University of Nis
Faculty of Occupational Safety
„Politechnica“ University of Timisoara
Faculty of Mechanical Engineering
23rd National Conference &
4th International Conference
NOISE AND VIBRATION
Niš, 17 - 19. 10. 2012.

MORPHOLOGY OF MODULAR TRAFFIC NOISE BARRIERS

Vladan Grković[1], Milan Kolarević[1], Zvonko Petrović[1], Miomir Vukićević[1]

[1] University of Kragujevac, Faculty of Mechanical Engineering Kraljevo, Serbia, grkovic.v@mfkv.kg.ac.rs

Abstract - *The paper presents the morphology of the existing solutions of modular noise barriers with detailed classifications and description of shapes of the main modules and their structures. The advantages of the modular approach and the specific characteristics which refer to integration of barriers into the topography and their visual integration into the environment for the purpose of accomplishing a positive aesthetic effect are particularly emphasized.*

Key words: *noise barrier, modular, morphology.*

1. INTRODUCTION

The dominant source of community noise is traffic (road, rail and air). The level of noise produced by means of transportation in the environment ranges within 70÷110 dB(A). Road traffic noise is the most common source of noise in all countries. It depends on [1]:

- the speed of vehicles
- the structure of the traffic flow
- the form of the surface
- terrain configuration
- meteorological conditions, and
- background noise.

Noise control can be carried out:

- at the noise source
- along the noise propagation paths
- at the receiver.

Manufacturers of road vehicles constantly make efforts to reduce the noise produced by the driving unit and pneumatics in contact with the base. However, it is not enough and that is why it is often necessary to apply the measures of noise control in road transport along the noise transmission paths from the source to the receiver, i.e. the object affected by noise. The level of noise along the propagation paths is reduced by applying:

- barriers (obstacles)
- tunnels
- natural obstacles (earth mounds), and
- a combination of the mentioned ways.

Noise barriers (acoustic screens) reduce noise to a satisfactory level by preventing the propagation of noise waves. Practical mitigation of the level of noise with the application of reflecting barriers ranges within 10-15 dB(A), and the application of absorbing barriers can improve this efficiency by additional 5 dB(A).

Classification of shapes and structures of modular noise barriers is presented in the continuation.

2. MORPHOLOGY OF MODULAR NOISE BARRIERS

2.1 Barrier morphology

Barrier morphology is *classification of the form and structures* relating to barriers. Essentially, barrier morphology is uncomplicated, as barriers are made up of a small number of essential parts. Barriers can be made either of one part or several modules. Even in one-part barriers three main sections can be noticed: a base section, a middle section and a top section.

Modular types of barriers are most frequently used. Modular construction of barriers is a system of construction of industrially made elements, which are assembled *in situ*. Individual modules (barrier wall, support structure and end profiles), except the foundation, are entirely manufactured in a factory, then they are transported to the site where they are assembled into a barrier.

The use of a modular structure results in a product which is composed of modules that are possible to replace and whose geometrical values or functions can be changed for the purpose of obtaining a sufficient number of different variants.

The main modules of a barrier can be:

1. Foundation
2. Barrier wall
3. End profiles
4. Support structure
5. Top edge

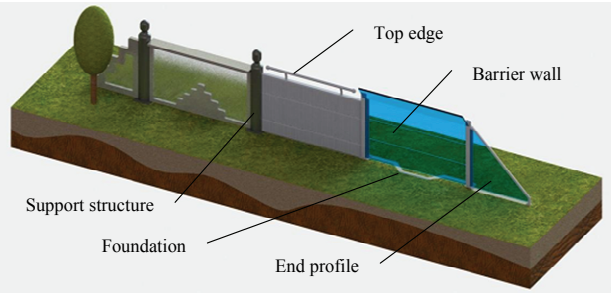

Fig. 1 *Barrier morphology*

In the process of barrier design, it is necessary to take into account the shape of its profile. It can be vertical, angled, partly concave or cantilevered. The barrier profile angle does not only affect the direction of noise reflection, but it also has some important aesthetic effects.

The barrier has two façades: the front one, i.e. the side which faces the traffic and the back one, which faces the protected

area. There is a frequent requirement that the front and rear façades should be different. This difference is realized by a combination with planting, with the application of different materials, etc. The requirement for reduction of the noise level usually refers to only one façade of the noise barrier.

