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# OUTDOOR AIR TEMPERATURE, THERMAL COMFORT, HEALTH AND PERFORMANCE AT A BUILDING CONSTRUCTION SITE IN ABUJA, NIGERIA

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**Abstract:** Results from previous research shows that high outdoor air temperature can be detrimental to thermal comfort, health and productivity. However, are the results applicable to building construction workers in Nigeria? In view of this question, this study investigated the effect of outdoor air temperature on the thermal comfort, health and performance of a sample of Sandcrete block layers at a building construction site in Abuja, Nigeria. The study involved literature review and a field experiment. The field experiment examined the thermal comfort, health and performance of a sample Sandcrete block layers at LT 28.5$^0$C and HT 37.01$^0$C. (LT) and (HT) are the lowest and highest naturally occurring outdoor air temperatures in the construction site during the study. Paired t-test and Wilcoxon-signed ranked test was used to analyse the data from the field experiment. Result from analysis of data shows that: the thermal comfort of the samples was significantly affected at HT 37.$^0$1$^0$C in comparison to LT 28.5$^0$C. Also core body temperature significantly increased at HT 37.01$^0$C in comparison LT 28.5$^0$C. Furthermore, sensation of skin burn, fatigue and negative mood significantly increased at HT 37.01$^0$C in comparison LT 28.5$^0$C. No significant change in symptoms of headache and dizziness was observed. Lastly, performance of the sandcrete block was slightly low at HT 37.01$^0$C in comparison to LT 28.5$^0$C. The conclusion from this study is that, high outdoor temperature (37.01$^0$C) is detrimental to the thermal comfort, health and performance sandcrete block layers in Nigeria. The result from this study complements the findings of another related research. Broadly, results from this study provides empirical data that may stimulate strategies of mitigating the effect of high outdoor air temperature on the thermal comfort, health and performance of workers during high outdoor temperatures at construction sites in Nigeria.

**Keywords:** thermal comfort, health, productivity, outdoor air temperature, field experiment

## Introduction

Probably in order to meet the rising economic challenge in Nigeria, skilled and unskilled craftsmen in the building construction industry have to work during seasons with extreme outdoor air temperatures. Interestingly, due to global warming people working outdoors are likely to face extreme outdoor temperatures especially during hot seasons (Liu et al., 2017). Furthermore, the results of the studies in the literature review below, shows that high air temperature can be detrimental to the thermal comfort, health and performance of workers, however are the results applicable to construction workers in Nigeria? In view of the research question posed here, this study aims to evalaute the effect of outdoor

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air temperature on the thermal comfort, health and performance of selected construction workers in Abuja, Nigeria. Abuja is the present federal capital city of Nigeria. Abuja was selected as the geographic context for this study for two reasons. Firstly, Abuja is belived to be fastest growing city in Nigeria in terms of building contructions, as such there are tendecies of carrying out construction works all year round in comparison to other places in Nigeria. Secondly, the logistics and permision for collecting data for this study was readily available from the building contruction site in Abuja.

**Literature review**

When it comes to the negative effect of air temperature, there are several studies with demonstrable effect of high and low air temperature on the thermal comfort, health and performance of persons. For example, a study which involved a qualitative focus group discussion at two construction sites in South Africa (Johannesburg and Upington) revealed that temperatures above 40 0C were associated with some negative effects such as irritability, sunburn, tiredness and work difficulty (Mathee et al., 2012). High air temperature above 340C resulted to thermal discomfort, increased heart rate and auditory canal temperature, these effects were reported from a field survey at some construction sites in South China (Fang et al., 2021).

The exposure to high outdoor air temperature has also been documented to cause heat stress and reduced labour productivity time by 0.57%, these results were obtained when Li et al. (2016) evaluated the impact of high ambient temperature on construction labour productivity of a sample of workers in Beijing, they compared the productivity of workers at two different periods (i.e.14.00-15.00 representing period of high outdoor air temperature) and 07.00 -09.00 representing period of moderate outdoor temperature). Similarly, the single reaction and choice reaction time of a randomly selected construction workers in Dubai have been shown to significantly deteriorate during summer in comparison to winter, they also reported that rate of accidents in construction sites could be higher in summer than winter (Bendak et al., 2022). Temperatures higher than $35^0$C have been shown to cause thermal discomfort, some health symptoms and decrement in accuracy of performing addition and subtraction tasks, the health symptoms that were significantly worse at 350C includes: sleepiness, fatigue, dizziness, headache, mood, wellbeing and difficulty in concentrating. These effects were observed when subjects were exposed for 3 hours to two temperature levels and one $C0_2$ level in a climatic chamber experiment, the temperature levels and $C0_2$ level are: 26 and $35^0$C, 3000 ppm (Liu et al.,2017). Ear drum temperature, skin temperature, heart rate and body weight loss have been shown to significantly increase at $35^0$C in comparison to $26^0$C (Liu et al., (2017). In addition, there are several research which their results shows that high air temperature can affect thermal comfort, health and performance (Srinavin & Mohammed, 2003; Langkulsen et al., 2010; Lan, et al., 2010; Venugopal et al., 2020; Somanathan et al., 2021).

