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Measuring Thermal Comfort At Educational Buildings Different Floors In Egypt

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1. Abstract

Achieving high levels of indoor environmental quality is an important issue for designers since it can lead to enhanced occupant productivity, satisfaction, economic benefits, and improved sustainability results. This means it has recently emerged as a hot study topic in underdeveloped countries. Because of their outsized impact on residents' thermal comfort and the city's overall energy consumption, Cairo's educational buildings are the subject of this investigation. The Egyptian Energy code was scoured for information on the various building materials utilized to evaluate the current state of thermal comfort in these structures. The correlation between floor height and thermal comfort was then compared using computational modelling.

The objective of this research is to investigate the impact of floor height on the thermal comfort of building envelopes in Egypt, specifically focusing on how it may affect the building's overall performance and energy efficiency. The study methodology will be designed by combining computer-based inquiries and comprehensive literature reviews. The Design-Builder program will be utilized to simulate the thermal characteristics of all authorized materials specified in the Egyptian energy code for building envelopes. The data will be analyzed and interpreted to determine the optimal floor within the same building.

2. Introduction

Contemporary modes of living necessitate that individuals allocate as much as 90% of their time to indoor settings to engage in their routine tasks. For optimal outcomes, individuals must experience a sense of ease and comfort within these designated areas. The investigation of indoor thermal comfort is contingent upon physical parameters, including temperature, humidity, air currents, and radiation. The adjustment of indoor temperature and humidity levels for optimal comfort is commonly achieved through the use of air conditioning, albeit at the cost of increased energy consumption. Given the escalating global energy costs, it is crucial to explore strategies that can curtail energy usage while simultaneously improving thermal comfort.

Egyptian residential buildings are a notable contributor to energy consumption, constituting roughly 40% of the overall energy consumption of buildings. Hence, identifying efficacious approaches to curtail energy demand in residential edifices can aid in mitigating the escalating expenses of energy utilization. The provision of thermal comfort for students is a critical aspect that educational buildings must address. Examining such structures in highly populated urban areas can serve to emphasize the significance of this research. The Arab Academy for Science and Technology and Maritime Transport edifice presented a noteworthy instance for analysis owing to its positioning and function as an educational facility. In light of Egypt's arid and warm climate, the regulation of thermal comfort's physical parameters through air conditioning is frequently required, albeit at a considerable energy cost. This approach can effectively regulate ambient temperature conditions and create a comfortable indoor environment for occupants while minimizing the need for air conditioning. Nevertheless, implementing thick wall layers necessitates a substantial land area, which incurs significant expenses in Egypt. Thus, it is imperative to reduce the thickness of walls while preserving the advantages of having thick wall layers(Morsy et al., 2017).

The selection of an appropriate floor is crucial in achieving optimal thermal comfort which could be helpful for decision maker in choosing suitable floor for some activities than another one. The present study employs Design Builder, a widely recognized software for conducting environmental assessments, to assess the thermal performance of five floors which are divided into one underground floor and four above the ground within the AASTMT facility. The assessment of thermal comfort will be conducted for every floor of the building. The investigation will also encompass an analysis of ranking the floors from best to worst one regardless the thermal insulation.

3. Literature Review

There are numerous possible definitions of thermal comfort, but they all convey essentially the same concept. As an illustration, thermal comfort is conceptualized as "a mental state that signifies contentment with the thermal surroundings"(Yao et al., 2009). As indicated by the aforementioned definition, thermal comfort is an exceptionally interdisciplinary area of research, including numerous facets of diverse scientific disciplines. We might also obtain the definition of "that state of mind that conveys happiness with the thermal environment" by consulting ASHRAE Standard 55-2010(ASHRAE, 2017).

Satisfying everyone in a given location is challenging due to the considerable physiological and psychological variances that exist across individuals. Comfortable environmental conditions vary from one to individual. Nevertheless, a substantial amount of laboratory and field data has been gathered, which furnishes the essential statistical information required to establish thermally acceptable conditions for a specific percentage of inhabitants. Monitoring and preserving thermal comfort is possible via both quantifiable and non-quantifiable measures. The measurable aspects of thermal comfort can be broadly categorized into three distinct groups: air, surface, and human-induced factors(Kumar et al., 2018).

