The project for noise barriers and other NRDs for transport infrastructures: An overall vision and implementation experience in the countries of southern Europe.

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Summary

This paper describes what should be addressed in the drafting of a project of noise barriers and minimum requirements that must be reflected in the technical specifications, based on conditions applicable from regulations, standards and CE marking.

Also experience gained after some projects, in southern Europe, is displayed.

PACS no. xx.xx.Nn, xx.xx.Nn

1. Introduction.

When considering action against traffic noise impact, given the enormous difficulty of reducing noise in the vicinity of a transport infrastructure, it is necessary to have all the possible options. Among them, installing barriers and noise reducing devices NRD on roads and railway lines, are usually considered.

Currently, the state of art in the definition, manufacturing and implementation of noise reducing devices and noise barriers, is highly developed, and the sector offers a range able to respond to technical requirements and design, that adequately resolves many situations.

2. Noise Reducing Devices for transport infrastructures. Why?

Because transport infrastructures generate acoustic pollution with very harmful effects for the health of residents, NRDs can become a sustainable option for mitigating the problem.

Therefore the NRD should be designed to reduce these effects, but specific topics of noise pollution in infrastructures must be considered:

- This is a pollution that we can define, unlike other types of pollution, as "a clean pollution", in fact, it only exists while one noise source is active and it disappears once this source stops the noise emission and there is no residual contamination. Thus, the fourth dimension, "time“, should be considered for the design of remedial measures and it is very important to keep in mind this aspect.
- Requires the existence of sensitive receptors for noise nuisance to cause adverse effects. Thus, the remedial measures shall be effective at the points where these receptors are located.

In general, noise is defined as unwanted sound which entails an associated discomfort, which can cause physiological and psychological damage (hearing loss, stress, cardiovascular and respiratory diseases).

The factors determining the discomfort are:

- Noise level
- Exposure time
- Discernibility

This last factor, usually not considered, is crucial in cases of noise pollution in low noise environments such as a truck pulsed traffic at some distance away in the silence of the night.

Then, these three factors should be considered in establishing an appropriate indicator of discomfort/impact, in order to establish the required NRD's acoustic efficiency.

2.1. Noise pollution: Generation of the problem and actions that can be undertaken.

Vehicle traffic generates noise emission which spreads to reach noise sensitive receptors. Then, we can act on the:

- Whole problem
  - Planning of transport infrastructure and management of the territory
- Noise emission
  - Improvements on vehicles, minimizing noise emission engine, exhaust, etc.
  - Actions designed to reduce the noise generated at the tyre-road interface or the wheel-rail interface.
- Noise propagation
  - Obstacles on the propagation of sound: noise barriers and noise reducing devices.
- Noise immission
  - Actions to improve the sound insulation around the receivers

Regarding the actions on the noise propagation, we can think about:

- The interposition of obstacles to the transmission, with adequate characteristics of airborne sound insulation and with adequate geometry improving the effect of sound diffraction at its edges.
- Change conditions of sound absorption, in the appropriate surfaces involved in the definition of the acoustic propagation path.

3. The fight against noise pollution of transport infrastructure using NRDs.

The problem is different for every situation: Streets; Urban highways; Interurban motorways; Railways; Airports and Harbours. The possibility of finding effective solutions using NRDs are also different.

The typical Noise Reducing Devices for infrastructures are:

- Plant screens. (Not really a NRD)
- Earth berms.
- Noise barriers.
- Mixed constructions.
- Partial or total covers of the driveway or the railway lines.
- Special devices.
- Absorbent treatments.

Some of these devices can be used in the different scenarios listed above, noise barriers being the most commonly used devices.

However, the design of noise barriers, for a given section of road or rail, is often very complex and involves conducting a thorough analysis of all the factors involved:

- Precise quantification of the acoustic problem to be solved and defining the acoustic efficiency that noise barrier must be provide with.
- Determine the location of the noise barrier with respect to the road or rail, in general, will be more effective the closer it is to the sound source. However, in most cases, the placement of the screen will depend on the availability of land and the need to guarantee security conditions for certain traffic that may be affected.
- Geometric design of the screen: height and length. Different calculation models exist with very different degree of reliability when optimizing the geometric sizing of the noise barrier.
- Design for building: There is great heterogeneity in the solutions adopted in different European countries. European Standards have been published in which, the applicable requirements for noise barriers, regarding its mechanical and stability behavior, is defined.
- Defining of the acoustic performance of the constituent materials of the noise barrier: we must avoid the possibility that the reflected waves can reach any other noise sensitive areas and/or decrease the efficiency calculated for the screen by multiple reflections between vehicle bodies and the screen's own reflections before deciding between installing an absorbent or reflective noise barrier.
- Design for maintaining the road safety and environmental conditions.
- Defining the service life of the screen: this is an aspect often neglected by designers, however, affects everyone else.