In the process of barrier design, it is also necessary to consider *the topography of the terrain*, i.e. rises and falls, earth mounds, etc.

2.2 Foundation

Foundation is one of the main modules of noise barriers whose aim is to transmit the entire load from the facility to the load-bearing ground without harmful stresses and deformations in the soil. It is one of the most important parts of the barrier because the stability and durability of the barrier depend on it. For proper design and construction of the foundation, it is necessary to know the barrier loads and have detailed knowledge of the soil, i.e. the composition of the terrain, its layers, physical properties, etc.

The foundation depth is a vertical distance from the ground surface to the contact surface between the foundation and the soil. According to the foundation depth, there are: shallow foundations and deep foundations. *Shallow foundations* are usually made at the depth of about one meter (at the depth up to which the ground freezes in frost-prone regions, i.e. at the depth at which there is the first stable layer of the ground). There are different shapes of shallow foundations: strip foundation, isolated foundations, foundation plates, grillage foundation.

Deep foundations are applied for supporting facilities on a deeper soil layer (or a rock), which has better physical-mechanical characteristics than the upper (surface) layer. There are different types of deep foundations, such as: piles, caissons, wells. Foundation is the only module that is always made *in situ*. According to the foundation shape, there are the following types:

2.2.1 Classical strip foundation

This way of support is applied when loads are small. The foundation is directly ground-supported, without extension (the footing) and with such a depth in the ground that is sufficient for the stability of the structure and safety against frost. Anchors to which the support posts are fixed are cast in the concrete foundation. The barriers with the height from 2 to 2.5 m are predominantly installed to this type of foundation.

Fig. 2 *Classical strip foundation*

2.2.2 Strip foundation with the footing

If there are heavy loads, which should be transmitted to larger surfaces so that ground loading would be within the allowed limits, reinforced concrete foundations with the footing are constructed. They are very economical for the case when there are strong winds and where the soil has small load-bearing capacity. The barriers with the height from 2 to 3.5 m are installed to this type of foundation through support posts which are fastened to the foundation by means of anchor bolts.

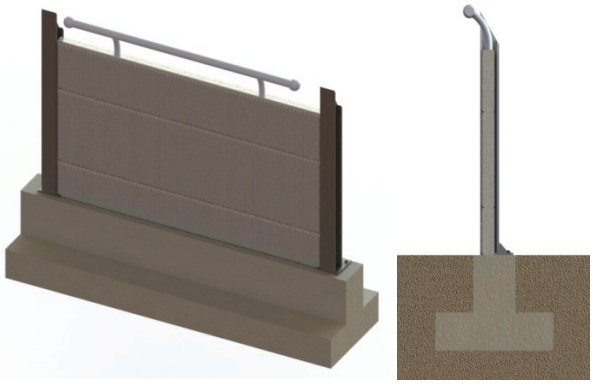

Fig. 3 *Strip foundation with the footing*

2.2.3 Zig-zag foundation

Zig-zag foundations are predominantly of a trapezoid shape, but they can also have an alternative curved shape. In the case when the weight load is small and when the soil has a satisfactory load-bearing capacity, at the places where there are strong winds, it is more rational to construct this type of foundation than the strip foundation with the footing. The barriers with the height from 2.5 to 3 m are predominantly installed to this type of foundation. The posts that carry the panels which form the noise barrier are anchored to the foundation.

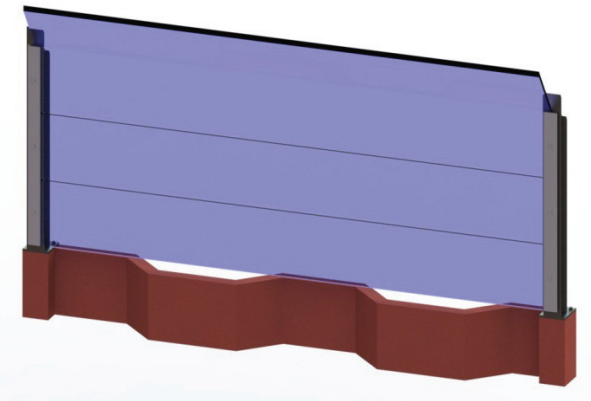

Fig. 4 *Zig-zag foundation*

2.2.4 Foundation with footings

They are foundations with isolated concrete footings (isolated foundations) into which the posts are placed. The footings can be with or without extension depending on the type of terrain. It is desirable, for the purpose of the footing structure stability, to connect them by concrete beams. The barriers with the height from 3 to 5 m are predominantly installed to this type of foundation.

