



An Evaluation of Climate Responsive Design Features of Buildings on Knust Campus Based on Mahoney Tables

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Authors' contributions

This work was carried out in collaboration between all authors. Author CK formulated the study and managed literature searches. Author SAA wrote the first draft of the manuscript and author SOA managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

The warm and humid climate of the Kwame Nkrumah University of Science and Technology (KNUST) necessitates that climate responsive buildings are thermally comfortable when laid down design principles are followed in the planning and construction of dwellings. An example of a climatic design guide leading to decision support principles toward the design of buildings is the Mahoney Tables. In this paper, the evaluation of buildings of two colleges which are characterized by old and new constructions is studied. The main aim is to find out which building type (old or new) were constructed based on climatic design principles. The evaluated results based on the Mahoney Tables showed that older buildings (95%) conformed to climatic design principles whilst some recently built structures (40%) were deficient in various aspects of sustainable design principles such as orientation. The study provides a direction and caution designers to use climatic responsive design principles in the planning and construction of buildings.

Keywords: Sustainable design; climate; buildings; Mahoney tables.

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1. INTRODUCTION

The fundamental components of our physical or built environment are buildings and consequently, the quality of buildings through architecture needs much to be desired [1]. Climate has always been the greatest factor for consideration when it comes to dealing with shelter and the built environment, and has also challenged man in his quest for a better life. Nevertheless, man has worked out systems or techniques to provide suitable conditions for existence. Climate responsive design has been seen as an important technique to accomplish this dream of man in the field of architecture. Buildings are designed to modify external environmental conditions creating suitable atmospheres for human comfort. Furthermore, buildings provide the microclimate required for human existence and define spaces for all human activities [2].

Traditional or vernacular architecture has precedence of using the building form, envelope and roof to create acceptable human conditions for dwelling [3]. However, contemporary buildings have been designed to rather employ mechanical techniques for making this possible with little consideration to climate. Technological advancement has made both heating and cooling of modern buildings much easier and therefore less concern has been given to climate for maintaining comfortable indoor environment [3]. The use of air conditioning (AC) alone according to the [4] as cited in [5] is responsible for about 15% of electricity consumed worldwide. Occupants' activities and the use of electrical and mechanical equipment dissipate heat into the building space [5]. The cooling of the indoor space for thermal comfort therefore becomes necessary and is expensive with the current trend in energy cost. The situation is even worse with the recent energy crisis in Ghana.

The aim of this study is to expound climatic responsive design principles for the warm climate region of Kumasi. An example of a climatic design guide leading to decision support principles toward the design of buildings is the Mahoney Tables. The principles of the Mahoney Tables form the variables around which this research revolves by answering questions such as

- What are the recommended specifications of the Mahoney Tables for the warm-humid climate of KNUST Campus?

- How are the principles of the Mahoney Tables incorporated in the design of buildings of Kwame Nkrumah University of Science And Technology (KNUST) Campus?
- What is the level of awareness of the use of the Mahoney Tables among architecture students?

The study focuses on comparing old and new buildings in the College of Architecture and Planning (CAP) and the College of Engineering (CoE). The study is expected to provide a direction and caution designers as to how to use climate responsive design principles in the planning and construction of buildings.

Several authors have provided related definitions for Climate Responsive Architecture. [6] has defined Climate Responsive Architecture as the type of architecture that is aimed at making sure occupants' thermal and visual comfort are achieved with little or no resort to non-renewable energy sources by integrating the elements of the site's climate efficiently. Other authors, [7] and [8] have come up with definitions that point to Climate Responsive Architecture as being the type of buildings that modifies climate, provides comfortable indoor environment for occupancy and reduce energy consumption.

[3] associates designing a building with local climatic considerations with some benefits as enhancing the use of natural energy and in the long run help to maintain its operational energy demand. Consequently, a climatically responsive design requires less energy usage since natural means (natural ventilation and solar shading) are employed in the design.

Carl Mahoney, working together with John Martin Evans and Otto Königsberger, came up with a set of tables outlining design recommendations which serve as a guide to climate responsive designs, and help designers from doing just guess work [9]. The Mahoney Tables consist of six tables; the first four tables are used for entering of temperature and relative humidity data, and used for comparing the requirements for thermal comfort. The last two tables are used for checking the right design criteria which is the outcome of design recommendations of designing and construction of the buildings [3]. The Design recommendations for architects to use for planning spaces are Building Orientation; Shading; Air Movement; Building Opening; Building Skin and massing; Spatial Organisation

[10]. The Mahoney Table usage in conjunction with these design recommendations can produce the best results desired. Detailed description of the Mahoney Tables is provided in [3] and [10] for further reading.

