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Traffic Noise Pollution in a Historical City Center - Case Study Project within Environmental Engineering Field of Study

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ABSTRACT

Noise reduction for urban areas, especially noise generated by traffic is one of the major problems in today's European cities. This paper is focused on more aspects that are addressing to traffic noise, like pavement, driver's behavior, frequency of stops, pick hours, traffic agglomerations, etc. Research leading to this paper was conducted within the project "Adaptation to the Climate Change" developed in partnership with Environmental protection Agency Sibiu, focusing for this case study on traffic related pollution in a historical city center of Sibiu. Were considered three types of pavements (cobblestones, streets covered with dense asphalt, and graded asphalt road surfaces), three types of vehicles (small passenger car, family car and SUV), and testing's were done using 3M Quest SoundPro Sonometer. Higher noise levels were registered for cobblestone and dense asphalt surfaces. Acoustic measurements and maps emphasizing studied are presented, and the identified parameters considered to be related to the traffic noise are given.

Keywords: *Environment, noise, road, traffic, urban areas.*

INTRODUCTION

Transportation is one of the major sources of environmental pollution in urban areas according to noise map established for major cities. This work is in the collaboration with Environmental Agency Sibiu, within the project Adaptation to climate change. Environmental engineering is a key field regarding the environmental issues and is coming with practical solutions for undesirable effects reduction. One of the case studies performed during the research on the project is traffic related pollution – specially undesirable and disturbing effects of noise pollution. Is this respect were investigated the nature, sources and level of noise produced in the city of Sibiu.

Several studies focused on air, water, health pollution generated by transportation (Foraster et al., 2011; Stroe et al., 2014; Ciudin et al., 2014b; Schiavon et al., 2014; Rada 2014). Nowadays, traffic related noise is the major source of environmental pollution in most European countries. Traffic noise pollution studies have been carried out by researchers around the world and more focused on road surface type like porous asphalt and dense asphalt surfaces, (Sandberg and Ejsmont, 2002; Golebiewski et al., 2003; (Griefahn et al., 2008; Paunovic´ et al., 2009; Rada et al., 2010; Istrate et al., 2014; Kumar et al., 2014). The present paper reports results from a particular case-study regarding the traffic noise levels measured on different road surfaces in historical city center of Sibiu. The traffic noise is view as problem in the chosen case-study, and for this reason for example the new waste collection plan propose a system without road transport and alternative solution for its treatment (Petrescu et al., 2010; Ciudin et al., 2014).

PRACTICE TO LEARN -– ENVIRONMENTAL AND SOCIAL IMPACT OF ROAD SURFACES

Theoretical knowledge achieved at the university courses are a very good base to start practical activities and perform real measurements, conducting to palpable results. To practice and perform filed tests are crucial for students, this kind of activities are motivating them and rise their confidence, also preparing for the future jobs. Field measurements are key factors for environmental engineering field of study. Research conducted within research grant “Adaptation to the climate change” is one of many grants developed in partnership with the universities, and such opportunities has to be a continuous stream line, especially for applied science fields, as the collaboration with industry and governmental agencies are focused on emerging issues, legislation reinforcement and world wide data dissemination.

Road surfaces influence the generation of noise by tire / road interaction and the propagation of noise from the vehicle engine and transmission system. The relevant factors for noise emission are the texture of the surface, the texture pattern and the degree of porosity of the surface structure and the speed (Kloth et al., 2008; Rada et al., 2010; Iannone et al., 2013; Istrate et al., 2014). Low-noise road surfaces today are either thin layer surfaces or porous asphalts with one or two layers. Porous asphalt has an open structure with about 20-25% air void inbuilt. As a result, it absorbs noise and drains water, thus increasing road safety. The noise reduction potential of porous asphalt is higher than for thin layers. Paving stones normally cause increased noise levels of 3-5 dB because of their very uneven surface structure (Kloth et al., 2008).

Pavement properties are influencing the comfort, the safety, the road noise the aesthetic, the maintenance frequency and the maintenance. Each urban pavement types have various advantages and disadvantages, thus the selection of urban pavement types is a multi-attribute problem (Ogut and Kutluhan, 2004) Traffic noise is affected also by the pavement age the older the pavement, the higher the noise level. Traffic noise together with the particulate can be considered an environmental pollution because it lowers the standard of living (Licitra and Ascari, 2014; Ciudin et al., 2014b; Cao and Guan, 2013; Ionescu et al. 2013; Agarwal and Swami, 2012; Torretta et al., 2012). Research in Europe and in the United States has indicated that it is possible to build pavement surfaces that will reduce the level of noise generated on roadways (Hanson, 2004). The surface types measured in this study are cobblestones pavements, dense asphalt surface and graded asphalt road surfaces.

