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NOISE CONTROL FOR A BETTER ENVIRONMENT

Location of noise barrier and their effect on road safety

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ABSTRACT

The result of modernization and rapid progress in human progress leads to a negative aspect - noise pollution. The noise barriers are undeniable factor when we are designing a new road or reconstructing an existing one for improving the performance characteristics of the road.

Nowadays, the noise is considered to be an extremely aggressive and widespread form of pollution. For this reason, it affects people, both physically and mentally. It fundamentally violates activities such as communication, sleep, exercise, rest. Of course, the main cause of noise is human activity and the desire to develop progress: the main source is road, rail, water and aircraft transport.

The subject of this scientific research will be traffic noise - it arises from road traffic as a result of the interaction between motor vehicles and the road.

Acoustic Walls are defined as solid, practical sound-proof precursors, creating a sound shadow zone behind them. The quantitative measure of the noise effect of the wall is its acoustic efficiency.

The location of the noise barriers/walls is essential, except for better acoustic efficiency but also for safety. There are no precise principles of where they can be installed in the legal base of the Republic of Bulgaria. This factor led to certain problem with road safety. The current practice in Bulgaria put a pattern in the design and build in noise barriers: they are built extremely closely to the noise source which is directly beside the road lane which has already placed restraining systems (range between 19 and 80cm) which makes them ineffective because it is not the observed the minimal necessary for the deflection of the guard rail.

Keywords: Noise, Road safety
I-INCE Classification of Subject Number: 30

1. INTRODUCTION

In the last decades, because of the increasing traffic and the development of civilization, we have encountered an unexpected problem - the increasing levels of road traffic noise.

In order to deal with this problem, the practice requires the use of noise barriers that are extremely diverse in terms of the materials they are made of, how they work and how they can be installed.

The European Commission divides the noise into several categories and subcategories:

1. Traffic noise

(a) vehicle noise (motor vehicle);

(b) the noise of two-, three- and four-wheel vehicles - from the exhaust system of internal combustion engines;

c) road contact noise of the vehicle tires, their trailers and their installation.

2. Aircraft noise

3. Railroad noise

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Points 2 and 3 will not be considered in the scientific work, as they are not relevant to the topic.

1.1. The problem in Bulgarian practice

The practice in Bulgaria is self-contradictory, most of the main roads are already built, which necessitate the installation of noise walls near the roadway because they were not plan in the first place. The requirement to comply with European Directive 2002/49 / EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise, as soon as a noise problem has been identified, has imposed immediately to install such noise barriers and for that reason some times the location is not very precise.

In Bulgaria there are no standardized norms or methodologies that the specialist to follow in the preparation of acoustic projects, they are a separate part of the projects, methodologies in the design and selection of the noise protection equipment on the materials, as well as methods during construction - ways of installation.

That is the problem with the Bulgarian practise.

Nowhere in the current legal framework, which affects the noise in Bulgaria, have guidelines for the elaboration of acoustic projects or technology for selection of noise protection (besides the acoustic consideration) devices or installation during construction.

If in a conceptual design or technical design is required an acoustic project or if it is assigned separately in the design assignment, the following basic information is given:

The technical justification requiring the design of the project;

The objective - to protect the population from the noise caused by traffic;

Requirements for acoustic and non-acoustic shields defined by EN 14388: 2015 Road noise abatement equipment. Specifications;

Part Constructive - Ready to meet European standards;

Part Geodesy.

The compliance with only these conditions is not possible to say that they are sufficient to indicate an acoustic design and subsequently install the equipment on site at an object.

By developing the Strategic Noise Maps in accordance with the terms of Directive 2002/49 / EC on the Assessment and Management of Environmental Noise, we have the opportunity to make a global assessment of the noise levels in a given territory caused by different sources and to present the previous, current and expected noise situation. There was developed update Strategy Maps in 2018 for 1122,606 km of road sections in the Republic of Bulgaria with traffic over 3 million vehicles per year.

In the countries with richer practice in the use of noise protection equipment there is a model: each has been made according to the specificity and characteristic of the Ordinance for designing of noise protection devices, which examine acoustic considerations; types of noise protection equipment; materials and methods for maintaining the surface of the facilities; aesthetic considerations; drainage and communal facilities; constructive considerations; considerations of road safety; product evaluation; installation considerations; maintaining the facility over time; the economic analysis is also considered; the design process is considered; performance evaluation.