Orientation has been defined by the Cairns Regional Council as the positioning of a building on a site in addition to the arrangement of its rooms within the site [11]. [12] suggests some considerations for the choice of orientation which includes the vista in different directions, roads around the site relating them to the position of the building, the nature of the climate among many others. [13] explained that an understanding of how to properly position a building on a given site can influence some factors such as window sizes and positions and planning of the internal spaces. Similarly, [14] gives some determinants for a particular orientation: the climatic factors of wind and solar radiation, as well as by considerations of view, noise and requirements of privacy.

The orientation of a building eventually determines how much energy it would use to provide thermal comfort for its occupants'. [15] affirms that the amount of sunshine is affected by the orientation of a building. Furthermore, [13] points out that orientation is directly linked with the prevailing wind direction and sunlight (daylight) and therefore the treatment of every facade of a building in different ways to acknowledge these is worth considering. Furthermore, the Mahoney Tables recommend all buildings to be in north-south orientation and rectangular in shape to reduce the exposure to the sun. By this, only a small area of the building is exposed to the solar radiation, thus creating comfortable interior conditions for occupancy. In a warm humid area like KNUST campus in Kumasi, [16], recommends that the orientation of buildings to the north and south axis enhances better building performance. Moreover, in warm-humid climatic zones, orienting a building to exclude excessive solar radiation and enhance the admission of diffuse daylight from the sky into the interior space must be the major consideration of any designer.

According to [17], shading is a technique or method of blocking the rays of the sun from getting into a building. [18] also states that the main source of heat build-up (gain) in a building is sunlight dissipated into its interior through the building envelope. The building envelope is constituted by elements such as roofs, walls and

windows are the main elements through which heat is built up in the interior of a space [17,19]. Consequently, these are the main areas through which heat is dissipated into the interior space from the external environment. Therefore, shading of these elements is important in any design.

Similarly, [20] has established various shading strategies and their order of effectiveness as follows: trees and shrubs, trellises, overhangs, awnings, shade screens, window coatings and interior shades. Several other modifications to any of the above can be done to enhance effective shading of the building. However, shading strategies installed in the interior rather minimise or control glare and are not effective in preventing solar gain into the space.

[18] explained that the most efficient shading devices thermally, are external shading devices describing that they intercept the solar radiation before it enters any enclosure. Exterior shading strategies have been established to be more effective in reducing solar radiation by 30-35% than their interior counterparts, which only reflect a small percentage of radiation and still release heat into the enclosure [21] as cited in [22]. Moreover, a research conducted by Division of Energy and Building Design at Lund University according to [17] revealed that, a building using external shading could have its cooling load and annual cooling demand decreased by a factor of two rather than using internal solar shading. The study then concluded that external shadings are much more efficient than internal types.

The Mahoney Tables recommend shading of buildings from cold or dusty hot winds and protection from the sun, sky glare and rain showers by using horizontal overhangs. Also, the Mahoney Table recommends deep verandas; wide overhangs and covered passages as effective for rain protection against the building.

Air movement in an enclosure is necessary for the enhancement of the general well-being of its occupants. [23] explains that the movement of air within an enclosure can take away exhaust gases, odour and sounds, mould spores and gases created by human activities within the space. Similarly, [24] has established that good air flow is a requirement for airborne sound transmission control. The paper goes ahead to state that the causes of health problems are as a result of odours and gases from outside and

adjoining buildings. In the same vein, [25] has explained that air carries moisture which imparts indoor air quality by taking away the distribution pollutants and microbial reservoirs and hence creating a serene atmosphere for the use of the enclosure as people will find it difficult to respire while going about their normal activities.

Air movement within a space creates an ambient atmosphere for human occupancy. [14] explain that the movement of air within a space accelerates convection, helping evaporation from the skin, thereby creating a cooling effect.

The Mahoney Tables [3] recommends that rooms should be single-banked with windows to ensure cross ventilation for air movement. Nevertheless, if air movement is insignificant, then double-banked could be employed, with room height greater than 2.75 m. Furthermore, Tables recommends spacing between two buildings to be 5 times the height ($5 \times H$) of one building from the other for effective breeze penetration.

