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RUCONBAR – INNOVATIVE NOISE PROTECTION SOLUTION MADE OF RECYCLED WASTE TYRES

Stjepan Lakušić, Dubravka Bjegović, Ivo Haladin, Ana Baričević, Marijana Serdar

laki@grad.hr, dubravka@grad.hr, ihaladin@grad.hr, abaricevic@grad.hr, mserdar@grad.hr

University of Zagreb, Faculty of Civil Engineering, Kaciceva 26, Zagreb
CROATIA

Abstract: *Ever increasing public demand for reduction of traffic noise levels in urban environment generates a growing demand for better noise protection solutions. Road and railway noise barriers are the most common and cost effective choice. Construction of noise barriers is possible out of various materials such as wood, steel or concrete, but due to strict market conditions and demands for durability and static stability concrete noise barriers are most frequently used across Europe. In order to achieve better sound absorption, concrete panels incorporate expanded clay or wood fibres as a noise absorbing layer. In order to replace expanded clay or wood fibres for the production of concrete noise barriers, Faculty of Civil Engineering University of Zagreb developed a new approach for forming the absorbing layer. Instead of using natural resources, whose usage degrades the environment and natural balance, it incorporates rubber granules - a product of end-of-life tyre recycling. Tested and applied solution is the innovative type of ecologically sound concrete noise barriers - Rubberized Concrete Noise Barriers or RUCONBAR. Namely, concrete can incorporate rubber granules from recycled tyres to form a porous noise-absorptive layer. Paper describes a process of product development together with optimal concrete mixture and design preparation and market analysis. Market analysis investigates its strong points and weaknesses compared to similar products on the market. Functionality aspect clearly demonstrates that RUCONBAR rubber concrete, expanded clay concrete and wood fibre concrete can be consider equal in terms of functionality. They share similar acoustic properties, the same durability and maintenance requirements, and excellent static stability. They however differ in the environmental aspect which gives RUCONBAR a competitive advantage over the conventional noise barriers by incorporation of 40% recycled rubber and only 40% of natural resources (aggregate). Furthermore, the paper presents the first implementation of RUCONBAR as a noise protection solution for Zagreb ZOO.*
Key words: *recycled rubber, concrete barriers, noise protection, absorption*

INTRODUCTION

Given the increased public demand for reduced traffic noise levels, there is a growing demand for better noise protection solutions out of which, highway and railway noise barriers are the most common and cost effective choice. As such, noise barriers concepts continue to strive for innovative and visually acceptable solutions, especially for urban areas. Nowadays, noise barriers are usually made out of concrete, wood or steel. Concrete barriers are usually combined with expanded clay panels within noise absorbing layer. In June 2002, EU delivered Directive 2002/49/EC [1] relating to

the assessment and management of environmental noise that provide directions for noise protection. According to the EU Transportation Strategy White paper – "European transport policy for 2010: time to decide" [2], large investments in roads construction are planned in these areas. Noise has been assessed as the one of the main environmental problems in Europe and traffic is one of the main sources of noise. The Republic of Croatia, neighbouring countries and new EU member states harmonized their regulations with the EU Directive 2002/49/EC [1] relating to the assessment and management of environmental noise and recommendations regarding noise protection. In other words, all roads and railways that are planned for construction or rehabilitation have to include noise protection solutions. On other hand, starting from year 2006 EU Directive 1999/31/EC [3] clearly prohibits any kind of disposal of waste tyres in environment. Predictably, quantity of waste tyres available for recycling significantly increased.

The proposed solution is to develop a concept of utilisation recycled tyres as new material for reduction of urban noise pollution, called **RUCONBAR**. The concept provides benefits in three directions which are: (1) environmental protection by preventing disposal of recyclable materials on landfills, (2) preventing landscape degradation from clay excavation by introducing new material and (3) noise protection of urban areas by utilisation of recycled materials. In its nutshell, it is a concrete based solution composed of absorbing and bearing layer (Figure 1). By incorporating 40 % rubber granules recycled from waste tyres recovered from end-of-life vehicles, absorbing layer is innovative solution in production of noise barriers. The outcome of this concept is a product that reduces utilisation of clay with recycled rubber made out of waste tyres for noise absorbing layer. For orientation, 1 kilometre of noise protection barriers of 3 m height (3 000 m^2 of noise protection) uses 46.4 t of recycled rubber granules which are obtained by recycling 7 800 waste car tyres.

