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A SIMPLIFIED METHOD FOR THE DESIGN OF ROAD TRAFFIC NOISE BARRIERS

I Ekici Sheffield Hallam University, School of Environment and Development
H Bougdah Sheffield Hallam University, School of Environment and Development

1 INTRODUCTION

Design and construction of environmental barriers requires the involvement of specialists from many disciplines. In addition to acousticians, architects, planners, landscape architects, civil engineers, highway engineers, structural engineers and geo-technical engineers, the community must also be involved for an effective and widely accepted solution [1].

The design of traffic noise barriers deals with a number of issues. These include acoustics, aesthetics, engineering as well as the landscape. Since noise barriers are intended, primarily, for the comfort and convenience of the people, two more factors should be added to the list of issues that inform the design process. These are the concerns of the local residents and those of the wider public representing various interest groups [2]. Given the prime function of barriers, which is the reduction of noise levels, any aesthetic or engineering solution that ignores the acoustic performance is doomed to fail.

This publication puts forward a simplified method for the design of road traffic noise barriers. The paper reviews existing design guidelines on noise barriers in the U.K. highlighting their shortcomings and suggesting a simplified procedure for choosing a suitable barrier type. The design method is intended, primarily, for new barriers. With slight modifications, however, it can be applied to existing ones to improve their performance. The designer is guided through the process by means of flow chart diagrams.

2 BACKGROUND

The main document for the design of environmental barriers in the U.K. is Section 5 in Volume 10 of the Design Manual for Roads & Bridges. Part 1 is mainly concerned with the impact of the barrier on the environment [3] while Part 2 deals with the technical requirements including the acoustic performance and engineering details [4].

These two documents cover a wide range of information about different aspects of barrier design, however alternative barrier profiles are only mentioned in passing. The information is not presented as guidance to help the designer choose the right option, but merely to quote certain examples of performance. In certain cases, the designer is simply advised to seek further help elsewhere (i.e. dispersive barriers and multiple diffracting edges). In some cases, the guidance can be contradictory as in the case of earth mounds. A short acoustic screen erected on top of an earth mound is promoted due to its beneficial effects, however the designer is also warned that this could diminish the noise absorbent effect of the vegetated slopes.

Although these documents provide the designers with an overview, acoustical guidance is not presented in an easily accessible manner. This may, sometimes, force inexperienced designers to seek solutions to detailed acoustical problems which may be beyond their capabilities.

It is clearly stated that the guide is not intended to "prescribe a standard range of barriers from which to make a selection"[3]. However, more substantial information on different types of barriers and their acoustical performance would give the designer the flexibility to deal with other factors more effectively.

Established barrier options could be listed, together with their acoustical performance, and non-acoustical limitations, so that the few effective barrier options can be identified. The next step would be to refine this option with input from the local residents and the wider public so that the impact of the design on the environment is minimised. In order to ensure the effectiveness of the solution, full construction details associated with each recommended option need to be included.

The design method presented in the forthcoming sections attempts to succeed where the existing guidelines failed. Information is presented in an easy-to-follow flow chart diagram. The designer progresses to the next step by the aid of simple questions, which mainly require yes/no answers. The method consists of two stages. The first one is where the main type of barrier is decided upon and the second one provides the essential refinements, if any, to be made to the design. With minor modifications, the method can also be used for checking or improving the acoustical efficiency of an existing design.

3 DESIGN OF NEW BARRIERS

For the purpose of this publication, the environmental barriers are classified broadly into three main categories. These are the wall type barriers, the earth mounds and the bio-barriers or the mounds with reinforced slopes.

Earth barriers have the advantage of being aesthetically pleasing and environmentally friendly. Due to their natural appearance they blend into the local environment and the public perception of these barriers is high. Depending on the availability of sufficient space and local fill material, their construction can be cost-effective. Therefore earth barriers are given priority over wall type barriers even though a flat-topped grass-covered earth mound has been shown to perform less well than a thin vertical wall of an equal height [5]. With so many factors favouring the applications of earth mounds, less effective acoustic performance can be remedied by making them higher. An increased height in the case of earth barriers have less visual impact and is not subjected to structural limitations such as wind loading.