Additionally, the Mahoney Table recommends varying window to wall area ratios for any given climate. For instance, large openings covering 40 –80% of north and southern wall areas (depending on the climatic zone), very small openings covering wall areas greater than 20% and medium openings covering 20 – 40% of wall areas [3].

Furthermore, the building skin or “envelope” serves several functions and the following below shows the various functions of the building skin. According to [26], the purpose of the building skin is to provide protection against external elements; moisture, air, and temperature ingress and egress. Meanwhile, [14] have stated that the building skin regulates the flow of heat into the building and as such creating comfortable interior environment.

However, the Centre for Sustainable Buildings and Construction [27] has explained that the building skin functions as the outer shell that protect the indoor environment as well as to facilitate its climate control.

Additionally, the recommendation by the Mahoney Tables state that external walls should be light in weight with low thermal capacity with internal wall being light for conditions where hot-dry conditions exists for a short time [3]. But there can be situations where both external and internal walls are massive (where annual mean

range temperature is over 20°C. Also, roofs should be light and well insulated with low thermal capacity but heavy roofs with substantial thermal capacity may be considered in some cases depending on the climatic area.

2. STUDY BUILDINGS AND APPROACH

The setting of the study is the College of Architecture and Planning (CAP) and College of Engineering (CoE) of KNUST in the city of Kumasi in Ghana. The city of Kumasi is located in the warm humid forest zone of Ghana. The climatic condition of Kumasi is categorized as sub-equatorial, with a daily average minimum and maximum temperature around 21.5°C and 30.7°C respectively [28]. According to [29], Kumasi experiences much higher rainfalls than northern part of the country, and has average total rainfall and mean number of rain days are 107.9 mm and 9.9 days respectively. The Kumasi Metropolitan Assembly [30] as cited in [28] has stated that Kumasi has an average humidity range of 60% to 84% depending on the season. There are two rainy seasons: March to July and September to October [28].

In all, CAP and CoE have 8 and 11 blocks of buildings respectively, comprising of classrooms, office spaces, studios, laboratories and workshops. All of the blocks are oriented in the north-south direction with the exception of blocks 6 and 8 of CAP. The blocks vary in the number of floor levels from a single storey to a highest of five storeys. The buildings have various roofing systems; mono-pitch, double pitches and flat concrete roofs. There are parapet walls for the roof which adds to the external aesthetics. The average spacing between the various blocks is calculated to be 11 m for CAP and 27.3 m for CoE. There is the existence of an excellent linkage by the use of paving among the blocks of buildings in both colleges; hence least distance is covered moving from one block to another. Cross ventilation is well utilised in the design of the buildings providing comfortable environment for the use of the spaces. Figs. 1 and 2 show the layouts of buildings at CAP and CoE respectively.

Students from CAP formed the research population. A sample size of 80 students from CAP was chosen for conducting the field work. The major data collection method used respondent filled questionnaires, specifically, closed-ended questions. However, open-ended questions were also used to provide a more

complete idea of the respondents' feelings, opinions and attitudes. Climatic data was obtained from the Ghana Meteorological Agency.

The case study method of data collection was used, where both the new and old buildings in the two colleges (Figs. 1 and 2) were carefully observed with respect to their orientation, window openings and sizes, air movement patterns, wall thickness, shading devices and methods, and general arrangement and organisation of spaces in the buildings.

Data collected were converted into charts, tables and percentages using computerised data analysis software known as Microsoft Office Excel. The results were then analysed within the context of the research objectives.

The Mahoney Tables were used to generate a set of reference tables as a guide to climate appropriate design [9]. The guidelines for entering data into the Mahoney Tables are presented and explained fully in [9, 3, 14, 31,32]. Results of thermal comfort analysis were obtained by entering the annual minimum and maximum temperature and relative humidity values to give design indicators for KNUST [31]. From these indicators, the elementary perspectives of the layout, shape, structure, etc. of a climatically responsive design were evolved.

Through purposive sampling, questionnaires were distributed to a sample size of 80 people (students and architects) chosen for the field work to ascertain their views and adherence to the use of climatic responsive design principles.






