THE BALTIC JOURNAL
OF ROAD AND BRIDGE ENGINEERING

2011
6(2): 102–106

# EXPERIMENTAL INVESTIGATION OF SCRAP-TIRE CRUMB RUBBER APPLICATION IN NOISE-SUPPRESSION STRUCTURES

**Albertas Venslovas[1], Daiva Aleksandravičiūtė[2], Raimondas Leopoldas Idzelis[3]**

*Dept of Environmental Protection, Vilnius Gediminas Technical University,*
*Saulėtekio al. 11, 10223 Vilnius, Lithuania*
*E-mails: [1]albertasven@yahoo.com; [2]daiva.aleksandraviciute@gmail.com; [3]aak@vgtu.lt*

**Abstract.** Experimental investigations into acoustic properties of building materials and structures manufactured thereof were conducted in a noise-suppression chamber. A study was made of the noise-suppression efficiency of scrap-tires of different crumb rubber, using the source of constant noise from loudspeakers "Bruel&Kjaer". For experiments, crumb rubber of 3 different sizes was used: crumb rubber I with the size of 0.5–1 mm, II – 4 mm, and III – 6 mm. Scrap-tire crumb rubber was placed into the samples of experimental structures of different thickness (50 mm, 100 mm, 150 mm and 200 mm). The experimental investigation results show that the coarsest crumb rubber (6 mm) is most efficient in suppressing low-frequency sounds (up to 300 Hz), when noise level reduction gets changed in the range of 31–35 dB, depending on the samples of the experimental structure. High-frequency sounds (over 800 Hz) are most efficiently suppressed by the finest scrap-tire crumb rubber (0.5–1 mm), noise level reduction changes from 53 dB to 64 dB.

**Keywords:** scrap-tires, rubber granules, noise, noise-suppression chamber, noise-suppression structures.

## 1. Introduction

With the development of industry, constant improvement of technologies, irrational and unconditional use of natural resources throughout the world, humanity faces not only the environmental pollution problems that condition the climate change, reduction of biological diversity, decay of natural ecosystems and separate natural components, but also its economic and production activity consequences – the huge amounts of waste. Therefore waste management is one of the priority environmental protection areas in the whole of the world.

Rubber waste, especially scrap-tire waste, is one of the most hardly manageable. Its management and utilization is a very urgent ecological problem of today. In the USA alone, the average annual number of scrap- tires accounts for 233 mln (Sullivan 2006), in Europe for 180 mln (Asdrubali *et al.* 2007), in Lithuania for about 15 000 scrap-tires (Silvestravičiūtė, Karaliūnaitė 2006). Vast amounts of scrap-tires are placed in dumps, where they cause a big danger of fire. During such fires poisonous smoke is released and fires are difficult to extinguish. This causes different environmental problems and forces to permanently seek for new possibilities and ways in the field of management, utilization and recycling of scrap-tires.

Rubber waste management may be subdivided into three main stages: waste recycling, waste incineration or its storage in specially installed dumps (Kizinievič *et al.* 2006). The environmentalists seek by various legal acts to prohibit the incineration of rubber waste and their burying in solid waste facilities (Mehta *et al.* 2004).

Currently, the most popular short-term scrap-tire management methods are: tire crumbling into rubber, metal and textile particles of different sizes; tire chopping and raw material production; use of tires as a scrap in the rubber industry for the manufacture of rubber components or new tires; construction of artificial reefs on the coasts (Collins *et al.* 2002) and installation of sports routes and golf sites (Staniškis *et al.* 2004). One of the complementary methods in tire repairing is rubber as a modificator appliance in bitumen and asphalt covering. Scientific research shows that asphalt mixtures with rubberised bitumen binders are characterised by high resistance to permanent deformations (Radziszewski 2007). Rubber and respectively selected binder can be used to make other structures. For example, in last century 90s Georgia has used tires and bentonitic binder to produce sound isolation plates "Askord" (Sivilevičius 2002). Such short-term ways for waste recycling and management, however, will not solve the problem of scrap-tire management; therefore the more efficient ways of this problem solution should be sought for.

One of such ways, in our opinion, is the application of crumb rubber of scrap-tires of different particles in noise-suppression structures. This is a sufficiently new method of tire management not only in Lithuania, but also in other

ISSN 1822-427X print / ISSN 1822-4288 online doi: 10.3846/bjrbe.2011.14
http://www.bjrbe.vgtu.lt

countries. Such utilization of scrap-tires would help in solving one more ecological problem of special importance – to reduce the increased noise level in the anthropogenic environment.