4. Rules to be taken into consideration for the design of noise barriers.

4.1. Legal regulations and ordinances.

It refers to all those laws enacted by the different competent authorities at EU, national, regional or local level that define, based on an adequate policy to reduce noise, the quality levels required in the acoustic environment and when, how and who should be responsible for compliance.
They are the basics for the definition of the needed acoustic performance of the NRD.

4.2. Technical rules of definition and calculation.

We consider in this section the regulations and technical instructions and basic rules that have been published by the competent bodies, that define the methods of forecasting and calculating of traffic noise levels and the predicted effectiveness of the different corrective measures.
They are the basics for the definition of the optimal solution and for drawing up the projects of NRDs.

4.3. Standards for control and quality assurance.

We consider in this section all regulations issued by different international organizations such as ISO and CEN, or by the relevant standardization bodies at national level (AENOR, BST, AFNOR, ÖNORM, DIN, ...), whose ultimate goal is to provide the systems of quality assurance for the whole NRD and materials used in its construction.
They are the basics for the definition of the technical specifications and plans of the NRDs.

4.4. Definition and calculation

Once the acoustic problem and the effectiveness required based on the applicable law has been defined, we can calculate and optimize the solution with the most appropriate method.
The differences between the rules and regulations of calculation used in different countries for predicting noise levels (NMPB-Routes, RSL-90, Standaard Rekenmethode, CRTN, etc.) usually reside in the kind of source and in the more or less simplified formulations of the main effects involved in the attenuation of sound propagation, are considered. In some countries even two levels of accuracy (simplified method and detailed method) have been proposed.
These calculation models are currently available in the market as calculation software (CADNA, IMMI, SOUND PLAN, PREDICTOR, etc.). While they are very useful tools for the definition and calculation of expected efficacy for a given acoustic barrier, it must be stressed that its use, though it may seem simple at first appearance, is quite complex and requires extensive experience in this field, otherwise, the results are very often inadequate, or even wrong.
When a calculation software is used, attention must be paid to avoid common mistakes:

- Check that traffic data input is correct.
- Check that the 3D model is properly constructed. Consolidate topography and check that the position of the sources, obstacles and receivers are correctly located.
- The definition of noise barriers should be done by an iterative optimization process. The use of any optimization functions of the software is not advisable.

To establish the stability and resistance to loads, the Eurocodes can be used.

4.5. Drafting technical specifications

Once we have calculated and optimized the solution, we must choose the type of product that results most appropriate and draft the technical specifications that define the requirements and its performances.
The standards for control and quality assurance drafted by CEN are the basics for this purpose:

- Because they allow the behavior of different types of NRDs to be compared.
- Because they allow the performance of different products of the same type of NRD to be compared.
- Because they allow the performance to be provided by the NRD in order to fulfill the acoustical and mechanical requirements for the service life established, to be defined.

The European Committee for Standardization, CEN, and in particular the WG6 Working Group, of the TC226 Technical Committee, is developing, the European standards EN regarding noise reduction devices for roads:

- EN 1793 Parts 1 to 6 Test method for determining the acoustic performance.

- EN 1794 Parts 1 to 3 Non-acoustic characteristics and fire reaction.
- EN 14389 Parts 1 and 2 Procedures for assessing long-term performance.
- EN 14388 Product standard & Annex Z (CE Marking).

The European Committee for Standardization, CEN, and in particular the WG40 Working Group, of the SC1 Subcommittee, of the TC256 Technical Committee, is developing, the European standards EN regarding noise reduction devices for railways:

- EN 16272 Parts 1 to 7 Test method for determining the acoustic performance.
- EN 16727 Parts 1 to 3 Non acoustic performance.
- EN XXXXX Parts 1 and 2 Procedures for assessing long-term performance.

With everything said so far, we should be willing to undertake the drafting of noise barriers.

5. Experience in the countries of southern Europe.

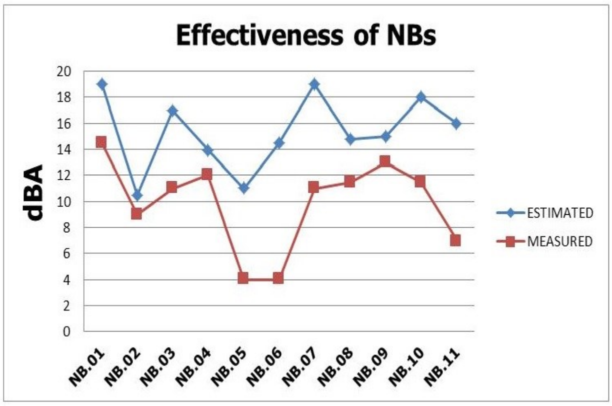
Everything previously mentioned so far seems relatively easy to apply, the experience of the projects and works of noise barriers carried out in some countries, especially in southern Europe, shows that not everything is so simple.

