Research Article

Iwona Szer* and Jacek Szer

The influence of external environment on workers on scaffolding illustrated by UTCI

<https://doi.org/10.1515/eng-2021-0093>

received October 29, 2020; accepted August 18, 2021

Abstract: The aim of the article was to present the influence of the external environment on people working on scaffolding. For this purpose, the heat load of a man was determined using the universal thermal climate index. The research was carried out on 40 facade scaffolds located in four voivodeships in Poland: Lower Silesia, Lublin, Lodzkie, and Masovian. The conducted analysis showed that employees may experience strong or very strong heat stress, and also extreme heat stress in isolated cases. The highest probability at 0.30 level occurs on scaffolds located in the Lodzkie voivodeship. Environmental conditions are therefore unfavourable for people working outside. This can lead to reduced concentration, longer reaction time, and greater fatigue, contributing to an increase in situations that could lead to accidents. Hazard identification allows to take safety measures that improve the comfort of work on scaffolding.

Keywords: scaffolding, environmental studies, construction workers, UTCI, work comfort

1 Introduction

The external environment affects people working on scaffolds. High or low temperature, changes in atmospheric pressure, strong wind, atmospheric precipitation, air pollution, or noise can cause adverse changes even in the body of an acclimated person. There may be a reduction in concentration, longer reaction time, fatigue, reduced motivation, dissatisfaction, or changes in the physiological functions of the human body. Construction workers

are one of the groups most exposed to the adverse impact of the external environment. In Taiwan in 2007, 76.3% of construction workers were exposed to excessive heat in the workplace [1]. Elevated air temperature above 30°C in 17.4% of workers working on construction sites in Hong Kong led to the occurrence of disorders, mainly dizziness and headaches. There have also been isolated cases of difficulties with breathing and heat cramp [2]. High temperature is also one of the causes of increased mortality. In Sydney, Australia, between 1993 and 2004, an increase in the maximum temperature by 10°C and air pollution caused an increase in mortality by 4.5–12.1% [3], while in France, a heat wave in August 2003 contributed to an increase in mortality by 4–142% depending on the region (location) [4]. In the years 2000–2010 in the United States, 359 people died as a result of exposure to heat in the workplace out of which 36.8% were employees in the construction industry [5]. Global warming causes extreme climate phenomena that will happen more often [6] and currently observed climate changes may indicate that heat waves will last longer and will be more intense.

People working on scaffolding are exposed to an increased risk of heat stress since work is often carried out at heights where the temperature is higher. This is caused by the effect of lighter warm air moving upward. Additionally, facade scaffolds are installed next to the building, so building envelopes can radiate more heat from their surface, further increasing the mean radiant temperature. Unfavourable and changing climatic conditions, together with work requiring prolonged physical effort, often performed under time pressure, can contribute to errors at work. As a result, the risk of accidental injury or events that could lead to an accident may increase. An accident at work is most often the result of many causes and circumstances, one of them may be working in uncomfortable environmental conditions. Research conducted in Poland on the basis of the analysis of 177 accident protocols concerning accidents occurring during works on scaffolding showed that human causes accounted for 27.4% of all the identified causes [7]. That is why it is crucial to study the impact of the external environment on people working on building scaffolding.

* **Corresponding author: Iwona Szer**, Department of Building Materials Physics and Sustainable Design, Lodz University of Technology, Al. Politechniki 6, 93-590 Łódź, Poland, e-mail: iwona.szer@p.lodz.pl

Jacek Szer: Department of Building Materials Physics and Sustainable Design, Lodz University of Technology, Al. Politechniki 6, 93-590 Łódź, Poland, e-mail: jacek.szer@p.lodz.pl

The article presents an analysis of the impact of climatic conditions on people working on scaffolding with the use of the universal thermal climate index (UTCI).

