Journal of Architectural Research and Development, 2023, Volume 7, Issue 6
http://ojs.bbwpublisher.com/index.php/JARD
Online ISSN: 2208-3537
Print ISSN: 2208-3529

Simulation Evaluation of Outdoor Noise Environment in Buildings

Cuicui Qin*, Qiliang Yu, Wenyu Zou

School of Construction Engineering, Shenzhen Polytechnic University, Shenzhen 518000, Guangdong Province, China

Corresponding author: Cuicui Qin, cuicui_qin@sina.com

Abstract: Green campus design has become an essential strategy to enhance campus life and learning. However, noise pollution remains a troubling aspect that impacts teaching and learning processes, even causing harm to the health of students and teachers. Therefore, acoustic environment quality design is crucial. This article focuses on the expansion project of a school campus in Shenzhen. We simulated and analyzed the outdoor noise environment separately for the proposed teaching building, as well as the existing buildings like the dining hall, teaching building, and laboratory building. The results showed that the proposed teaching building was mainly affected by surrounding noise, with the worst outdoor noise being in classrooms adjacent to the teaching building in the south and the basketball court at the west of the classroom, with maximum noise values reaching 73 dB and 66 dB, respectively. In the future, these rooms should be renovated to achieve an excellent indoor soundproof environment.

Keywords: Green campus; Outdoor noise; Simulation analysis; Acoustic environment

Online publication: November 28, 2023

1. Introduction

Green buildings are characterized by their minimal resource consumption, eco-friendliness, and their ability to contribute to a harmonious natural environment throughout their entire life cycle. With the shift from basic three-dimensional space to a comprehensive perception of architectural space, architects began to prioritize the architectural acoustic environment. The acoustic environment is a crucial aspect of the architectural setting, and satisfaction with the acoustic environment has been shown to have significant weight in the overall evaluation of indoor environments [1]. Mourshed and Zhao discovered that the acoustic environment was the third most important design factor in healthcare spaces ahead of factors such as lighting, space, color, and landscaping [2]. Additionally, numerous studies have revealed that the acoustic environment has a significant impact on users' emotions [3,4], behavior [5,6], perception [7], recovery, and health [8-10]. In campus buildings, noise can somewhat affect campus life and teaching activities, it might even impact the health of teachers and students. Therefore, it is crucial to design an acoustic environment for a comfortable indoor environment. In this article, under the background of green campus construction and taking an expansion project of a high school campus in Shenzhen as an example, this article simulates and analyzes the outdoor acoustic environment using simulation software to improve campus acoustic environment design. The results showed that the acoustic environment can be through such measures as improving the soundproofing of building envelope structures, using soundproof windows and doors, and taking soundproofing measures for windowsills and ceilings. The purpose of this article is to promote campus acoustic environment transformation, emphasizing the importance of integrating campus acoustic environment design into the planning and design of new or expanded buildings in their construction phase. Besides, this article also aims to promote green campus design.

2. Research method

2.1. Research objective

The project is located on a school campus in Shenzhen city. The existing buildings include a laboratory building, a teaching building, and a comprehensive building. The building to be added is a teaching building. The proposed teaching building is located on the east side of the basketball court. Building 1 is the proposed teaching building. Buildings 2–5 are existing buildings, with Building 2 being the comprehensive building, Building 3 being the dining hall, Building 4 being the teaching building, and Building 5 being the laboratory building. The project site plan is shown in **Figure 1**.

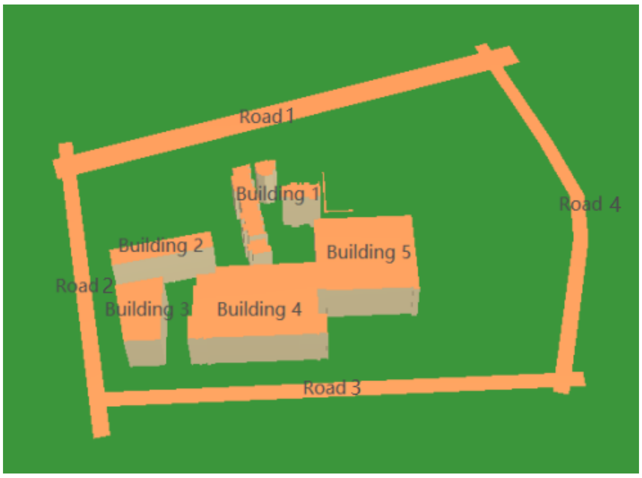

Figure 1. The project site plan

As this project involves teaching buildings, considering that the reading and singing sounds from the classrooms may cause noise interference between the buildings, simulated analyses have been conducted on the outdoor noise environment of the existing cafeteria, teaching building, and laboratory building, the proposed teaching building, and the proposed comprehensive building, with the proposed teaching building being the main focus and the research subject. Considering the influence of the reading and singing sounds (surface sound source) in the classrooms of the existing cafeteria, teaching building, laboratory building, and proposed comprehensive building, as well as the basketball court and surrounding traffic noise (linear sound source), this study investigates whether the proposed teaching building will be subject to noise interference from the existing and proposed buildings during its subsequent use.

