THE ALTERNATIVE SOLUTION OF ABSORPTIVE NOISE BARRIERS

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Abstract: The noise from traffic on roads can unpleasantly affect humans, and therefore we must search for means to reduce the intensity of the noise. It can be achieved either by reducing the sound intensity at the source (active measures) or by preventing the transmission of sound by shielding structures (passive measures). In both cases this can be achieved in several ways, which are briefly described in the article. Two main ways are typical for passive measures - either the sound is absorbed by a solid construction and it is subsequently converted to another energy (heat), or the sound is reflected off a monitored area. The combination of these two methods of noise reduction brings modern combined acoustic barriers with higher efficiency. One of such method is presented here, but the idea of sound absorption massive structure is replaced by the idea of damped oscillation lightweight construction.

Key words: noise, traffic, barrier, stop, alternative solutions

1 Introduction

Long-term effects of noise on humans are gradually reflected on their mental and physical health. Therefore, efforts to increase protection of people from exposure to excessive noise in both at home and at a workplace, as well as outdoors. These efforts are supported by the European Union regulations, which are gradually incorporated and harmonized with the legislation of the Czech Republic. The reason for finding new ways to suppress noise is the limit values tightening.
The dominant noise source is road transport, which grows every year. Solutions to reduce this burden on the population has to be sought. One of the ways is to build noise barriers, which, together with other measures, significantly contribute to improving the conditions for a good life. Finding new ways to prevent the spread (transmission) of noise or streamlining existing barriers is still a current topic.

2 Absorption and sound reflection

The ratio of the reflected intensity Ir and the total intensity I0 creates a reflectance factor ρ [-], the ratio of the absorbed intensity Ia and total intensity I0 creates an absorption coefficient α [-]. The absorbed intensity Ia progresses further through the obstacle to its end, then the intensity It [W/m2] is radiated out. The ration of the radiated intensity It and the total incident intensity I0 is a transmittance coefficient (sound reduction) τ [-]. During the transmittance of the absorbed intensity Ia a part of intensity Iq [W/m2] converts into heat and then it is further conducted out through the structure. The image describing reflection and absorption of a sound intensity is shown in Fig.1.

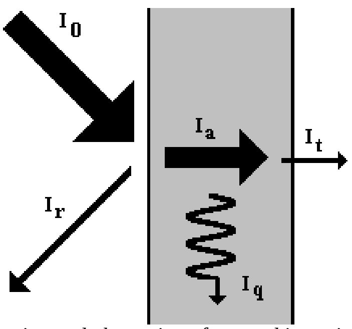

Fig.1: Reflection and absorption of a sound intensity impacting on an obstacle (Reichel, Všetička, 2009)

It is evident that factors ρ, α, τ can take values in the interval <0, 1>. (In laboratory conditions, the absorption coefficient α can take value greater than 1, but this is caused by multiple reflections of sound in a reverberation room in the lab.)
Absorption of sound waves is dependent on several other factors, i.e. the roughness and porosity of the barriers and the frequency of the incident sound. The sound waves with high frequency (short wavelength) are better absorbed. The incident sound waves cause that the grains and other particles, which is the elementary structure composed of, start to vibrate. Vibrations cause friction and immediate conversion of acoustic energy into heat. To convert a sufficient amount of energy, the area where the friction occurs, has to be adequately large. For this reason, porous substances or flawed structure substances are suitable for sound absorption. Sound is spread through fine pores, whose total area is, due to the volume, very large, respectively, the sound is well absorbed by the incurred spaces (Rubáš, 2011). On the contrary, surfaces that are smooth (glass, tile, etc.) have a low absorption coefficient, but they reflect the sound well and they have a high reflexion coefficient.

3 The measures to reduce traffic noise

Regarding unwanted traffic noise, we look for measures to reduce the noise to an acceptable level represented by health limits. For this reason, we choose active and passive methods of protection against noise pollution from transport.

4 Active methods of protection against traffic noise

Active protection means a method of reducing noise emissions from the sound source. The road traffic has started to develop this kind of protection in the 1970s due to the increasing number of cars.

4.1 Reducing vehicle noise

The European Union adopted a directive "Directive 70/157/EEC - Council Directive of 6 February 1970 on the approximation of the laws of Member States relating to the permissible sound level and the exhaust system of motor vehicles." This Directive sets limit values for noise emissions from vehicles, which push on car manufacturers to reduce noise motor vehicles. The Directive has been amended several times with stricter limits. The professionals generally considered the directive being ineffective because cars had fulfilled the emission value before the introduction of the Directive.