Fig. 1. Map of the college of architecture and planning
(Source: KNUST Development Office, 2014)

1, 2..8 etc. Blocks in the College Soft landscape Parking Areas



Fig. 2. Map of the college of engineering
 (Source: KNUST Development Office, 2014)

Legend

-  Blocks in the College
-  Soft landscape
-  Parking Areas

3. FINDINGS AND DISCUSSION

For clarity in presentation, only the recommended specifications and detailed recommendations of KNUST achieved with Tables 3 of the Mahoney Tables are presented. The observed recommended specifications for a building to be designed on the campus of KNUST are grouped under eight headings (Table 1): layout, spacing, air movement, openings, walls, roofs, outdoor sleeping and rain protection. Tables 2 and 3 present how the design of the various blocks in CAP and CoE considered the various recommendations of KNUST Campus from the Mahoney Tables.

In all, there are 6 old (blocks 1-6) and 2 new (blocks 7-8) buildings comprising 75% and 25% blocks of the college respectively. In all, there are 8 old (blocks 1-4, 6, 9-11) and 3 new (blocks 5, 7-8) buildings comprising 73% and 27% blocks of the college respectively. Some blocks in the CAP And CoE are shown in Figs. 3 and 4 respectively.

With regard to Building Orientation, all the 6 old and 1 new building of CAP and all buildings of CoE (both old and new) are oriented in north-south direction as recommended by the Mahoney Tables. As stated by [33], proper orientation maximises day lighting; thereby

decreasing the use of artificial lighting. Six blocks out of the 8 blocks in CAP and all 8 old blocks of CoE employ the use of natural lighting and ventilation fully with little use of artificial systems. Also, [34], recommends orientation of buildings in the north-south direction for better building performance and this emphasizes the fact that these 6 blocks CAP and 10 blocks of CoE have better building performance than Blocks 6 and 8 of CAP and Block 8 of CoE which has to rely on AC for achieving thermal comfort.

Shading in all the buildings studied is effective. According to [35], the most easily and effective areas of solar shading are the north and south elevations through orientation which 5 of the old blocks and 1 new block satisfy in terms of shading.

For shading by orientation, 83% of the old blocks fulfil this requirement with the remaining 17% going for the new blocks of CAP. However,

in CoE, 100% of the blocks, both the old and new fulfil this requirement for shading by orientation. Also, [18] has explained that external shading devices are the most thermally efficient way of intercepting the sun rays before entering any enclosure and this points out that all the 19 blocks in both colleges have various ways of external shading including horizontal fins, vertical and horizontal projections, recesses and verandas. In summary, there is a 100% shading of all the blocks in the two colleges as recommended by the Mahoney Tables.

Air Movement in majority of the buildings is well facilitated. [36] has stated that air movement takes place as a result of either pressure or pressure difference creating an ambient atmosphere for human occupancy. With air moving in the south-west direction and considering the fact that 83% of both the old and new buildings of CAP and 100% of all buildings at CoE are well oriented with large wall areas to



Fig. 3. Some blocks at the college of architecture and planning
(Field Survey, 2014)



Fig. 4. Some blocks at the college of college of engineering
(Field Survey, 2014)

Table 1. Recommended specifications for buildings on KNUST campus derived from Mahoney table

1. Layout:	All buildings should be in north-south orientation and rectangular in shape to reduce exposure to solar radiation and compact courtyards for thermal storage.
2. Spacing:	Protection from cold and hot winds is required and compact planning if air movement is not significant.
3. Air Movement:	There should be single-banked rooms with windows to ensure cross ventilation but in the case of double banking, temporary cross ventilation must be assured with room heights greater than 2.75 m.
4. Openings:	There can be large openings covering 40-80% of north and south wall areas, very small openings covering less than 20% of wall areas or medium openings covering 20-40% of wall areas but avoiding openings in west walls. Windows must be provided at body heights on windward side.
5. Walls and floors:	Both external and internal walls must be light weight with low thermal capacity.
6. Roofs:	A light but well insulated roof with low thermal capacity is recommended for this area.
7. Outdoor sleeping:	Outdoor sleeping areas may be provided on roofs, balconies or in patios for outdoor relaxation.
8. Rain protection:	There must be protection from heavy rains by the use of deep verandas, wide overhangs and covered passageways as well as adequate rain water drainage.

receive the prevailing winds, natural ventilation within these blocks is achieved by the pressure difference created. The air movement is further facilitated by single-banked and cross ventilated rooms in both the old and new blocks as specified by the Mahoney Tables. However, one side of two floors of one of the new blocks (Block 7) of CAO is double-banked with stack effect to facilitate the air flow within the rooms. Block 3 of CoE which has double-banked arrangement is however designed to facilitate air flow within the rooms through cross ventilation.