2 UTCI

The UTCI allows to determine the heat loads of a man in various thermal conditions of the external environment. Table 1 presents the scale of assessment stress of heat stress of the human body. UTCI was created on the basis of a Fiala multi-node model of human heat transfer [8]. The UTCI is one of the newest indices defined as the equivalent air temperature at which, under certain environmental conditions, the basic physiological parameters of the body take the same values as in real conditions [9,10]. The full determination of the UTCI value consists of multiple calculation of the heat balance of a human being. The UTCI is expressed with $^{\circ}\text{C}$. The UTCI can be presented as a function [9,10]:

$$\text{UTCI} = f(T_a, v_p, v_a, dT_{\text{mrt}}), \quad (1)$$

where T_a – air temperature ($^{\circ}\text{C}$), v_p – water vapour pressure (hPa), v_a – wind speed at 10 m above the ground (m/s), and dT_{mrt} – difference between the mean radiant temperature and air temperature ($^{\circ}\text{C}$)

3 Research methods

3.1 Scaffolding measurement data

The examination of the scaffolds were carried out by five teams from the Faculty of Civil Engineering and Architecture

Table 1: The scale of assessment of heat stress of the human body [9]

UTCI ($^{\circ}\text{C}$)	Stress category
>+46	Extreme heat stress
+38.1 to +46.0	Very strong heat stress
+32.1 to +38.0	Strong heat stress
+26.1 to +32.0	Moderate heat stress
+9.1 to +26.0	Thermoneutral zone
+0.1 to +9.0	Slight cold stress
–12.9 to 0.0	Moderate cold stress
–26.9 to –13.0	Strong cold stress
–39.9 to –27.0	Very strong cold stress
<–40.0	Extreme cold stress

at Lublin University of Technology, Faculty of Management at Lublin University of Technology, Faculty of Civil Engineering, Architecture, and Environmental Engineering of Lodz University of Technology, and the Faculty of Civil and Water Engineering at Wrocław University of Science and Technology [11]. The article presents the results, which are part of the research in which information about the scaffold, its surroundings, and users of the scaffold were collected. On the scaffolds, the following parameters, among many, were examined:

- climatic parameters of the outdoor air (temperature, relative humidity, wind velocity, and direction), atmospheric pressure [12], lighting, sound level [13], and dust level;
- technical parameters: deviations from the ideal geometry of the scaffold, technical condition of parts of scaffolds, strength in the anchoring, forces in the stands, load-bearing capacity of the ground, frequency of vibrations of scaffolds, the influence of wind on the structure of the scaffold, and operational loads [14,15];
- physiological parameters of employees (heart rate measurement), distance, and number of moves [16].

The research was carried out on facade construction frame scaffolds. This article presents the results for 40 scaffolds located in Lower Silesia, Lublin, Lodzkie, and Masovian voivodeships. The scaffolds on which the measurements were taken were examined from January 2 to September 1, 2017. The lowest scaffolding was 5.17 m high, while the highest scaffolding was 57.33 m high. The surface of scaffolds ranged from 40.40 to 1500 m².

Taking into consideration the specificity of works performed on the construction scaffolds, the research was carried out in accordance with an individually adapted research program. Research on each scaffold was carried out during one working week. Measurements were taken between 8 a.m. and 4 p.m. in working time of employees on most construction sites. On each day, three series of measurements were performed. The first would start at 8 a.m., the second at 11 a.m., and the third at 2 p.m. Additionally, due to the extended working time of employees on one scaffold located in the Lublin voivodeship, measurements were also taken at 5 p.m. At each spot, the scaffold measurement was performed with the same set of instruments. After measuring the parameters at the first spot, the researchers moved on to the second point. Each series of climatic parameters measurement lasted from one to about one and a half hours depending on the number of measurement spots. The number of spots on the working deck depended on the width of the scaffold and ranged from one to four spots. The number of examined platforms

depended on the height of the scaffold. It ranged from one to three scaffold levels (the first one, the highest one, and one in the middle of the height). In total, measurements were taken in six, eight, nine, or twelve scaffold spots. An example of the scaffold scheme together with the selection of the measurement spots is shown in Figure 1.

3.2 Measuring instruments

Measurements of the climatic parameters were taken with the use of the multifunction AMI-310 (serial 3P160401496) instrument with probes manufactured by KIMO, France, and an atmospheric module MCC (registering the air temperature, relative humidity, and atmospheric pressure) and a vane probe SH 100 measuring the wind velocity were connected. The atmospheric module (4P160311474) measures temperatures from -20 to 70° , with resolution of 0.1°C , and accuracy of $\pm 0.4\%$ and relative air humidity from 5 to 95% , with resolution of 0.1% , and accuracy of $\pm 1.8\%$ (for temperature between 15 and 25°C), ± 0.04 ($T_a - 20$)% (for temperature less than 15°C and greater than 25°C). The vane probe (4P170318644) measures wind speed 0.2 to 30m/s with resolution of 0.01m/s and accuracy $\pm 3\%$ ($\pm 0.1\text{m/s}$) for wind speed of 0.3 – 3m/s and $\pm 1\%$ ($\pm 0.3\text{m/s}$) for wind speed 3.1 – 35m/s . In each measurement field, the air temperature and relative humidity were measured at the height of the employee's face, about 1.5m above the level of the platform. The duration of the measurement in one spot was 4min with sampling interval of 1s . At the same time, the wind velocity was measured first in the perpendicular direction and then in the direction parallel to the facade. The registration of wind velocity in each direction lasted 1min with a sampling interval of 1s .