4.2 Reducing speed limits

The movement of a vehicle on a road makes noise, which consists of individual sound sources - engine noise, aerodynamic friction, tire rolling, bodywork vibrations etc. The dominant source of noise depends on the speed. In practice, the situation is following: in low speeds of the vehicle the overall noise defines the dominant engine noise. In a turning point and at a certain speed - the dominant source of noise is rolling. Bendtsen, Andersen (2005) mention a value inflection point at 40 km/h for motorcars and 60-70 km/h for trucks (Chocenský, 2010).
Fig. 2 shows that the reduction of speed under 50 km/h in municipalities does not produce a significant effect.

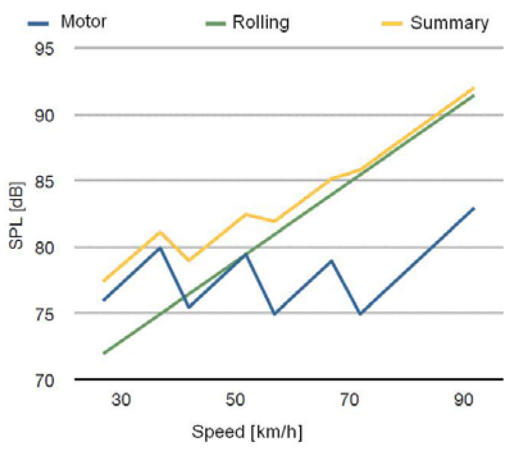

Fig. 2: The projection of the relationship between the overall vehicle noise, rolling noise and engine noise (Chocenský, 2010)

4.3 Noise reduction of tire rolling over communication

The current development of active measures focuses on finding options to reduce noise from the tire rolling on road surfaces. This is done by monitoring of properties of a road, surfaces and type of tires. The investigation revealed that the occurrence of noise on the road is caused by a particular texture (roughness) of the surface of the distortion from 0.5 m to 0.5 mm and by porosity of the surface. Therefore, new asphalt and concrete road surfaces are designed in that way to be able to moderate charater of a surface. Due to the great amount of kilometers of existing road the application of the new designed surfaces is a long-term issue, even not currently performed in a newly constructed roads in the Czech Republic, because it is expensive comparing to existing materials and commonly used materials. Examination of tire parameters (width, hardness, pattern coats, etc.) currently provides ambiguous and often divergent results, which are probably caused by non-unified assessment methodology.

5 Passive methods of protection against traffic noise

There are used various forms of barriers that protect the outside environment and inside protected spaces of buildings against noise spread. Barriers are placed either as close as possible to the source of noise (barriers along roads), or in place of immission noise (in front facade of the building or soundproof glazing). Another option might be to change the route of transport outside the protected outdoor environment (ring roads, tunnels).

5.1 Acoustic barriers landscaping

The easiest way to create a barrier is landscaping. The road is usually below the surrounding terrain (in a slot), or soil layers are swept along the road and form a terrain wall (a bank). When building a new road there is possible to use existing undulations, but it requires careful preparation at the time of processing of the project documentation. It is understandable that sometimes neither careful planning ensure expected result (an example might be the territorial area of the Netherlands). Another advantage of terrain walls is their good sound absorption due to grassing and planting of greenery, or their increase by absorption or reflective barriers, which are described in the following paragraphs.
The considerable terrain wall dimensions to achieve the same effect as a vertical barrier can be understood as a disadvantage of that solution. (Fig. 3).

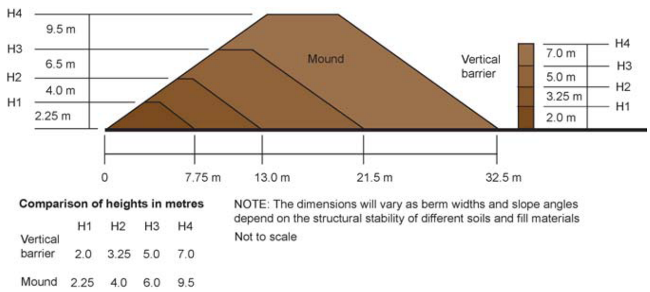

Fig. 3: The ratio of height (and width) of the terrain wall and its effectiveness in comparison with a vertical green (Kotzen, English, 2009)

5.2 Absorption barriers

Absorption barriers are the most common type of barriers in countless variations. Their popularity has been gained due to its relatively low production and assembly demands. From the technical point of view, mostly supporting dense structure with a highly porous surface exist. It could be for example the following: the reinforced concrete structure and the outer surface is profiled from cellular (porous) concrete, as it is shown in Fig. 4.