3.1. Thermal comfort models

As comfort index-based control has become the norm in the development of indoor thermal comfort conditions, the basic assumptions of thermal sensation/comfort models are called into question by the absence of a definite correlation between thermal preference and thermal feeling. However, the relation between the thermal environment and the comfort of the people has brought two distinguishable concepts;

a) The heat balance approach. b) The adaptive approach(Aydin Gezer, 2003)

The inception of these models can be attributed to Nevins et al. (Nevins, 1966) provided illustrations of empirical forecasts pertaining to heat sensation ratings. Fanger conducted a series of studies that are widely regarded as seminal in the field. His objective was to establish a universal equation that could be utilized to evaluate indoor thermal comfort via prediction models.

Empirical comfort index-based models, including Predicted Mean Vote (PMV) and Standard Effective Temperature (SET), were formulated on the physiological basis of a steady-state model of thermal exchanges between the human body and the environment. The indices described before are utilized to determine the thermal comfort specifications of a structure. The commissioning and operating phase of heating, ventilation, and air conditioning systems constitutes the second application(Ye et al., 2003).

3.2.Energy and thermal comfort using simulation tools.

The empirical investigations comprising this study are conducted utilizing computer simulation and evaluation tools. DesignBuilder 4.5, one of the Building Performance Simulation (BPS) tools comprising over 389 distinct tools, is the primary application utilized(Attia et al., 2011). DesignBuilder, as stated by Attia , is applicable across the entirety of the design process. In addition, it features a user interface that is developed with the architects' language in mind and is oriented on visuals. The case study was modelled and updated using the software Design Builder. The findings were subsequently imported into Microsoft Office applications for visual representation in the form of tables and charts(Attia, 2011).

4. Methodology and Building model

The experiments that are detailed in this manuscript were executed with the DesignBuilder simulation application. It permits concurrent evaluations of the performance of all building components, including window glazing, HVAC systems, controls, indoor air quality, human thermal comfort, and energy consumption, in addition to facade and wall construction.

The model utilised in all simulations comprised a centre module of a five-story college structure containing lecture rooms and offices on the majority of the building's floors. As the actual condition of the building all the building data were conducted by the real inspection and collection ways and then it has been used as an input data for the building model, these building layout and 3-D shape at DesignBuilder is shown at figure 1.

The following input data for the building was validated:

The first floor has been repeated for the all floors as it has the highest number of zones as it must be the same floor plan to avoid any effect of orientation or building sides dimensions.

Depending on the zone type, metabolic rates might vary, ranging from the standard metabolic rate for studying to the light office job metabolic rate.

Minimum of 12 l/s-person of fresh air for the entire structure.

Energy loads differ based on the classification of the space: computer labs have relatively high usage, office zones have moderate usage, and lecture rooms have relatively low usage.

In actuality, split air conditioning units comprised the HVAC system in operation.

The building construction of the main effective parts was as shown in table 1:

Table 1: Construction materials used in main components of building structure

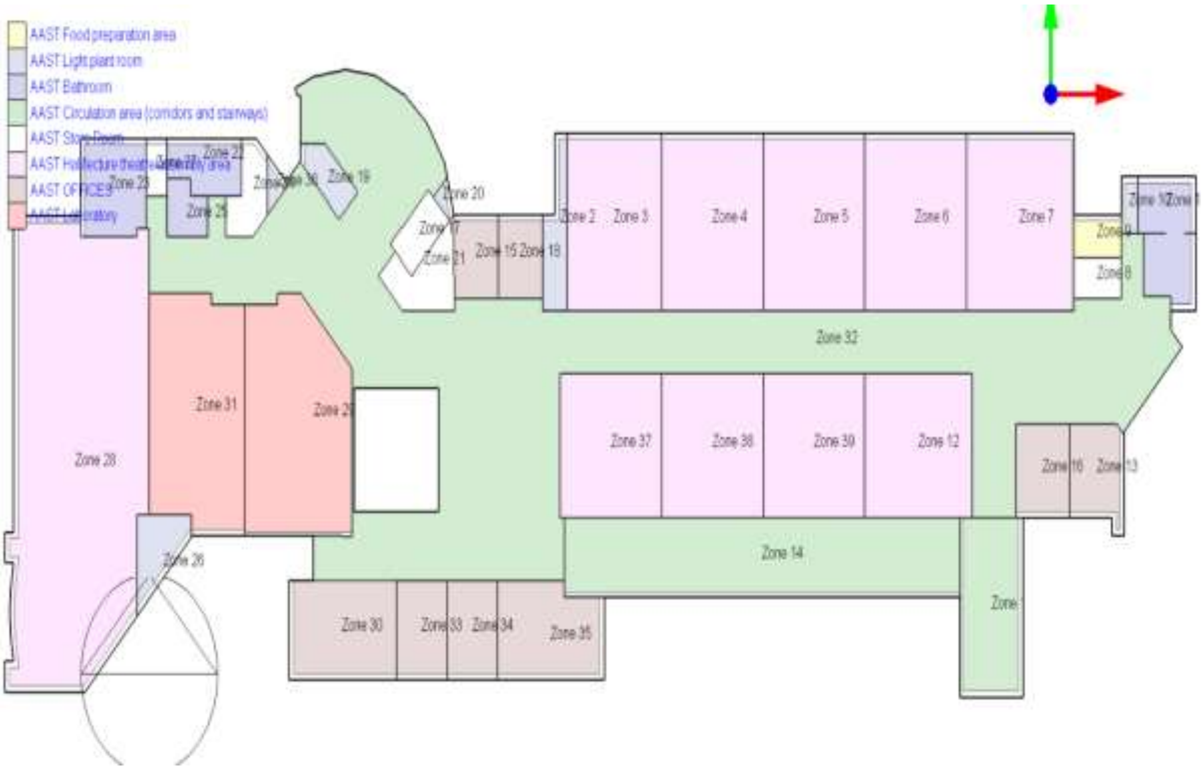
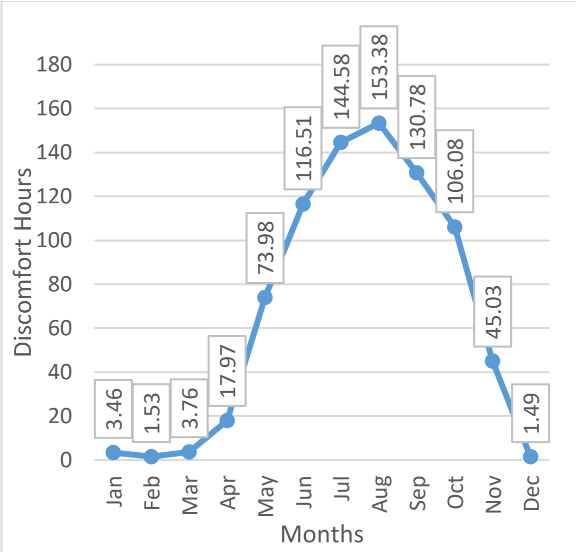


Figure 1: Ground Floor Plan

5. Results and Discussion.

The number of hours of discomfort has been utilized to quantify the thermal comfort impact. When constructing a building, the floor that causes the least amount of discomfort is the optimal choice for achieving the desired thermal comfort effect. The subsequent figures will illustrate the output outcomes. The findings will indicate which material's impact on thermal comfort is presented initially:

	Number of Layers	1	2	3	4	5	6	7
Thickness	Roof (mm)	50	30	30	30	250	30	5
	Typical slab (mm)	50	30	30	30	250	30	5
	External walls (mm)	5	20	30	250	30	20	5
Construction Material	Roof (mm)	concrete tiles	plastering	sand stones	sand stones	concrete slabs	plastering	painting
	Typical slab (mm)	concrete tiles	plastering	sand stones	sand stones	concrete slabs	plastering	painting
	External walls (mm)	finishing	gypsums plastering	plastering	wall concrete blocks	plastering	gypsums plastering	painting finishing