2.2. Simulation software

the Sound Environment Design for Urbanism (SEDU) software was developed by the research team of Tsinghua. It was used for noise calculation, evaluation, and prediction in this paper. SEDU is a software program that adheres to international standards such as ISO9613-2:1996 specified by the International Standardization Organization (ISO), as well as Chinese standards like GB/T17247.2-1998 and HJ2.4-2009, outlined in China's Environmental Impact Assessment Technology Guidelines (HJ), and JTG B03-2006, which is part of China's Highway Construction Project Environmental Impact Assessment Standard (JTG). The software strictly follows national standards and can sequentially calculate both indoor and outdoor acoustic environments. The outdoor calculation results can serve as boundary conditions for subsequent indoor sound insulation performance calculations.

Considering the complexity of the surrounding noise environment after the completion of the project, a software was used to simulate and calculate the noise values during the day and night, including the noise distribution on the project site, the noise distribution on the noise-sensitive building at a height of 1.5 meters along the building study plane, and the noise distribution on the facade of the noise-sensitive building.

2.3. Analysis model

An outdoor acoustic environmental simulation analysis model was established based on relevant data such as architectural design drawings. The model mainly included objects such as evaluation target buildings, surrounding buildings, sound barriers, roads (including rail transit), and green belts.

The main source of outdoor noise in construction sites was traffic noise, and industrial noise sources might also be one of them based on the surroundings of the project. The noise sources for this project are shown in **Table 1**. It should be noted that the speed and traffic volume of the vehicles in the table were set based on the actual situation of the project. The roads around the campus are bituminous concrete roads.

Table 1. Traffic noise sources

Road	Time period	Design speed (km/h)	Small vehicles		Medium vehicles		Large vehicles	
			Hourly traffic flow	Noise grade 1 at 7.5 m dB(A)	Hourly traffic flow	Noise grade 1 at 7.5m dB(A)	Hourly traffic flow	Noise grade 1 at 7.5m dB(A)
Road 1	Day	60	400	72	50	72	0	79
	Night	60	100	72	20	71	0	78
Road 2	Day	60	200	72	20	72	0	79
	Night	60	80	72	20	71	0	78
Road 3	Day	60	200	72	20	72	0	79
	Night	60	80	72	20	71	0	78
Road 4	Day	60	200	72	20	72	0	79
	Night	60	80	72	20	71	0	78

According to the Code for Design of Primary and Secondary School Buildings (GB50099-2011), Article 4.3.7, the noise level of reading and singing in classrooms transmitted to 1 m outside is about 80dB, and the noise level of sports facility surroundings during physical education classes is about 70 dB–75 dB. Therefore, during the simulation, the noise level at the edge of the basketball court was set to a line source of 75 dB. A vertical sound source was set at a distance of 1m from the new teaching building 1 exterior, with a noise level set to 80 dB.

3. Results and discussions

Through software simulation calculations, the site noise distribution was predicted under two working conditions – daytime and nighttime. Color maps of the site noise distribution and noise distribution along the research plane at a height of 1.5 meters above the ground were formed, and color analysis and data analysis of the noise level distribution on the facade of the participating buildings were performed. The legend is detailed in **Figure 2**. The site noise distribution is shown in **Figure 3**.

