SITENOISE - AN IMPROVED METHOD OF PREDICTING NOISE FROM OPEN SITES

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1. INTRODUCTION

As part of a research study into 'The Control of Noise at Surface Mineral Workings'[1] on behalf of the Department of the Environment, WS Atkins was asked to assess and, if necessary, improve the application of predictive noise models to such workings.

Almost all noise prediction methods currently used for minerals sites in the UK are based on British Standard BS5228:Part 1:1984 'Noise control on construction and open sites'[2]. This Standard contains a prediction procedure founded on simple, well-proven acoustics principles, but consciously ignoring certain factors such as ground attenuation (by vegetation, etc.) and meteorological conditions (particularly wind direction). It has a simplified approach to barrier screening. Furthermore, it provides limited guidance on practical application to large and complex sites, particularly those having a network of haul roads. Although anecdotal evidence suggested that the procedure over-predicted noise levels, WS Atkins was unable to find any detailed investigations into its accuracy for surface mineral workings.

A number of more-sophisticated prediction procedures have been devised for other types of noise source. This paper describes the investigation to assess BS5228 and other procedures for use in surface minerals work, which has resulted in an improved procedure. It also outlines a subsequently-developed computer program, siteNoise, which facilitates the accurate prediction of noise from many types of complex open sites and suggests that the program also has applications for railway noise.

2. NOISE MEASUREMENT STUDIES

A comprehensive noise and physical measurement study was made at four mineral workings, namely two opencast coal sites, a sand and gravel pit and a limestone quarry. A total of 18 measurement positions were used in the analysis. Data was measured for long periods of up to three weeks, to record the effects of changes in weather, wind direction and in the workings themselves.

For each site, sound power levels were measured for each item of plant; the daily L_{eq} values were measured at various points within and outside the site; up-to-date contour maps of the site were obtained and detailed information was recorded on the movements and times of work of all machinery. The plan of a typical opencast coal site is shown in Figure 1, which gives some idea of the size and complexity of such sites.

By using such detailed data, the study was expected to indicate what prediction accuracy each of the various techniques could achieve. It is recognised that such detail would not always be available in practice.

3. ASSESSMENT OF EXISTING NOISE PREDICTION PROCEDURES

The scope of this study was to assess and, if necessary, improve the applicability of existing noise prediction techniques to surface mineral workings. Four procedures were investigated: BS5228 (op. cit.); 'Calculation of Road Traffic Noise[3] (CRTN); the Oil Companies Materials Association procedure[4] (OCMA); and the Petrochemical Industries Procedure (CONCAWE)[5].

BS5228 and CRTN both use A-weighted decibels (the latter also uses the L_{10} index) whilst OCMA and CONCAWE predict noise levels in octave bands. After an initial appraisal, OCMA was not used for any detailed predictions as it is similar to CONCAWE, but less detailed in approach.

Because of the extent and complexity of the sites, it was decided that the best way of testing the various procedures would be by computer modelling. Three-dimensional computer representations of all the sites were built using WS Atkins' RoadNoise software[6], which is an implementation of the CRTN road traffic noise prediction procedure. Ad-hoc modifications were then made for the different algorithms being tested. Particular care was needed in representing the different types of noise source utilised by the various procedures.

4. ASSESSMENT OF THE CONCAWE PROCEDURE

The CONCAWE procedure was devised for a type of installation very different from an open site. Because it works in octave bands and uses point sources, a number of approximations had to be made in adapting it to such sites, and the results were disappointing despite the sophisticated procedures especially for wind and meteorological effects. The ideal result is a correlation coefficient (r) of 1, a regression slope of 1 and intercept of zero. The best results were obtained without the meteorological correction, which gave r = 0.82, but the regression slope was 0.6 at best.

5. ASSESSMENT OF BS5228

BS5228 recognises three types of noise source: stationary, haul roads, and 'mobile plant on site', ie. plant moving about within a restricted area.

