Proceedings of The Institute of Acoustics

THE REVISION OF CALCULATION OF ROAD TRAFFIC NOISE 1988

P. G Abbott and P. M. Nelson

Transport and Road Research Laboratory, Crowthorne, Berkshire

1. INTRODUCTION

The technical memorandum "Calculation of Road Traffic Noise" (CRTN) was first published in 1975(1). It describes procedures for both predicting and measuring the noise from road traffic, and is intended to be used primarily as the method for calculating entitlement to sound insulation treatment of residential properties under the Noise Insulation Regulations 1975(2) of the Land Compensation Act 1973. In addition, it is also referred to in the Departments' Manual of Environmental Appraisal of road schemes(3), and has general application in highway design and land use planning.

The method has performed well for many years, but it was realised that its range of application was limited. Ambiguities in interpretation also led to difficulties in determining entitlement under certain conditions. TRRL was given the responsibility of researching and revising the method following the findings of the Working Party on the Review of the Noise Insulation Regulations 1975, and in 1988 a revised CRTN was published(4).

At the time of writing, the current method for calculating entitlement to noise insulation is the 1975 version of CRTN, although it is expected that the revised method will come into effect later in 1988.

This paper summarises the major changes that have been made to the method.

2. PRESENTATION

The presentation of the method has been improved to assist interpretation, reduce ambiguities, and to provide a clearer sequence by which calculations are carried out in practice. The revised method is divided into three sections.

Section 1 deals with the general procedures for predicting road traffic noise at a point in the vicinity of a road or road network. The procedures are shown diagrammatically in fig 1. This section consists of five main parts which enable the user to:

1. divide the road scheme into one or more segments such that the variation of noise within each segment is small, ie less than 2 dB(A);

2. calculate, for each segment, the basic noise level at a reference distance of 10 metres away from the nearside carriageway edge, as a function of the vehicle flow, traffic composition, average traffic speed, road gradient and road surface texture;

3. assess for each segment the noise level at the reception point taking into account distance attenuation and screening of the source line;

4. correct the noise level at the reception point to take account of site layout features, including reflections from buildings and facades, and the size of the source segment;

5. combine the contributions from all segments to give the predicted noise level at the reception point for the whole road scheme.

Section II of the revised method describes the additional procedures which may need to be considered when predicting traffic noise for particular types of traffic conditions, screening, or site layout not covered in Section I. Section III gives the procedures to adopt when it is necessary to measure traffic noise, and gives general advice on the use and quality of the instrumentation.

The layout of the annexes has been improved and additional examples included.

3. THE METHOD

Where possible, the method has been extended to cover a wider range of application without the need for additional input data. The following sections summarise some of the main areas of the revision.

3.1 Traffic Speed And Composition, And Roads On Gradients

When determining the basic noise level it is assumed that the road is level and that the traffic speed, averaged for all vehicles travelling in both directions, is 75 km/h. For different traffic speeds the basic noise level is adjusted according to the chart reproduced here as figure 2, which also shows how allowance can be made for the percentage of heavy vehicles.

When the road is not level, an additional correction is required for the influence of the gradient on the noise emitted by the traffic stream. In the previous method, two corrections for road gradient are given. These corrections are reproduced in figure 3, correction A being used when input speeds are actually measured values, correction B being used when traffic speeds are estimated from the road classification.

This approach assumes that the measured speeds already contain the influence of gradient on average traffic speed. When traffic speeds are estimated from the road classification, the method assumes that increasing gradient causes the speed to fall and that this leads to a reduction in the basic noise level. This effect is taken into account by the lower correction for gradient given by line B.

In practice, this has proved to be an oversimplification. Indeed, it can be seen from figure 2 that even though the speed/noise level function decreases with speed over much of the range, this feature is not present at low traffic speeds with a high percentage of heavy vehicles, where the inverse can occur with noise levels increasing with decreasing traffic speeds.