Figure 1: An example of a scaffold scheme with marked measurement spots.

3.3 Determination of UTCI index

The use of UTCI index in construction conditions is often difficult or impossible due to the lack of adequate software or a large amount of data. Therefore, for this analysis a simplified universal index of heat stress of UTCI* was used [10]. The indicator of correlation between UTCI and the simplified UTCI* is 0.9956 (the determination coefficient is equal to 0.9913) and is statistically significant at 0.01 level. The values of the UTCI* as well as UTCI are also a measure of heat stress of the human body (Table 1). On the basis of the mean temperature and relative humidity of the air as well as the wind velocity, the simplified UTCI* was calculated according to the formula [10]:

$$\text{UTCI}^* = 3.21 + 0.872T_a + 0.2459T_{\text{mrt}} + 2.5078v_{10} - 0.0176\text{RH}, \quad (2)$$

where T_a – air temperature ($^{\circ}\text{C}$), T_{mrt} – mean radiant temperature ($^{\circ}\text{C}$), RH – relative air humidity (%), and v_{10} – wind velocity at 10m height (m/s).

Due to the small impact of the mean radiant temperature on the simplified UTCI* and in order to simplify the calculation, the mean temperature of radiation on the clothing surface equal to the air temperature was taken into consideration. In addition, when people work on scaffolding, they are often covered by a protective net. The resultant wind velocity at a height of 10m in both directions was calculated according to the formula:

$$v_{w10} = \sqrt{(v_{10}^{\rightarrow})^2 + (v_{10}^{\uparrow})^2}, \quad (3)$$

where $v_{10}^{\rightarrow}$ – wind velocity at a height of 10m in parallel direction to the facade and $v_{10}^{\uparrow}$ – wind velocity at the height of 10m in perpendicular direction to the facade.

The wind speed in both the directions at a height of 10m was calculated according to the formula [10]:

$$v_{10} = \frac{v_z}{\left(\frac{h_z}{h_{10}}\right)^{0.2}}, \quad (4)$$

where v_z – wind velocity measured on the scaffolding (m/s), h_z – height at which wind velocity was measured (m), and h_{10} – 10m height (m).

4 Research results

Table 2 contains the minimum and maximum values of the simplified UTCI* calculated on the basis of measurements on 40 scaffolds for three series of measurements,

Table 2: UTCI* for Lower Silesia, Lublin, Lodzkie, and Masovian voivodeships

Location	Time of the day	UTCI*	
		Minimum (°C)	Maximum (°C)
Lower Silesia	8 a.m.	-7.9	38.0
	11 a.m.	-3.2	40.3
	2 p.m.	-2.6	46.2
Lublin	8 a.m.	-10.6	35.5
	11 a.m.	-9.5	38.0
	2 p.m.	-2.8	47.6
Lodzkie	5 p.m.	2.5	28.2
	8 a.m.	0.2	43.0
	11 a.m.	-0.0	45.1
Masovian	2 p.m.	1.9	50.0
	8 a.m.	-1.0	46.3
	11 a.m.	-1.6	42.0
	2 p.m.	0.8	42.4

which began: the first at 8 a.m., the second at 11 a.m., the third at 2 p.m., and in Lublin voivodeship for the fourth series of measurements starting at 5 p.m. Values have been calculated separately for the Lower Silesia, Lublin, Lodzkie, and Masovian voivodeships.

The UTCI* values depend on the time of the day and the location of the scaffolding. The minimum value -10.6°C of the UTCI* was observed on the scaffolding located in the Lublin voivodeship, for measurements starting at 8 a.m. The maximum value of 50°C was observed on the scaffolding located in the Lodzkie voivodeship for measurements commencing at 2 p.m.