5.1 Haul Roads

Haul roads within a minerals site are complex, twisting and undulating around the site, as seen in Figure 1. This complexity must be accurately modelled if good predictions are to be obtained, but BS5228 gives no guidance on this. However, CRTN suggests this should be done by dividing the haul roads into straight, uniform segments and then calculating the contribution from each segment. The formula given by Para A3.4.2 of BS5228 for haul roads contains no correction for angle of view. However, as shown in Appendix 4.1.A of the Noise Advisory Council's 'A Guide to Measurement and prediction of the equivalent continuous sound level, L_{eq}'[7], it is simple to correct for this by subtracting an amount equal to 10 $\log_{10}$ (θ/180) where θ is the angle of view of the segment of haul road in degrees. Its effect may not be significant on small sites, but its omission can lead to serious over-prediction at greater distances from the haul road. For example, at 100m from a haul road 500m long, omission of the angle of view causes a 1 dB(A) over-prediction, increasing to 8 dB(A) at 1km from the road.

5.2 Mobile Plant on Site

BS5228 treats mobile plant as follows. The closest distance of approach (not necessarily the perpendicular distance) between the source path and the receiver is found and the distance correction is applied as if the plant were a stationary source at that point. To allow for the time that the plant is further away from the receiver, the ratio between the traverse length (the distance travelled by the plant) and the closest distance of approach is calculated. This ratio is then used to find an 'equivalent on time' from a table: this varies from 100% when the ratio is 0.5, to 8% when the ratio is 10.

This treatment gives rise to some difficulties. Firstly, there is no procedure to deal with cases where the path of the plant is screened for some part of its length. Secondly, it is unable to distinguish between cases where the traverse path is offset by different amounts from the perpendicular. An alternative approach would be to use the angle of view correction, effectively treating the mobile plant as a haul road, which would allow sub-division when propagation is non-uniform. When applying an angle of view correction, it should be remembered that the distance correction for L_{eq} of a moving point source is 3 dB(A) per doubling, not 6 dB(A) as for a fixed point source. (This point was not noticed during the study leading to the surface minerals report, which may account for the lack of improvement produced by this particular modification discussed below).

A constant must also be allowed to take into account the notional amount of movement of the plant. Comparison with the BS procedure shows a reasonable match using a constant of -8 dB(A).

6. IMPROVEMENTS TO THE BS5228 PROCEDURE

Once the basic procedure was implemented, a number of modifications were tested by borrowing 'soft ground' and barrier corrections from CRTN and CONCAWE. The results are shown in Table 1. The study showed that, contrary to expectations, BS5228 as it stands gave very good prediction accuracy provided the contribution from each haul road was corrected for the angle of view it subtended at the receiver. The basic method had a slight tendency to over-predict which was reduced by adding in a soft ground correction derived from the CONCAWE approach. With this additional correction, the correlation coefficient was r = 0.85, with a slope of 0.95 and intercept of 4.5.

It was found that the CRTN soft ground attenuation was too great when extrapolated to the large distances (up to 2km) involved in this study.

It was interesting to note that the addition of the sophisticated CRTN or CONCAWE barrier correction unexpectedly worsened the prediction accuracy. These provide for greater amounts of barrier attenuation than the 10 dB(A) maximum given by BS5228. The effect has not been explained but could be due to the 'canyon effect' (ie. reflection of sound between the rock faces) which reduces the effectiveness of barriers.

Finally, the meteorological correction from CONCAWE introduced a large scatter into the results. This correction is very sensitive to small variations in meteorological conditions, especially wind direction, leading to instability which is unacceptable in a planning tool.

More stable results are obtained with a positive wind component (such as assumed by CRTN). In such conditions, both soft ground and barrier effects are reduced, which increases the measured noise level. This may be a factor in explaining the good performance of the basic method.

7. SITENOISE

7.1 Features

SiteNoise is a software implementation of the basic BS5228 procedure, with optional enhancements to utilise the CRTN barrier calculation procedure and for soft ground absorption (both the CRTN and CONCAWE-derived attenuation curves).

It uses the three-dimensional modelling procedure derived from roadNoise: ground, barrier and receiver models can be shared between the two. It can be used for a wide variety of open sites where L_{Aeq} calculations are required, and also for modelling linear sources, particularly railways.