At certain speeds the noise produced by cars is dominated by the sound of the tires rolling on the road surface. At lower speeds, below 40-50 km/h, the engine noise also becomes important. The noise produced by the tyres depends on the road surface and the type of tyre. The most important factor is the roughness of the road surface (texture) and the tread of the tyre. Everyone is familiar with the effects of driving on paving stones, cement block paving or cobblestones. Average noise levels over 65 dB can lead to health problems (Leeuwen, 2003). Using a low-noise surface reduces traffic noise at the source. A reduction of 3 dB from 76 to 73 has the same effect as either reducing the traffic by half or doubling the distance from the source of the noise (Asphaltalliance, 2004).

Tire / road interaction noise can be described by different mechanisms: The aerodynamic noise generated by air pumping, when air is forced out (and sucked in) between the rubber blocks of the tire and the road surface as the tire rolls by: this source is typically the most important in the frequency range between 1000 and 3000 Hz. If the road surface is porous with a high built-in air void, the air can be pumped down into the pavement structure, and the noise generated from air pumping will be reduced. If the pavement has an open but not porous surface structure, the air pumping noise will also be reduced to some extent. Noise from vibrations of the tire surface: the aggregate at the top layer of the pavement forms the pavement texture. When the rubber blocks of the tire hit these stones, vibration is generated in the tire structure. These vibrations generate noise typically dominated by the frequency range between 300 and 2000 Hz. With a smoother pavement structure, the generation of vibrations and noise is reduced. The vibration generated noise can also be reduced if the pavement is elastic. In the driving direction, the pavement surface and the curved structure of the tire forms an acoustical horn which amplifies the noise generated by the tire /road interaction. If the pavement side of this horn is noise absorbing, the amplification by the horn is reduced. The most effective low noise surfaces are currently porous asphalt and thin-layer asphalt. Thin layer surfaces either can be open graded asphalt concrete, stone mastic asphalt or a combination pavement. The noise reduction potential is based upon a low aggregate size of the mixture (e.g. a maximum aggregate size of 6mm on urban roads and 8mm on highways).

The noise level near the road depends on the noise generated by the traffic but, also the characteristics of the pavement surface. The noise generated by the vehicle can be classified into three general categories: the power unit noise (engine, fan, exhaust and the transmission, etc.), the aerodynamic noise, which is related to the turbulent airflow around the vehicle, and the tire/pavement noise. The power unit noise and the tire/pavement noise are the important sources of noise levels for roadside noise. The speed of the vehicle also affects the noise level. Generally it is thought that tire/pavement noise can be described as two mechanisms: the mechanical vibrations of the tire, which includes the tread impact and adhesion mechanisms and the aerodynamic phenomenon (Hanson et al., 2004).

COBBLESTONE PAVEMENTS – ENVIRONMENTAL AND SOCIAL IMPACT

All citizens are at some point affected by noise, which can have a considerable impact on people's quality of life. As stated in WHO's Guidelines for Community Noise (Berglund et al 1999, p. iii), about half of the EU citizens (EU 15) are estimated to live in areas which do not ensure acoustical comfort for residents: 40% of the population is exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dB(A) during daytime, and 20% to levels exceeding 65 dB(A). At night, more than 30% are exposed to sound levels that disturb sleep (exceeding 55 dB(A)).

In 2002, Directive 2002/49 relating to the assessment and management of environmental noise was adopted by the European Parliament and Council. This Directive will guide and steer activities on noise in Member States and large conurbations in the coming years. The directive describes environmental noise as "unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport, road traffic, rail traffic, air traffic, and from sites of industrial activity" (Directive 2002/49/EC). Ambient or environmental noise covers long-term noise, from transport and industry sources, as distinct from noise caused by neighbors, construction sites, pubs, etc.

Many streets of historical city centers within Europe are paved with cobblestones, both car roads and pedestrian areas in order to keep the old look and historic appeal of the cities. Cobblestone pavements are also common pavements in Sibiu city center. This type of surface is not universally loved. While some studies prove that walking on cobblestones is healthy, others are reporting this kind of pavements as uncomfortable and noisy. In some cities of the world, cobblestone surfaces are also a hot topic. At the same time cobblestone surfaces can be pedestrian-friendly – when they are used on the road. Firstly, because this type of surface naturally reduces vehicle speeds, decreasing the risk of pedestrian accidents. Driving on this kind of surfaces is also very noisy, which may be annoying for car passengers, but it helps to keep pedestrians alert for the proximity of vehicles. Around the world, the attitude of urban planners regarding cobblestone pavements is variable. In some places, there are plans for substituting cobblestones with asphalt. But in many cities, cobblestone surfaces are also the first choice for the pavement of newly pedestrian areas.