Fig. 4: Absorption wall with the surface of the autoclaved cellurar concrete (porous concrete) (Fotogalerie | Liadur.cz , 2012)

Very similar solution of an absorption barrier is the use of fibreboard concrete instead of a porous concrete. Wooden tiles which form a perforation surface can be another modification of the barrier. The improved absorptive properties can be achieved by the so called “sandwich” structure where mineral wool is added into the middle layer of the construction. There are many variations of a “sandwich” structure. As an example there can be mentioned a composition, where the structural frame consists of an outer shell of aluminum perforated plate and the inner part is filled with mineral wool with an air gap.
An interesting solution seems to be the use of natural materials, where the structural frame is covered by vines, small shrubs or scrub pines. The disadvantage of most absorbent barriers is their low aesthetics, robustness, and (often underestimated) opacity. Creating a continuous solid opaque barrier can divert the spreading sound, but it could affect human psyche – it could trigger feelings of uneasiness and isolation from society.

5.2 Reflective barriers

The principle of sound reflection was explained in the second paragraph. The reflective barrier is a barrier with a smooth surface with minimum of pores for a perfect reflection of sound. The material is chosen from the field of thermoplastics, often in clear or tinted transparent form. This type of barrier is younger than an absorption barrier. Color glazing creates an interesting aesthetic solution and transparency adds lightness in volume to the construction. The disadvantage is the fact that they do not diminish the energy of the incident sound, but only reflect it elsewhere in the environment.
Current reflective barriers are usually made of transparent thermoplastic synthetic polymer - polymethyl methacrylate (PMMA) - colloquially also called Plexiglas or acrylic glass. Contractors usually guarantee over 10 years to degradation by UV radiation.

5.3 Greenery

Greenery itself has a rather low insulation and it is chosen as a supplement to other types of barriers to decorate long lines of sound barriers. Despite the fact that the greenery varies with the seasons, creating a compact continuous greenery is not an easy process which lasts relatively long time.

5.4 The combination of reflective and absorbent barriers

There is represented noise level of passing vehicles along the measuring station in Fig.5. In the diagram the blue curve presents the progress of the sound level without a barrier. The green curve presents a flow chart of sound pressure level in the following situation: the same vehicle is passing the measuring station with an absorption barrier. The red curve shows a similar situation, only with the usage of a reflective barrier. We can observe that the effectiveness of the reflective barrier is radically reduced in the time interval when the vehicle passes close to the measuring station.

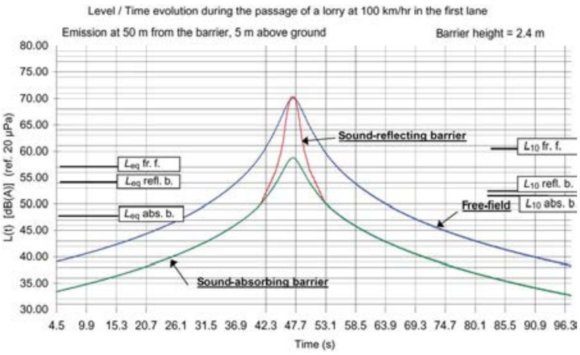

Fig.5.: Monitoring of the variations in noise level during passing a vehicle along a measuring station (Kotzen, English, 2009)

A combination of reflective and absorbent barrier seems to be interesting as it is shown in Fig. 6. Note the upper part of the barrier consists of reflective solar collectors.

Fig. 6: A combination of reflective and absorptive barrier in Copenhagen, Denmark

Absorbent panels and acrylic panels are alternately held in the area of the barrier. A similar principle of the barrier dividing on a reflective and absorptive function is used by many other manufacturers (or a combination of a barrier assembled of some products of two different suppliers). This system seems to be a reasonable compromise of absorptive and reflective barriers.

6 Absorption of sound energy by the reflective barrier vibrations

As there has been already mentioned, the reflective barrier only changes the direction of spreading the sound, but it does not reduce its intensity. Therefore, it is appropriate to ask whether it is possible to ensure at least some possibility of absorption of a reflected sound – as the combined barrier mentioned in the previous paragraph. The disadvantage of this system is to reduce the glass surface at the expense of absorption plates.

6.1 Damped oscillation

During the spreading of a sound there occur oscillating movements (waves) of molecules in a flexible environment around its equilibrium position. If these movements are periodic in time with sine curve, it is called the harmonic oscillation. Dealing with the harmonic oscillation it is useful to understand these phenomena, but these are highly idealized conditions and they almost do not occur in the real world. In fact, when a hanging weight vibrates on a spring, after a certain period the oscillation stops. This is caused by the surrounding forces (in this case in particular, the force of gravity). It dampens vibrations, and therefore such a vibration is called damped. In the real environment it is influenced by many more factors and to design such a system model is very complicated and very exacting task of calculations.