Regular reports are made on the condition of the built facilities and on the need to build new ones in different locations.

All these are government duties.

2. OVERVIEW OF THE ACOUSTICAL CONSIDERATION

2.1. What is sound and the difference from noise

In order to understand the action of the noise walls, we need to have an idea of what they are protecting us. For this reason, we will look them as two distinct elements sound and noise. It is clear that noise comes from the sound, but it is psychologically regarded as harmful and therefore unpleasant, so we have to find a way to protect ourself from it. Here comes the role of noise screens.

2.1.1. Sound – definition

The sound, from a physical point of view, is a vibration that spreads in a rigid, liquid and gaseous elastic environment. A sound source can be any body that vibrates in an elastic environment. One of the major dimensions in sound science is the frequency of jitter, which is the number of oscillations per unit of time. In the most common case, this is one second. Measured in Hertz (Hz) - 1 Hz is flicker with period in one second.

The creation, distribution and detection of sound is the subject of Acoustics by physics. It has been scientifically proven that the human ear perceives mechanical oscillations at frequencies ranging from 16 to 20,000 Hz. These oscillations are called acoustic or just sound. Frequencies below 16-20 Hz are called infrasound, and over 20,000 Hz - ultrasound.

Psycho-physiological perception - These dimensions are defined in a complex way - the sound can be both pleasant and unpleasant, soothing or irritating, quiet or piercing to a painful sensation. There is also a fairly objective picture of the impact of the sound, these being the height, the timbre and the force, still called loudness.

The most important thing is the quality of force or loudness. To be perceived by a person, it must have some minimal intensity - the threshold of hearing (detailed in Figure 1). Above this threshold, the sound becomes painful. The frequency of the sound depends on these limits. The volume or intensity level measure is B (Bell), the ten-fold lower value dB (decibel) is accepted.

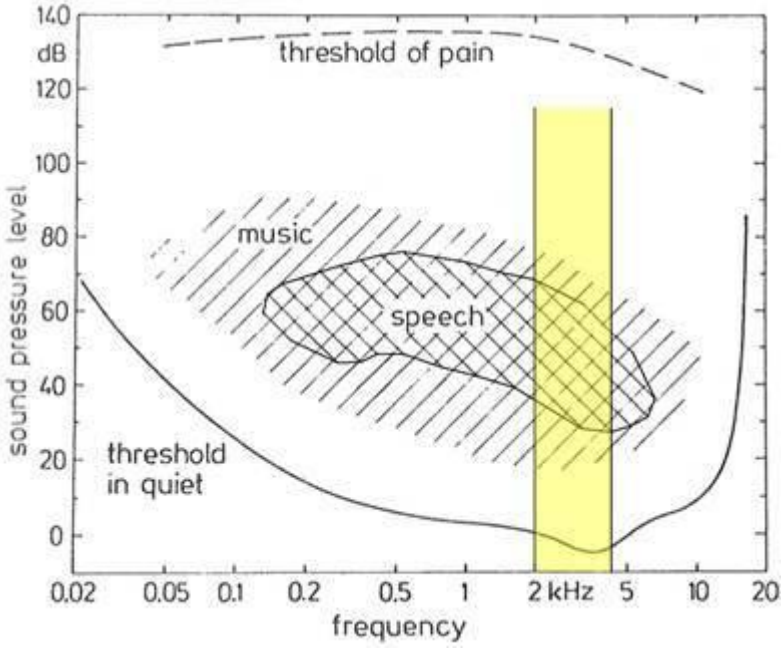


Figure № 1 Threshold of painful hearing (1)

The relevant acoustic characteristics of unpleasant sounds can be found in the pitch information and in the frequency range between 2000 Hz and 4000 Hz, where the ear is most sensitive. Such (unpleasant) sounds seem to evoke a physical reaction in the listener - in other words, the galvanic skin response changes significantly, and in addition, knowledge about the origins of the sounds (e.g., scratching fingernails on a chalkboard) leads to more negative ratings and stronger physiological effects. (1)

2.1.2. Noise - definition

Noise is the negative side of the sound, and from a physical point of view there is no difference between the two definitions. Noise is psychologically defined, these are sounds that irritate the human ear, considered to be unfavorable to the body.