In all, the old buildings of both CAP and CoE had between 18-75% of their north and south areas covered with openings except block 6 of CAP, while the new had between 5-70% of wall areas covered with openings as specified by the Mahoney Tables. Nevertheless, as stated by [24], openings permit daylight into a space, offer views outside, provide natural ventilation and offer entry into a room. The varying sizes of openings in buildings studied facilitate [24] statement. But in summary, the old buildings have the highest percentage (75%) of building opening for air flow than the new buildings (70%) falling within the range specified by the Mahoney Tables.

The Centre for Sustainable Buildings and Construction [27] has stated that the skin of a building is the outer shell which protects the

indoor environment and facilitates its climate control around the building. All the external and 95% of all internal walls of both the new and old buildings of both CAP and CoE are made 150 mm thick sandcrete blockwork which modify the harsh climatic conditions of the external environment. Various roof types ranging from mono-pitched to gable roof are used for both new and old blocks which exclude the rains from affecting their occupants. Also, all the roofs of both blocks are made of light reflective roofing material, predominantly made of long span aluzinc sheets, as the Mahoney Tables recommend. Two of the new blocks (Blocks 2 and 3) of CoE, however, are made of clay roofing tiles.

The Mahoney Tables also recommends the nature of spacing for breeze penetration and protection from hot and cold winds. The spatial organisation of both the old and new blocks of CAP is generally made of a grid-like arrangement system with highest spacing among the blocks being 27.5 m, thus making the entire composition compact. However, the new blocks (5, 7 & 8) of CoE have central and grid-like arrangement systems for respectively, while that of the old blocks consists of linear and grid-like arrangement systems. The highest spacing among the blocks is measured as 70 m making up a dispersed composition.

Table 2. Evaluation of blocks of CAP based on recommendations from the Mahoney tables

Block no.	1	2	3	4	5	6	7	8
Layout								
North-south orientation	√	√	√	√	√	x	√	x
Rectangular shape	√	√	√	√	√	√	√	√
Windows in North-south	√	√	√	√	√	√	√	√
Windows in East-West	x	x	x	x	x	√	√	√
Spacing								
Between blocks (m)	8-10	8-11	8-10	8.5	1.5-28	1.5-25	6-28	8
Overall height (m)	10	5	10	3	12	4.5	18	18
Air movement								
Single-banked rooms	SB	SB	SB	SB	SB	SB	DB/SB	SB
Room heights (m)	3	4	3	2.7	3	3	3	3
Air-conditioned (some)	√	√	√	√	√	√	√	√
Openings								
Window-to floor ratio (%)	31	33	31	75	75	7	70	70
Walls and floors								
External Walls	SB	SB	SB	SB	SB	SB	SB	SB
Internal Walls	SB	SB	SB	SB	SB	SB	SB	SB
Floors	CS	CS	CS	CS	CS	CS	CS	CS
Roof								
Mono-pitch	√	x	√	√	√	x	x	x
Double pitch	x	√	x	x	x	√	√	√
Light material	√	√	√	√	√	√	√	√
Insulated	√	√	√	√	√	√	√	√
Parapet	x	√	x	x	x	x	√	√
Outdoor sleeping								
Outdoor sleeping	x	x	x	x	x	x	x	x
Balcony	√	x	√	x	x	√	√	√
Foyer	x	√	x	√	x	x	x	x
Verander	√	x	√	x	x	√	x	√
Outdoor seating	x	x	x	x	x	√	√	x
Rain protection								
Deep verander	√	x	√	x	x	√	x	√
Covered passages	√	√	√	x	x	x	x	x
Rain Gutter / Pipe	√	√	√	x	√	x	√	√
Spatial organisation								
Grid-like	√	√	√	√	√	√	√	√
Central	x	x	x	x	x	x	x	x
Linear	x	x	x	x	x	x	x	x

SC – 150 mm Sandcrete Blocks; CS – 150 mm Concrete Slab; SB - Single Banking; DB - Double Banking

4. QUESTIONNAIRE AND INTERVIEWS RESULTS

4.1 Students' Responses

Out of a total of 80 questionnaires administered, a total number of 70 students responded to questionnaires and were retrieved by the researcher, representing 87.5% of the total questionnaires administered. Of this number, first

year students represented 14%, second year, 29%, third year, 43% and fourth year, 14%.