According to the flow chart in Figure 1, the first question to be answered is whether the right-of-way situation provides readily available land for the construction of earth mounds. Where the available space for achieving the required design height is sufficient, the availability of local fill material needs to be considered. Where a road construction contract produces surplus material, the earth mounds can be constructed for a negligible cost [4], otherwise the cost of transporting fill material from another site should be considered. This adds to the construction cost of an earth mound.

If the availability of space is limited, naturally resting soil would not be self-supporting and reinforced slopes would be essential to achieve the vertical height required, within a limited horizontal stretch. In this case, bio-barriers and mounds with steeper reinforced slopes are always

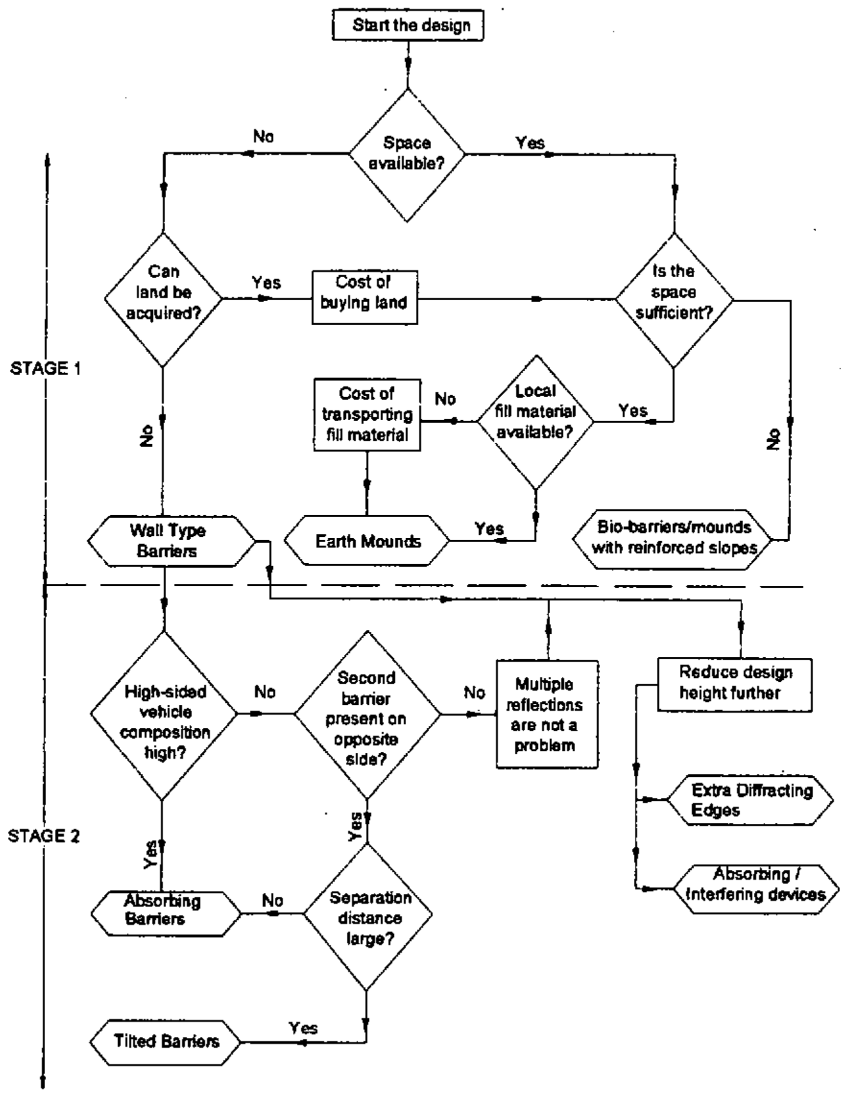

Figure 1: Selection process for new barriers

available as options. They may appear man-made due to their unnatural slope angles and hence aesthetics will be a consideration. The need for maintenance and irrigation to ensure the presence of dense plantation at all times are other factors which increase the unwillingness of the designer to put these options into practice. However successful designs do exist and examples of bio-barriers in real life applications can be seen throughout Europe [2].