7.2 Modelling a Site

The first step in the modelling procedure is to obtain a three-dimensional representation of the site and its surrounding topography. This is usually done by digitising from maps or plans or by using an existing digitial ground model, such as MOSS. The position of all workings is entered, again in three dimensions. There are two types of workings, static and mobile, but at the modelling stage, the actual working activities are not important. It is only necessary to obtain a reasonably accurate physical representation of the location of the workings, which can be checked by producing a computer-drawn plot of the model and then overlaying this onto the original drawings. The acoustical analysis will be made automatically during the calculation phase. The next step is to create a table of plant noise data. This is either in the form of sound power levels or in terms of an activity L_{Aeq} at 10m. The table also contains information on the height of the noise source within the item of the plant itself, to enable an accurate calculation of the amount of screening of different sizes of machine.

The final stage is to allocate activities to workings. This is done by selecting a working location and allocating an item of plant to it: the percentage on time is also given along with the vehicle flow rate and speed if it is a haul road. Any number of activities can be allocated to a working - for example, a fleet of dump trucks and lorries using a haul road, or excavators, drill rigs and concrete truck mixers associated with a piling operation. A further facility enables each activity to be allocated to an activity category: the total noise level for any combination of categories can be calculated. Amongst many possible applications, this facility can be used to produce the noise level for different types of activity, such as haul roads versus fixed plant, or to produce a project programme giving the noise level in each week of the project.

Because of the way that the various features of the site are held separately in the computer model, it is straight-forward to modify one feature, such as the location of a haul road or the height of a barrier, and to re-calculate the effect on noise levels. This makes siteNoise an excellent design tool. The software shares contouring and report generation modules with roadNoise, which helps the noise effect of a site to be visualised in detail.

8. APPLICATION TO RAILWAYS

The Noise Advisory Council's Guide to L_{eq} (op cit) describes methods of calculating noise from a number of sources including railways. However, section 4.3 of the Guide, relating to railway noise, is not very helpful as it uses a calculation which is based on deriving L_{Aeq} from a knowledge of L_{Amax} which varies in a complex manner depending on the relationship between the distance of the reception point from the track and the length of the train. However, it is not necessary to base a calculation on L_{Amax}.

As already pointed out, moving point sources are adequately represented by the 'Haul Road' equation of BS5228, provided a correction is made for the angle of view. In *energy* terms, a line source can be regarded as a number of point sources: for a railway train, this is probably a more accurate interpretation: each wheel acts as a separate source. Consequently, the 'Haul Road' equation is equally applicable to railway trains, provided a value can be found for the 'sound power level' term.

An 'effective sound power' can be deduced by measuring the L_{AX} of a train pass-by and using a re-arranged form of the 'Haul Road' equation:

$$L_{WAmeas} = (L_{AXmeas} - 35.5) + 33 + 10\log_{10}v + 10\log_{10}d - 10\log\left(\frac{\theta}{180}\right)$$

Note that a measurement is needed for each speed of train (length can be corrected by factoring the sound power term accordingly). In practical cases, the speed of the train will show some dispersion about a mean value. It may therefore be simpler to omit the speed term in the above equation, thereby incorporating this into the effective power level. In such a case, the speed term should also be omitted when using L_{WA} in siteNoise.

This application is currently awaiting an opportunity for a large-scale test.

9. CONCLUSION

Experience shows that the enhanced procedures produce reliable results. SiteNoise has now been adopted by a number of planning authorities, consultants and, following a rigorous testing procedure, by British Coal.