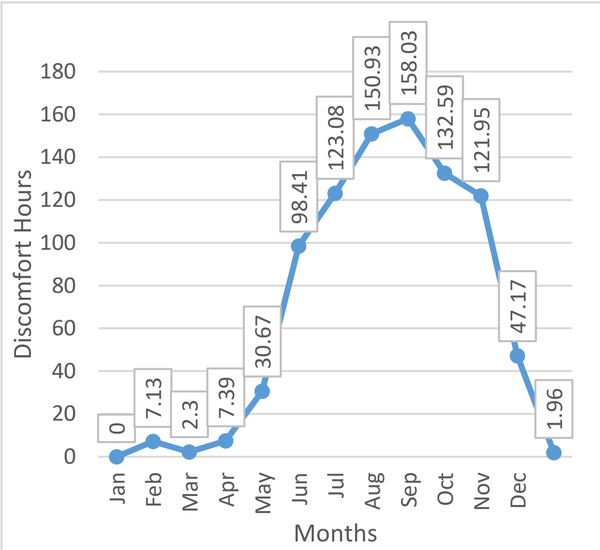
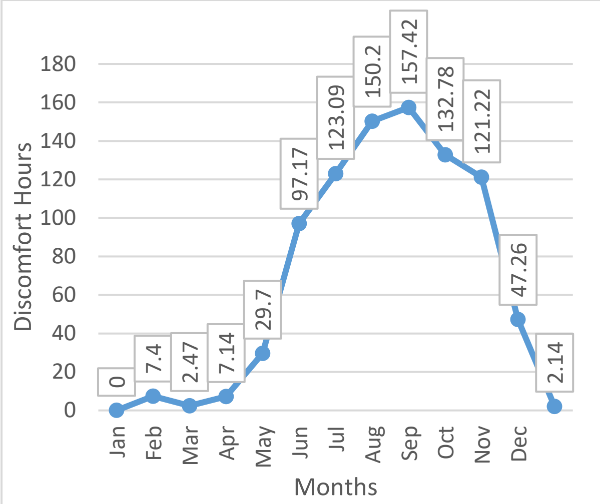


