SOFTENING THE HABITATS
SUSTAINABLE INNOVATION IN MINIMAL MASS STRUCTURES AND LIGHTWEIGHT ARCHITECTURES

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Optimization of a membrane structure design for existing project of children's playground in the city of Krupina

Vojtech CHMELÍK*, Jozef KURÁŇ*, Monika RYCHTÁRIKOVÁ[a]

* Department of architecture, The Faculty of Civil Engineering, STU Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia
[a] KU Leuven, Faculty of Architecture, Hoogstraat 51, 9000 Gent/ Paleizenstraat 65, 1030 Brussel, Belgium

Abstract

In this article, we discuss the impact of structural membrane (with a covering function) placed above already existing children's playground situated in a residential area, on the overall acoustic comfort. Without any doubt, covering of the playground, allows the usage of the place during the whole year cycle. This in principle good intention consequently increases the number of present people and number of sound reflections between ground and covering structure, and thus, in terms of acoustics, it will result in increased amount of sound sources. Frequent objection of inhabitants of residential areas at close neighborhood from playgrounds is a concern about noise and acoustic discomfort. This paper deal with an impact of a membrane structure (shading element) on the noise conditions in the given outdoor public place. Discussed possibilities aim at design optimization such as suitable material choice, shape and suspension height of the structural skin from an acoustic point of view. Consideration process is based on number of calculations and acoustic simulations performed for different cases. Result is an optimized and multi-functional design for covering membrane structure, fulfilling aesthetic, operational and acoustic requirements. Resulting optimized design will be also compared with situation in which a similar glazed covering structure would be used.

Keywords: playgrounds, sound absorption, room acoustics, acoustics, membrane structure, acoustic comfort

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1. Introduction

Deficiency of safe, contemporary and valuable outdoor public spaces and playgrounds for children in Slovakia belongs to often discussed topics on city level, which most often leads to planning and designing of completely new facilities. In most of the cases the initiative is taken by city councils together with urban planners. Structural membranes with shading functions are, in this context not completely explored yet and might therefore open new strategies with variety of possibilities.

Revitalization of existing urban places especially in less developed regions in Slovakia and a focus on establishment of attractive and up-to-date living environment that would strengthen the identity of the given environment are essential in term of slowing down the economic and social migration. Children's playgrounds belong to important identifying elements in children's education. They establish bond and establish the relationship with the place where children grow up and gave them a chance to perform safe activities and to keep healthy physiological habits (van Mechelen, 2000, p.1610) They also serve as an alternative to the emerging dependence on digital information tools. General trend is also focused on connection of different social groups, such as seniors, children, foreigners etc. towards social integrity of the residential community. In a view of inclusive design, it is necessary also necessary to place the inclusion elements for the integration of disabled children into the game process (Shaw, 1987).

When designing children's playgrounds, the convenient accessible distance must be guaranteed, in order to keep an optimal form of social control. On the other hand, the proximity of playgrounds can cause acoustic discomfort to the surrounding dwellings on the other hand. Well-chosen acoustic solutions can reduce the noise disturbance associated with the use of playground elements and properly applied roofing above playgrounds can help in (1) Increase in perceived visual attractiveness, (2) improvement of acoustic comfort and (3) longer playing times over the whole year.

The use of children's playgrounds on average is 26.7 times during the summer and 18.9 times during the winter. Applying a suitable covering construction can increase the usage in adverse weather conditions (Gundersen, 2016, p.116).

2. Description of the case study

For this article a real study case was chosen, located in the eastern part of the small historic town of Krupina in residential part Majersky rad. From the western side of the site is a river with a regulated flow and reinforced shores. The existing terraced roads, pathways, hardened areas of smaller scale, outdated children's areas, grasslands, green areas, growing greenery of deciduous and coniferous trees of different species are placed here (Figure 1).

The project for the revitalization of the inter-block has resulted in the reconstruction of the whole urban public spaces. The main aim of the revitalization was to increase its attractivity, aesthetics, functional and cultural-social values by creating space for relaxation, restoring public greenery, restoring the urban and park furniture, design of new park paths ways and pedestrian routes, building of the playground and outdoor fitness facilities meeting current safety standards in the meaning of the applicable legislation and standards.

Design of layout, functional use as well as material choice and design of technical aspects of new elements for playgrounds, outdoor fitness facilities and community areas is addressed with a strong emphasis on safety. All proposed assemblies needed to meet the requirements mentioned in standards (STN EN 1176, 2018; STN EN 117, 2018). Position also takes into account the suitability of orientation on the cardinal directions. The top layer of impact surfaces is formed by mats of recycled rubber of the prescribed thickness, optionally surfaces with natural materials.