**Methods**

***Samples***

The samples are from a large scale prototypical residential housing contruction site in Lugbe area of Abuja.The samples were Sandcrete block layers, they often lay sandcrete blocks to form external and internal walls of buildings. Block layers were chosen as sample for this study, this is because their work output (pay) is usually measured by the number of sancrete blocks layed within a specific time of a day, usaually between 07.30 – 16.00. Out of the 43 sandcrete block layers in the construction site, 30 were randomly selected to participate in this study, however, 21 were finally selected to participate. The 21 samples were selected to participate in the present field experiment, this is bacuse they had no history of smoking and alchohol intake as well as blood pressure related issues, these datawas collected via a questionaire before the field experiment. The samples were in the age range of 30- 38, as wll they have fair understanding of English language. It was assumed in this study that the samples have similar skills in sandcrete block laying, they were also dressed in similar clothing insulation value of 0.5 clo. The metabolic rate of the samples was estimated to be 3.0 met (ASHRAE,2004). The sandcrete block considred in this study is the hollow sandcrete blocks, it made from a mixture of cement, sand and water,it is usually 450mm long, 225mm wide and 225mm high (field work measurement during this study, 2021).See Figure 1 for a sample of hollow sandcrete block.

*Figure 1: Hollow sandcrete block*

***Measures***

ASHRAE (2004) 7 point thermal sensation voting scale was used to measure the thermal comfort of the samples, this voting scale is the widely used in thermal comfort studies. The health of the samples was measured via core body temperature and the following subjective responses: sensation of skin burn, tiredness, mood, headache, and dizziness. Core body temperature was measured with a hand held digital thermometer (BEURER FT 85 Digital forehead Thermometer). The subjective responses mentioned here was measured five point Likert scale. Performance of the samples was measured by the average number of sandcrete blocks laid by the samples during the field experiment. Lastly, The Wet Bulb Globe Temperature data logger was used to measure the outdoor temperature (Brand name: Gain Expres).

***Design of the field experiment and procedure***

The field experiment was conducted by repeated measures on a working day in March 2021. This means that thermal comfort, health and performance of the samples was measured in one day at two different outdoor temperature levels using the same samples and procedure. This is described in the two paragraphs below. The two outdoor temperature levels mentioned here are referred in this field experiment as LT and HT, Low outdoor air temperature and high outdoor air temperature) respectively.

Experiment at LT: Between 7am-10am (3hours), the 21 samples laid sandcrete blocks from 0 to a height of 1.5 meter above the casted concrete floor level in 3 prototype 5 bedroom bungalow design. After 3 hours they were requested to stop work, this was immediately followed by concurrent measurement of the outdoor air temperature as well as their thermal comfort, health and productivity. Afterwards the samples were requested to rest for 2 hours (10am- 12pm), they also had biscuits and water during the break.

Experiment at HT: Again, between 12pm -3pm (3hours), the 21 samples performed similar work at the same height mentioned above in 3 prototype 5 bedroom bungalow design at the same site. After 3 hours, they were requested to stop work, this was immediately followed by concurrent measurement of the outdoor air temperature as well as their thermal comfort, health and productivity.

***Data analysis***

The commercially available SPSS version 24 was used to analyse the data from the field experiment. Skew and Kurtosis test was utilised in testing normality. The paired t-test was utilised in analysing normally distributed data while the Wilcoxon-signed ranked test was utilised in analysing non-normality distributed data.

***Results***

The temperature, when the thermal comfort, health and productivity of the samples were measured at the field experiment is 28.5 and 37.01$^0$C respectively.These figures (28.5 and 37.01$^0$C) represent the low (LT) and high (HT) outdoor temperature levels used to evaluate the thermal comfort, health and performance.