Figure 2:Under-Ground floor discomfort hours

Figure 3:Ground floor discomfort hours



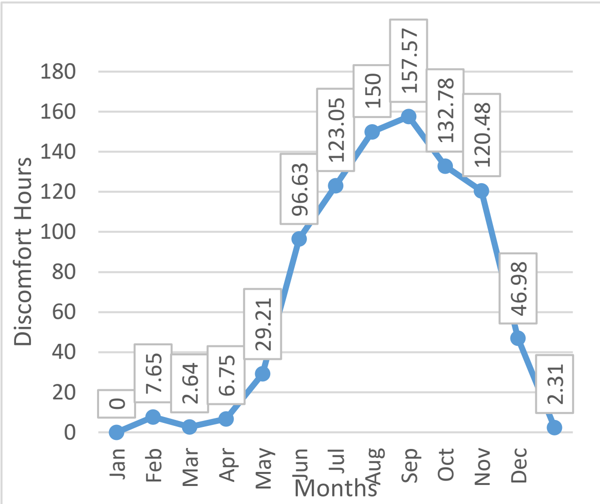


Figure 4:1st floor discomfort hours

Figure 5: 2nd floor discomfort hours

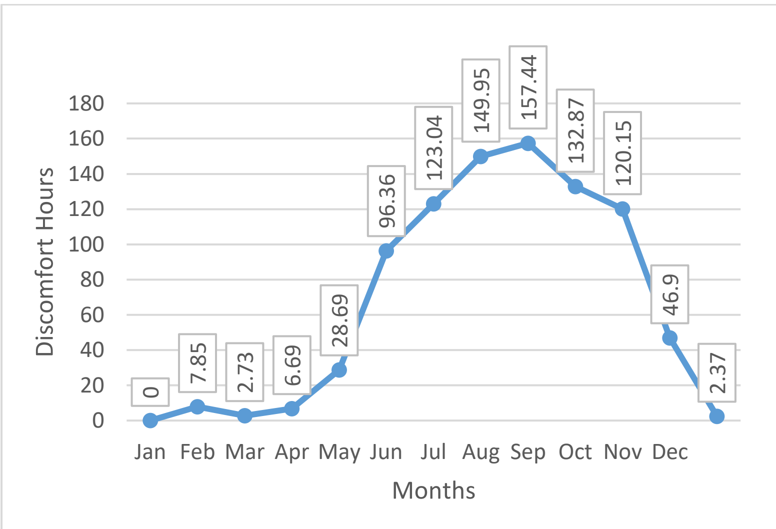


Figure 6: 3rd floor discomfort hours

In terms of the amount of discomfort hours experienced during the year, Figures 1, 2, 3, 4, and 5 all exhibit a behavior that is nearly identical. It is without a doubt the summer months that are accountable for the greatest number of hours of pain, which accounts for approximately 75 percent of the total hours.

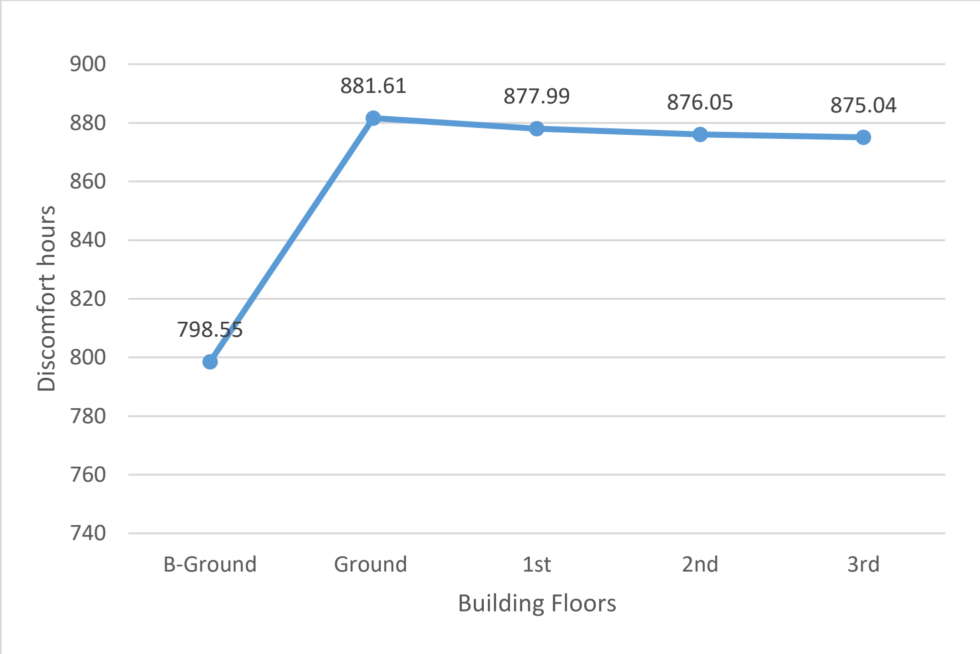


Figure 7: Total yearly Discomfort hours for each floor

Figure 6 illustrates the optimal floor, which unequivocally demonstrates that the underground floor was the most cost-effective option due to its minimal pain hours. Consequently, the discomfort hours on the upper levels were greater as a result of the action of soil, which provides a comparable effect to thermal insulation that was not implemented on any floor. Concentrating on above-ground levels, Figure 7 demonstrates that as one ascends the floors, thermal comfort improves, as indicated by the data.