The northern part of the area is focused on socio-cultural activities and active children play. The southern part predominantly hosts children's activities. The middle part focuses on active use. The proposal considers revitalization of the existing longitudinal pedestrian path in the north-south direction, alongside the Krupinica River. The sports and fitness activities will also be added to the existing playgrounds in the form of a multipurpose field set up on an area of existing green in the central part. Concerned territory is complemented by small areas with furniture for seating and communication of the visitors. Concerned territory has a linear character, functional territories are predominantly situated in the extended parts of inter-space areas. The division of the solved territory is based on the main pedestrian path, situated along the Krupinica watercourse. The color of individual areas depends on their use. Playing surfaces have an applied rubber surface on EPDM base.

Figure 1: The overall view on the solved are

As the surface under the gaming elements, a single-shell rubber granulate based on EPDM plays a role of a shock absorber. The surface is easy to move with a stroller and accessible for immobile children. In the design, the surface is graphically represented by mountain meadows. Natural materials are used for impact area beneath the rope-play assembly. The functional area is accessible by bicycles. Within the social and community area, it is proposed to build a gazebo for the needs of the community, parked seating, and petanque playground with natural materials. Design in the northern part of the treated area resolves the reclamation of the existing grassy area, the addition of the green vegetation, planting of hedges, reconstruction and completion of existing pedestrian communications.

Figure 2: Chosen middle part of solved area in detail

Pedestrian corridor in the form of an asphalt walk along the river Krupinica, as the development of longitudinal communication, is proposed in the middle part of the designed area. Near the footbridge, in the middle part of the solved territory, functional area designed for fitness and active sports as well as community use is proposed. The area is placed along the length of the pedestrian street, embedded in the existing green (Figure 2).

Inspired of previously conducted studies (Kiyama, 1998, p. 239; Sakagami, 1996, p. 237; Polomová, 2016, p. 306; Urbán, 2017, p. 93; Maywald, 2016, p. 238), in this article we will discuss the influence of covering of the playground by structural skins (ETFE) and its benefit in terms of noise situation when compared to glass.

3. Assessment of the acoustic comfort

In order to understand the acoustic situation in the playground better, 3D acoustic models were constructed, and several acoustic simulations were performed. Room acoustic prediction algorithm (Odeon software) was used, that is based on an image source method and special ray-tracing method with advanced scattering model (Christensen, 2013).

3.1. Description of the acoustic model

Predictions were performed for two kinds of roof shapes (Fig.3) and two types of playground covering materials: (1) glass and (2) ETFE foil – 2 layer cushion, i.e. in total 4 different architectural cases were compared. Values of sound absorption coefficient of both materials could be found in Table 1. From acoustic point of view, first, the simulations were done for one sound source (representing an instructor, teacher or parent present in the playground) and 7 receivers (listening kids) and second, the situation with 8 sources (kids playing) and receivers' grid (to monitor the distribution of sound pressure level they produce together). The curved surface of cushions was taken into account through increased scattering of particular surfaces.

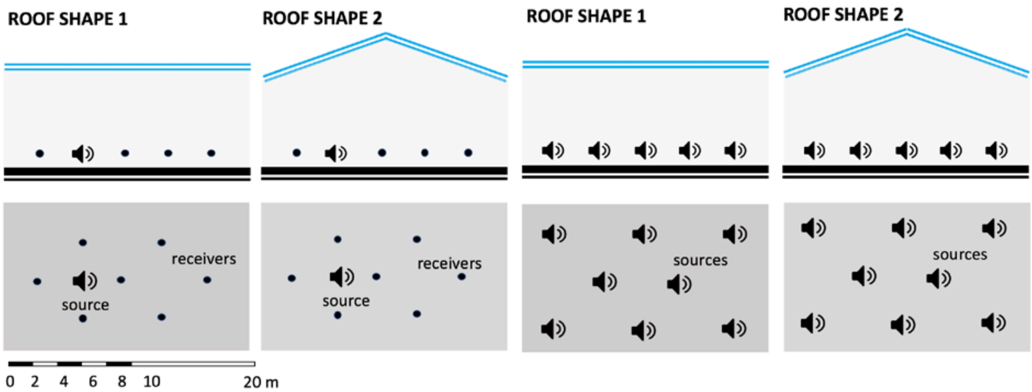

Figure 3: Spatial models of playground with two kinds of roof shape and material

3.2. Results and analysis

Sound pressure level in this paper is expressed through parameter sound strength G (dB) defined in ISO 3382 (ISO 3382, 2012). G values allow comparisons between different measured or simulated cases with different absolute sound power levels of sound source. G presumes sound power level of sound source L_W = 31 dB, resulting in sound pressure level of 0 dB at 10 m distance from the source in free field situation. By using G values, we can compare different cases and re-calculate very fast the noise situation cause by any sound power level. For instance, the L_W of a talking person is around 70 dB. In such a case we can simply add +40 dB to all simulated results, to get an idea about the resulting absolute sound levels in case of talking person.