For these reasons, the previous CRTN tended to underpredict the basic noise level for severe gradients with low estimated average traffic speeds.

In the revised version of CRTN this problem has been overcome by obtaining a more general correction for the reduction in traffic speed due to road gradient. The functional form of the speed correction is shown in figure 4 of this paper and was derived from traffic speed observations on roads with different gradients(5). This can then be used to adjust the estimated traffic speed before entering the speed value in the correction chart, figure 2. The noise level correction for gradient is then obtained using correction A in figure 3.

3.2 Road Surface Correction

During the development of the previous version of CRTN it became clear from preliminary research that the basic noise level generated by a stream of traffic depended upon some characteristics of the road surface type and /or texture pattern. Although, at that time, little was known about the influence of the surface pattern, it was known that certain types of deeply textured grooved concrete road surface finishes were producing high noise levels. Consequently, in the absence of more detailed information, the method included a broadly based correction to cater for the increased noise generated by these very deep textures. Since the publication in 1975 of the previous CRTN, a great deal of research on tyre/road surface noise has been done by TRRL, and the results of this research have now been included in the revised version of CRTN(6).

Principally, it has been found that the noise generated as a result of the road surface can be related to the materials used and texture pattern of the road surface, ie whether it is a concrete surface with a transverse texture pattern or a bituminous material with a randomised texture pattern, and upon the average texture depth of the surface as determined by the sand-patch test(7). From the reseutls of this research the following formulae have been derived to correct the basic noise level:-

Concrete Surfaces:-
Correction = 10 log(90TD + 30) - 20 dB(A)

Bituminous Surfaces:-
Correction = 10 log(20TD + 60) - 20 dB(A)

where TD is the texture depth in mms.

It should be noted that these corrections are identical when the skidding performance as measured by the ΔBFC value are the same for both surface types(6).

In addition to the surface texture, the average speed of the traffic is important. For most conventional road surfaces the corrections are only relevant for high speed roads where tyre/road surface noise levels dominate other vehicle noise sources. To account for this speed dependence, the above corrections are only applied when the average speed is 75km/h or more; for average speeds less than 75km/h the basic noise level is reduced by 1 dB(A).

It should be noted that, for high speed roads, the basic noise level has been increased in the revised method by 1 dB(A) to refer the method more closely to the textures achieved on motorways and other high speed road constructions. This follows from the consideration that in developing the previous method a wide range of road surface types were implicitly incorporated when evaluating the empirical determinants of the basic noise level. Therefore, the adjustment upwards of 1 dB(A) reflects the average difference in reference level between modern high speed road textures and the national average textures of the roads included in the development of the previous method. The correction formulae given to account for the actual road texture are, of course, entirely consistent with this fundamental change in the basic noise level.

Although the above considerations apply for the vast majority of road surface finishes, research at TRRL and elsehwere has consistently shown that road surface materials which are designed to be permeable to surface water exhibit a different behaviour and have to be treated separately in the calculation of the basic noise level.

These surface types exhibit high acoustic absorption characteristics which can significantly reduce traffic noise levels. A specification for this type of surface has recently been included in the British Standard, BS 4987(8). Research has shown that, for these materials, the noise generated by road traffic is leargely independent of the surface texture of the material and the reductions in noise typically achieved ranges between 3 and 4 dB(A) depending upon the proportion of heavy vehicles in the traffic stream(9). Accordingly, in the revised method, for pervious macadam surfaces a reduction of 3.5 dB(A) is applied to the basic noise level.

3.3 Propagation over mixed surfaces

In determining the noise level at a given receptor position the method takes into account the attentuation with distance of the basic noise level assuming propagation occurs over either a 'hard' sound reflecting surface or a 'soft' acoustically absorbing surface.

Where the ground cover is a mixture of both types of ground classification, the original method advises using the attenuation rate corresponding to the type which is most prevalent, ie more than 50% of the total ground cover area. This procedure can lead to large discrepancies in the predicted levels where the reception point is distant from the road and where the proportion of ground cover types are similar. For these conditions, a small difference in the ground classification can lead to the ground being classified as either totally hard or totally soft. For such situations the difference between hard and soft ground attenuation can be as high as 8 dB(A).