6.2 The design of alternative construction

Contemporary urban planning and architectural conception of the environment gives a clear direction to the use of advanced (composite) materials with an emphasis on increasing efficiency, "multifunctionality" and aesthetics. This is also applied to building of noise barriers, especially in the developed countries of Western Europe, North America and Japan. Although the noise level in the Czech Republic is a discussed topic, it is rather the result of commitments towards the European Union. In addition, the modern trends in the field of noise barriers are generally received slightly half-hearted by the professional public.
The most built noise barrier in the Czech Republic is the absorbent barrier made of the load-bearing reinforced concrete panel with porous outer layer (or a modification of wood-fiber concrete, etc.), which is inserted between concrete pillars. In some cities there are often promoted reflective barriers made of acrylic glass which are rather complementary absorbent barriers.

6.3 Flexible setting of the barrier

The idea of a reflective surface vibration is based on the concept of flexible setting of the reflective surface under the condition that the setting is rigid enough to prevent sagging, and at the same time flexible to dampen vibrations. Schematic setting of the barrier is shown in Fig.7.

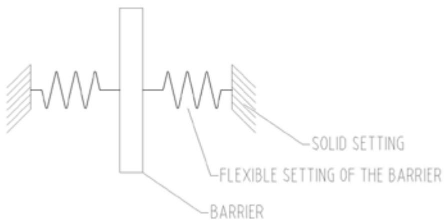

Fig. 7: Flexible setting of the reflective barrier

Assuming flexible setting of a shape variability structure, such as wraps, seems to be appropriate. The fact is that for perfect efficiency of a reflective barrier the structure must not contain any interruptions. When achieving this requirement there may be a problem in the junction of two slabs that move independently of each other. The parts which can move just in one direction of the anticipated direction of sound would be a solution of such a situation. The solution avoids the possibility of crossing slabs and the mutual displacement in one direction. Schematic representation is shown in Fig. 8.

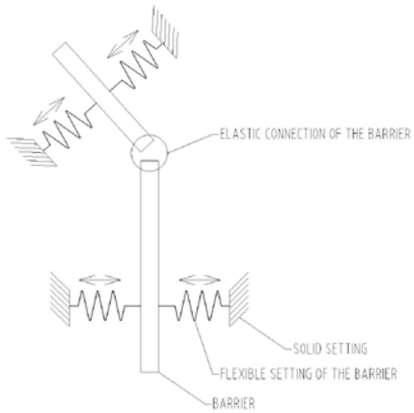

Fig. 8: Diagram of a flexible setting of two bent slabs

It is worth considering the use of laminated safety glass. Laminated glass consists of several layers of glass panes with different properties. The outer layer of glass can form a so-called self-cleaning glass. Safety and reliability increases bonding (the broken glass pane is maintained by an inner foil). Another advantage is the density, which is approximately double of PMMA. Higher weight could contribute to damping of vibrations. As the selling price of laminated glass is similar to PMMA, it would be interesting to do a more detailed analysis of these two materials.

6.4 Laboratory measurements of the effectiveness of the noise barrier

As there has been already mentioned, the model description of such a system to determine efficiency is very difficult. In practice an effectiveness of acoustic barriers is determined by a test pattern and the actual effectiveness is detected in a laboratory. The laboratory measurements and assessing the effectiveness of noise barriers were issued in technical standards "CSN 1793-1 Device for reducing road traffic noise - Test method for determining the acoustic properties - Part 1: Determination of sound absorption laboratory method" and the other "CSN 1793-1 Facilities for road traffic noise reducing - Test method for determining the acoustic properties - Part 2: determination of air sound insulation by laboratory methods." These standards assign a code, according to the identified values of sound absorption and sound insulation, that indicates their effectiveness in shielding sound.

7 Conclusion

In the first part of the article the theoretical foundation of ways to prevent the spread of the sound through a space are described. There are also presented and described the original and current trends in the construction of noise barriers, which are divided into two main streams - absorptive and reflective barriers - including their advantages and disadvantages.
In the second part the consideration that each oscillation of the system is damped by surroundings is discussed. This consideration is applied to the reflective acoustic barriers and thus presented as a possible way to improve the reflective barriers in the absorption of sound energy rather than other ways that are typical for absorptive barriers. The idea of damped oscillation of the reflective barriers, is not supported by any calculations, but generally there can be expected that an absorption of sound energy occurs. In the technical practice, to measure the effectiveness of the proposed amendments, laboratory measurements on an actual element that has the most accurate predictive value are performed.

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