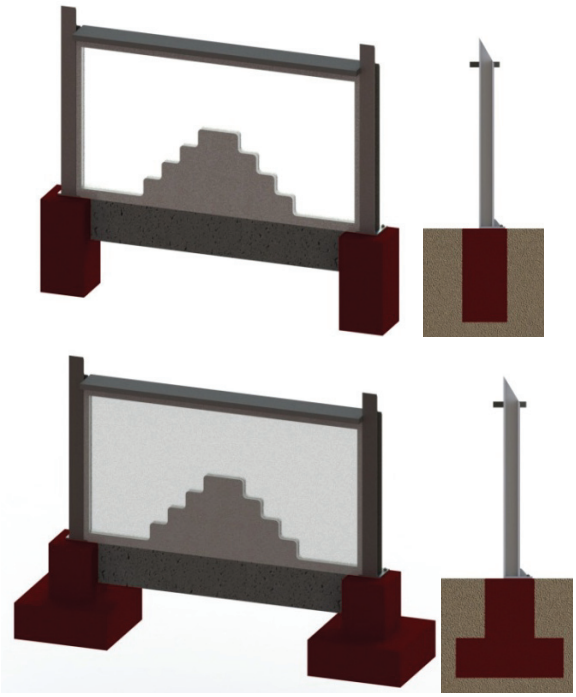

Fig. 5 *Foundation with footings*

2.2.5 Foundation connected with the bottom section

This is the type of concrete foundations which is partly in the ground, and partly above the ground. The part above the ground represents the bottom section of the barrier, it is cast together with the foundation *in situ* and can be up to 1.5 m high. They are predominantly used at high embankments, higher than 3 m, where winds are medium. The bottom section actually replaces the base section of the noise barrier and most often serves as protection from traffic. The total height of the barrier wall and the bottom section is up to a maximum of 3m.

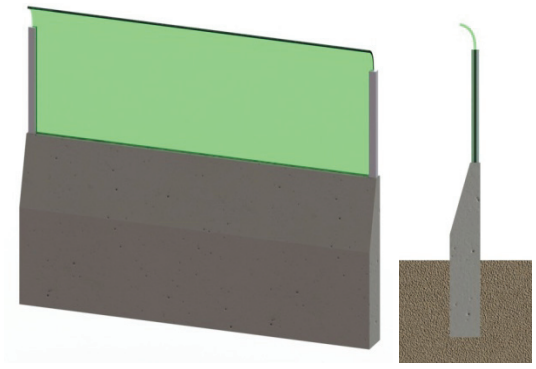

Fig. 6 *Foundation connected with the bottom section*

2.3 Barrier wall

The barrier wall is the major and largest module of a noise barrier. It performs the main role of the barrier, which means that it reduces the excessive noise to a satisfactory level by reflection, absorption or diffraction.

In this module three units can be noticed:

- lower part (base section)
- medium part (middle section)
- upper part (top section)

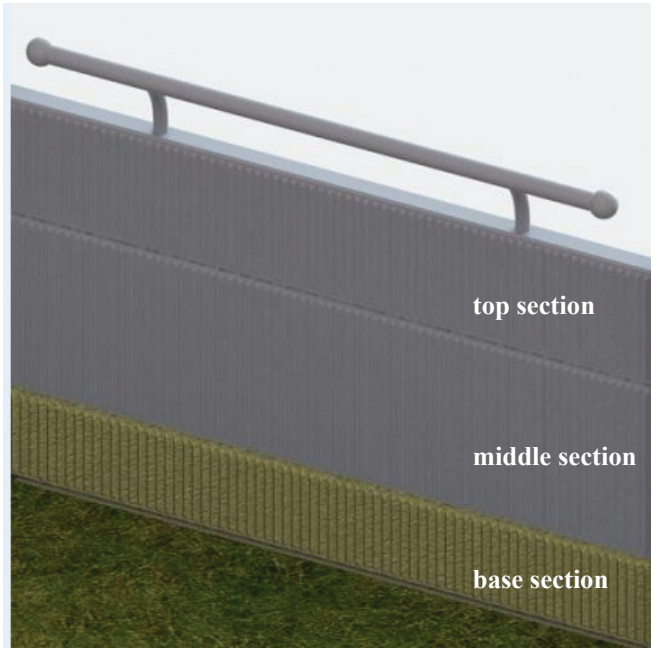

Fig. 7 *Barrier wall*

The barrier wall is rarely made out of one part, and it is often the case that certain sections are assembled of several panels of the same or different type.