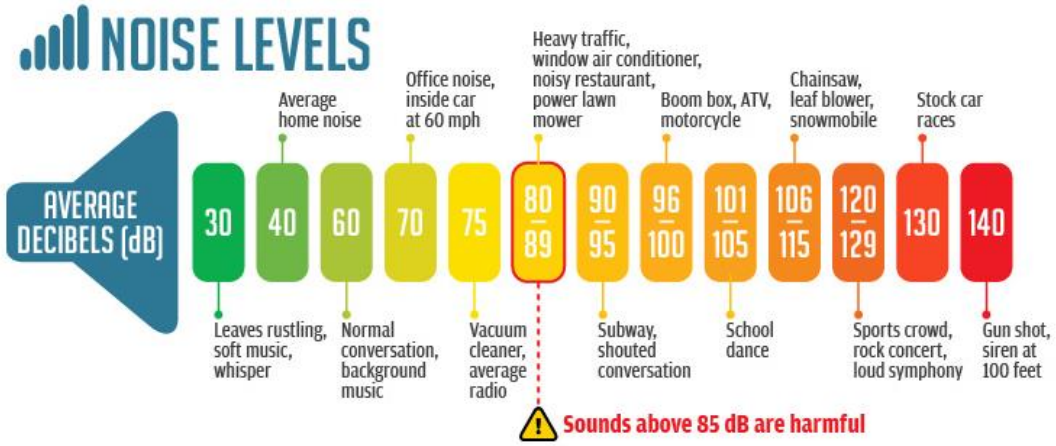


Figure 2 Noise levels (2)

The definition of noise is also noted in the Environmental Protection Act. In the sense of the law, "environmental noise" is an unwanted or harmful sound caused by human activity. In the Ordinance on environmental noise indicators the concept of "discomfort" has been introduced, and this assessment is also subjective.

Noise is related to technical progress, urbanization and some other peculiarities of modern man's life. It will not be exaggerated if we define noise as one of the most serious negative environmental factors in our time. (3)

The impact of noise and the ways of its limitation can be assessed from different points of view.

- Health-prophylactic, in which the most important is the prevention and treatment of health-induced health disorders.
- Engineering-technical, where the aim is to reduce the noise from different sources.
- Architectural and urban planning, where the noise is reduced by placing its sources outside the areas of habitation, proper construction of the territory around the noisy transport arteries, construction of noise protection structures.
- Building acoustics, which includes measures to reduce room noise.
- Economic and social, related to direct and indirect losses due to treatment of occupational diseases, reduced working capacity and other harmful effects of noise.

2.1.3. Transport noise

Transport noise arises from road traffic as a result of the interaction between motor vehicles and the road. This noise is directly related to the intensity, speed and structure / composition of the transport stream, the quality of the pavement, the level and road characteristic of the road in the investigated stretch.

The traffic noise of the two-lane roadway and the axis of the end-lanes for four-lane roads and motorways are taken as the source of the traffic noise. The height of the source is taken 0.5 m from the pavement level. A protected site is called a settlement, resort, or other area within a traffic noise zone above the admissible norms and for which a noise abatement action is required. (4)

3. NOISE BARRIERS/WALLS

3.1. Traffic noise can be reduced by means of various measures, such as speed limitation, bypass routes, renewal of the composition, increased distance between noise source and protected object, building of noise barriers.

Noise barriers reduce the sound which enters a community from different sources by either absorbing it, transmitting it, reflecting it back across the highway, or forcing it to take a longer path. This longer path is referred to as the diffracted path. (5)