Where space is not available, the opportunity of buying the land should be explored. This would have additional cost implications. The next point would be the consideration of whether the land to be purchased is enough or limited for the purpose of constructing an earth mound. If the space is neither available nor can it be acquired, then erection of wall type barriers may be inevitable.

If a wall type barrier is the preferred option, the second stage of the design procedure would provide the necessary or possible refinements to the design. In this case, degradation due to multiple reflections should be a prime consideration. Figure 2 illustrates where multiple reflections would be a problem. In these cases, the options available to prevent multiple reflections include tilting the barrier backward from the vertical position and the application of absorbing materials [6]. The distance between the reflective surfaces (L) in relation to the barrier height (H) determines which option should be used. The decision shifts from absorbing barriers towards tilted barriers, as this distance increases. When the reflecting surface is situated up to 5 times the barrier height, the use of absorbent materials is recommended. As the separating distance increases up to 10 times the barrier height or more, sloping the barrier becomes a more feasible option [7]. Tilt angles of 10 - 15 degrees are required for narrow roadways but 3 degrees are enough for wide roadways [8].

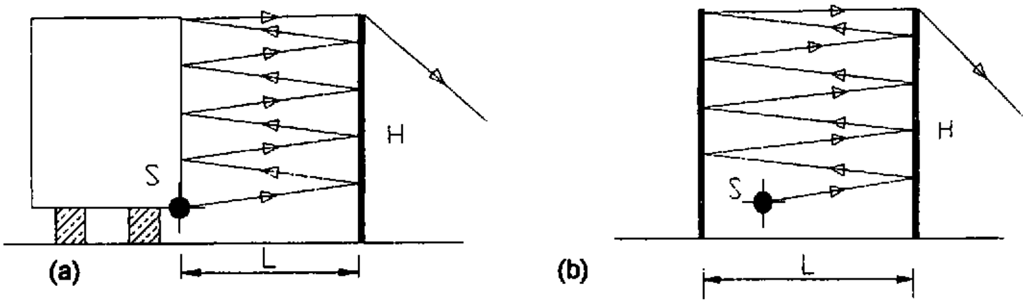

Figure 2: Multiple reflections caused by (a) high-sided vehicles and (b) parallel barriers.

Should it be desirable, the height of a wall type barrier can be reduced by considering the options explained in the flow chart. These options will be explored in greater depth in the next section.

Preliminary data from physical scale modelling of flat-topped grass-covered mounds, currently being undertaken at the Sheffield Hallam University, indicated that they performed slightly better than an equal height vertical screen. It should be noted however that the receiver positions investigated were located deep in the shadow zone. As reported by other workers, as the receiver distance exceeds 20 meters, the insertion loss offered by the earth mound is consistently 1 dB less than a vertical screen [5].

Initial results show that a single small height barrier decreases the performance of an earth mound when the slope is already highly absorbing. Further increase in the height of the barrier eventually yields positive acoustic gains. This gain appears to be due to considerable increase in the path length difference rather than the absorbing properties of the ground. However the extra barrier ceases to be " a short height barrier" and its visual impact on the environment can not be concealed.

Application of multiple small height barriers, however, gave slightly increased acoustic performance over the earth mound with no modifications. The next stage in the investigation will be to optimise the size and number of short screens required to give the maximum acoustic gains with minimum visual impact, while making the most of the beneficial ground effects.