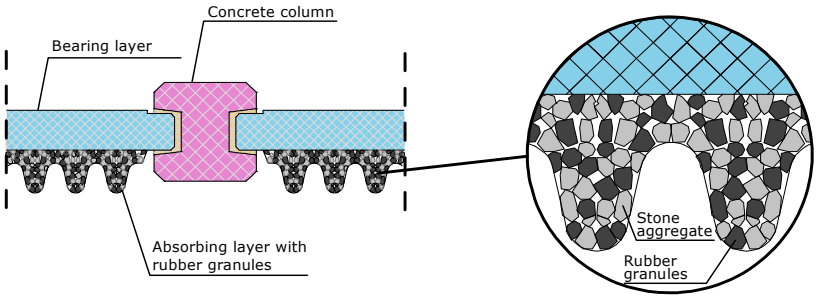

Figure 1 *RUCONBAR cross section*

Namely, concrete can incorporate rubber granules from recycled tyres to form a noise-absorptive layer of Rubberised Concrete Noise barriers (RUCONBAR) which has been tested, proven and patented by the Faculty of Civil Engineering, University of Zagreb by 2010.

DEVELOPMENT OF THE IDEA

For the production of high absorptive lightweight concrete with optimised mechanical and durability properties rubber granulates were used in concrete mixture as substitution of part of the aggregate. During development phase was observed that presence of larger amount of rubber granulates (40% of aggregate volume was replaced with rubber granulates) in concrete mixture has major influence on properties of fresh and hardened concrete. In order to enhance the concrete workability and ease the placement during production, chemical admixture (superplasticizer) was added. Presence of superplasticizer helps concrete mixture to obtain needed workability during casting period. Investigated mixtures with main differences in mixture design are shown in Table 1.

Addition of rubber particles in to the concrete mixture usually causes decrease of mechanical and increase of penetrability properties compared to normal concrete. On the other hand, it was proven that addition of rubber granulates enhances concrete resistance to freezing and thawing, mechanical impact, chloride diffusion and fire, which are all important properties for materials utilised as part of the infrastructural system [5][6][7]. The rubber granulates will influence mechanical and penetrability properties depending on two major parameters: a) adhesion between the rubber and cement matrix and b) quality of the rubber granulates/cement paste interface, which is highly influenced on the presence of zinc stearate in tyre formulation [8].

Table 1 *Investigated concrete mixtures with addition of rubber particles*

	Mixture																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Cement	8%	11%	11%	12%	13%	11%	11%	10%	10%	9%	9%	9%	8%	8%	8%	8%	10%	10%
Water	11%	6%	7%	5%	3%	5%	4%	5%	5%	5%	5%	5%	5%	5%	5%	5%	6%	5%
Air	0%	7%	5%	5%	7%	6%	5%	3%	3%	2%	2%	3%	3%	3%	3%	3%	5%	4%
Mineral admixture	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%	3%	3%	0%	0%
Chemical admixture	0%	1,88%	1,92%	1,82%	1,68%	1,37%	1,40%	0,09%	0,09%	0,08%	0,08%	0,09%	0,08%	0,08%	0,09%	0,09%	1%	1%
Waste	0%	22%	23%	23%	47%	54%	78%	35%	35%	53%	53%	35%	53%	53%	34%	34%	31%	40%
Natural resources	81%	52%	53%	54%	28%	23%	0%	48%	48%	31%	31%	48%	31%	31%	47%	47%	47%	40%

The most important property of the described noise protection barriers is the ability of noise absorption. Acoustical absorption is the property of any material that changes the acoustic energy of sound waves into another form (often heat). Due to the fact that RUCONBAR contains untested material in its absorbing layer the testing of absorbing properties has been necessary in order to determent its sound absorbing behaviour. The testing has been conducted through all the phases of material development (18 mixtures) on small laboratory samples (Figure 2) in Kundt's tube.