In revising this apsect of the method an investigation into the propagation over mixed ground was carried out. It was concluded that, to a reasonable approximation, there was a linear relation between hard and soft ground attenuation dependent on the proportion in area of sound absorbing ground to the total ground cover area between the reception point and the road. Consequently, in the revised CRTN a method is given which allows the user to interpolate between hard and soft ground propagation according to the real proportions of these ground conditions under the propagation path.

3.4 Reflection Effects From Opposite Facades

Where there are houses, other substantial buildings or a noise fence or wall beyond the traffic stream along the opposite side of the road, the noise from the traffic can be reflected back towards the reception point. The extent of this depends upon the size of the reflecting facades and their position in relation to the reference position. In the previous method an allowance of 1 dB(A) is made, provided the reflecting facades occupy more than half the length of the road segment under consideration. In practice, this rather simple correction can lead to inconsistencies, primarily because it does not take into acocunt the position of the reflecting facades relative to the receiption point or allow for differing effects due to the number of contributing facades.

To overcome these problems, the results of a model developed by Hothersall and Simpson(10) were used. Using geometrical reflection theory they derived expressions for reflections from opposite facades in terms of the facade and receptor distances from the source and the angles subtended by the source and image source lines at the receiver. In addition to this work, further analyses were also carried out at TRRL and an improved correction formula for the reflection from opposite facades derived. This has been included in the revised method and is given by:-

$$\text{Correction} = 1.5\ (\theta'/\theta)\ \text{dB(A)}$$

where θ' is the sum of the angles subtended by all the reflecting facades on the opposite side of the road facing the reception point which are at least 1.5m above the road surface, and θ is the total angle subtended by the source line at the reception point, see figure 5.

Although the above procedure does not completly take into account the effect of distance, the results, in most cases, are not significantly different from those obtained using a more exact solution involving a more complex procedure(10).

3.5 Screening by more than one obstruction

Where a road is screened by more than one obstruction, the previous method advises calculating the attenuation provided by each screen in turn and selecting the value which, when combined with the basic noise level, gives the lowest predicted noise level. The method therefore ignores the potential benefit to be derived by secondary screening.

In the revised method, consideration has been given to the effect of secondary screening using the results of scale model investigations(11) and barrier geometry theory. Additionally, some site measurements were available mainly at locations which were screened by two rows of fairly continuous housing. Using all the available data the following formula was derived to calculate the overall attenuation provided by two barriers:-

$$A_C = -10\log\left[\text{antilog}(-A_A/10)+\text{antilog}(-A_BJ/10)-1\right]\ \text{dB(A)}$$

where A_C is the combined attenuation for two barriers.
A_A is the performance of the most effective barrier.
A_B is the performance of the least effective barrier.

and $$J = \left[\frac{\text{distance between barriers}}{\text{distance between source and receptor}}\right]^{1/4}$$

N.B. A_A and A_B are negative values.

Generally, this formula will provide a combined performance value similar to the performance of the most effective screen or barrier, which is, therefore, similar to the previous method. However, under certain conditions, particularly when one barrier is positioned close to the source and a similar barrier is close to the receiver, the above formula may allow a further 2.5 to 3 dB(A) extra attenuation than that resulting from applying the method in the previous CRTN.

3.6 Low Traffic Flows

The philosophy underlying the CRTN method relies upon the assumption that individual vehicles in the traffic stream act as omnidirectional and incoherent point sources which, when present in sufficient numbers to form a traffic stream, produce a line source of sound energy which obeys the fundamental laws of line source propagation. With these provisos, the effect of varying the numbers of vehicles in the traffic stream does not affect the characteristics of the source, and its magnitude can then be represented by a unique logarithmic function of the flow number. The following form has been found to apply in most cases and has been incorporated in both the previous and revised versions of CRTN:-

$$L \propto 10 \log Q$$

where L is the basic noise level dB(A) and Q is the vehicle flow.