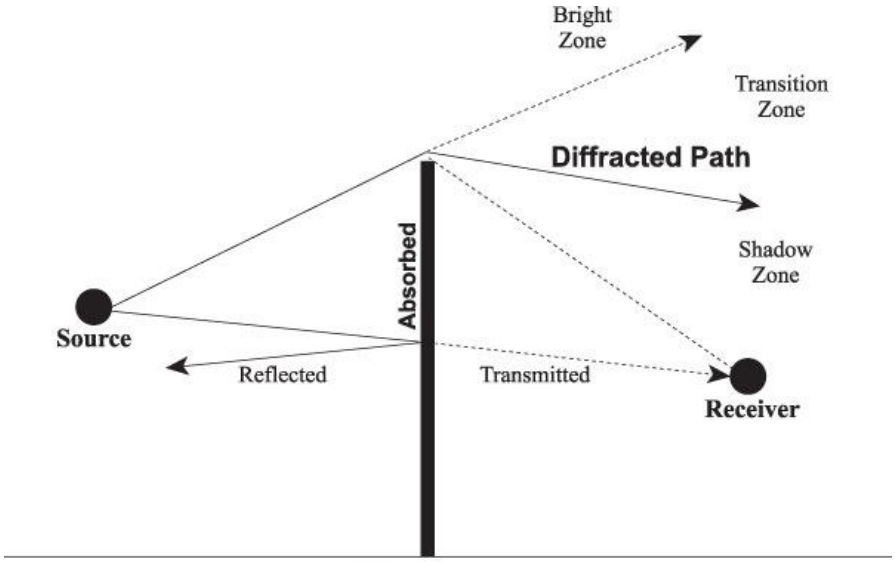


Figure 3 Barrier absorption, transmission, reflection, and diffraction (6)

The quantitative measure of the screen noise effect is there acoustic efficiency, which is defined as the difference between the noise levels at the pre- and post-calculus point of view, even under the same conditions.

The acoustic performance of the screen depends on its height and length, the distances between it and the source between it and the computing point as well as the heights of the computing point and the acoustic center of the source above the surface of the territory but not dependent on the noise characteristics of the transport streams.

Typically, a 5-dB(A) IL can be expected for receivers whose line-of-sight to the roadway is just blocked by the barrier. A general rule-of-thumb is that each additional 1 m of barrier height above line-of-sight blockage will provide about 1.5 dB(A) of additional attenuation.

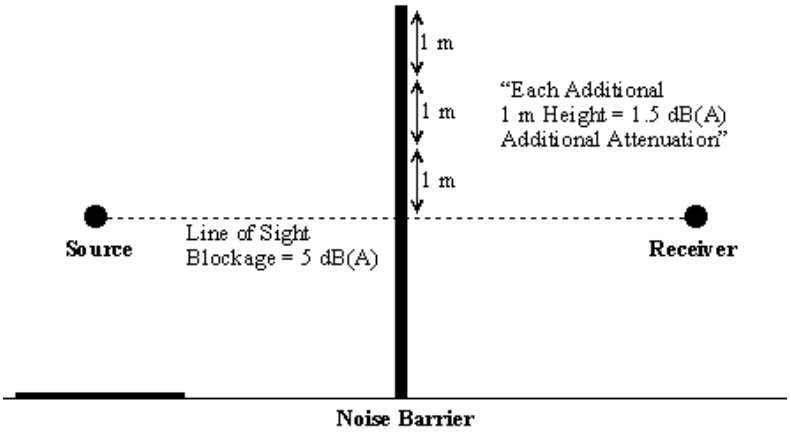


Figure 4 Line-of-sight

Noise barriers should be tall enough and long enough so that only a small portion of sound diffracts around the edges. If a barrier is not long enough, degradations in barrier performance of up to 5 dB (A) less than the barrier's design noise reduction may be seen for those receivers near the barrier ends. A rule-of-thumb is that a barrier should be long enough such that the distance between a receiver and a barrier end is at least four times the perpendicular distance from the receiver to the barrier along a line drawn between the receiver and the roadway (see Figure 4). Another way of looking at this rule is that

the angle subtended from the receiver to a barrier end should be at least 80 degrees, as measured from the perpendicular line from the receiver to the roadway. (5)

