inter•noise 96
25th Anniversary Congress – Liverpool

INCE: 56

SURVEY OF ENVIRONMENTAL NOISE AND VIBRATION FROM LONDON UNDERGROUND TRAINS

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1. INTRODUCTION

A survey of the environmental noise and vibration resulting from LUL train operations has been carried out. The principal purpose of this work was to determine the number of dwellings in London that are affected by noise from LUL trains both on the surface and in tunnel. The data obtained will support initial impact studies and significantly enhance the critical evaluation of Environmental Impact Assessments.

The study was carried out over three years during which period the methodology for the survey was developed, tested over sections of the Railway, modified and finally extended across the entire System to provide a comprehensive database.

2. METHODOLOGY AND SUPPORTING MEASUREMENTS

The survey is essentially statistically based, using measurements from a limited number of carefully selected sites to produce generic distributions of noise and vibration as a function of parameters such as distance from the track or tunnel. This approach was taken in order to avoid the impracticality of a comprehensive measurement-based survey over the entire Railway and was developed in recognition of the fact that the survey was intended to provide a global view of the noise impact.

Since airborne noise predominates for surface track whereas re-radiated noise from ground borne vibration is the significant contributor from underground trains, separate methodologies were required for surface and underground track.

Surface Sections

A section of track (c. 20km on the Piccadilly Line) was selected initially for detailed examination. Measurements of train pass-by noise were taken at a number of sites along this section and these were used to determine representative source noise levels in terms of Single Event Levels (SEL).

From Ordnance Survey (OS) maps, details of properties adjacent to the track together with data on the source term SELs (determined from measurements), train traffic flow and train speed were used to calculate the noise level at the receiver position (i.e. a selected typical property facade). Counting the number of properties appropriate to the selected receiver position and then summing these results by noise level provided the number of properties affected within a band of noise levels for this selected section of track.

From this initial step it was determined firstly that the prediction could be limited to a distance of 200m either side of the track, since at greater distances the noise levels had fallen to being close to the average background, and secondly that the distribution of numbers of properties by noise level remained relatively stable, provided there were no major changes in track type (i.e. elevated or in cutting).

A more limited set of predictions was subsequently used for other surface sections of the Railway, where noise levels were either predicted only on one side of the track with the other side assessed by inspection or, where similarity was sufficient, the detailed distribution obtained for the Piccadilly Line was applied generically.

Rail surface roughness is a fundamental factor affecting the level of rolling noise generation from trains and will vary over the length of the Line. Account was taken of this variation in the noise source reference term, and hence in the noise distribution.

Source term noise variation distributions as a function of rail roughness were determined for 4 Lines (Metropolitan, Jubilee, Piccadilly and Central). These distributions were normalised and then used to re-distribute the numbers of properties in each noise level band. The relative similarity of these individual roughness distributions indicated that a generic distribution could be produced and applied to the other Lines.

Finally by combining the individual Lines, the overall results were determined, giving the number of properties affected by different levels of airborne noise from trains operating on the surface sections of the Railway in terms of $L_{Aeq,24h}$ and L_{Amaxf}.

Underground Sections

For the underground sections of the Railway, the relationship between ground vibration as a function of distance away from the tunnel was established. This was achieved by undertaking a series of measurements at selected sites in a line orthogonal to the line of the tunnel. This process was repeated at a number of locations for a range of tunnel depths.

From the measurements taken in dwellings a relationship between L_{Amaxf} and L_{Vmax} was determined to be: $L_{Amaxf} = L_{Vmax} - 50$, where v is the vibration velocity referenced to 10^{-8} m/s.

Data on dwellings in London were obtained from statistical records of Local Authorities and corrections were applied to the property densities to take account of open "green" spaces, the Royal Parks for example. For purpose built flats, a correction was made for the attenuation in re-radiated noise (above 16Hz) in upper floors.

The increase in noise due to the presence of points and crossings was estimated to be c. 3dB and affected approximately 3% of dwellings in the vicinity of underground track. Accordingly this correction was incorporated into the predictions.

The base data of L_{Vmax} vs. slant distance from the tunnel was combined with tunnel depth information (estimated from station depths) and the various corrections outlined above to give property numbers vs. noise levels.

Validation

Measurements were taken at a number of sites adjacent to the Piccadilly and Metropolitan Line tracks in order to check the accuracy of the predictions. The sites were chosen from the many receiver positions used in the computer predictions. For the Piccadilly Line there was generally very good agreement between prediction and measurement. For the Metropolitan Line however there was a tendency for over prediction of noise levels; the main reason for this is considered to be below average levels of rail roughness for the few sites where measurements were taken. A substantially increased set of measured data would be required to satisfactorily test the significance of deviation from the predicted values.

3. DISCUSSION

The aim of this study was to provide a global picture of the noise impact of London Underground's service train operations on the environment. It is considered that the assumptions used have not introduced any systematic error and thus will be statistically justified. This means however that for determining noise levels at specific sites, a more detailed prediction process would have to be used in which all the local conditions were taken into account.

Surface Sections

For the surface predictions, a boundary was placed on the extent of the prediction out to a distance of 200m from either side of the track. This implies a cut off in the predicted numbers of properties affected by the lower levels of noise but is of no consequence since at properties further afield, railway noise was generally masked by background noise.

Underground Sections

The lithography of London does vary and can be expected to affect the attenuation of vibration from track to receiver. However the data used to formulate the vibration vs. distance relationship derived from a number of locations around the System. To a degree therefore, the predictions take account of changing lithography, albeit in a very generalised sense.

For ground borne noise, L_{Amaxf} values above 60dB(A) are predicted for a very small number of properties. This is a high level of re-radiated noise and would be expected to elicit strong complaints. A review of the investigations into public complaints revealed however only one case where noise levels of this magnitude were measured. Similar disparity is reflected at the lower levels. The onset of complaints is generally accepted as being L_{Amaxf} = 40dB. Only a tiny fraction (c. 0.5%) of the 56000 dwellings predicted in this category results in identifiable complaints to London Underground. There are several reasons why such an apparent anomaly, at least in number, might exist in addition to the clearly demonstrated insensitivity of residents to such disturbance. Two in particular are worth noting.

Firstly the property density data was applied uniformly across the expected populated areas of each borough. Many of the underground Lines follow the path of main roads and thus the most affected properties will be those adjacent to roads where it is likely that there will relatively higher background noise levels.

Secondly there appears to be a trigger to public complaints in addition to absolute noise level. Thus occupants may experience noise levels well in excess of 40dB L_{Amaxf} value and yet only register complaint if some other event occurs, a sudden change in noise character for example.

4. CONCLUSIONS

Ambient noise increase from the surface operations of the Railway is limited in general to a corridor some 200m either side of the track.

Of the total number of estimated dwellings in the areas covered by underground sections of the Railway, it is estimated that ~6% experience re-radiated internal noise levels in excess of the 40dB(A), L_{Amaxf} criterion.

At both high (> 60dB(A)) and lower levels (40dB(A)) people are much more tolerant than had been assumed previously.

5. ACKNOWLEDGEMENT

Acknowledgement is given to Ashdown Environmental Ltd for their assistance in carrying out the initial computer predictions.