4 IMPROVING THE PERFORMANCE OF EXISTING BARRIERS

In urban and semi-urban environments, wall type barriers are commonly used instead of earth mounds due to physical constraints. With time, these barriers can have their screening effect reduced as a consequence of ever increasing traffic volumes or as a result of multiple reflections from a second barrier opposite an existing one.

4.1 Dealing With Multiple Reflections

Before even considering how the acoustic performance of an existing wall type barrier can be improved, it is vital to ensure there is no degradation in the design performance of a screen due to multiple reflections. These may occur when there are highly reflecting surfaces present close to the noise source. This could be due to a second barrier on the opposite side of the road [9] or due to high-sided vehicles running close to the screens [10]. This reverberant build up of traffic noise eventually increases the noise levels on the opposite side of the reflecting surface.

According to Figure 3, any one of the two phenomena mentioned above is likely to degrade the performance considerably. Under these conditions application of absorbing materials is recommended as a solution. For this to be effective, the average absorption coefficient of the absorbing materials in practice should be at least 0.8 [4].

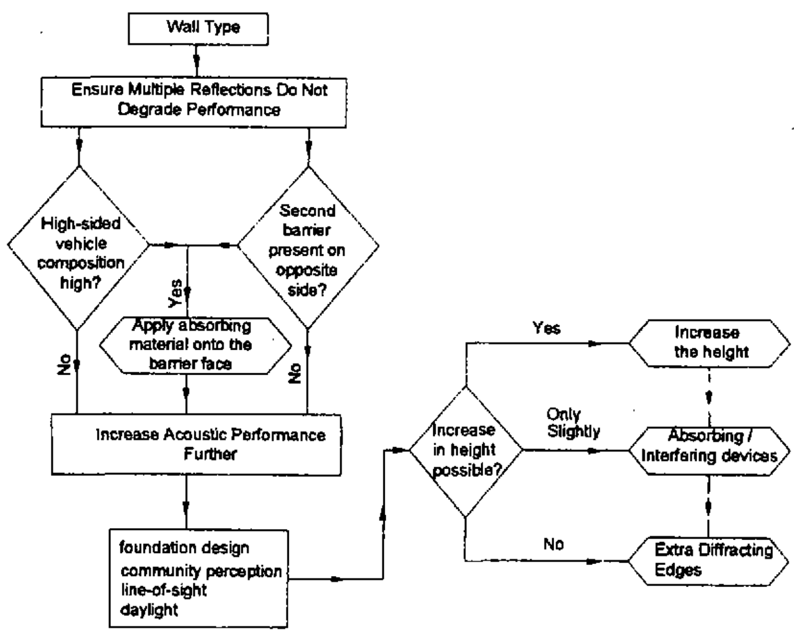

Figure 3: Improvements to existing barriers

4.2 Increasing The Acoustic Performance

Once "multiple reflections" have been considered, the designer can concentrate on increasing the acoustical efficiency of the barrier to offset any increase in noise levels due to large traffic volumes.

Modifications that can be made to an existing wall type barrier are classified into three different categories. The decision depends on how much height increase is possible. If no increase in height is allowed the only option is attaching extra diffracting edges. If a slight increase is allowed, then interfering/absorbing devices can also be used. If there is no such restriction, then increase in height is also a consideration as well as the other options mentioned above. Although it may not be desirable to increase the height of a barrier due to non-acoustic considerations, there may well be cases requiring or allowing this option. After the line-of-sight has been intercepted, every additional metre of barrier height is expected to provide 1.5 dB(A) improvement in the insertion loss. The factors influencing the decision whether or not the height could be increased are non-acoustic considerations which will be discussed below.

Increasing the barrier height could bring with it complaints from the local community that the daylight falling onto their gardens and windows is reduced, or the line-of-sight from their property has been restricted. Even if this option is justified with the consensus of the public, extra load on the foundations due to the wind should be considered. This problem can be solved by strengthening the foundations, which will incur extra costs. Alternatively, the extra height could be constructed in the form of transparent panels to avoid obstructing the line-of-sight further, or reducing the amount of daylight falling onto the property. In addition to the high cost of the transparent panels and the frequent need for maintenance, extra wind loading would still be a problem.