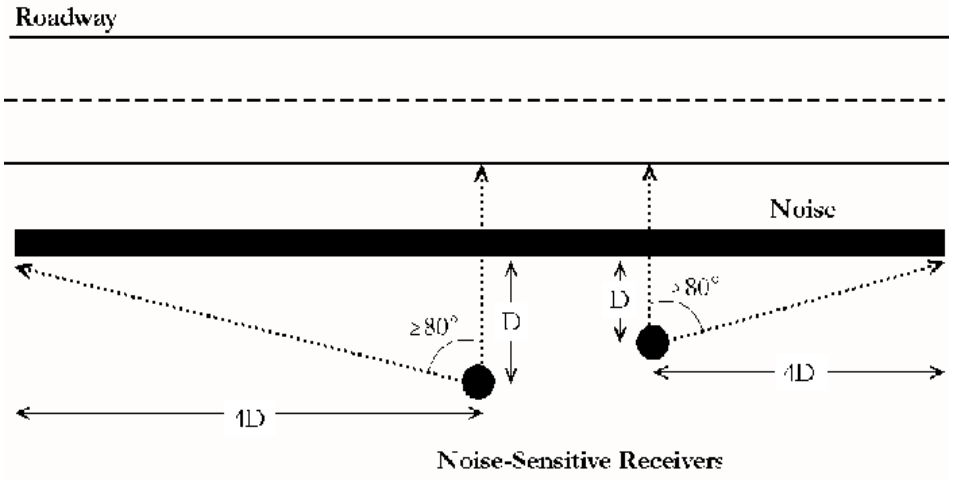


Figure 5 Barrier length

The main effect of noise reduction through the walls is achieved thanks to the sound shadow due to the diffraction of sound on the free edge of the screen.

In order to consider a noise barrier as effective, the most important thing is to be designed properly.

The noise barriers or walls can be extremely different. We can categorise them by several characteristics:

- Depending on the geometry – could be vertical or tilted; curved (see figure 5);
- Depending on the way they work – absorbing or reflecting the noise;
- Depending on their construction – material; configuration, weight and panel transparency.
- According to the way of construction – monolithic or prefabricated;
- Depending on the possibilities for acoustic reduction: noise berms – approximately 3 dB; area with plants (10 m width) depending on the plant from 3 to 15 dB; panels from concrete - approximately 45 dB, depending on the absorbing characteristic of the material; walls of steel supporting structure and combined acoustic panels - sandwich type – from 5 to 15 dB; wood panels – no more than 10 dB; Supporting glass and monolithic polycarbonate panels – from 20 to 30 dB; panels filled with recycled PVC materials – 30 dB; etc.

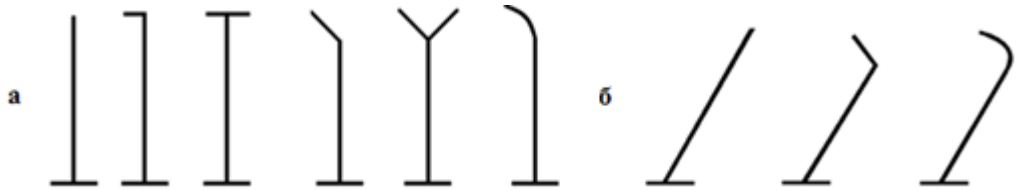


Figure 6 Geometry of noise barriers a) vertical; b) tilted

4. ROAD SAFETY

There is no exact definition of traffic safety because it is a combination and interaction of many factors that make up the modern point of view of the discipline.

According to the contemporary understand of road safety this is the safety of traffic, the main thing that forms this science is the understanding of the four basic elements that includes:

- Driver;
- Automobile;
- Road;

- Environment.

According to the philosophy of Royal Haskoning DHV, an independent international company with over 130 years of experience in engineering and in our case of traffic safety the basic principles of sustainable safety are:

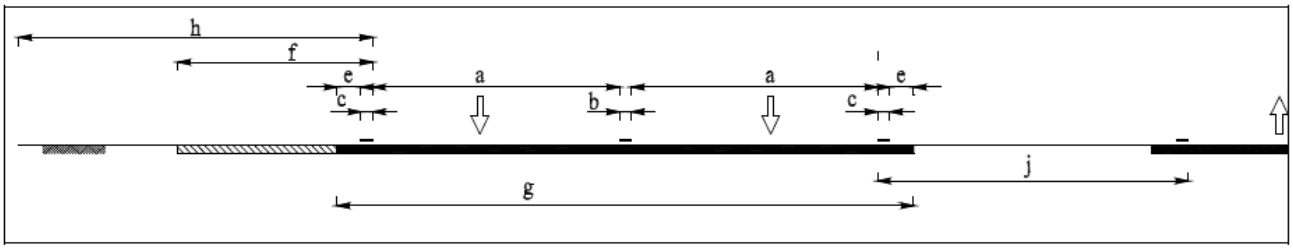
- Human measures are ruling (clarity, predictability, comprehensibility);
- Prevention before cure (e.g. reducing speed rather than guard rails in sharp curves). (7)

As mentioned before the system for road safety consist driver-automobile-road-enviorenment. It is necessary for the elements in the road transport system to interact and be sufficiently adaptive to ensure safety. In this respect, the road and the environment of the road must be designed and executed in such way as to induce adequate behavior of the road users and to the greatest extent be tolerant of any mistakes in their behaviour.