Noise barriers were first used in the countries of southern Europe in the late 80s and early 90s and, although some qualitative studies carried out by authorities, like the qualitative study, carried out in 2003 by the Spanish Ministry of Environment on eleven different noise barriers shows the differences regarding the Leq calculated and measured (Figure 1), and show that, in general, most of the noise barriers are effective in diverse degree, when:

- The calculation assumptions and baseline data were correct.
- The project definition was sufficiently detailed and has been respected in the construction and subsequent maintenance.

Also it was found that some of the largest deviations observed, besides the existence of secondary noise sources that have not been considered in the calculation, were the result of the coincidence with serious construction deficiencies.

In general, many of the deficiencies noted are generated when the definition of noise barriers is included in the overall project of a new infrastructure. The consultants in charge of the desing, often spend little time and less resources on an item that is considered irrelevant.



NB.01	Benisanó (Valencia - Spain)	Road
NB.02	Paseo de las Artes (Madrid - Spain)	Urban Road
NB.03	Las Rozas, A-6 (Madrid - Spain)	Highway
NB.04	Paseo de las Artes 2 (Madrid - Spain)	Urban Road
NB.05	Torrejón (Madrid - Spain)	Highway
NB.06	Est. Méndez Alvaro (Madrid - Spain)	Railway
NB.07	Av. Manuel Azaña (Madrid - Spain)	Urban Highway
NB.08	Parque Breogán (Madrid - Spain)	Urban Road
NB.09	Godella (Valencia - Spain)	Highway
NB.10	Gilet (Valencia - Spain)	Highway
NB.11	Leganés (Madrid - Spain)	Railway

Figure 1. Results of a qualitative study, carried out in 2003 by the Spanish Ministry of Environment on eleven different noise barriers.

On many occasions, they rarely take the necessary time to consolidate topographic 3D model data, and the software calculates solutions that are taken for garanted to be good without an analysis of whether they are consistent or not. (Figure 2).

The most frequent errors were generated by improvisation and the ignorance of the consequences of modifying the design considerations, together with the lack of detail in the construction drawings, usually without a clear definition of the location of the sound barrier. (Figure 3).

In the most suitable case, where the project of the noise barrier has been drawn independently of the project of the infrastructure, then normally provides a more complete documentation and a more precise definition of technical specifications is given.

However, some shortcomings appear quite often, relating to the lack of knowledge of the product standards EN, mentioned above, and appropriate consideration in the technical specifications of the project.

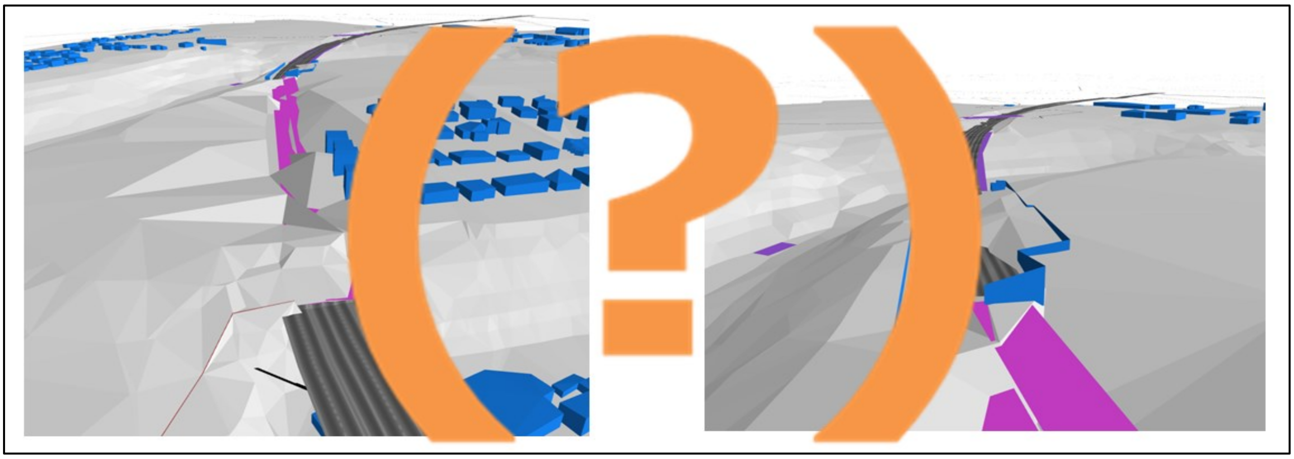


Figure 2. Mistakes in the topographic 3D model.

