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RISK ANALYSIS ON SCAFFOLDINGS EXPOSED TO NOISE

The article presents the results of environmental tests performed on scaffolding that were focused mainly on the sound level. The parameters on which we base our analysis are the value of daily noise exposure level and peak sound levels on scaffolding. The noise that affects construction workers on scaffolding, may increase the risk of accidents. We present the results of measurements for twenty two scaffolds in five cities. The analyses carried out confirmed the qualitatively expected dependencies but they allowed us to quantify the impact of the noise on which construction workers on the scaffolding are exposed. The noise occurs continuously throughout the day and can cause faster fatigue, thereby it can increase the risk of accidents in noisy work environment.

Keywords: environmental studies, noise, scaffolding, sound level

1. Introduction

The main use of construction scaffolding is to support construction work at elevated locations or those that are more difficult to reach. In addition, the scaffolding is also used in other areas, such as the renovation of technological lines, in shipyards, as support structures for advertising, as a cover for mass events, as estrangements, as temporary structures, as decorative elements, etc. The often complex design of scaffolding causes the multiplicity of opportunities for occurrence and development of dangerous situations, understood as all unforeseen events which are a threat to people in or around the scaffolding. Employee behavior and their psychophysical state largely depend on structural stability and environmental factors. Environmental factors, i.e. physical stimuli of the external environment, affect both the people at work, and the construction.

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These include impacts such as noise, temperature, humidity, pressure, wind, light, vibration, dust, rainfall, icing, electromagnetic fields, radiation.

The subject literature deals primarily with accidents that occurred on scaffolding, e.g. [1–3], aspects of strength testing of scaffold components, FEM modelling [4] or wind behavior [5]. There is little information on the impact of noise, which is one of the important environmental factors.

The paper presents an analysis of noise impact on people working on scaffolding. All scaffolds tested were located in large cities (Łódź, Warszawa, Poznań, Wrocław, Lublin), while several of them in smaller cities near large agglomerations.

Work carried out on a scaffold by a construction worker is counted among particularly dangerous occupations of increased risk. The division of factors affecting occupational safety has been presented in [6–8]. One of the harmful factors is the noise that occurs on the scaffolding and its surroundings.

Noise can be severe, disruptive and can adversely affect human health. The negative effects of noise on the human body are varied, and their size and subsequent consequences depend on many factors. The effects of noise on the human body can be auditory and non-auditory.

Prolonged exposure to noise, with an equivalent sound level A above 80 dB, usually results in permanent loss of hearing. Permanent hearing loss may also occur in the case of single exposure to noise, if the peak sound pressure level exceeds 135 dB [9].

Non-auditory effects of noise on the human body are a stress factor leading to disorders of the respiratory system, circulatory system, and other organs. The noise also has a negative effect on the nervous system. In addition, noise reduces speech intelligibility and the perception of warning audio signals. The masking of speech and warning signals not only makes communication difficult, but above all increases the risk of accidents in a noisy environment. Noise is also a problem when we perform activities related to controlling and signaling. To a large extent, it limits the ability to observe and analyze information. It slows down the reaction time and has a negative impact on the decisions made.

2. Subject of study

The measurements and their results described in this paper were a part of the bigger research on façade frame scaffoldings [10]. This research was conducted by five teams consisting of employees from: Faculty of Civil Engineering and Architecture (Lublin University of Technology), Faculty of Management (Lublin University of Technology), Faculty of Civil Engineering, Architecture and Environmental Engineering (Lodz University of Technology) and Faculty of Civil Engineering (Wroclaw University of Science and Technology).

As part of the research activities, the following studies were planned: collecting general information about scaffolding, scaffolding inventory, damage inventory, load inventory, surveying measurements, scaffolding force measurements, anchoring measurements, research of the bearing capacity, dynamic measurements of the scaffolding, atypical event recording [11], employee life parameters measurements, surveys with employees, measurements of environmental parameters, lighting intensity, atmospheric pressure, air temperature, relative humidity, wind speed [12–13], sound level, air pollution.

Sound level tests were conducted in the middle of the span. The measurements were carried out in six, nine or twelve places on the scaffolding (the number depends on the size of the scaffolding).

Measurements were taken in the extreme fields and fields evenly spaced on the scaffold using the following scheme:

• 3 or 4 measurements at the first full level (work platform),
• 3 or 4 measurements at half height (work platform),
• 3 or 4 measurements at the highest level (work platform).