10. REFERENCES

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(3) Calculation of Road Traffic Noise. Department of Transport. HMSO 1988 ISBN 0 11 550847 3

(4) Procedural Specification for limitation of Noise and Equipment for use in the Petroleum Industry. Oil Companies Materials Association. Specification No. NWG1

(5) The propagation of noise from petroleum and petrochemical complexes to neighbouring communities. CONCAWE Report No. 4/81

(6) ROPLAN - Software for modelling noise from road schemes. K R Tompsett. Proc IOA Vol 7 Pt 2 pp 355-359

(7) A guide to the measurement and prediction of the equivalent continuous sound level, L_{eq}. The Noise Advisory Council. HMSO 1978

Table 1 : Prediction Acccuracy for BS5228 Modifications

Modification	Correlation r	Intercept	Slope
BS5228 with haul road angle of view corr'n	0.80	8.4	0.84
CONCAWE soft ground correction or BS5228 barrier correction, whichever is the most effective	0.85	4.5	0.95
CONCAWE barrier correction	0.79	22.6	0.65
CONCAWE soft ground correction or CONCAWE barrier correction, whichever is the most effective	0.76	24.4	0.64
CRTN soft ground correction or BS5228 barrier correction, whichever is the most effective	0.73	14.1	0.79
CRTN barrier correction	0.80	11.1	0.85
CRTN soft ground correction or CRTN barrier correction, whichever is the most effective	0.67	19.7	0.71
CONCAWE soft ground correction or CRTN barrier correction, whichever is the most effective	0.79	14.8	0.80
CRTN soft ground correction or CONCAWE barrier correction, whichever is the most effective	0.73	24.0	0.65
Angle of view correction for mobile plant on site	0.76	13.9	0.77

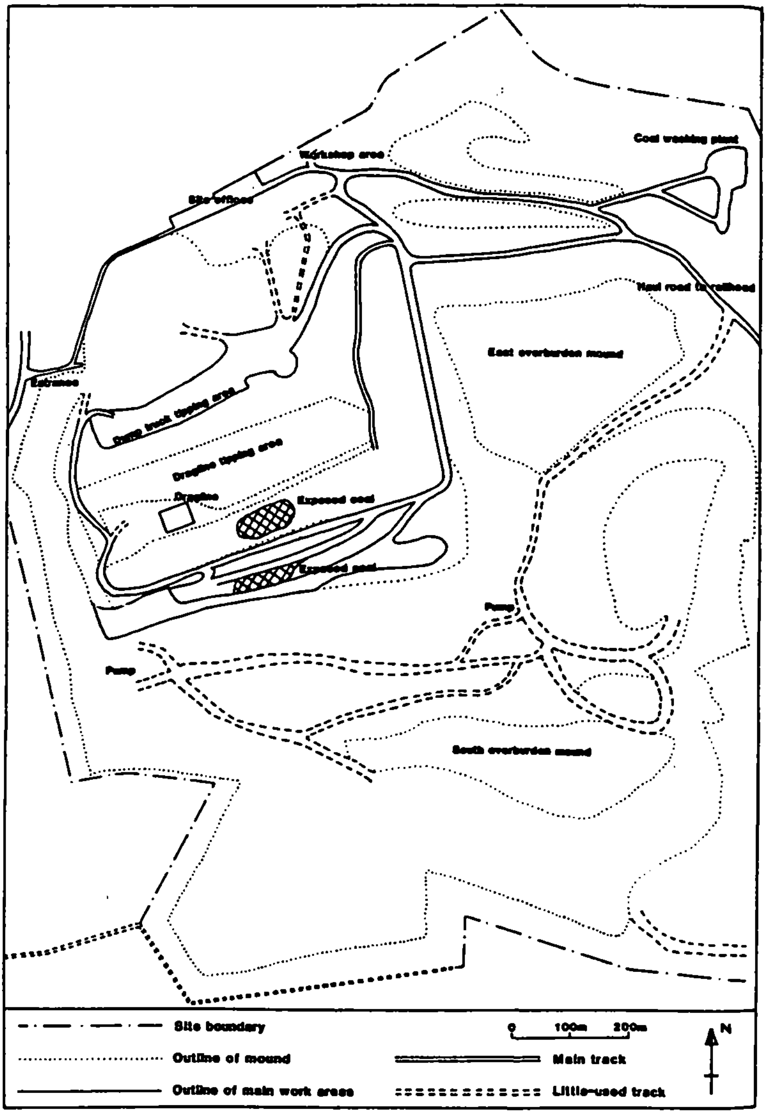

Figure 1 : Plan of Typical Opencast Site