As it is known, people are under the constant effect of noise generated by machines, various equipment and of some other type; it is especially felt in the places where industrial and transport centres are concentrated, e.g., in railway stations, on highways, etc. Within the urban territory, noise is factor, most irritating the human organism. Noise is the universal problem, covering all the spheres of human life and work (Rimovskis, Ramonas 2005). Vehicle-generated noise in the city centre causes a negative impact on the working capacity of the centre residents and their health and rest at night due to the frequently exceeded permissible noise levels (Grigonis, Paliulis 2009).

Investigations, carried out by the scientists from Belgium, showed that in the European Union, in the living environment, the main noise sources are: motor transport 40%, neighbours 16%, airships 11%, trains 9%, industry 7%, etc. (Descornet, Goubert 2006). And the growth of traffic flows in larger Lithuanian cities has become a difficult dilemma (Viteikienė, Zavadskas 2007). Noise suppression walls are commonly selected for protection from motor transport and train noise. In the structures, noise reflecting materials are most widely employed, though such walls may be used only in broad streets and roads. In narrow streets, noise-absorbing walls shall be constructed. This is a stimulus for the researchers to search for materials with good sound-absorbing properties.

The aim of the work is to evaluate the possibilities for the application of different-particle scrap-tire crumb rubber in noise-suppression structures in order to tackle two priority environmental problems: reduction of the amount of scrap-tires and increased noise level in the environment.

## 2. Materials and methods

Investigation of the possibilities for the application of chipped scrap-tires in noise-suppression structures was carried out in a noise-suppression chamber in *Dept of Environmental Protection of Vilnius Gediminas Technical University*. The chamber is specially intended for investigation of acoustical properties of building materials and structures manufactured thereof (Grubliauskas, Butkus 2009; Grubliauskas 2009).

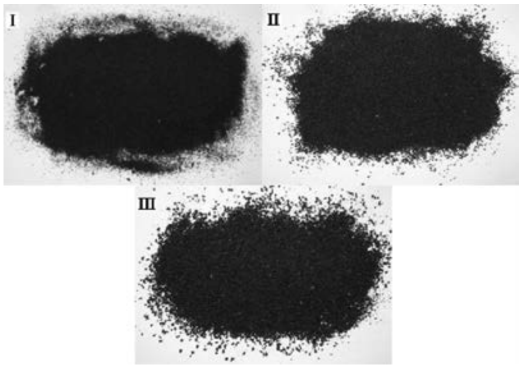
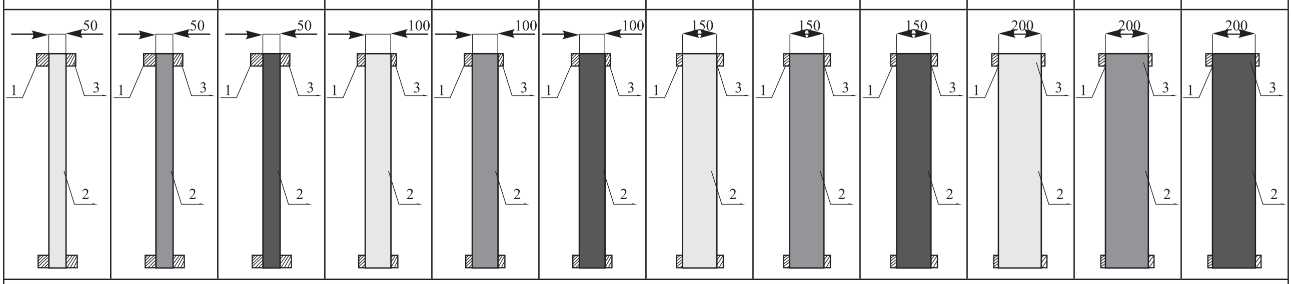



**Fig. 1.** Scrap-tire particles: crumb rubber I – 0.5–1 mm; crumb rubber II – 4 mm; crumb rubber III – 6 mm

In the noise-suppression chamber, rectangular particles of scrap-tire crumb rubber of three different sizes underwent study: crumb rubber (finest) I with the particle size of 0.5–1 mm, crumb rubber II – 4 mm and crumb rubber (coarsest) III – 6 mm (Fig. 1). The samples of experimental structures, which are of rectangular parallelipiped form, 1.0×1.0 m in size, are filled with those crumb-rubber particles. The samples of experimental structures of four different thicknesses were used for investigation: 50 mm, 100 mm, 150 mm and 200 mm (Table 1). A grid is fixed on the wooden frame of the structures.