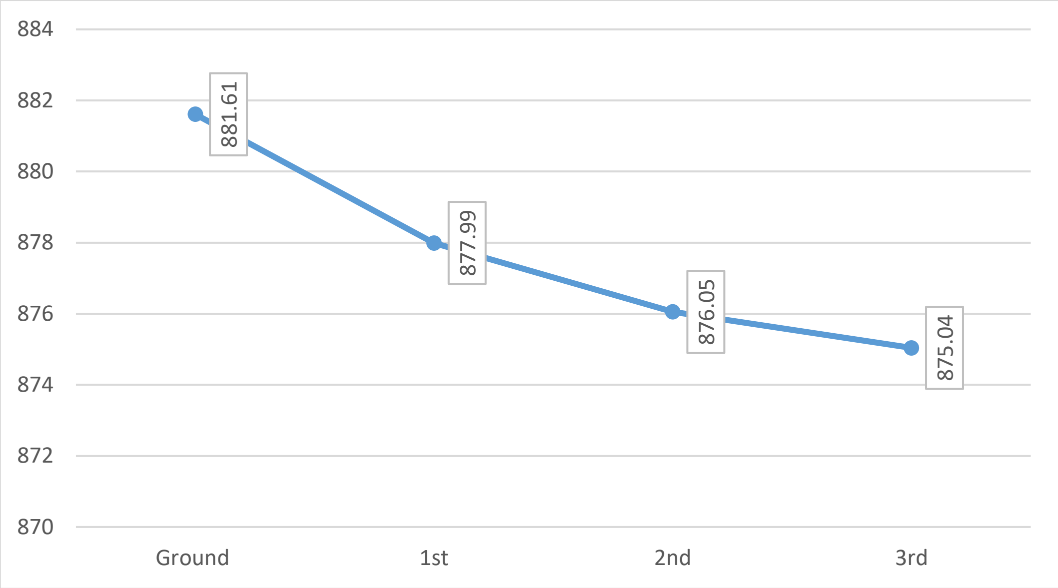


Figure 8: Total Yearly Above ground floors discomfort hours

6. Conclusion

In conclusion, the findings of our research highlight the significant impact that floor location has on the level of thermal comfort experienced within high-rise structures. The results presented in Figure 6 make it abundantly clear that the underground floor is the most cost-effective alternative, as it is the one that experiences the least amount of pain hours in comparison to the upper levels. This difference in the number of hours that people experience discomfort is primarily attributable to soil-induced consequences, which are analogous to the absence of thermal insulation. While this is going on, Figure 7 depicts a distinct pattern of increasing thermal comfort with increasing levels above ground level. The statistics show that there is a gradual rise in thermal comfort measures with elevation. This is indicated by the rising temperature.

The use of cutting-edge thermal insulation technologies ought to be given prominent consideration in the construction of future buildings in order to maximise the level of thermal comfort across all floors. The reduction of external temperature impacts can be accomplished by the enhancement of thermal insulation, which can effectively alleviate discomfort, particularly in higher levels. It is possible for architects and engineers to proactively solve thermal comfort concerns by exploiting these insights and pursuing breakthroughs in thermal insulation. This will ultimately result in improved occupant satisfaction and building sustainability in vertical urban areas.

7. References

ASHRAE 2017. Thermal Environmental Conditions for Human Occupancy.

ATTIA, S. 2011. State of the Art of Existing Early Design Simulation Tools for Net Zero Energy Buildings: A Comparison of Ten Tools.

ATTIA, S., HENSEN, J., BELTRAN, L. & HERDE, A. 2011. Selection criteria for building performance simulation tools: Contrasting architects' and engineers' needs. Journal of Building Performance Simulation, 5**,** 1-15.

AYDIN GEZER, N. 2003. THE EFFECTS OF CONSTRUCTION MATERIALS ON THERMAL COMFORT IN RESIDENTIAL BUILDINGS; AN ANALYSIS USING ECOTECT 5.0.

KUMAR, S., SINGH, M. K., MATHUR, A., MATHUR, S. & MATHUR, J. 2018. Thermal performance and comfort potential estimation in low-rise high thermal mass naturally ventilated office buildings in India: An experimental study. Journal of Building Engineering, 20**,** 569-584.

MORSY, M., FAHMY, M., ELSHAKOUR, H. & BELAL, A. 2017. Effect of Thermal Insulation on Building Thermal Comfort and Energy Consumption in Egypt.

NEVINS, R. G. 1966. Temperature-Humidity Chart for Themal Comfort of Seated Persons. Ashrae Transactions, 72**,** 283-291.

YAO, R., LI, B. & LIU, J. 2009. A theoretical adaptive model of thermal comfort – Adaptive Predicted Mean Vote (aPMV). Building and Environment, 44**,** 2089-2096.

YE, G., YANG, C., CHEN, Y. & LI, Y. 2003. A new approach for measuring predicted mean vote (PMV) and standard effective temperature (SET∗). Building and Environment, 38**,** 33-44.