In line with the good practices of EU countries, road design should mainly focus on the so-called FOUR PRINCIPLE OF SECURITY:

1. Functionality: preventing unintended use of the infrastructure;
2. Homogeneity: preventing major variation in speed, direction and mass of vehicles;
3. Predictability: preventing uncertainty among road users;
4. Forgivingness: preventing that humans' errors leads to accidents.

According to the *Sustainable safe road design* a practical manual from the World Bank the cross section of the distributor road type I, dual carriageway (see Figure 6) have obstacle free zone. (8)



a (lane) = 3.10 m	f (emergency zone) = 2.40 m
b (separation line) = 0.15 m	g (pavement width) = 7.25 m
c (edge line) = 0.15 m	h (obstacle free zone) = 4.50 m - 6.00 m
e (edge strip) = 0.30 m	j (median = 3.90 m

Figure 7 Cross section for dual carriageway

After everything reviewed so far, in the Bulgarian practice the understanding of cross section till now was radically different, because in 2018 was published new version of the National design guide for infrastructure. There we find the adaptive obstacle free zone, but till now every noise barriers were designed and built by the old version were there was no such zone.

4.1. Noise barriers and theirs effect on road safety

From the Noise Barrier Design Handbook from Federal Highway administration we find qualitative evaluation of safety:

Qualitative evaluation with the thought/review of the following factors is considered imperative in the design of noise barriers where safety concerns exist:

- **Barrier location** - The location of the barrier may be able to be modified to place it in a position where it is less vulnerable to impact by vehicles.

- **Barrier attachment/reinforcement details** - Barrier component attachment and/or reinforcement details may be modified.

- **Barrier type** - The type of barrier may be modified in terms of its material type and/or configuration.

- **Barrier protective devices** - In addition to the considerations listed above, the potential for a noise barrier being impacted can be reduced by the placement of a protective barrier/restraining system (steel guard rail, concrete Jersey barrier, etc.) between the noise barrier and the highway traffic or by erecting a higher than normal safety shape barrier in front of a noise barrier in close proximity to traffic. Since protective barriers are themselves considered an obstruction, any such protective barrier must be designed in compliance with appropriate standards. In addition, the consequences of impact of a vehicle hitting the protective barrier must be weighed against impact consequences which would exist in the absence of such a protective device.

Several factors should be considered when we are choosing the location of the noise barriers:

4.1.1. Sight Distance

Sight distance (as impacted by noise barriers) is a factor requiring consideration along horizontal curve sections of highways and at locations where a barrier terminates near a highway's or ramp's intersection with another roadway.

4.1.2. Traffic Protection

Noise barriers are protected from vehicular impacts when constructed within the recovery zone (clear zone/obstacle free zone) normally provided for vehicles. Devices used to provide such protection include metal or wood guard rails (or guide rails) or concrete safety shaped (Jersey barriers) protective barriers. Metal and wood guardrails are placed at a distance in front of the noise wall equal to or greater than the maximum deflection of the guard rail.

4.1.3. Emergency Access

Noise barriers can often interrupt the path between the highway and adjacent local roadways. This can be dealt with providing section with overlapping or building an access doors.

4.1.4. Fire Safety

Noise barriers may also interrupt the path between the highway and a source of water required to be accessed in the event of a fire or spill on the highway. The solutions can be providing with hose couplers incorporated into noise barrier panels; in the panel to be mounted valves or to be provided with small covered openings.

4.1.5. Glare

Glare is generally a problem on noise barriers with smooth surfaces, such as metal and transparent barriers. It is more prevalent on lighter coloured surfaces and can be a problem in daytime (low sun angle) and nighttime (due to headlights) periods and is particularly bad during nighttime periods when the barrier may be wet.

4.1.6. Shatter Resistant

When a noise barrier is impacted by a vehicle, the effect of barrier components shattering is a concern. The effect is of particular concern where the barrier is located on a structure overpassing another highway causing potential injury to nearby vehicles, pedestrians, or adjacent residents.

4.1.7. Icing and Snow Removal

Design of noise barriers in climates subject to ice and snow conditions should consider the placement of barriers a sufficient distance from the travel way to assure adequate space for storage of plowed snow and to assure that the barrier can withstand the additional loads that may result from

plowed snow being both thrown and piled up against the barrier. Barriers also will shade portions of highways at some time during the day. (5)

5. PRACTICE IN BULGARIA

In this point will be surveyed several examples from the Bulgarian practice. On this stage of our experience we observe noise barriers only built on highways.