Frequency distribution was used to systematize and group statistical material. First, the values of the simplified UTCI* were sorted in ascending order and then the resulting series were divided into separate subsets – groups. Due to the sample size – above 30, to facilitate the analysis, the values were grouped into classes depending on the length. The number and ranges of the classes were chosen in such way so that they would give a clear idea of the distribution. Based on the number of observations in the sample, the number of classes was calculated according to the formula [17,18]:

$$(a) k_1 = \sqrt{n}, \quad (b) k_2 = 1 + 3, 322 \ln n, \quad (c) k_3 \leq 5 \ln n, \quad (5)$$

where n – number of observations.

The next step was to determine the range of the measured characteristic equal to the difference between the maximum and minimum values of the simplified UTCI*.

Table 3 presents the number of classes in each voivodeship calculated according to equation (5(a)–(c)) and the corresponding lengths of classes approximately equal to the range quotient and the number of classes.

The minimum number of classes was 11, while the maximum was 35, which corresponds to the length of the class range from 1.43 to 5.28. Proper selection of the length of the class range is necessary for the correct description of the characteristic. If too large range is accepted on the histogram, then important changes of a given size will not be visible. In case of too small ranges, the charts jump from zero to high values, or there may occur ranges which do not contain samples. While analysing the obtained lengths of ranges of classes, the average length of the range was set at 3. For such assumed range of class in Figure 1, histograms show the number of occurrences of a given UTCI* for ten scaffolds located in Lower Silesia, Lublin, Lodzkie, and Masovian voivodeships. Analysing the obtained histograms, we can notice the differences in UTCI* values depending on the scaffolds location. The class containing the modal value for the Lublin and Masovian voivodeships is the class ranging from 12.5 to 15.5°C, but the class for the Lublin voivodeship is larger by 14 occurrences. The class containing the highest modal value is the class comprised between 30.5 and 31.5°C in the Lower Silesia voivodeship.

In order to illustrate the differences between measurements at different times of the day Figure 2 presents the histograms with number of occurrences on 40 scaffolds for measurements taken at 8 a.m., 11 a.m., 2 p.m., and 5 p.m. The modal value for measurements starting at 8 a.m. is in the range from 24.5 to 27.5°C, at 11 a.m. it is in the range from 27.5 to 30.5°C, at 2 p.m. it is in the range from 30.5 to 32.5°C, and for measurements starting at 5 p.m. it is in the range from 9.5 to 12.5°C. On one scaffold

Table 3: The number and length of ranges of classes

Location	k_1	k_2	k_3	ΔUTCI_1 (°C)	ΔUTCI_2 (°C)	ΔUTCI_3 (°C)
Lower Silesia	31	11	15	1.72	4.94	3.62
Lublin	32	11	15	1.80	5.28	3.85
Lodzkie	35	11	15	1.43	4.44	3.24
Masovian	29	11	15	1.66	4.48	3.28

Figure 2: Histogram of UTCI* on 40 scaffolds measured for: (a) Lower Silesia, (b) Lublin, (c) Lodzkie, and (d) Masovian voivodeships at (e) 8 a.m., (f) 11 a.m., (g) 2 p.m., and (h) 5 p.m.

located in the Lublin voivodeship, it was only possible to take measurements at 5 p.m. Consequently, it is difficult

to analyse the distribution for measurements starting at 5 p.m.

Figure 3 shows the histograms for the scaffolds tested in the first, second, and third quarters of 2017.

The modal value for measurements performed in the first quarter ranges from 6.5 to 9.5°C, in the second quarter ranges from 24.5 to 27.5°C, and in the third quarter ranges from 30.5 to 33.5°C.

The heat stress of employees working on scaffolding in various thermal conditions of the external environment were also analysed. Table 4 presents the probability of occurrence of heat stress based on the classes of the human body loads according to the UTCI* for the Lower Silesia, Lublin, Lodzkie, and Masovian voivodeships. Table 4 also presents the probability of occurrence of heat stress for measurements taken at 8 a.m., 11 a.m., 2 p.m., and 5 p.m. and on all 40 scaffolds.

These values were calculated as the ratio of the number of measurements in a given class of heat stress to the number of all measurements on the analysed scaffolds. Due to the minimum UTCI* value of -10.6°C , classes of heat stress with values below this value were omitted.

In analysing the values obtained, it can be observed that the construction workers work in the thermoneutral zone most of the time. The highest probability on the level

of 0.56 occurred for scaffoldings located in Masovian voivodeship, while the lowest on the level of 0.37 occurred for scaffoldings located in Lubelskie voivodeship, and for all scaffolds, the probability was 0.46. Analysing the time of the day, the highest value of 0.74 is observed for measurements performed after 5 p.m.