Attaching sound absorbing or interfering devices onto the top of an existing barrier has been reported to have considerable acoustical effects. In Japan absorbing devices, namely absorbing cylinders **[11]** or absorbing mushrooms **[12]**, have been used, and the reported acoustical gains are 2-3 dB(A). In the UK, barriers with interfering devices attached on top have been tested on site **[13]**. Although the full-scale performance was around 2 dB(A), it was found that most of this was due to diffraction and not to interference. These devices cause only a small increase in the height of a barrier.

Extra diffracting edges have been proven to be both acoustically and structurally sound solutions. Addition of a horizontal cap **[14]** or vertical shallow panels attached on either side of the barrier top **[15]** can increase the acoustical efficiency, partly due to increase in the path difference and mainly due to extra diffraction. The main non-acoustical advantage of these solutions is that the height of the barrier is not increased. In the case of T-profile barriers the snow loading and the lifting effect of the wind on the horizontal cap are structural considerations which will need attention during the design. In this respect the vertical shallow panels appear like a more cost-effective solution compared to the horizontal cap, especially when their slightly higher acoustical performance is taken into account..

5 DISCUSSION

The main source of advice for the design of environmental barriers is the Manual for the Design of Roads and Bridges (Volume 10, Section 5, Parts 1 and 2). The information contained in this document is often difficult to interpret particularly when the designer is inexperienced. The need for a simple approach to select the appropriate design option has been argued for in this paper. The method being put forward covers both new barriers as well as existing ones.

More and more designs are being added to the long list of already known barrier types. These have been reviewed elsewhere **[16]**. Reactive barriers are another recent examples where considerable gains have been reported **[17,18]**. Only the most promising profiles have been incorporated into this design method where on-site performance checks indicated positive gains. However as the acoustic performance of various designs are confirmed with measurements and as the engineering problems inhibiting their use are overcome, there can be no excuse for avoiding their applications.

The design process for new barriers can be undertaken in two stages. Initially, the most favourable type of barrier is selected on the basis of availability of space for erection and the cost implications.

The second stage is where the type of acoustic treatment to be applied to the barrier is selected on the basis of some simple logical tests, where no specialist knowledge of acoustics is required.

Considering the average insertion loss of barriers in practice was observed to lie between 5 and 12 dB(A) **[19]**, the targeted insertion loss values should be at least 10 dB(A). This reduction will be subjectively perceived as halving the noise levels.

Similarly a design procedure, for improving the performance of existing wall type barriers, based on simple yes/now tests and little knowledge of acoustics is being proposed. The main advantage of both methods is the shortening of the design process and the reduction in the costs of afterthought mitigating measures.

The reported benefits of the modifications discussed in the preceding section vary. However, almost all are said to have made only modest contributions to an existing barrier, up to about 3 dB(A) in real life applications. An existing barrier may already possess high degree of screening performance and it may prove difficult to enhance this performance greatly. Realistically, 3 dB(A) should be the targeted additional increase in the acoustic performance, which is subjectively the smallest noticeable change in noise levels.

When a modification is being made to an existing design there is always the danger of not putting it into the context of the already existing. It is always desirable to get the design right from the first time. In the cases however, where improvements are necessary and unavoidable, even if the acoustical benefits of a modification sound tempting, extreme care should be shown so that the extra additions do not seem like "an afterwards thought".

6 CONCLUSIONS

This paper addresses the need for simplified noise barrier design guidelines. The flow chart diagrams are proposed to aid the designer in making a decision on the most favourable design option without the need to consider detailed acoustical performance . The method can be used for both new and existing barriers. It is hoped the proposed method will shorten the design process which in turn would produce more effective designs solutions at lower costs.

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