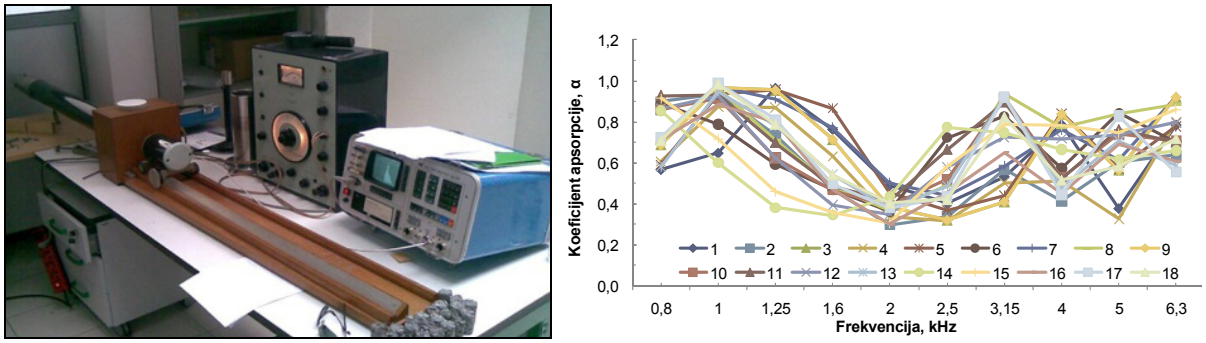

Figure 2 *Sound absorption properties of small samples*

After conducting described testing on small samples, an optimal mixture has been selected to create real scale sample (10 m^2 panels) which has been tested in a reverberation room in accordance with HRN EN ISO 354:2004 i HRN EN 1793-1:1999 standards (Fig. 3).

Fig. 3 *Real scale test samples in the reverberation room*

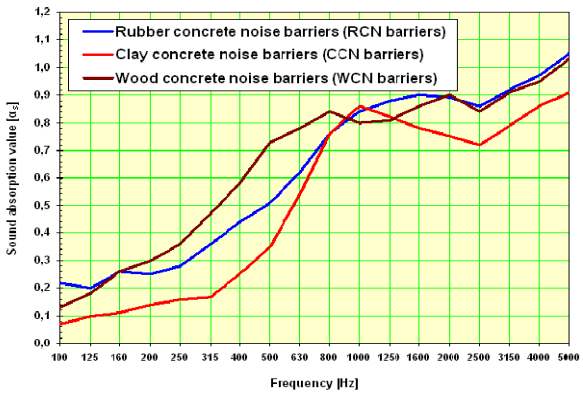

Fig. 4 *Comparison of sound absorption coefficient*

The results of the sound absorption coefficient (α_S) testing on real scale samples are described as a function of frequency. Following symbols have been used for result description:

f – mean frequency of third of octave,
α_S – sound absorption coefficient,
DL_α – sound absorption value expressed as a difference of A-valued sound pressure levels.

Description of results has been given along with the results of sound absorption coefficients (α_S) of noise protection barriers with absorbing layer made of expanded clay and wood-concrete (Fig. 4). According to the measurement results in accordance with the current standards, RUCONBAR noise protection barrier has been listed under A2 class of sound absorption based on the sound absorption value DL_α = 6dB. Some of the competitive products can achieve higher classes of sound absorption, which greatly depends on the cross section of the absorption surface. The comparison of sound absorbing properties has been conducted on samples with similar absorbing surface cross sections. Conducted testing indicate satisfying absorption properties and the possibility of their improvement through further development with the goal of reaching class A3 of sound absorption.

Further research includes production of panels with different cross-section of absorption surface and its testing in reverberation room with the goal of achieving higher class of sound absorption properties. Implementation and on-site testing of RUCONBAR panels on a test section of highway is also a part of the further product development (Figure 5).

Figure 5 *Installation of test section of RUCONBAR panels*

COMPARISON OF RUCONBAR WITH SUBSTITUTE SOLUTIONS

Comparing the recent experiences in material usage for noise barriers (Figure 6), it can be easily concluded that concrete noise barriers have favourable market characteristics in terms of price and performance. The common absorbing layer at concrete noise barriers is expanded clay.

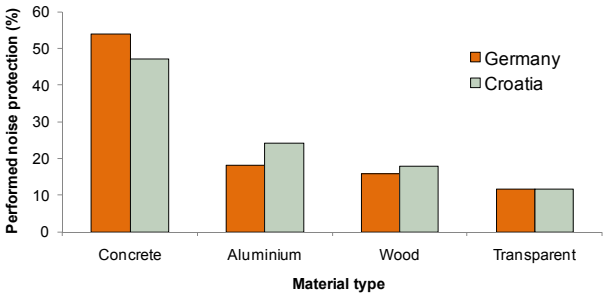

Figure 6 *Materials in noise barriers products*

Comparison of noise barriers can be conducted only if comparison is done within the same materials; following RUCONBAR should be compared with concrete barriers. Similar in appearance, almost equal from functionality aspect, they differ only by environmental sustainability. In accordance with South-eastern European climate, concrete barriers are often the only possible solution for reduction of noise pollution. Robustness and weight of concrete noise barriers ensures them a satisfactory static stability especially in areas with strong winds like those present in Croatia.