As regards thermal comfort, descriptive statistics of the thermal sensation votes of 89% of the samples is between 0 and +1 at LT 28.5$^0$C Inversely, at HT 37.01$^0$C , 93 % of the thermal sensation votes of the samples is between +2 and +3. Thermal sensation votes in range of 0 and +1suggest thermal satisfaction and votes in the range of +2 and +3 suggest thermal dissatisfaction (ASHRAE 2004). Further statistical analysis of the thermal sensation votes of the samples using Wilcoxon-signed ranked test showed that the thermal comfort of the samples was significantly higher at HT 37.01$^0$C in comparison to LT 28.5$^0$C ($Z = -4.102$ ,$p<0.001$). Overall, the results from descriptive statistics and Wilcoxon-signed ranked test showed that the samples were thermally satisfied at LT 28.5$^0$C and thermally dissatisfied at HT 37.01$^0$C.

As regards health: Result from paired t-test showed that the core body temperature of the subjects, significantly increased at HT 37.01$^0$C in comparison to LT 28.5$^0$C, (M=36.8, at LT 28.5$^0$C; M=37.9, at HT 36.01$^0$C, p= 0.040). Also, result from Wilcoxon-signed ranked test showed that sensation of skin burn significantly increased at HT 37.01$^0$C in comparison to LT 28.50C (Z= -3.475, p< 0.001). Again, the symptoms of Fatigue significantly increased at HT 37.01$^0$C than at LT 28.5$^0$C (Wilcoxon-signed ranked test, Z= -3.991 p< 0.001). Lastly, the symptoms of negative mood significantly increased at HT 37.01$^0$C than at LT 28.5$^0$C (Wilcoxon-signed ranked test, Z= -4.095, p< 0.001).

In contrast, there was no significant effect observed in symptoms of headache between LT 28.5$^0$C and HT 37.01$^0$C (Wilcoxon-signed ranked test, Z= -1.265 p= 0.206). Similarly, there was no significant effect observed in symptoms of dizziness between LT 28.5$^0$C and HT 37.01$^0$C (Wilcoxon-signed ranked test, Z= -264, p= 0.792).

As regards performance, there was no significant difference between the mean number of sandcrete blocks laid at LT 28.5$^0$C and HT 36.01$^0$C, however, the average number of sandcrete blocks laid was a bit higher at LT 28.5$^0$C than at HT 37.01$^0$C (M=182, SD=88 at LT 28.50C; M=167, SD=79 at HT 36.01$^0$C, p= 0,162)

**Discussion**

The purpose of this study was to examine the effect of outdoor air temperature on the thermal comfort, health and performance of a sample of construction workers. This is because literature search shows that there seems to be paucity of previous studies linking outdoor air temperature, health and performance of construction workers in Nigeria. Thus, this brings us to asking one research question in this present study. The research question is that, are the results of previous related studies applicable to building construction workers in Nigeria?

Interestingly, the results from this present study shows that there is a negative link between high outdoor air temperature, thermal comfort, health and performance of building construction workers in Nigeria. This is primarily because the results from this study shows that high outdoor air temperature (HT 36.01$^0$C) affected the thermal comfort, health and performance of the samples utilised for this study. Thus, the results from this present study are consistent with the findings of several authors earlier documented in section 1.0 of this study (e.g. Mathee et al., 2012; Fang et al., 2021; Li et al., 2016; Bendak et al., 2022).Their findings show that high outdoor air temperature can be detrimental to people that are working outdoors in construction sites. Specifically, the results from this study resonates the one of the conclusion reported by Liu et al. (2017), the author concludes that temperatures above 35$^0$C can be detrimental to the thermal comfort, health and performance of humans.

Future, research concerning the effects of outdoor air temperature on the thermal comfort, health and performance in Nigeria could be extended to other trades men in the construction industry. Also, future research on the effects of outdoor air temperature on the thermal comfort, health and performance of trades' men in the construction industry in Nigeria should focus on longitudinal studies. Lastly future studies should aim at objectively validating the health symptoms observed due to high air temperature in this study. The key contribution of the result from this study are two. First, results from this study provides empirical data that could promote strategies of limiting the effect of high outdoor air temperature on the health and productivity of people that are working outdoors in Nigeria. Second, results from this study complements the findings from previous research concerning the link between air temperature, health and performance. One limitation of this study is that the samples used for this study is relatively small, thus generalisation of the results to construction sites in Nigeria may not be applicable. Another limitation of this study is that the health of the samples was not measured objectively.

In conclusion, the results of this study provides some evidence that elevated outdoor air temperature (temperatures above $36^0$C) can affect the thermal comfort, health and performance of trades' men in the construction industry in Nigeria, particularly trades men that are working under high outdoor temperatures for 3hours and above.

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