An exemplary scaffolding with the arrangement of measuring points is shown in Figure 1.

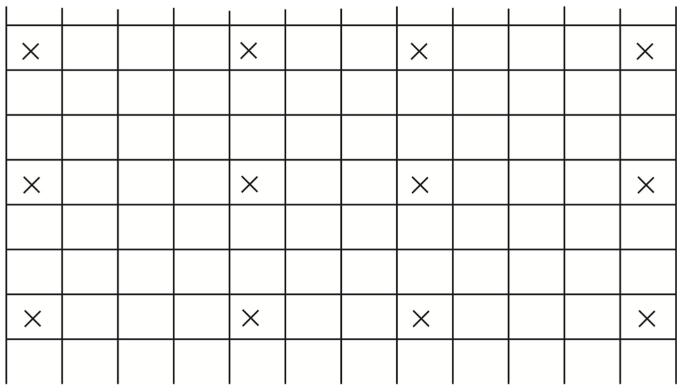

Fig. 1. Scaffolding view and exemplary arrangement of measurement points

Measurements were made at 3-hour intervals, i.e. the first round of tests from 8.00, second round of research from 11.00, third round of research from 2.00 PM. The aim of recording data at various times of the day was to obtain information on how the level of noise during the day changes. Measurements were carried out for five consecutive days of the week. As a result, a fairly complete view of the noise impact on workers' performance on the scaffolding was obtained.

The DB200 sound level meter was used to measure the sound level. Two parameters were recorded simultaneously at each measuring point for approximately six minutes: A-weighted equivalent sound level – L_{Aeq} and C-Weighted peak sound level – L_{Cpeak}.

Noise sources, typical for construction works that occur on scaffolding or in their vicinity most often that have an impact on noise affecting employees are grinders, drills, winches, table saws, hammers, concrete mixers, excavators, pneumatic hammers, blowers. The power level of these sources is usually quite large and the impact depends on the source distance from the specific employee.

The basic groups of noise sources are:

- machines that are energy sources, e.g. combustion engines (maximum sound levels A up to 125 dB), compressors (up to 113 dB),
- pneumatic tools and motors, e.g. manual pneumatic tools: hammers, cutters, grinders (up to 134 dB),
- cutting machines, circular saw blades for metal (up to 115 dB),
- machining machines, e.g. mechanical hammers (up to 122 dB),
- metal cutting machine tools, e.g. grinders, drills (up to 104 dB).

There are also other noise sources, not related to construction works that have impact on the resultant sound level that affects employees. These are communication noises coming from streets adjacent to the construction site [14].

Because of construction noise is generally fluctuating, it is reasonable to use the continuous steady-state indicator $L_{Aeq,T}$, which is calculated by taking an average of the fluctuant noise level during a period of time (1). Noise exposure level $L_{EX,8h}$ is calculated by normalizing $L_{Aeq,T}$ to the length of a typical working day, according to the calculation procedures proposed in PN-EN ISO 9612:2011 (2, 3).

$$L_{Aeq,Tm} = 10\log\left[\frac{1}{N}\sum_{i=1}^{N}10^{0,1L_{Aeq,Tmi}}\right] \tag{1}$$

$$L_{EX,8h,m} = L_{Aeq,Tm} + 10\log\left(\frac{T_m}{T_0}\right) \tag{2}$$

$$L_{EX,8h} = 10\log\left[\sum_{m=1}^{M}10^{0,1L_{EX,8h,m}}\right] \tag{3}$$

where:
m – the divided task m,
N – the total number of task samples,
T_m – the duration of task m,
T_0 – the reference duration, T_0 = 8 h,
$L_{Aeq,Tm}$ – the A-weighted equivalent continuous sound pressure level for task *m*,
$L_{EX,8h,m}$ – the noise contribution from task m to daily noise exposure level.

The basic type of noise that is assessed at workplaces is the noise in an audible range. The risk assessment resulting from exposure to noise can be made on the basis of recorded parameters. If A-Weighted maximum sound level

L_{Amax} is lower than 109 dB or C-Weighted peak sound level L_{Cpeak} is lower than 129 dB, it is considered that the risk of exposure to noise is low (negligible). If A-Weighted maximum sound level L_{Amax} is higher than 109 dB but lower than 115 dB or C-Weighted peak sound level L_{Cpeak} is higher than 129 dB but lower than 135 dB the risk of noise exposure is medium (acceptable). Where A-Weighted maximum sound level L_{Amax} is higher than 115 dB or C-Weighted peak sound level L_{Cpeak} is higher than 135 dB, noise exposure is considered to be massive (unacceptable) [9].