During experiments, in the noise-suppression chamber, for the structures under study (samples of experimental structures 1, 4, 7, 10 (Table 1)), the sound-absorption coefficient α, which describes sound energy loss in the material, is determined.

**Table 1.** Samples of the experimental structures




| No 1 | No 2 | No 3 | No 4 | No 5 | No 6 | No 7 | No 8 | No 9 | No 10 | No 11 | No 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 – grid | | | | | | | | | | | |
| 2 – crumb rubber I | 2 – crumb rubber II | 2 – crumb rubber III | 2 – crumb rubber I | 2 – crumb rubber II | 2 – crumb rubber III | 2 – crumb rubber I | 2 – crumb rubber II | 2 – crumb rubber III | 2 – crumb rubber I | 2 – crumb rubber II | 2 – crumb rubber III |
| 3 – frame | | | | | | | | | | | |

The coefficient α value changes within the range 0–1. The higher the value of the coefficient obtained the better sound absorption of the structure. Volumetric sound-absorption coefficient α is found from the Eq (1):

$$\alpha = \frac{\ln\left(\frac{I}{I_0}\right)}{l}, \quad (1)$$

where $I$ – intensity of sound-absorbed wave, W/m$^2$; $I_0$ – sound-wave intensity at the threshold of audibility, $I_0 = 10^{-12}$ W/m$^2$; $l$ – thickness of structure, cm (Kaulakys 1999).

The sound level (dB), but not the sound intensity, is measured in the noise-suppression chamber, and therefore if the relation between those values is known, i.e. $L = 10\lg\left(\frac{I}{I_0}\right)$, where $I_0 = 10^{-12}$ W/m$^2$, the value of the volumetric sound absorption coefficient is found:

$$\alpha = \frac{\ln 10^{\frac{(L_1 - L_2)}{10}}}{l}, \quad (2)$$

where $L_1$ – medium sound pressure level in the source room, dB; $L_2$ – medium sound pressure level in the target room, dB.

The density of different scrap-tire crumb rubber is determined. Scrap-tire crumb rubber is poured into the cylinder with the volume of $10^{-3}$ m$^3$. Crumb rubber density is calculated according to the Eq (3):

$$\rho = \frac{x_2 - x_1}{V}, \quad (3)$$

where $x_1$ – cylinder mass, kg; $x_2$ – cylinder mass with crumb rubber, kg; $V$ – cylinder volume, $V = 10^{-3}$ m$^3$.

Scrap-tire crumb rubber of different sizes and the cylinder were weighed thrice. For weighing, the scales BP 3100 P, which may weigh max 3100 g, were used.

The accuracy of experimental measurements and data reliability is evaluated by calculating the average square deviation of the arithmetic mean of measurement data and absolute error (since $n < 25$, the errors are evaluated by Student method, where $p = 0.95$).

## 3. Results and evaluation

During investigations, the ability of different scrap-tire crumb rubber to absorb noise was determined. The noise suppression characteristic, comprising the difference of the sound level in the source room, and the sound level in the target room, was studied. The results obtained make it possible to compare the acoustical properties of different scrap-tire crumb rubber, using the constant noise propagating source.

The experimental investigation results show that if the samples of experimental construction of 50 mm in thickness are filled with crumb rubber, the different noise level reductions are obtained (Fig. 2). The data received allow the statement to be made that for low-frequency reduction (up to 300 Hz) it would be best to use crumb rubber III (6 mm), the noise level reduction of which reaches even 32 ± 0.3 dB. Investigations carried out with crumb rubber I and II show that the use of those materials for suppression of low- and medium-frequency sounds (300–800 Hz) is inefficient, since the sound waves of the said frequencies are poorly suppressed (Fig. 2). For suppression of high-frequency (over 800 Hz) sounds, it would be most efficient to use the finest crumb rubber (0.5–1 mm), since noise level reduction of this crumb rubber reaches 53 ± 0.1 dB.

The results obtained also show that the structure of samples, 100 mm in thickness, filled with different crumb-rubber tire particles, at low frequencies (up to 300 Hz) suppresses the noise better when crumb rubber III (6 mm) is used. In this case the noise level reduction reaches 35 ± 0.1 dB (Fig. 3). For high-frequency (over 800 Hz) sound suppression it is best to use the finest crumb rubber (0.5–1 mm), since noise level reduction of this crumb rubber reaches 57 ± 0.2 dB.