2.3.1 Bottom section

The bottom section of the barrier wall may in reality be obscured by planting, grass or perhaps a kerb or safety fence. Planting reduces pollution from car exhaustion gases and provide the barrier with a good visual effect and better integration into the environment. This section is sometimes cast of concrete *in situ*, together with the foundation. The holes for necessary drainage of collected water and passing of small animals are most often left between the bottom edge and foundation. During the design, it is necessary to make sure that the bottom section should be in an appropriate proportion to the sections of barrier above.

2.3.2 Middle section

The middle section (barrier body) is likely to form the largest visually apparent part of the barrier. Ideally, to avoid visual clutter and disharmony, the middle section of the barrier should only comprise a single material with the possibility of changing its form and colour.

2.3.3 Top section

In rural areas, it is desirable that the barriers should be concealed by vegetation or appear transparent so that they could be integrated into the landscape. The top section is most often made of transparent materials so that the barrier could blend into the backdrop of the sky or vegetation background.

This can also be the case in urban areas in which a lot of barriers use transparent or lighter materials at the top to reduce the overall apparent height of the barrier and allow light to pass through.

2.4 Top edge of the barrier

Most barriers have a simple or unobtrusive top edge. Designs sometimes allow themselves to design special forms of top edges for the purpose of improving aesthetic appearance of the barrier.

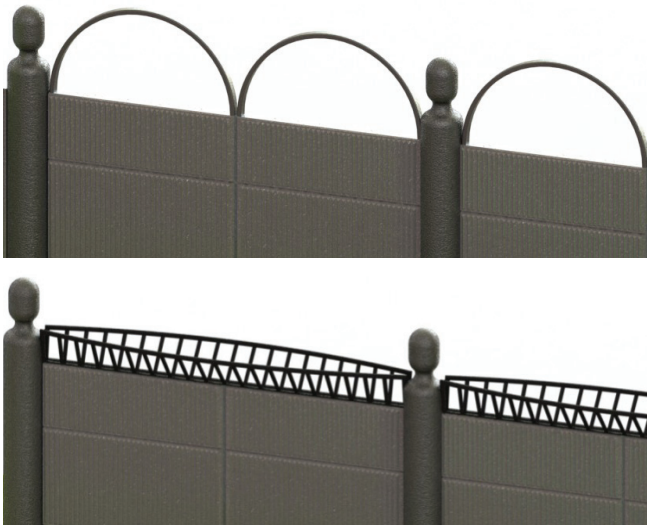

Fig. 8 *Top edge as a decorative element*

Research has shown that special forms of top edges, such as: T-profile, Y-profile, arrow profile, etc. create the diffraction effect and thus reduce the noise level. In addition to diffracting elements, pipe-like absorbers with the cross section in the form of a ball or pear can also be mounted at the top. Application of special forms of top edges additionally reduces noise by 1÷2.5 dB(A), which enables reduction in the barrier height. Lower barriers reduce the level of concealing the environment, which can improve the aesthetic influence on the community and drivers.

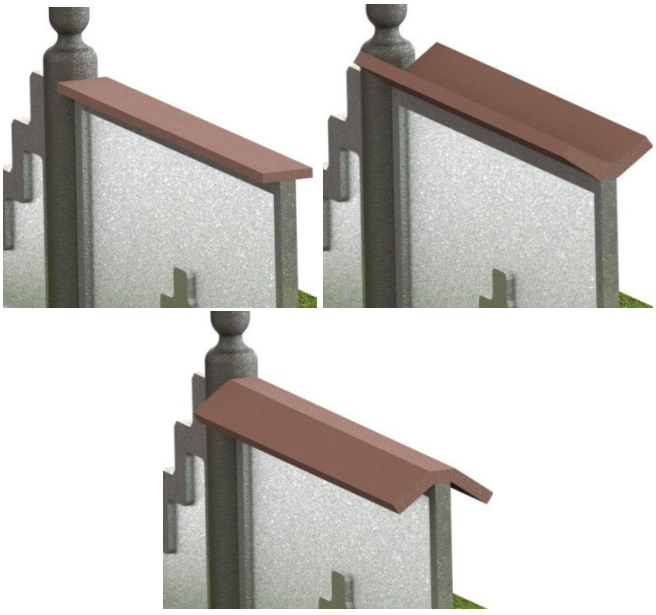

Fig. 9 *Diffracting forms of top edges*

Although special top edges have certain acoustic and aesthetic advantages, the costs of their manufacture usually exceed the costs of manufacture of higher barriers with the classical form of top edge which have the same acoustic effect, so that there are trends to eliminate top edges from use.