However, as the flow reduces, the individual vehicles become progressively more separated in the traffic and begin to behave more as independent point sources. This change in the flow pattern has an effect on both the distance attenuation, which becomes more closely similar to point source propagation, and the flow term which, when expressed in terms of changes in L10, also takes on a different form(12).

The previous method does not recognise these characteristics of the source, as the method was designed specifically to deal with moderate and high vehicle flows where both distance attenuation and flow coefficients remain effectively constant over the range of application. However, for low vehicle flows the previous method will tend to over-predict L10 with a maximum theoretical error rising to 4 dB(A) approximately. Although low vehicle flows are rarely encountered in entitlement calculations, situations can occur when using the method to examine traffic management changes where traffic flows may be very low. For example, where a bypass is constructed such that nearly all traffic is diverted onto the new road(13).

To cater for these situations the revised CRTN provides correction formulae for low vehicle flows in the range:-

$$50 \leq q < 200 \text{ vehicles per hour}$$

and,

$$1000 \leq Q < 4000 \text{ vehicles per 18-hour day.}$$

The correction to the basic noise level for vehicle flows in these ranges is given by:-

$$\text{Correction} = -16.6\ (\log D)(\log C)^2\ \text{dB(A)}$$

where $D = 30/d'$,

d' is the shortest slant distance between the reception point and source line, (NB the correction applies only when $d'<30$ metres),

and $C = q/200$ or $Q/4000$

depending upon whether the correction is applied to an hourly L10 or L10(18-hour) dB(A) value respectively, and q and Q are the hourly and 18-hour traffic flows respectively.

The above formula was developed using a computer simulation model developed at TRRL(14) and was later checked using site data.

In defining the flow ranges where this method is to be applied it is recognised that when traffic flows are below 50 veh/h or 1000 veh/18-hour day, calculations become unreliable and measurements should be carried out.

3.7 Roads in Retained Cut and Noise Barriers Flanking Both Sides of the Road

Where a road is flanked on both sides by substantial noise reflecting surfaces, such as retained walls or purpose-built noise barriers, the screening performance of such barriers can be reduced due to reflection effects. the previous method makes allowance for these effects. For example, for the case of a road in a retained cut, the reflection correction is determined from the depth of cutting and the angle subtended to the vertical by the retaining walls. For dual barriers, however, the reflection correction is 1 dB(A), which is added to the basic noise level irrespective of the heights of the barriers and other site layout features. These procedures in the previous method led to the following criticisms:-

1. Although the method treats retaining walls and purpose-built noise barriers as hard reflecting surfaces, the difference in the procedure for calculating the reflection correction can be as much as 5 dB(A) under similar propagation conditions.

2. Both procedures for calculating the reflection correction are independent of site layout eg where the retaining walls or barriers vary in height and distance of separation.

3. Where barriers are erected on top of retaining walls, no advice is given on which correction should be applied to take account of reflection effects.

To improve the method to take account of these deficiencies, a computer model has been developed based upon ray path techniques to simulate the results obtained from scale model work that formed the basis of the reflection correction for retained cut in the previous method(15). The computer model was then extended to investigate the variation in the reflection correction for different receiver positions and changes in the distance separation between the screening and reflecting walls. An interpolation technique was then developed to take account of the effect of differences in the height of the screening and reflecting walls.

In the revised method a compatibile procedure for calculating the reflection correction for both dual barriers and retained cut situations has been included. In calculating the reflection correction the revised method takes into account the site layout parameters shown in figure 6. Briefly, these are:- the relative heights of the reflecting (Y) and screening (W) walls and their distance of separation (E) together with the relative position of the reception point (α,β). The revision also includes additional procedures to enable the reflection effects to be calculated where purpose-built noise barriers are erected on top of retained cut as shown diagrammatically in figure 7. The relevant parameters ie W, Y and Φ, are calculated by treating the barrier and retaining wall as a single structure.