Experimental investigation data, obtained when filling the structure of samples, 150 mm in thickness, with crumb rubber of different sizes, show that at low frequencies (up to 300 Hz) all 3 types of scrap-tire crumb rubber suppress the sound in a similar way, i.e. noise level reduction for crumb rubber II and III reaches 28 ± 0.1 dB, and for crumb rubber I – 25 ± 0.1 dB (Fig. 4). For suppression of medium-frequency sounds (300–800 Hz), most efficient is the use of crumb rubber II and III, as their noise level reduction reaches up to 34 ± 0.2 dB. For suppression of high frequency (over 800 Hz) sounds, however, the finest crumb rubber (0.5–1 mm) is most efficient for use, since noise level reduction of this crumb rubber reaches 60 ± 0.3 dB.

When studying the sample of experimental structures, 200 mm in thickness, we determined that if the structure is filled with scrap-tire crumb rubber of different sizes, the use of crumb rubber III (6 mm) would be most efficient for low-frequency (up to 300 Hz) reduction, as noise level reduction in this case reaches 33 ± 0.1 dB (Fig. 5). And for high-frequency (over 800 Hz) sound suppression the finest crumb rubber (0.5–1 mm) would be used, since noise level reduction with this crumb rubber reaches 64 ± 0.2 dB.

Filling the sample of experimental structures, 200 mm in thickness, with the finest crumb rubber (0.5–1 mm) we receive that this crumb rubber suppresses high-frequency (over 800 Hz) sounds most efficiently, whereas low-frequency (up to 300 Hz) sounds are suppressed most poorly in this case (Fig. 6).

The density calculation results of scrap-tire crumb rubber of different sizes (Table 2) show that the coarsest crumb rubber (6 mm) has the highest density (463.44 ± 0.02 kg/m$^3$) and therefore best suppresses low-frequency sounds (up to 300 Hz), and finest crumb rubber density is by 16% lower, therefore suppresses well high-frequency sounds (over 800 Hz).

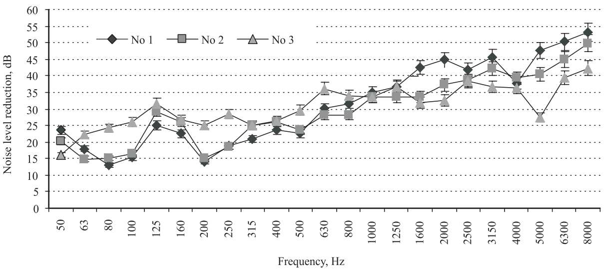



**Fig. 2.** Results of noise level reduction in the samples of experimental structures (No 1, No 2, No 3 – sample structures in Table 1)

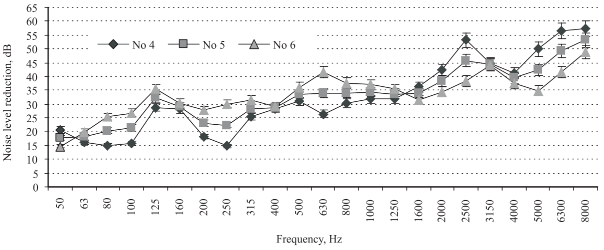



**Fig. 3.** Impact of No 4, No 5 and No 6 samples of experimental structures (Table 1) on noise suppression efficiency

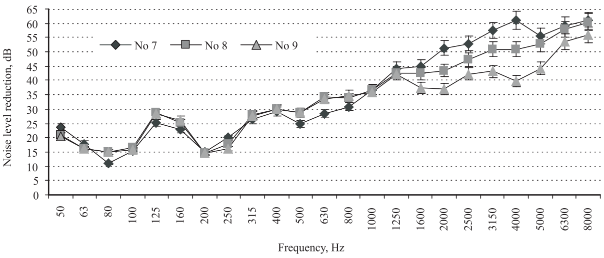



**Fig. 4.** Results of noise level reduction of samples of experimental structures No 7, No 8 and No 9 (Table 1)

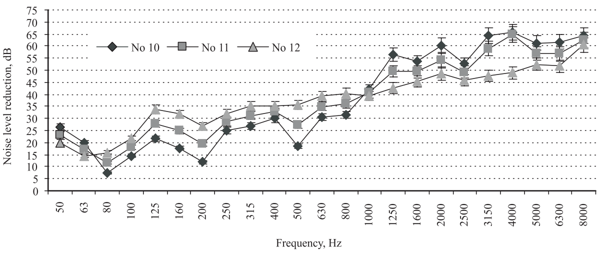



**Fig. 5.** Impact of No 10, No 11 and No 12 samples of experimental structures (Table 1) on noise suppression efficiency