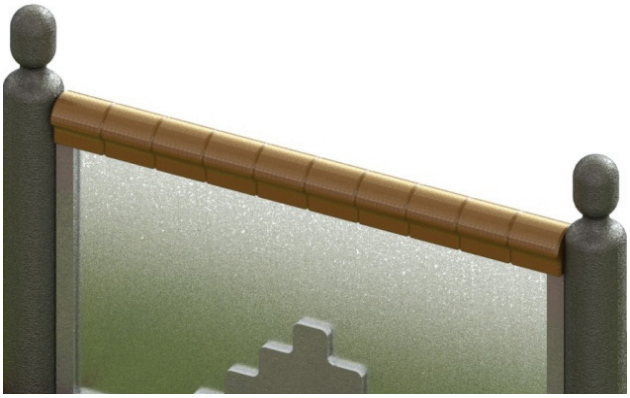

Fig. 10 *Absorbing forms of top edges*

2.5 End profiles

The end profile of the barrier is usually placed as an “add on” to the full length and height of the main barrier and it is essentially more of an aesthetic detail than an acoustically functional element. The task of the end profile is to provide a gradual visual transition, instead of an abrupt one, from a space concealed by the barrier to an open space without the barrier.

In barriers located in an urban zone, the abrupt ending of the barrier is frequently visually acceptable. An appropriate appearance may be achieved by the use of a characteristic profile, which integrates well with the overall barrier design. If it is necessary to disguise the barrier ends, then it is most simple to envelop it in planting, but it would be visually more pleasing to have planting along the barrier on both sides. However, most barriers tend to taper, step up or break up when they start or finish, and sometimes specific shapes are used.

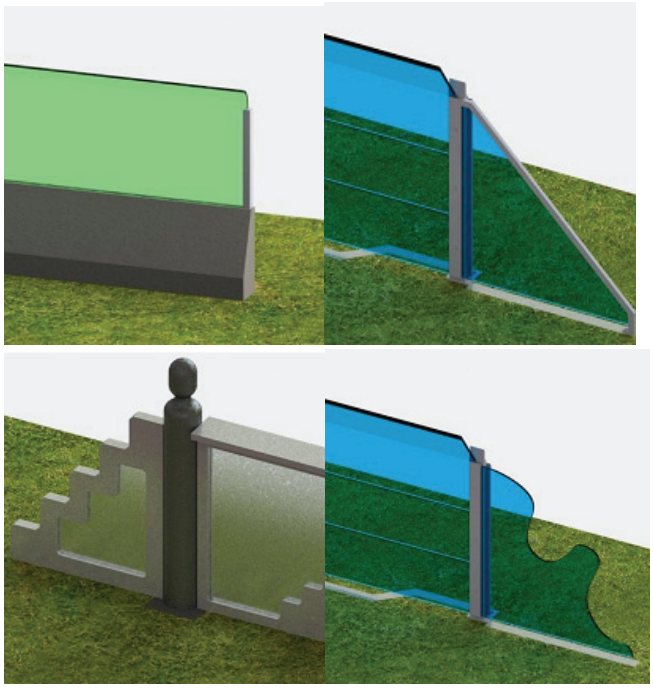

Fig. 11 *Shapes of barrier ends*

2.6 Support structure

The barrier can be subjected to significant loading, especially wind loading, and must be designed to satisfy certain conditions. This function is assumed by the support structure which can be visible or concealed within the façade.

Most barriers are formed from noise panels, which are directly positioned between vertical posts. In modular barriers, the support posts are frequently bolted onto the concrete base – foundation. In large spans, where the number of support posts is small, it is often necessary to provide lateral support structures to the panels, which is usually placed from the rear side. If barriers are smaller by their overall dimensions, precast panels can be bolted directly onto the foundation, and the use of support posts is thus avoided.