Table 1: Values of sound absorption coefficient α(-) over frequencies for both roof materials used in simulations

	63	125	250	500	1000	2000	4000	8000
GLASS	0,1	0,1	0,07	0,05	0,03	0,02	0,02	0,02
ETFE	0,41	0,41	0,21	0,26	0,17	0,08	0,02	0,02

Figure 4 shows the results of sound pressure level decay with distance from the sound source in case of 4 alternatives mentioned above. Picture-left shows the situation at low frequencies (125 Hz), middle one for 1000 Hz and picture-right results for very high frequencies (8 kHz). All data are compared to free field situation, which expresses the fastest sound level decay with distance (if no obstacles are present in free field situation). From simulated results we can conclude, that at low frequencies, the sound pressure level at the playground will be ca 2 dB lower in cases with roof shape 1 and when ETFE is used. Interestingly in high frequencies the material of roofing doesn't matter anymore. It is because the sound absorption of high frequency sound by air is very high.

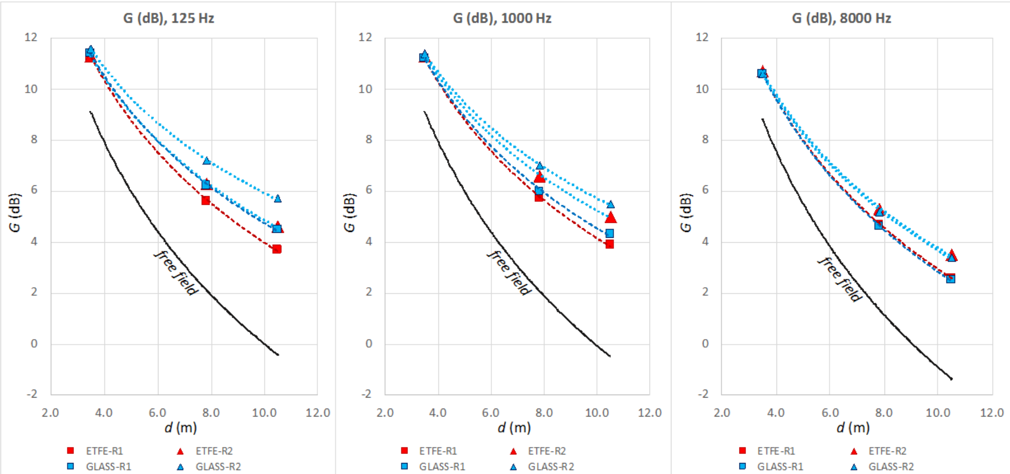

Figure 4: Spatial model of playground with two kinds of roof material

The second experiment was based on simulation of multiple sound sources under the four roof conditions. If we look at the results in so called audience place, we will see, that the differences are very small. This means that in case of the roof, placed very high above the ground, its influence will be low, and the type of material used for the roof will not influence the acoustic conditions much. Figure 5 shows the noise levels for roof shape 1 made out of ETFE (left) and glass (right) at 125 Hz. It is clear, that the roof material will influence the values of sound pressure level only little and only inside the playground and thus not significantly out of the covered part.

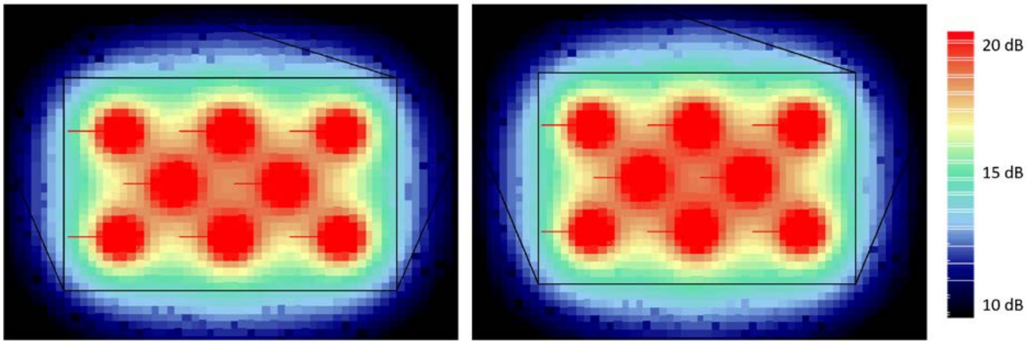

Figure 5: Sound strength G, as simulated from multiple sources equally distributed over the playground for roof shape 1, in height of 1.5 m (horizontal plane). Results at low frequencies (125 Hz) in case of ETFE (left) and glass roofing (right),

