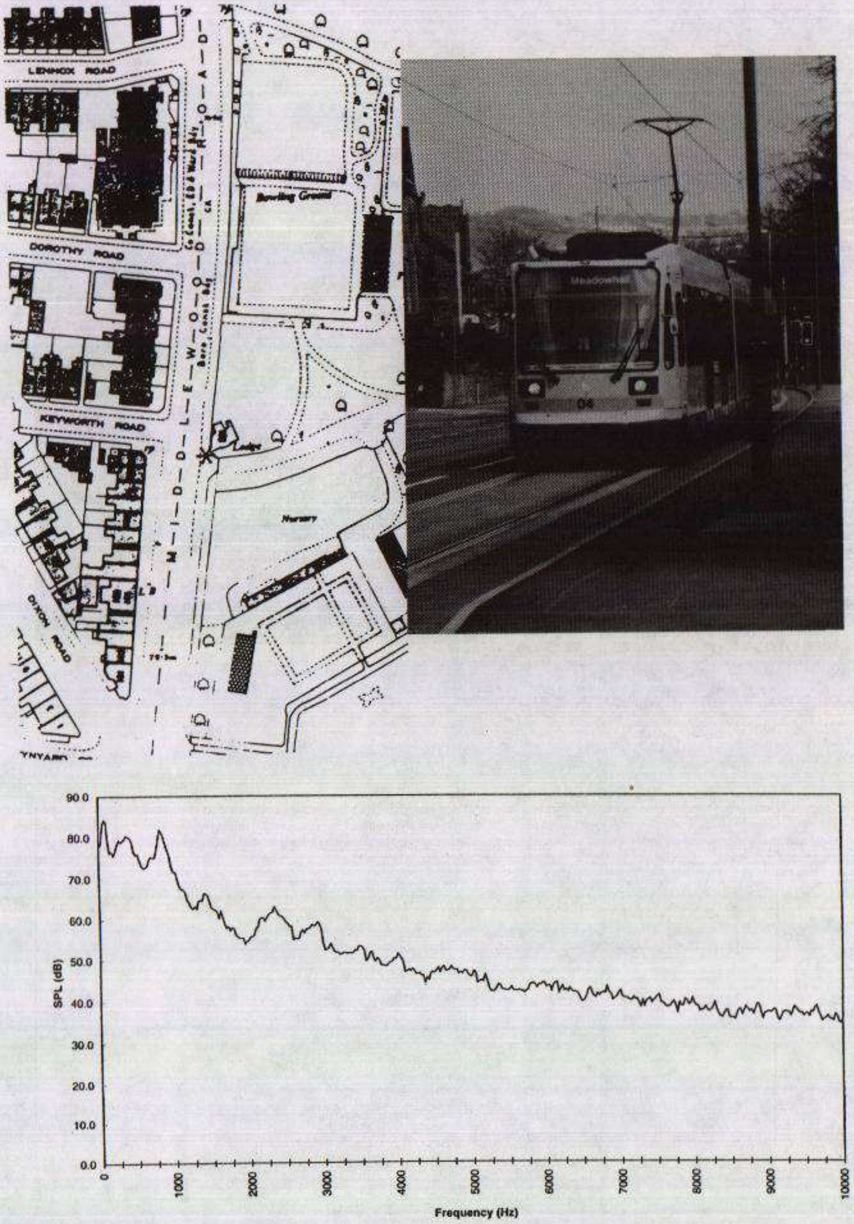

Figure 1. Hillsborough Park, map location and average spectrum of noise

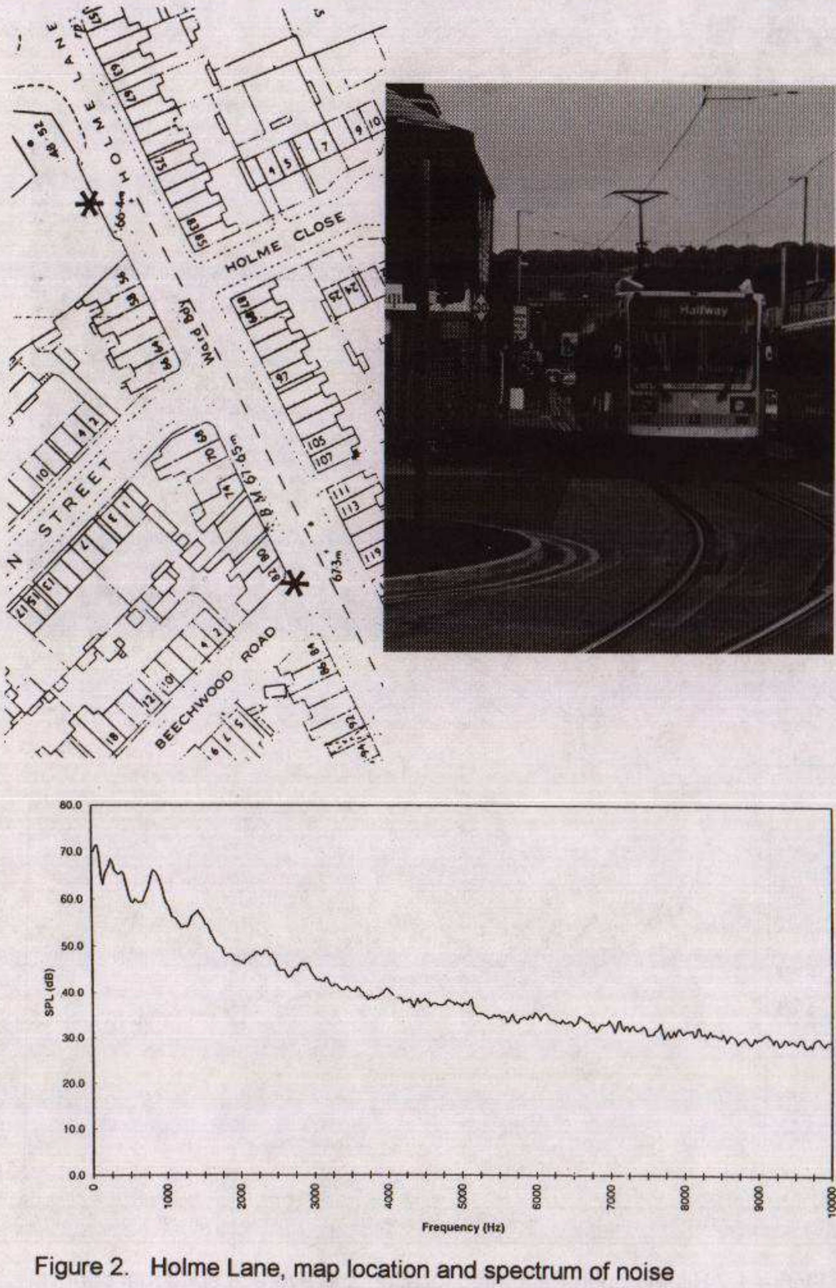

Figure 2. Holme Lane, map location and spectrum of noise