As with any other architectural forms, the support structure of a barrier may be used as a functional as well as an aesthetic element. The structure may then have an important visual function, which contributes to its integration or non-integration in the surrounding landscape.

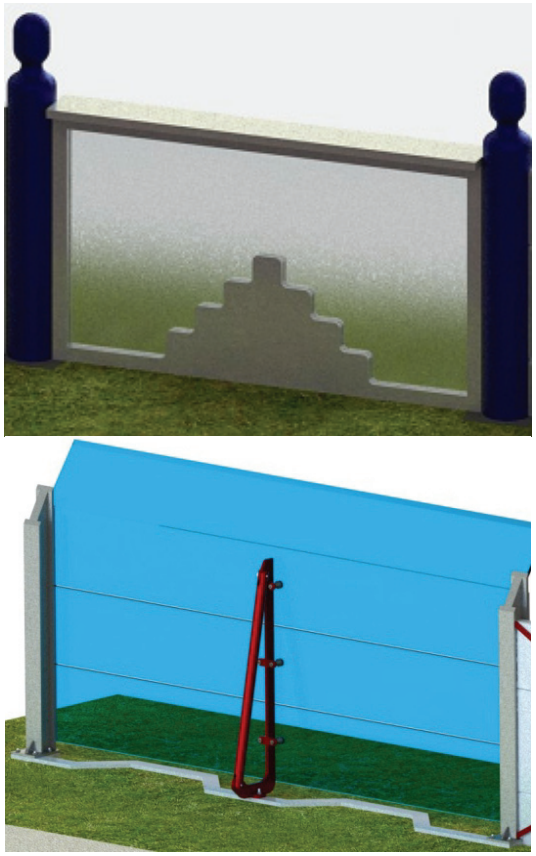

Fig. 12 *Support structure of a barrier*

An important barrier module, especially from cost, weathering and maintenance considerations, are fixings. They should allow the barrier to be fitted into place and allow for the easy removal and replacement of damaged panels or modules. At the same time, this is the most important advantage of a modular structure because in case of damage of certain modules of the barrier it will be faster and cheaper to replace the module than repair it. The barrier appearance remains the same as before the damage.

Fixings are mostly simple components. They are bolt joints between the posts and the foundation, grooves in which noise panels are inserted and similar fixing elements that provide easy mounting and disassembling of certain modules. More complex fixings sometimes appear only in the top section of the barrier when it is necessary to provide the connection between the top parts of the barrier which have a decorative or functional character.

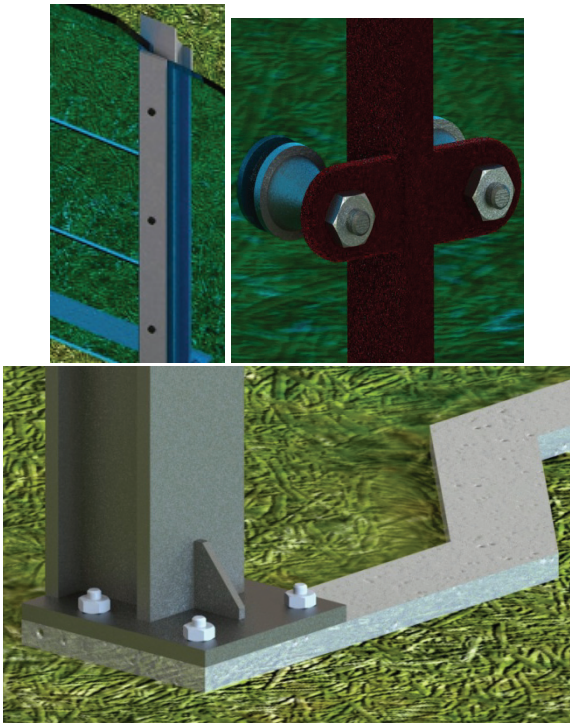

Fig. 13 *Fixings of the barrier*

3. CONCLUSION

Design of means for active and passive noise protection was planned within the project TP37020 – "Development of methodologies and means of noise protection in urban areas" (UrbaNoise). In addition to development of methodologies and means of active noise protection, a considerable part of the project activities was devoted to design, construction and testing of means of passive noise *protection*, such as modular noise barriers and noise absorbers intended for different conditions of use and application.