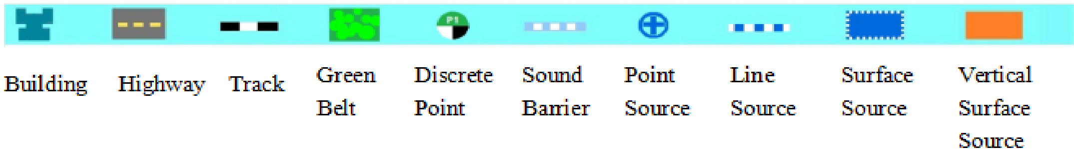

Figure2. Legend

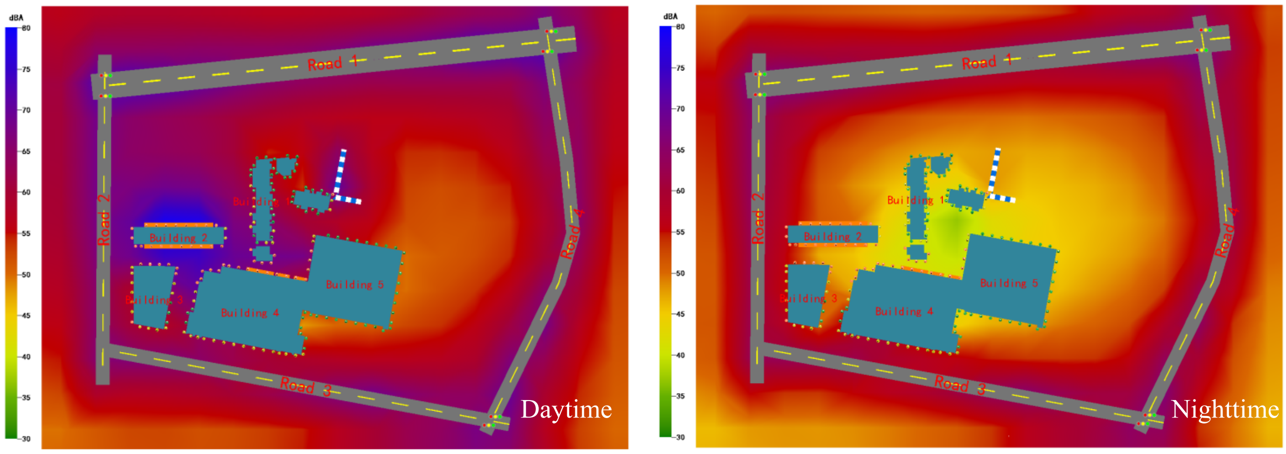

Figure 3. Sound pressure level distribution at a height of 1.5 m above the ground during the daytime and nighttime

The distribution of noise along the research plane at a height of 1.5 meters above the ground in daytime and nighttime for each participating building was analyzed, and the upper and lower numbers inside the circles in each building's top view indicate the maximum noise values during daytime and nighttime, respectively. The outdoor daytime and nighttime noise analysis for this project is shown in **Figure 4**.

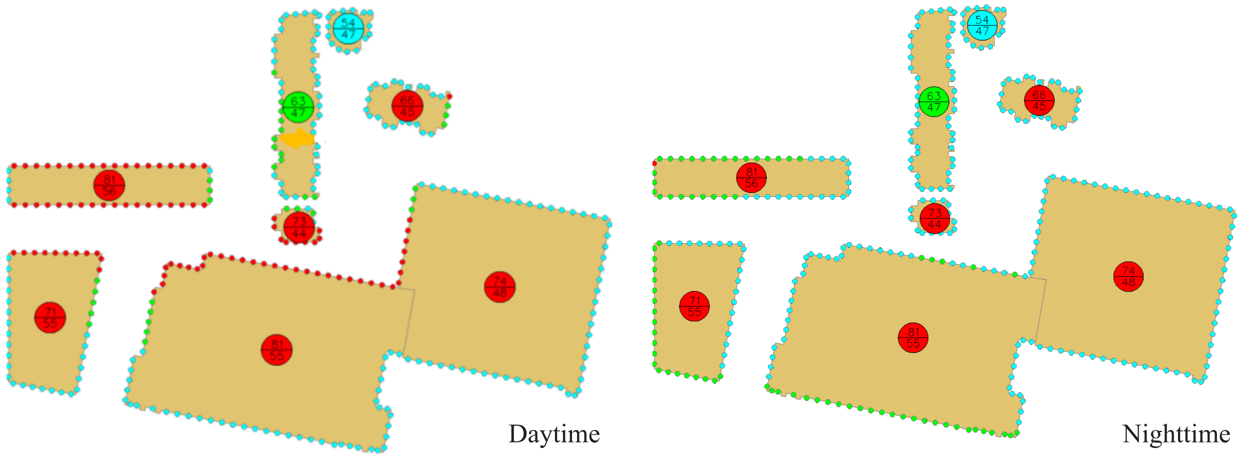

Figure 4. Sound pressure level distribution at a height of 1.5 m above the ground during the daytime and nighttime

Based on the above analysis, the proposed teaching building would be affected by noise from the surrounding area, and the maximum outdoor noise at the facade was 73 dB. The most unfavorable main function room was the classroom adjacent to the southern teaching building and the classroom on the western side of the basketball court, with maximum outdoor noise values of 73 dB and 66 dB, respectively. These two rooms with the most unfavorable outdoor noise should undergo indoor noise evaluation.

4. Conclusion

The outdoor noise environment of buildings on campus was studied in this paper. Through software simulation and result analysis, the outdoor noise situation of the buildings can be summarized as follows.

The proposed teaching building was affected by noise from the surrounding area, with the maximum outdoor noise at the facade being 73 dB. The most unfavorable main function rooms were the classroom adjacent to the southern teaching building and the classroom west of the basketball court, with maximum outdoor noise values of 73 dB and 66 dB, respectively. When calculating indoor background noise, these two rooms were the most unfavorable in terms of noise levels.

The building expansion plan can be designed based on the above outdoor noise simulation results to avoid potential indoor sound environment problems and create a comfortable indoor environment. This will also promote green and ecological design and transformation of campus environments.

Funding

The research was supported by the following projects:

(1) Education Research and Reform Projects of Shenzhen Polytechnic University, China (Project No. 7022310092)

(2) 2022 Green Building Design Golden Course Construction Project of Shenzhen Polytechnic University, China

(3) 2023 Guangdong Provincial Education and Teaching Reform Research and Practice Project, China

(4) 2021 College Student Innovation Project of Shenzhen Polytechnic University, China (Project No. P-20210607-39632)

(5) 2023 Education and Teaching Reform Project of the Higher Vocational Civil Engineering and Water Resources Instruction Committee of Guangdong Province, China (Project No. 2023TJSL21)

(6) University Students' Science and Technology Innovation Cultivation Fund Project of Guangdong Province (Project No. pdjh2021b0896)

Disclosure statement

The authors declare no conflict of interest.

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