If RUCONBAR is compared with much light-weighted noise barriers, such as those made of wood, aluminium or Plexiglas then emphases should be made on fact that those barriers can hardly be compared with concrete barriers in terms of functionality. Use of those materials for production of barriers requires regular maintenance, which ultimately significantly raises costs and brings in question the justification of their application. Such noise barriers have commonly been used in the smaller urban centres where they fit far better in the present architecture. However, development of

new concrete solutions and possibility for design show that nowadays concrete can compete on an equal basis with those solutions.

Although worldwide similar solutions incorporating recycled rubber in concrete for noise protection can be found, in Europe are present only noise barriers made from recycled rubber bounded by polyurethane and glued on concrete bearing layer. Even though it can seem that implementation of those barriers is environmentally justified, because of the large share of waste materials in absorption layer, it was demonstrated that presence of only rubber in absorption layer can be environmentally hazardous. It is widely known that tyres are extremely flammable material which can cause long-lasting fires with significant emission of greenhouse gases. So the use of those solutions can result in safety and legal issues in case of inflammation of vegetation, accidents or vandalism, due to rapid spread of flame together with dense smoke. In order to reduce rubber flammability, flame and smoke retardants are introduced into those mixtures during manufacturing process which afterwards significantly reduces recyclability of those materials. RUCONBAR is made out of 40% recycled rubber by total volume; incorporation of rubber granulates in concrete significantly reduced RUCONBAR flammability due to presence of aggregate and cement paste. Reduced flammability and better appearance present RUCONBAR as environmentally more acceptable solution.

ECOLOGICAL IMPACT OF RUCONBAR

RUCONBAR is eco innovative product with clearly defined **environmental benefits and resource efficiency in a life-cycle approach**: *environmental performance* (through significant decrease of carbon footprint and material recycling), *better use of natural resources* and easy visible *economic sustainability*. RUCONBAR reaches two major environmental problems, noise pollution and waste tyres management through ecologically and economically more efficient way – using waste to develop new product while the product itself is used for noise pollution protection. Improved environmental performance was evaluated considering entire Life Cycle of RUCONBAR comparing it with expanded clay noise barriers. Expanded clay noise barriers are most frequently applied barriers in Croatian market. Life-cycle analysis of CO_2-eq savings (resources - production - placement & use - disposal/recycling) is based on available data for life cycle of RUCONBAR and of noise barriers from expanded clay (Figure 7). Results indicate that RUCONBAR achieves 31 % of total CO_2-eq avoidance in the respect to the expanded clay.

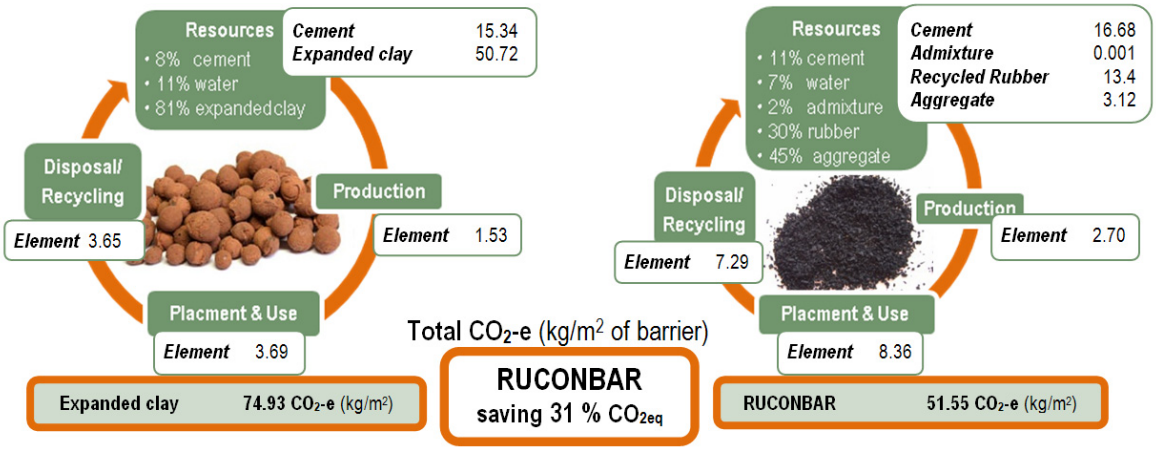

Figure 7 *Comparison of noise barriers production process: expanded clay vs. recycled rubber*