The main problem actually is the condition of cobblestone pavements, which often have holes and irregular surfaces. But when the pavement is well-maintained, it is a good strategy for controlling traffic speeds and enhancing pedestrian safety, especially in residential areas. In a foreseeable future we might expect a significant reduction of road traffic noise both through the use of more efficient pavements and because of the growing popularity of hybrid and full electric vehicles.

CASE STUDY

Investigated area presented in figure 1 is composed from 3 types of pavements: streets covered with cobblestones, streets covered with dense asphalt, and graded asphalt road surfaces. Table 1 bellow presents testing parameters and experimental results. Vehicles used in this study were selected as being the most representative cars for the region: family car - Dacia Logan, small passenger car - Volkswagen Polo and SUV - Dacia Duster. Road noise was recorded by 3M Quest SoundPro Sonometer at 7.5 m from the road center and at a height of 1.7 m. For each testing cars, the noise level was registered separately and later while driving in the traffic.

Figure 1: Map of historical city center of Sibiu, Romania

Vehicle speeds for each car used in the study were of 30, 50 and 70 km/h, and recorded with variable speed profiles as shown in figure 2. Records were performed according to ISO Standard 11819-1:1997: dry pavements, wind speed < 5 m/s, air temperature between 5°C and 30°C, and pavement temperature between 5°C and 50°C. The fact that cobblestones pavement generate more noise can be explained by the fact that the age of stones roads are relatively high, around 100 years, the resonance of narrow and crowded houses in the historical center contribute significantly to sound amplification. The results of this study confirm the fact that several parameters should be taken into account while measuring noise level for each street in particularly.

Table 1: Representative types of the road surfaces and testing parameters

Aggregate type	Aggregate size	Air / Surface temperature	Car speed km/h	Noise dB(A) Polo	Noise dB(A) Logan	Noise dB(A) Duster
graded asphalt	10 mm	22 ^{0}C /20 ^{0}C	30	52	53	62
			50	54	54	64
			70	56	57	66
dense asphalt	16 mm	20 ^{0}C /20 ^{0}C	30	53	55	58
			50	55	57	67
			70	58	59	70
cobblestones	100 x 100 mm^2	21 ^{0}C /19 ^{0}C	30	59	60	89
			50	62	62	93
			70	63	64	96

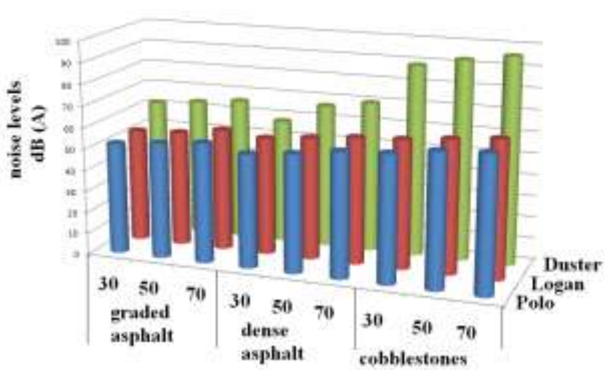

Figure 2: Noise levels for different aggregate types

It was observed that sound is absorbed in the pores of the pavement, while converted in heat energy, which is influenced by the pavement material's absorption coefficient and frequency and angle of incidence. Until recently, traffic noise was remediated through construction of noise wall barriers or purchase of right-of-way buffer zones where feasible. Recently, researchers are looking at source control issues. A major contributor of highway noise is at the tire/pavement interface, which means that quieter tires or quieter pavements could lead to substantial reductions in traffic-generated noise (Gibbs et al., 2005). Based on the testing's done with the 3M Quest SoundPro Sonometer the typical noise levels are: cobblestones is approximately 72 dB(A); dense asphalt is approximately 59 dB(A); graded asphalt is approximately 57 dB(A).

CONCLUSION

Road surface physical characteristics influence traffic-generated noise. Higher noise levels were registered for dense asphalt surfaces if compare to graded asphalt. The highest noise levels were recorded for cobblestones pavements. The authors believe that high noise level for cobblestones pavement are also due to the building resonance, being influenced by the street morphology and also by the buildings of historical center. It have been identified that a low noise road surface can be built at the same time considering safety, durability and cost using one of the following approaches (Hanson et al., 2004): a surface with a smooth surface texture using small maximum size aggregate; a porous surface, such as an open graded friction course (OGFC) with a high air void content; a pavement-wearing surface with an inherent low stiffness at the tire/pavement interface.

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