Although the revised procedure is more complex, it does enable the prediction method to be applied to a greater range of site configurations.

4. OVERALL PREDICTION ACCURACY

Comparing the predicted noise levels using the previous method with a data bank of 2064 measurements, the mean prediction error (measured minus predicted) is -0.6 dB(A) with an r.m.s error of 2.5 dB(A)(12). It has not been possible to compare the predicted noise levels using the revised method with the original data bank. However, a small survey consisting of 46 measurements at 10 different locations has been carried out. Comparing the predicted and measured noise levels using the previous method gives a mean prediction error of -0.4 dB(A) with an r.m.s error of 2.1 dB(A) and for the revised method the mean prediction error is +0.1 dB(A) with an r.m.s error of 1.0 dB(A). Based on this small sample there is no significant difference in the prediction accuracy of the revised method. However, the main aim of the revision was to extend the range of application of the method and, therefore, in these situations the overall accuracy of the method will be improved by the revision.

5. CONCLUSIONS

The main aim of the revision of CRTN has been to extend its range of application and under these situations to improve the prediction accuracy. In particular, the revised method allows calculations to be carried out taking into account the following factors which the current method does not fully consider:-

1. The effect of road surfaces on traffic noise levels.

2. The propagation of traffic noise over mixed types of ground cover.

3. The reflection of traffic noise from facades located on the opposite side of the traffic stream.

4. The additional attenuation of traffic noise offered by secondary screening.

5. The change in the traffic flow function with traffic noise level for low traffic flows.

6. The effects on the reflection of traffic noise due to changes in the design of roads situated in retained cut or flanked on both sides by purpose-built noise barriers.

6. REFERENCES

The work described in this paper forms part of the programme of the Transport and Road Research Laboratory and the paper is published by permission of the Director.

<u>References</u>

1. Department of the Environment, Welsh Office. Calculation of Road Traffic Noise, London (H.M. Stationery Office), 1975.

2. House of Commons. Building and buildings. The NOISE INSULATION REGULATIONS. 1975. Statutory Instrument No. 1763, London (H.M. Stationery Office), 1975.

3. Department of Transport. Manual of Environmental Appraisal, Assessment Policy and Methods Division, Department of Transport, London, 1983.

4. Department of Transport, Welsh Office. Calculation of Road Traffic Noise, London (H.M. Stationery Office), 1988.

5. Martin and Voorhees Associates. Crawler lane study - an economic evaluation, London, 1976.

6. Franklin, R.E, D.G. Harland & P.M. Nelson. Road surfaces and traffic noise. Department of the Environment TRRL Report LR 896. 1979. Transport and Road Research Laboratory, Crowthorne.

7. Road Research Laboratory. Instructions for using the portable skid-resistance tester. Ministry of Transport, Road Note No 27. London, 1969 (H.M. Stationery Office).

8. British Standards Institution. Coated macadam for roads and other paved areas. BS 4987, 1988. British Standards Institution, London.

9. Nelson, P.M. & N.F. Ross. Noise from vehicles running on open-textured road surfaces, Department of Environment, Department of Transport, TRRL Report SR 696, Crowthorne (Transport and Road Research Laboratory), 1981.

10. Hothersall, D.C. & S. Simpson. The Reflection of Road Traffic Noise. Journal of Sound and Vibration 90 (3), 399-405, 1983.

11. Foss, R.N. Noise barrier screen measurements, double barriers. Research program report 24.3 (apl-uw 7618), Washington State Highway Commission, Department of Highways, Washington, 1976.

12. Delany, M.E et al. The Prediction of Noise Levels L10 due to Road Traffic. Journal of Sound and Vibration 48(3), 305-325, 1976.

13. Mackie, A.M. and C.H. Davies. Environmental effects of traffic changes. Department of the Environment, Department of Transport. TRRL Report LR 1015. Crowthorne, 1981 (Transport and Road Research Laboratory).