The analysis of the obtained values shows that employees working on scaffolding may be exposed to the occurrence of extreme, very strong, or strong heat stress. For easier analysis, the values that present the probability of extreme, very strong, or strong heat stress are bolded in Table 4. The highest probability (extreme, very strong, and strong heat stress) at the level of 0.30 occurs on scaffoldings located in the Lodzkie voivodeship, while the smallest one is 0.11 on scaffoldings located in the Lublin voivodeship.

The highest probability of occurrence of heat stress at the level of 0.31 occurs for employees working on scaffolds from 2 p.m. There is no probability of heat stress occurring for working hours after 5 p.m.; however, only on one scaffold it was possible to take measurements at 5 p.m.

Table 5 presents the probability of occurrence of heat stress based on the classes of the human body loads

Figure 3: Histogram of UTCI* on 40 scaffolds measured for: (a) first quarter, (b) second quarter, and (c) third quarter of the year.

Table 4: The probability of heat stress occurring in the Lower Silesia, Lublin, Lodzkie, and Masovian voivodeships and for measurements taken at 8 a.m., 11 a.m., 2 p.m., and 5 p.m. and on all 40 scaffolds

Stress category	Location				Time of the day				All scaffolds
	Lower Silesia	Lublin	Lodzkie	Masovian	8 a.m.	11 a.m.	2 p.m.	5 p.m.	
Extreme heat stress	0	0	0	0	0	0	0.01	0	0
Very strong heat stress	0.05	0.03	0.12	0.04	0.03	0.06	0.11	0	0.06
Strong heat stress	0.16	0.08	0.18	0.08	0.06	0.15	0.19	0	0.13
Moderate heat stress	0.28	0.20	0.23	0.19	0.21	0.25	0.22	0.02	0.23
Thermoneutral zone	0.37	0.54	0.40	0.56	0.56	0.42	0.40	0.74	0.46
Slight cold stress	0.12	0.12	0.06	0.11	0.12	0.11	0.07	0.23	0.10
Moderate cold stress	0.02	0.02	0	0	0.02	0.02	0.01	0	0.01

Table 5: The probability of heat stress for measurements taken in the first quarter, second quarter and third quarter of the year

Stress category	Quarter		
	I	II	III
Extreme heat stress	0	0	0
Very strong heat stress	0	0.04	0.13
Strong heat stress	0	0.11	0.22
Moderate heat stress	0	0.23	0.30
Thermoneutral zone	0.59	0.54	0.34
Slight cold stress	0.36	0.07	0.01
Moderate cold stress	0.05	0	0

according to the UTCI* for measurements taken in the first quarter, second quarter, and third quarter of the year. In the first quarter of the year, 6 scaffolds were measured, in the second quarter 22 scaffolds, and in the third quarter 12 scaffolds were measured.

Construction workers mostly work in the thermoneutral zone in the first quarter. Also in Table 5, values that present the probability of extreme, very strong, or strong heat stress are bolded. The highest probability in extreme, very strong, and strong heat stresses at the level of 0.30 occurs on scaffolds measured in the third quarter.

5 Conclusion

The aim of the research was to determine the impact of the external environment on employees working on scaffolding. The research has shown that the UTCI* values depend on the time of the day and the scaffolding location and range from -10.6 to 50°C . The analyses show that employees may experience strong or very strong heat stress, and in some cases also extreme heat stress. The highest probability at 0.30 level occurs on scaffolds

located in the Lodzkie voivodeship. If we take into account the time of the day, the highest probability of -0.31 may occur for employees working from 11 a.m. Due to the fact that during work on scaffolding, there is an increased risk of dangerous situations that may lead to an accident, employees should work in the least unfavourable environmental conditions. In most cases we have no influence on external environment conditions. We can only monitor them, and if there is a danger of heat stress occurrence, then we can introduce protective measures that improve the comfort of work on scaffolding. Physical effort should be reduced or limited. It is also necessary to provide employees with the possibility of temporary use air-conditioned rooms or shaded areas, and provide drinking water so that they could hydrate the body.

Acknowledgments: The article was prepared as a part of the project supported by the National Centre for Research and Development within Applied Research Programme (agreement No. PBS3/A2/19/2015 “Modelling of Risk Assessment of Construction Disasters, Accidents, and Dangerous Incidents at Workplaces Using Scaffoldings”).