3. Results of research

The results of the recorded acoustic parameters from all noise sources for the selected day, selected hour and selected one measuring point are shown in Figure 2. For each measurement point, in each hour from the recorded data A-Weighted equivalent sound level $L_{Aeq,T}$ were calculated and C-Weighted peak sound level L_{Cpeak} and A-Weighted maximum sound level L_{Amax} was determined.

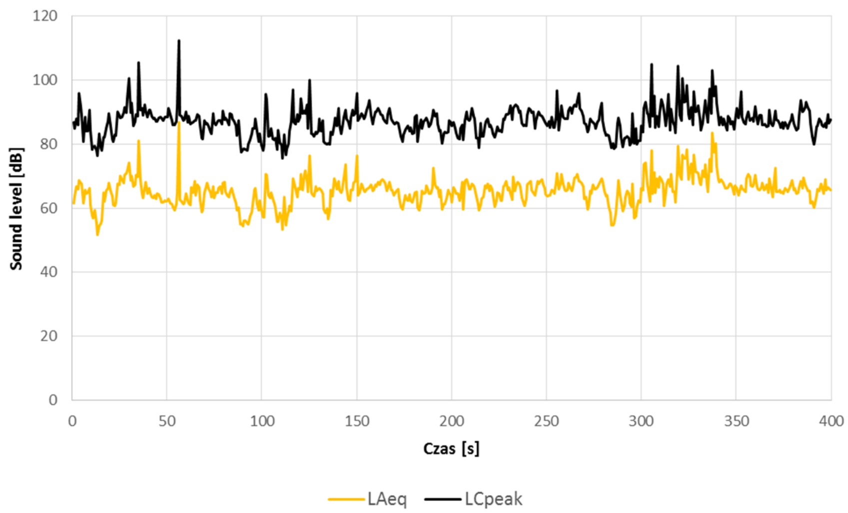

Fig. 2. C-Weighted peak sound level (upper graph) and A-weighted equivalent sound level (lower graph) registered at one measuring point

In this analysis, for each measurement point, in each round from the recorded data C-Weighted peak sound level L_{Cpeak} was determined and A-weighted equivalent sound level $L_{Aeq,T}$ were calculated from witch $L_{EX,8h}$ was calculated.

The analysis of noise was not conducted strictly according to the PN-EN ISO 9612 standard. The specifically customized research program, which took the unusual chracteristics of work on scaffolds into consideration, was developed. The proposed program deviated from analysis standards commonly applied for workplaces.

The basic element of all statistical analyzes of a finite cardinality is the determination of the variable distribution observed in this cardinality, i.e. the assignment of values assumed by a given variable of their respective frequency occurrence. The distribution of the analyzed variable can be represented by a histogram. The histogram is used to visually assess the nature of the variable distribution. In the frequency distribution graph, for example, you can see which value occurs most frequently, whether most of the observed values are close to the average, etc. Such charts were created for 22 tested scaffolds in individual cities.

Since the change in the sound level by 1 dB is imperceptible, and only the change by 3 dB is palpable, the measurement range of sound levels is divided into 3 dB subranges, in which the occurrence frequency of a given sound level was calculated.

The diagrams (Fig. 3) show the distribution of the equivalent sound level, maximum sound level and peak sound level for one selected area.

Table 1. The probability of a dangerous situation occurrence having impact on an employee's health

Location	**The number of exceeded L_{Cpeak} values = 129 dB**	**The number of all measurements**	**The probability of exposure to excessive noise**
Łódź	5	2 827	0.0017
Lublin	29	2 280	0.0127
Poznań	8	2 258	0.0035
Warszawa	29	2 335	0.0124
Wrocław	32	2 532	0.0126

The occurrence frequency of excessive sound level values on scaffolds was also analyzed. Table 1 illustrates the probability of a dangerous situation occurrence having impact on an employee's health due to exposure to noise. The values were defined as the ratio of the number of measurements for which peak sound level exceeding 129 dB was observed to the number of all measurements on analyzed scaffoldings.