14. Nelson, P.M. A computer model for determining the temporal distribution of noise from road traffic. Department of the Environment, TRRL Report LR 611. Crowthorne, 1973 (Transport and Road Research Laboratory).

15. Delany, M.E., A.J. Rennie and K.M. Collins. Scale model investigation of the traffic noise propagation. National Physical Laboratory Report Ac 58, 1972.

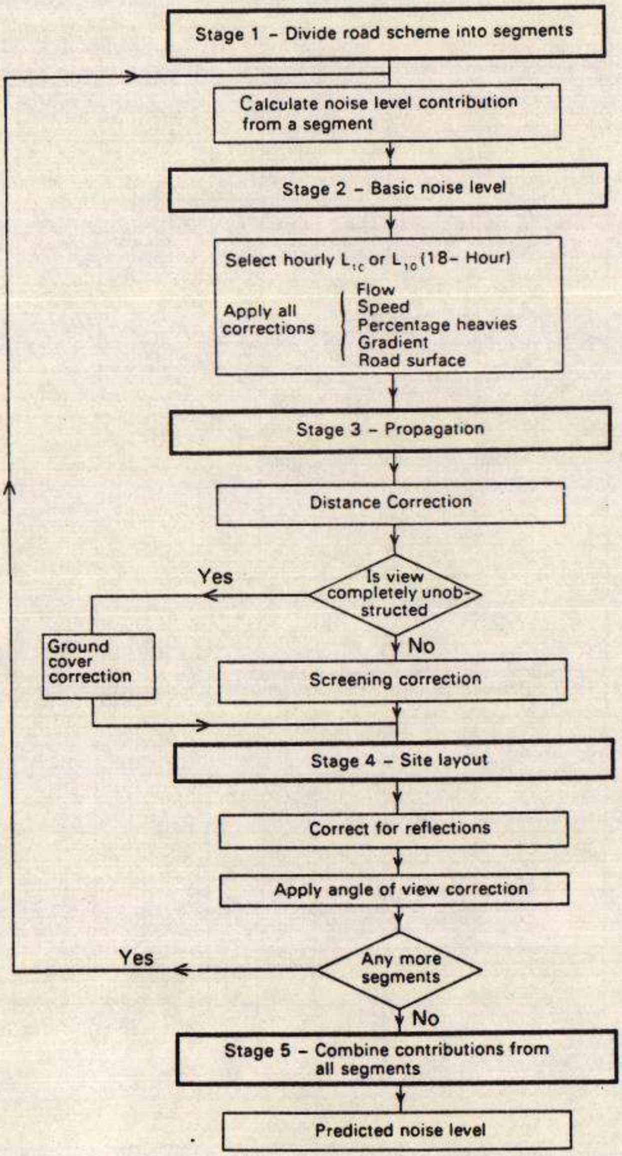
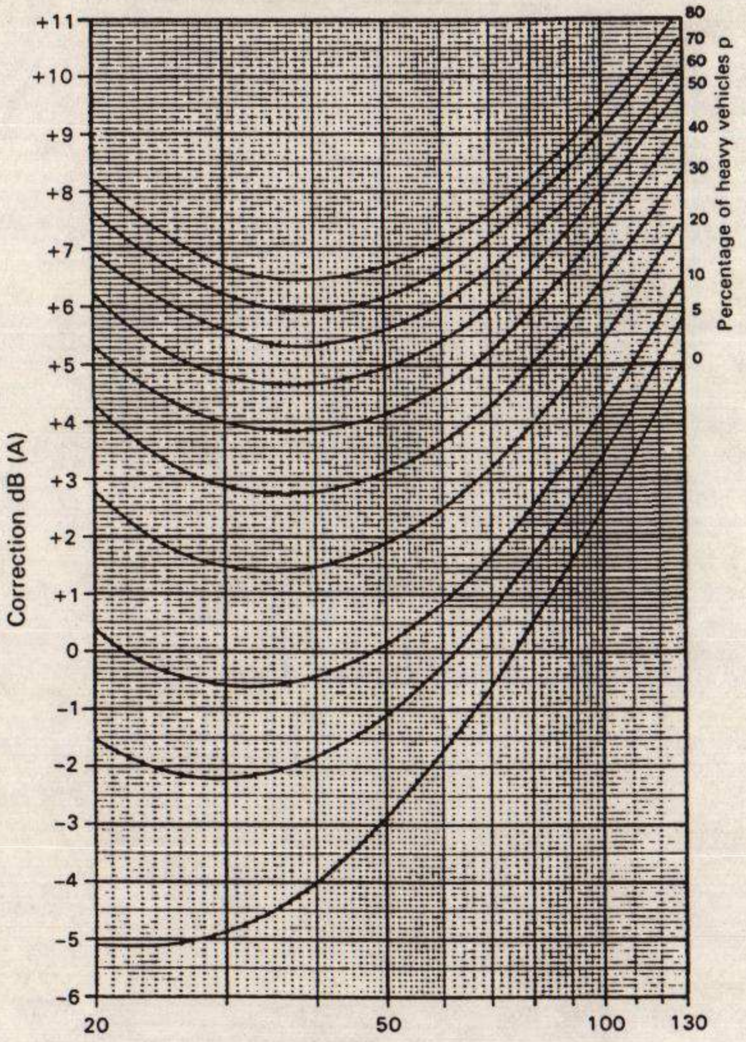