Figure 3. Errors in the location of the sound barrier.

We will see some examples in Figures 4 and 5, to illustrate some of the most frequent mistakes, particularly related to road safety and durability.

The acoustic barriers can prevent proper operation of the safety barriers. The deterioration not only affects the aesthetics, but can also pose risks to road safety and reduce acoustic effectiveness.

Some identified problems, are a result of the inadequate interpretation of product standards EN by some notified bodies and some manufacturers, which have led to the drafting of the mandatory Declaration of Performance (DoP) with errors that actually overestimate levels offered by products.

Many producers, kept in their Declaration of Performance, the sound absorption coefficient DL_{α}, obtained according to EN1793-1:1998, without plugging the gaps in the back of the samples tested, so, many products, currently distributed in the market, ensure reaching the DL_{α}=20 dB, which is overestimated by 5 to 7 dB, due to resonator effect generated in the empty gaps between panels and the wall in the tests. We hope that this problem is solved with the latest revision of EN1793-1:2013.

Figure 4. The acoustic barrier prevents proper operation of the safety barrier.

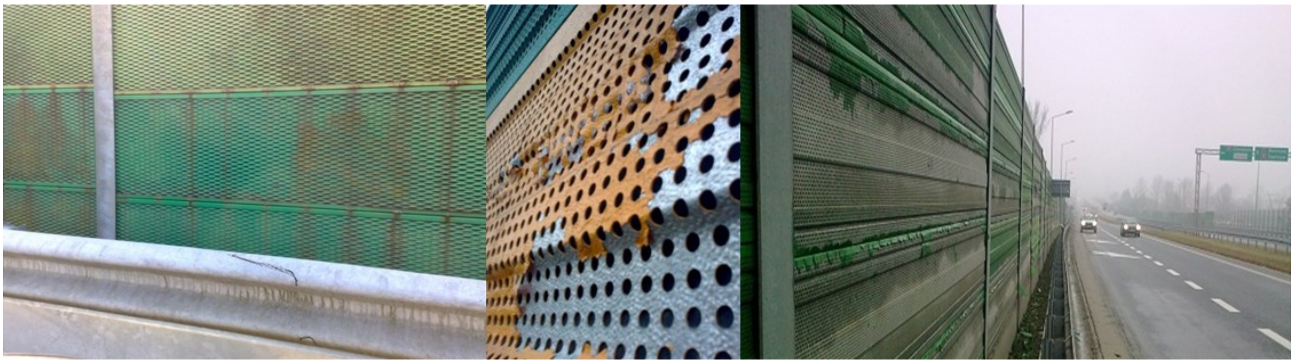


Figure 5. Effects of deterioration on the noise barriers.

Another problem identified, having serious economic consequences, as well as for the road safety, is the evaluation of the resistance to wind loads of products through calculations, which is permissible according to EN 1794-1. Practical experience shows that the calculation procedures applied, usually considerably overestimate, by 2 to 4 times, the resistance of the panels.

Tests of the same type of panel shows different results to those obtained by calculation: sample sandwich panels 4 m long with perforated corrugated sheet 0.6 mm and blind corrugated sheet of 0.8 mm.

By tests: Wind Load Design = 0’52 KN/m^2

By calculation: Wind Load Design = 2’4 KN/m^2

6. Conclusions and recommendations

The factors involved in the design are complex and should be properly considered and with the right level of detail, in particular, the optimized sizing design of noise barriers and considerations relating to road safety and durability.

It is not enough to have a program of advanced calculus if you do not have an expert in using it. A lack of trained and experienced technicians involved in the drafting of projects can lead to unsatisfactory results.

The technical specifications must be properly drafted: without any deficiencies in the product definition, without contradiction, without unappropriate and/or unjustifiable demands, etc., which are often the result of "cutting and pasting" which is too often used, and the ignorance of contents of existing rules that, even if they do not cover all aspects, are helpful for drafting these technical specifications.

Budgets must be clearly defined and must correspond to the requirements of the specification, otherwise, considering the drawbacks that are generated in the process of awarding the work, it woul be very difficult to guarantee satisfactory results.

Figure 5. Effects of wind loads on noise barriers in Portugal and in Spain’s A8 and M50 highways, assesed by calculations.

WE MUST AVOID THE RISK OF THE TRAFFIC NOISE REDUCING DEVICES, BECOMING LITTLE MORE THAN "CANVAS FOR GRAFFITI”