Conflict of interest: Authors state no conflict of interest.

References

- [1] Lin RT, Chan CC. Effects of heat on workers' health and productivity in Taiwan. *Glob Health Action*. 2009;2(1).
- [2] Jia YA, Rowlinson S, Ciccarelli M. Climatic and psychosocial risks of heat illness incidents on construction site. *Appl Ergon* [Internet]. 2016;53:25–35. doi: 10.1016/j.apergo.2015.08.008.
- [3] Vaneckova P, Beggs PJ, de Dear RJ, McCracken KWJ. Effect of temperature on mortality during the six warmer months in Sydney, Australia, between 1993 and 2004. *Environ Res*. 2008;108(3):361–9.

- [4] Vandentorren S, Suzan F, Medina S, Pascal M, Maulpoix A, Cohen JC, et al. Mortality in 13 French cities during the August 2003 heat wave. *Am J Public Health*. 2004;94(9):1518–20.
- [5] Gubernot DM, Anderson GB, Hunting KL. Characterizing occupational heat-related mortality in the United States, 2000–2010: an analysis using the census of fatal occupational injuries database. *Am J Ind Med*. 2015;58(2):203–11.
- [6] Aalst MK Van. The impacts of climate change on the risk of natural disasters. *Disasters*. 2006;30(1):1–5.
- [7] Hoła A, Sawicki M, Szóstak M. Methodology of classifying the causes of occupational accidents involving construction scaffolding using Pareto-Lorenz analysis. *Appl Sci*. 2018;8(1):48–54.
- [8] Fiala D, Lomas KJ, Stohrer M. Computer prediction of human thermoregulatory and temperature responses to a wide range of environmental conditions. *Int J Biometeorol*. 2001;45(3):143–59.
- [9] Bröde P, Fiala D, Błażejczyk K, Holmér I, Jendritzky G, Kampmann B, et al. Deriving the operational procedure for the Universal Thermal Climate Index (UTCI). *Int J Biometeorol*. 2012;56:481–94.
- [10] Błażejczyk K, Kunert A. Bioclimatic conditioning of recreation and tourism in Poland (in Polish). Warsaw: Polish Academy of Sciences; 2011.
- [11] Błazik-Borowa E, Szer J. Basic elements of the risk assessment model for the occurrence of dangerous events on scaffoldings (in Polish). *Przegląd Budowlany*. 2016;10:24–9.
- [12] Szer I, Szer J, Hoła B. Evaluation of climatic conditions affecting workers on scaffoldings. *Advances and Trends in Engineering Sciences and Technologies III – Proceedings of the 3rd International Conference on Engineering Sciences and Technologies, ESaT 2018; 2019*.
- [13] Jabłoński M, Szer I, Szer J. Probability of occurrence of health and safety risks on scaffolding caused by noise exposure. *J Civ Eng Manag*. 2018;24(6):437–43.
- [14] Szer I, Błazik-Borowa E, Bęc J, Robak A, Szulej J, Wielgos P, et al. Technical factors affecting safety on a scaffolding. In: *Towards better safety, health, wellbeing, and life in construction – bloemfontein*. Bloemfontein, South Africa: Department of built environment, Central University of Technology; 2017. p. 154–63.
- [15] Lipecki T, Jamińska-Gadomska P, Bęc J, Błazik-Borowa E. In-situ measurements of wind action on scaffoldings. Paper presented at the conference: EACWE 2017 - 7th European-African Conference on Wind Engineering, 4–7 July 2017, Liege, Belgium.
- [16] Czarnocki K, Błazik-Borowa E, Czarnocka E, Szer J, Hoła B, Rebelo M, et al. Scaffold use risk assessment model for construction process safety, towards better safety, health, wellbeing and life in construction – Bloemfontein. Bloemfontein, South Africa: Department of Built Environment, Central University of Technology; 2017. p. 275–84.
- [17] Szer I, Błazik-Borowa E, Szer J. The influence of environmental factors on employee comfort based on an example of location temperature. *Arch Civ Eng*. 2017;63(3):163–74.
- [18] Kryszicki W, Bartos J, Dyczka W, Królikowska K, Wasilewski M. Probability calculus and mathematical statistics in problems. Warsaw: Polish Scientific Publishers PWN; 1999.