Fig. 1 Flow chart for predicting noise levels from road schemes



$$\text{Correction} = 33\ \text{Log}_{10}\left(V + 40 + \frac{500}{V}\right) + 10\ \text{Log}_{10}\left(1 + \frac{5p}{V}\right) - 68.8\ \text{dB(A)}$$

Fig. 2 Correction for mean traffic speed, V and percentage of heavy vehicles, p

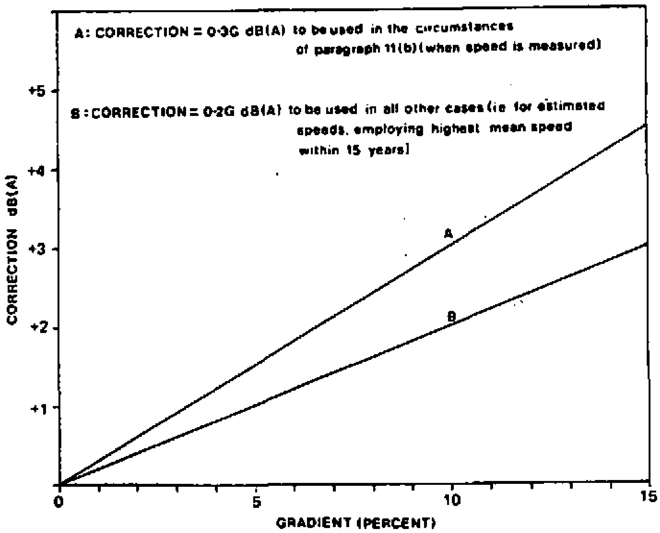
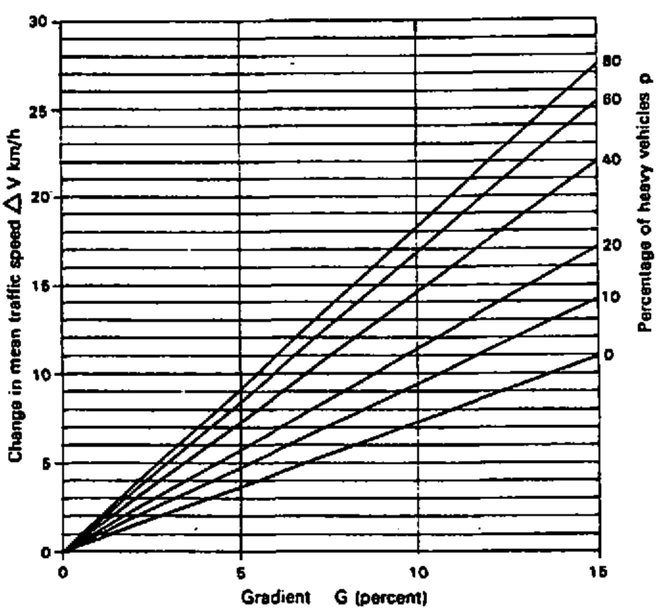
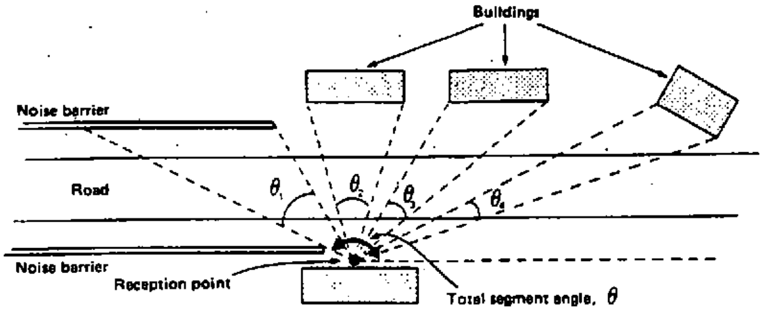