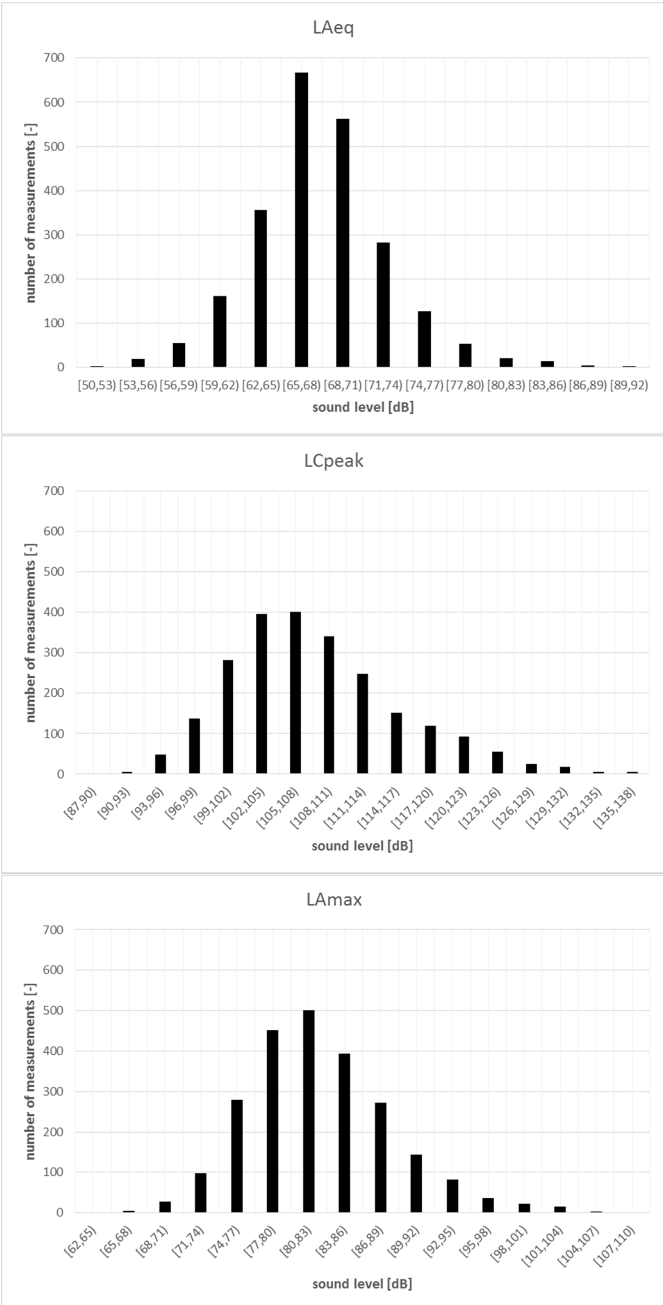

Fig. 3. A-weighted equivalent sound level, C-weighted peak sound level and A-weighted maximum sound level LAmax registered on scaffolds in Warszawa

4. Conclusion

Exposure to noise on scaffolding is primarily associated with the performance of specific activities, machinery usage or technological processes. Noise is the most common detrimental factor in this work environment. A construction worker working on a scaffolding is frequently exposed to the noise that exceeds acceptable levels.

Based on the presented graphs, it can be concluded that the A-weighted equivalent sound level most often reached values between 65–68 dB and the A-weighted maximum sound level between 80–83 dB. The A-weighted equivalent sound level registered on the analyzed scaffolds varied from 50 dB to 90 dB and the A-weighted maximum sound level from 62 dB to 110 dB.

C-Weighted peak sound level usually reached values between 105 dB and 108 dB, but it exceeded 129 dB many times, which can be considered dangerous. This situation took place on 38 scaffoldings from 110 tested.

Values above 135 dB, which are unacceptable values, also occurred during taking measurements on 7 scaffoldings. Such situations should be considered harmful to health, and a high-risk, due to the protection of hearing.

The level of exposure to noise can be more effectively reduced by incorporating preventive measures into the design of work stations and places of work and by selecting work equipment, procedures and methods so as to reducing the risks at source.

Employers should make adjustments in the light of technical progress and scientific knowledge regarding risks related to exposure to noise, with a view to improving the health and safety protection of workers.

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