Comparing the recent experiences in waste tyre recycling of EU members with Croatian and South-eastern European countries it is obvious that these markets obtain large amounts of abandoned waste tyres. On the other hand, production of concrete noise barriers with expanded clay is limited by the amount of available clay, because required quality clay needed for production of expanded clay is available only on few excavation sites in Europe. In addition, the excavation leaves behind devastated environments whilst production of expanded clay by burning of natural clay in rotary kilns causes significant gas emissions into the atmosphere.

In respect of **resource efficiency**, RUCONBAR project is reducing exploitation of raw material and contributing to the optimal use of natural resources. Replacing 50% volume of natural aggregate in concrete mixture by recycled waste tyres generates direct savings of 77 kg of aggregate per m^2 of noise barrier. Each m^2 of noise barrier using RUCONBAR saves 33 kg of expanded clay or 6.6 kg of natural clay. If we consider that RUCONBAR could fully replace noise barriers with expanded clay in Croatia, in three years savings in natural clay could reach 0.3 million kg only in Croatia. Additional value of RUCONBAR is that it is further reusable upon deconstruction.

CONCLUSION

Innovative and environmentally friendly concept of RUCONBAR is applicable in all EU and beyond but it is most applicable in those countries that have need for waste tyres management and demand for noise protection barriers due to underdeveloped traffic infrastructure. Every year about 3.4 million tonnes [9] of waste tyres are generated in Europe. In the EU15, only 5 % of waste tyres are uncontrollably disposed in landfills. In the 12 new EU member states and Western Balkan, averagely 29 % of waste tyres are disposed in landfills, annually. With the introduction of EU Directive in those countries, which bans landfilling of whole (July 2003) and shredded (July 2006) tyres, it is clear that there is need to increase recycling capacities and develop markets for utilising recycled tyres. RUCONBAR provides an opportunity to accelerate transit and adoption period of these countries and reduce the gap between them and EU15 countries in the field of noise pollution and waste tyres management. RUCONBAR production in each country of these contributes jointly to the implementation of the Waste Management which yields significant ecological benefits in reduction of noise pollution and waste tyres disposal. Furthermore, it also contributes to economic growth and environmental performance, all conformed to Lisbon strategy.

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RUCONBAR – ИНОВАТИВНО РЕШЕНИЕ ЗА ЗАЩИТА ОТ ШУМА, НАПРАВЕНО ОТ РЕЦИКЛИРАНИ ОТПАДЪЧНИ ГУМИ

Stjepan Lakušić, Dubravka Bjegović, Ivo Haladin,
Ana Baričević, Marijana Serdar

University of Zagreb, Faculty of Civil Engineering, Kaciceva 26, Zagreb
CROATIA

Ключови думи: *рециклирана гума, бетонови бариери, защита от шум, поглъщане.*

Резюме: *Нарастващата обществена потребност за намаляване на нивата на шума, предизвикан от пътното движение в градска среда, генерира нарастващо търсене на по-добри решения за защита от шум. Пътните и железопътните шумозащитни бариери са най-често срещаните и представляват ефективен избор от гледна точка на цените. Шумозащитни бариери могат да се изградят от различни материали като дърво, стомана или бетон, но поради пазарните условия и изискванията за издръжливост и статична стабилност в цяла Европа най-често се използва бетон. За да се постигне по-добро поглъщане на звука, бетоновите панели включват глина или дървесни влакна като шумопоглъщащ слой. С цел да се замени глината или дървесните влакна за производство на шумозащитни бетонови бариери, Строителният факултет при Университета в Загреб е разработил нов подход за формиране на абсорбиращ слой. Вместо да се използват природни ресурси, чието използване влошава околната среда и естествения баланс, се включват каучукови гранули – продукт на рециклирани гуми. Изпробвано е и се прилага решение за иновативен тип екологично чисти шумозащитни бетонови бариери – гумирани бетонови шумозащитни бариери (Rubberized Concrete Noise Barriers или RUCONBAR). Докладът описва процеса на разработването на продукта, както и оптималната бетонова смес и подготовката за проектиране и анализ на пазара. Представено е и първото приложение на RUCONBAR като решение за защита от шума в Зоологическата градина в Загреб.*