Taking into account the trends of approaching the European Union, our country has assumed the obligation to harmonize the domestic legislation with the EU legislation. In the field of noise protection and in compliance with the Directive 2002/49/EC of the European Parliament and the Council of the European Union, Serbia has made a series of laws and bylaws. The next phase will be the obligation to monitor noise in settlements and along the main roads, to establish endangered zones and measures for reduction of noise in them as well as quiet zones and measures for their preservation.

One of the ways to reduce noise along the main roads is construction of noise barriers. Since in our country there are no companies that deal with this problem, this project is important because it represents a manner of developing means of adequate noise protection and offering them to companies as a new production programme. It is an opportunity to employ domestic industrial capacities and save considerable amounts of money because the price of a noise barrier in the European Community, depending on its characteristics, size, etc. is around 1.000.000 € per kilometer.

Acknowledgement: The paper is a part of the research done within the project TR37020. The authors would like to thank to the Ministry of Education and Science of the Republic of Serbia for supporting this research.

REFERENCES

[1] M. Praščević, D. Cvetković: *Environmental Noise*, Unive-rsity of Niš, Fakultet zaštite na radu, Niš, 2005.

[2] B. Kotzen, C. English: *Environmental Noise Barriers , A guide to their acoustic and visual design*, Second edition, Taylor & Francis e-Library, London and New York, 2009.

[3] G. G. Fleming, H.S. Knauer, Cynthia S.Y. Lee, S. Pedersen: *Noise Barrier Design Handbook, Highway Traffic Noise*, http://www.fhwa.dot.gov/environment/noise/noise_barriers/design_construction/design/index.cfm

[4] M. Kolarević, Z. Šoškić, Z. Petrović, B. Radičević: *Noise Protection In Urban Environment- Description Of A Project*, Mechanics, Transport, Communications, Academic journal, Todor Kableshkov University of Transport,Sofia, ISSN 1312-3823, issue 3/2011, pp.IV-69-IV-78.

[5] R.E. Klingner, M.T. McNerney, Ilene Busch-Vishniac: *Design Guide For Highway Noise Barriers*, Research Report 0-1471-4 , Center for Transportation Research The Unive-rsity of Texas at Austin, November 2003

[6] H. Knauer, S. Pedersen: *FHWA Highway Construction Noise Handbook*, Highway Traffic Noise, **Error! Hyperlink reference not valid.**

[7] R.F. Blum: *A Guide to Visual Quality in Noise Barrier Design*, Highway Traffic Noise, http://www.fhwa.dot.gov/environment/noise/noise_barriers/design_construction/visql/acknowledge.cfm

[8] *Guidelines on Design of Noise Barriers*, Environmental Protection Department and Highways Department Government of the Hong Kong SAR, Second Issue, January 2003

[9] *Cutting down noise with precast concrete and masonry barriers,* British Precast, 2005, http://www.britishprecast.org/documents/CuttingDownNoise.pdf

[10] *B. Berglund, T. Lindvall, D. H. Schwela (editors): Guidelines for community noise. WHO. World Health Organization 1999. www.who.int/docstore/peh/noise/guidelines2.html*

[11] A. Zlatković, *Analysis of railway vehicles noise management,* Master thesis, Faculty of Traffic Engineering, Belgrade, 2010.

[12] *Design Guide For Environmental Barrier,* Volume 10 Section 5, Part 1 HA 65/94, 2001

[13] *Environmental Barriers: Technical Requirements,* Volume 10 Section 5, Part 2 HA 66/95, 2001.

[14] *Highway Traffic Noise Analysis And Abatement Policy And Guidance* by U.S. Department of Transportation, Federal Highway Administration, Office of Environment and Planning Noise and Air Quality Branch, Washington, D.C., June 1995

[15] *Directive 2002/49/EC* of The European Parliament and The Council of The European Union

[16] *Serbian standard ISO 1996-1,2*, Official Gazette of Republic of Serbia,

[17] [17] *Law on environmental noise protection of Republic of Serbia*, Official Gazette of Republic of Serbia, No. 36/2009

[18] *Regulation on noise indicators, limiting values and methods for estimation of noise indicators, annoyance and detrimental effects of noise*, Official Gazette of Republic of Serbia, No. 75/2010

[19] *National strategy of sustainable development*, Government of Republic of Serbia, Belgrade 2008

[20] http://www.silence-ip.org

[21] http://www.imagine-project.org

[22] http://www.mfkv.rs/urbaNoise