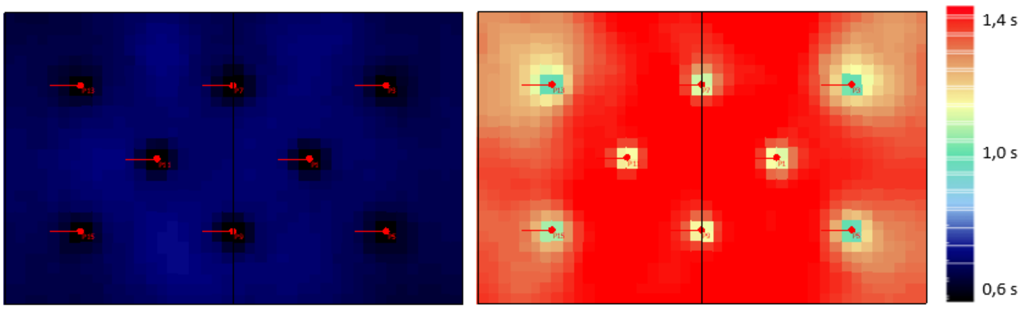

Figure 6: Reverberation time T_{30} (s) for cases with roof shape 2. Results at low frequencies (125 Hz) in case of ETFE (left) and glass roofing (right).

4. Conclusions

It can be concluded, that in architectural design and urban planning, choice of the shapes and materials should be influenced not only by aesthetic features. In prediction of a visual comfort, a lot can be resolved by proper visualisation of spaces. In terms of soundscape, acoustic prediction software is necessary and is a very useful tools important to understanding the overall comfort issues.

Based on the simulation results in the performed study we can conclude, that in semi-open spaces such as children playgrounds, the covering will influence noise situation mainly at low frequencies. However, once the shape of the roof is not flat, creating a certain “room effect” and annoying reverberation can cause acoustic discomfort, once the roof is based on hard material as glass. Here, the benefit of structural skins can be seen.

Results have thus confirmed that the overall sound pressure level in semi-open spaces will be most significantly influenced by direct sound and therefore only small differences were found between the two material cases with flat roof in terms of noise levels. However, the roof shape, if made out of hard materials, such as glass, can locally contribute to reverberation of sound and create less pleasant space.

References

Christensen C. L. , Koutsouris, G. and Rindel, J. H. The ISO 3382 parameters. Can we measure them? Can we simulate them? *International Symposium on Room Acoustics*, Toronto, Canada. June 2013.

Gundersen, V., Skår, M., O'Brien, L., Wold, L.C., Follo, G. (2016): Children and nearby nature: A nationwide parental survey from Norway, *Urban Forestry & Urban Greening* 17, 116-125.

Kiyama, M., Sakagami, K., Tanigawa, M., & Morimoto, M. (1998) A basic study on acoustic properties of double-leaf membranes. In *Applied Acoustics*, 54(3), p. 239-254,

Maywald, C., (2016) Sustainability-The Art of Modern Architecture, In: *Procedia Engineering* 155, p.238 – 248

van Mechelen W., Twisk, J.W., Post, G.B., Snel, J., Kemper, H.C. Physical activity of young people: the Amsterdam Longitudinal Growth and Health Study. In: *Med Sci Sports Exerc*. 2000 Sep;32(9):1610-6.

Polomová, B., Vargová A. (2016), Night Image of Tensile Facades, *Procedia Engineering* 155, 306-312

Sakagami, K., Kiyama, M., Morimoto, M., & Takahashi, D. (1996) Sound absorption of a cavity-backed membrane: A step towards design method for membrane-type absorbers. In *Applied Acoustics*, 49(3), p. 237-247

Shaw L.G. (1987) Designing Playgrounds for Able and Disabled Children. In: *Weinstein C.S., David T.G. (eds) Spaces for Children. Springer*, Boston, MA

Urbán, D., Zelem, L., Maywald, C., Glorieux, C., Rychtáriková, M. (2017): Influence of transparent roofing systems on room acoustic properties of large atria, *Akustika* 29, Czech Republic, 93-98. ISSN 1801-9064.

ISO 3382:2012 Acoustics -- Measurement of room acoustic parameters. ISO/TC 43/SC 2 Building acoustics. 2012

STN EN 1176 Playground equipment and surfacing - Part 1: General safety requirements and test methods. SUTN 2018

STN EN 1177 Impact attenuating playground surfacing - Methods of test for determination of impact attenuation. SUTN 2018