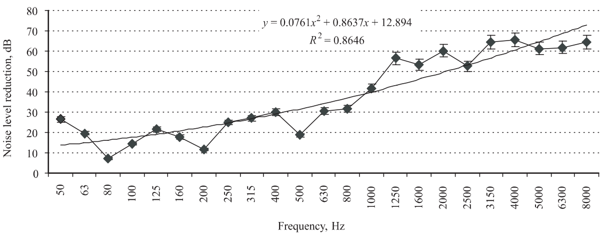



**Fig. 6.** Noise level reduction in the sample of experimental structure No 1 (Table 1)

**Table 2.** Specifications of scrap-tire crumb rubber of different sizes

| Material | Mesh size, mm | Density, kg/m$^3$ |
|---|---|---|
| Crumb rubber I | 0.5–1 | 387.44 |
| Crumb rubber II | 4 | 442.65 |
| Crumb rubber III | 6 | 463.44 |

Experimental investigation results confirm the data of other authors where it is stated that rubber sound absorption efficiency depends on the size of rubber particles and layer thickness (Pfretzschner 2002). It was also determined that sound absorption of scrap-tire crumb rubber of different sizes decreases, and most optimum sound absorption is reached with crumb rubber ~1 mm in size. Sound absorption efficiency at high frequencies increases with the reduction of crumb rubber size (Asdrubali *et al.* 2007, 2008).

Sobral *et al.* (2003) carried out experiments in a Kundt's tube, and the following values of sound absorption coefficient of crumb rubber (0.5–1.5 mm in size) were received: at the low-frequency band (100–315 Hz), the average sound absorption coefficient equals to 0.2, whereas according exploratory data, while filling structures of different thickness with finest crumb rubber, the average sound absorption coefficient values are by 15–35% higher (0.23–0.27). For the medium-frequency band (400–1250 Hz) the average of sound absorption coefficient values, received by the same authors, equaled to 0.59, and according to investigation data, when filling structures of different thickness with finest crumb rubber, the average sound absorption coefficient values are by 34–43% lower (0.34–0.39). At high frequencies (1600–4000 Hz), while filling samples of experimental structures, 150 mm and 200 mm in thickness, with finest crumb rubber, the average sound absorption coefficient values received were by 7–21% higher, as compared to Sobral *et al.* (2003) experimental data (the average value of sound absorption coefficients is equal to 0.53).

## 4. Conclusions

The results, obtained after performance of an experiment in a noise-suppression chamber, show that at high frequencies (over 800 Hz) scrap-tire crumb rubber of all 3 sizes (0.5–1 mm, 4 mm and 6 mm) are most effective in noise suppression when the thickest sample of experimental structures (200 mm) is employed.

Low-frequency sounds (up to 300 Hz) are suppressed most effectively by the coarsest crumb rubber (6 mm), when the samples of experimental structures (50, 100 and 200 mm) are filled with it. Noise level reduction changes in the range of 32–35 dB.

High-frequency sounds (over 800 Hz) are suppressed most effectively by the finest crumb rubber (0.5–1 mm). When filling the samples of experimental structures of different thickness, 50, 100, 150 and 200 mm, with this crumb rubber, noise level reduction changes from 53 dB to 64 dB. If thickness of finest crumb rubber increases by 50 mm, noise level suppression efficiency increases by 3–4 dB.

To suppress high-frequency (1600–4000 Hz) sound, it is recommended to use noise-suppression structures, manufactured from finest crumb rubber (0.5–1 mm), which are 150 mm and 200 mm in thickness. The sound absorption values of such structures equal to 0.57 and 0.64.

## References


Asdrubali, F.; D'Alessandro, F.; Schiavoni, S. 2008. Sound Absorbing Properties of Materials Made of Rubber Crumbs, in *Acoustics '08 Paris*. June 29 – July 4, 2008, Paris. 12 p.

Asdrubali, F.; Baldinelli, G.; D'Alessandro, F. 2007. Evaluation of the Acoustic Properties of Materials Made from Recycled Tyre Granules, in *Proc. of the 36th International Congress and Exhibition on Noise Control Engineering "Inter-Noise 2007"*. August 28–31, 2007, Istanbul, Turkey. 11 p.