5.1. Trakia highway A1

Yambol - Karnobat from 277+595 to 325+280

In this section the noise barriers are located on four places: on 276+450 direction Burgas-Sofia; on 278+300 direction Sofia-Burgas; on 285+090 direction Sofia-Burgas and on 316+600 direction Sofia-Burgas.

The main problem from road safety point is the close distance from the restraining system and the noise device - 37,5cm. The noise barrier is mounted via continuous footing from concrete 50 cm and steel post HE160A (16cm) with height 3m.

Photo 1 Noise barrier

Photo 2 Distance between the restraining system and the noise barrier – 37.5cm

Photo 3 Continues concrete footing – 50cm

Photo 4 Wooden noise barrier

The restraining systems are N2W5 with maximum deflection of 1.7 m.

5.2.Struma highway A3

Dolna Dikanya – Dupnitsa from 305+200 to 322+000

Wooden noise barrier on 306+000 direction Blagoevgrad - Sofia

Photo 5 Noise barrier

Visible continues concrete footing.

Dupnitsa – Blagoevgrad from 322+000 to 359+453.82

Photo 6 Noise barrier

Photo 7 Noise barrier

The noise protecting panels are attached via continuous concrete footing and steel poles HE160A. The distance from the restraining system to the noise barrier is 54 cm with maximum deflection of 1.7 m. Furthermore the concrete footing is with height 50 cm, which upon impact the front axle will break and the automobile will flip. In the case of the stationary steel poles they are a fixed system, and according to Technical rules for the application of road restraint systems on the national road network and EN 1317-2:2010 Road restraint systems - Part 2: Performance classes, impact test acceptance criteria and test methods for safety barriers including vehicle parapets, that kind of danger is classified as third degree of danger which requires H1 restraining system. (9, 10)

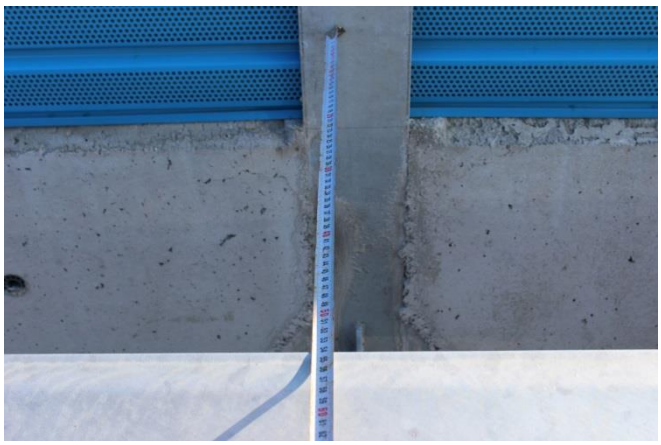


Photo 8 Distance between the restraining system and the noise barrier – 37.5cm

In the beginning of the section is observed reinforced in the restraining systems but not enough.

Photo 9 Noise barrier

Photo 10 Noise barrier

Photo 11 Distance between the restraining system and the noise barrier – 40 cm

Photo 12 Distance between the restraining system and the noise barrier – 19 cm

5.3.Maritsa motorway A4

There are total six sections in which there are built noise barriers. The following example is from km 60+000.

Photo 11 Noise barrier

Photo 12 Distance between the restraining system and the noise barrier – 40 cm

The restraining system is H1W5 - maximum deflection of 1.7 m.

6. CONCLUSION

In the projects executed to this point in Bulgaria, for constructing noise protection devices, the only feature that is being considered is acoustic efficiency. From the examples above, it becomes clear that installation is unacceptable under the available conditions. Nowhere in the designs is noted that the road safety requirements, mentioned in the paper, has been complying and taken considered.

Because of the small amount of experience with installation of the noise protection equipment we need to improve our method in designing and building on time to eliminate further errors.

The purpose of the overview of world practices and in particular countries that have more and longer experience in designing and installing noise-protection walls and equipment, is to see if a standardized document, specification, or manual can be prepared to aid the future practice when selecting materials and wall mounting because the inappropriate practice in Bulgaria should be stopped.

The other motive of the paper is to see if we can find, are there any better ways in designing noise barriers that can be adapted in Bulgaria based on the mistakes made so far.

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