Fig. 3 Correction for gradient, G (per cent), current method



$$\Delta V = \left[0.73 + \left(2.3 - \frac{1.15p}{100}\right)\frac{p}{100}\right] \times G \text{ km/h.}$$

Fig. 4 Reduction in mean traffic speed, V in terms of the percentage of heavy vehicles, p and gradient, G used when speeds are estimated by class of road



$$\text{REFLECTION CORRECTION} = +1.5\left(\frac{\theta'}{\theta}\right)\ \text{dB(A)}$$

where $\theta' = \theta_1 + \theta_2 + \theta_3 + \theta_4$

and θ = TOTAL SEGMENT ANGLE

Fig. 5 Reflection correction for facades facing the reception point on the farside of the traffic stream

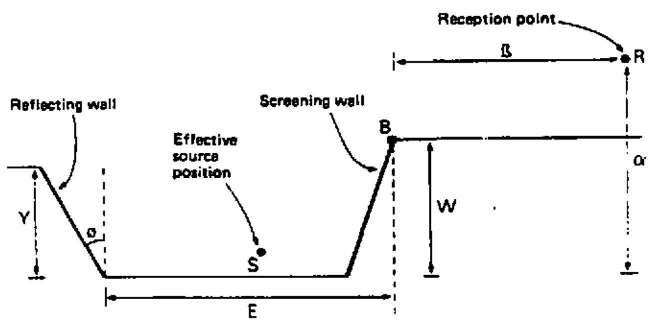


Fig. 6 Site parameters for calculating reflection correction for roads in retained cut or flanked by barriers

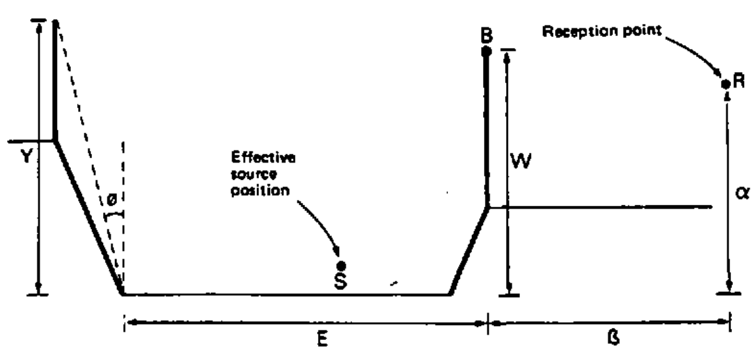


Fig. 7 Dual barriers on top of retained cut