Collins, K. J.; Jensen, A. C.; Mallinson, J. J.; Roenelle, V.; Smith, I. P. 2002. Environmental Impact Assessment of a Scrap Tyre Artificial Reef, *ICES Journal of Marine Science* 59 (Suppl): S243–S249.
doi:10.1006/jmsc.2002.1297

Descornet, G.; Gaoubert, L. 2006. *Noise Classification of Road Pavements*. Task 1: Technical Background Information, Draft report. 58 p.

Grigonis, V.; Paliulis, G. M. 2009. Traffic Restriction Policies in Lithuanian Cities Based on Vilnius Case Study, *The Baltic Journal of Road and Bridge Engineering* 4(1): 36–44. doi:10.3846/1822-427X.2009.4.36-44

Grubliauskas, R. 2009. *Aplinkos triukšmo ir jo mažinimo, taikant lengvas konstrukcijas, tyrimai bei skaitinis modeliavimas* [Research and Digital Modelling of Environmental Noise and its Reduction by Applying Light Structures]: PhD thesis. Vilnius: Technika. 138 p. ISBN 978-9955-28-431-4.

Grubliauskas, R.; Butkus, D. 2009. Chamber Investigation and Evaluation of Acoustic Properties of Materials, *Journal of Environmental Engineering and Landscape Management* 17(2): 97–105.
doi:10.3846/1648-6897.2009.17.97-105

Kaulakys, J. 1999. *Fizinė technologinė aplinkos tarša. Triukšmas ir vibracija* [Physical and Technological Environmental Pollution: Noise and Vibration]. Vilnius: Technika. 100 p.

Kizinievič, O.; Mačiulaitis, R.; Kizinievič, V. 2006. Use of Rubber Waste in the Ceramic, *Materials Science* 12(3): 237–242.

Pfretzschner, J. 2002. Rubber crumb as granular absorptive acoustic material, in *Proc. of the Forum Acusticum, Sevilla*, MAT-01-005-IP.

Radziszewski, P. 2007. Modified Asphalt Mixtures Resistance to Permanent Deformations, *Journal of Civil Engineering and Management* 13(4): 307–315.

Rimovskis, S.; Ramonas, Z. 2005. *Apsauga nuo triukšmo* [Protection against Noise]. Šiauliai: Šiaulių universiteto leidykla. 76 p. ISBN 9986-38-621-7.

Mehta, Y.; Jahan, K.; Laicovsky, J.; Miller, L.; Parikh, D.; Lozano, A. L. 2004. Evaluation of the Effect of Coarse and Fine Rubber Particles on Laboratory Rutting Performance of Asphalt Concrete Mixtures, *Journal of Solid Waste Technology and Management* 30(2): 75–91.

Silvestravičiūtė, I.; Karaliūnaitė, I. 2006. Comparison of End-of-life Tyre Treatment Technologies: Life Cycle Inventory Analysis, *Aplinkos tyrimai, inžinerija ir vadyba* [Environmental Research, Engineering and Management] 35(1): 52–60.

Sivilevičius, H. 2002. Asfaltbetonio mišinio gamybos kokybės gerinimo teoriniai principai ir praktiniai būdai [Theoretical Principles and Practical Methods of Improving the Quality of Asphalt Mix Production], in the *Conference "Environmental Engineering"*. May 23–24, 2002, Vilnius, Lithuania. Vilnius: Technika. 82 p.

Sobral, M.; Samagaio, A. J. B.; Ferreira, J. M. F.; Labrincha, J. A. 2003. Mechanical and Acoustical Characteristics of Bound Rubber Granulate, *Journal of Materials Processing Technology* 142(2): 427–433. doi:10.1016/S0924-0136(03)00623-X

Staniškis, J. K.; Bagdonas, A.; Česnaitis, R.; Karaliūnaitė, I.; Miliūtė, J.; Silvestravičiūtė, I.; Šleinotaitė-Budrienė, L.; Varžinskas, V.; Uselytė, R. 2004. *Integruota atliekų vadyba* [Integrated Waste Management]. Kaunas: Technologija, 223–227.

Sullivan, J. P. 2006. *An Assessment of Environmental Toxicity and Potential Contamination from Artificial Turf using Shredded or Crumb Rubber*. Ardea Consulting. 43 p.

Viteikienė, M; Zavadskas, E. K. 2007. Evaluating the Sustainability of Vilnius City Residential Areas, *Journal of Civil Engineering and Management* 13(2): 149–155.


*Received 31 May 2010; accepted 2 February 2011*