Some of the results of the interviews are outlined and discussed. On climate consideration in designing (Fig. 5), it is evident from this result that 64% of the total respondents very often take into consideration issues concerning climate hence coming out with designs which appropriately responds to the climatic demands in the setting of the buildings. Fig. 5 shows the responses.

Table 3. Evaluation of blocks of CoE based on recommendations from the Mahoney Tables

Block No.	1	2	3	4	5	6	7	8	9	10	11
Layout											
North-south orientation	√	√	√	√	√	√	√	√	√	√	√
Rectangular Shape	√	√	√	√	√	√	√	√	√	√	√
Windows in North-south	√	√	√	√	√	√	√	√	√	√	√
Windows in East-West	x	x	x	x	√	x	√	√	√	x	x
Spacing											
Between Blocks (m)	45	7-45	7-12	10-12	40-70	4-35	35-37	4-20	10-58	10-58	10-14
Overall height (m)	4	7	7.5	12.5	18	16	7.5	12	10	5	5
Air Movement											
Single-banked	SB	SB	DB	SB	SB	SB	DB/SB	SB	DB	DB	SB
Room heights (m)	3	3	3	3	3	3	3	3.5	3.5	3.5	3.2
Air-conditioned (some)	x	√	√	√	√	√	√	x	√	√	x
Openings											
Window-to floor ratio (%)	31	75	70	70	70	60	35	18-25	18-30	18-30	35
Walls and floors											
External walls	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC
Internal walls	SC	SC	SC	SC	SC	SC	SC	SC	TIMB	SC	SC
Floors	CS	CS	CS	CS	CS	CS	CS	CS	CS	CS	CS
Roof											
Mono-pitch	x	√	x	X	x	x	x	x	x	√	x
Double pitch	√	x	√	√	√	√	√	√	x	x	√
Light material	√	√	√	√	√	√	√	√	x	√	√
Insulated	√	√	√	√	√	√	√	√	√	√	√
Parapet	x	x	√	x	x	x	x	√	√	x	x
Outdoor sleeping											
Outdoor sleeping	x	x	x	x	x	x	x	x	x	x	x
Balcony	x	x	x	x	x	x	x	x	x	x	x
Foyer	x	x	x	x	√	x	√	√	x	x	x
Verander	x	√	x	√	x	√	x	x	x	x	x
Outdoor seating	√	x	x	x	x	√	x	x	x	x	x
Rain protection											
Deep verander	√	√	x	√	√	√	x	x	x	x	x
Covered passages	√	x	x	x	x	x	x	x	√	x	x
Rain Gutter / Pipe	x	√	√	x	√	x	√	√	√	√	x
Spatial organisation											
Grid-like	x	√	√	√	x	x	√	√	x	x	√
Central	x	x	x	x	√	x	x	x	x	x	x
Linear	√	x	x	x	x	√	x	x	√	√	x

SC – 150 mm Sandcrete Blocks; CS – 150 mm Concrete Slab; TIMB - Timber Partitions; SB - Single Banking; DB - Double Banking

However, 6% (neutral to never) of the respondents voted otherwise, evident of the fact that there is the need to further intensify the education on the reason for designing with consideration for climate.

Questions regarding exposure of respondents to design guide (Table 4) revealed that only 66% of the respondents had been exposed to some form of design guide in the field of architecture. The

results also show that efforts by various stakeholders in exposing respondents to design guides should be intensified. This is because 34% of the total respondents indicated they had never heard anything about design guides. Table 4 indicate this result.

On the usage of design guide in designing, the results indicated that the respondents did not always use design guides in designing of spaces

(Fig. 6). Forty percent (40%) of the respondents stated that they occasionally use design guides in designing while 16% indicated that design guides are always used by them when planning spaces. In all, the results show that respondents have to be encouraged and entreated to use design guides always. This is because the end result of using design guide is coming out with climate responsive design which this study seeks to expound.

were not aware of the Mahoney Tables. Only 1% of the respondent claimed to have heard about the Mahoney Tables. Students have indicated by this result that greater awareness creation campaign should be embarked upon.

Table 4. Exposure of respondents to design guide

	Frequency	Percentage (%)
Yes	46	66
No	24	34
Total	70	100

On awareness of the Mahoney Tables (Fig. 7), 81% of the total respondent pointed out that they

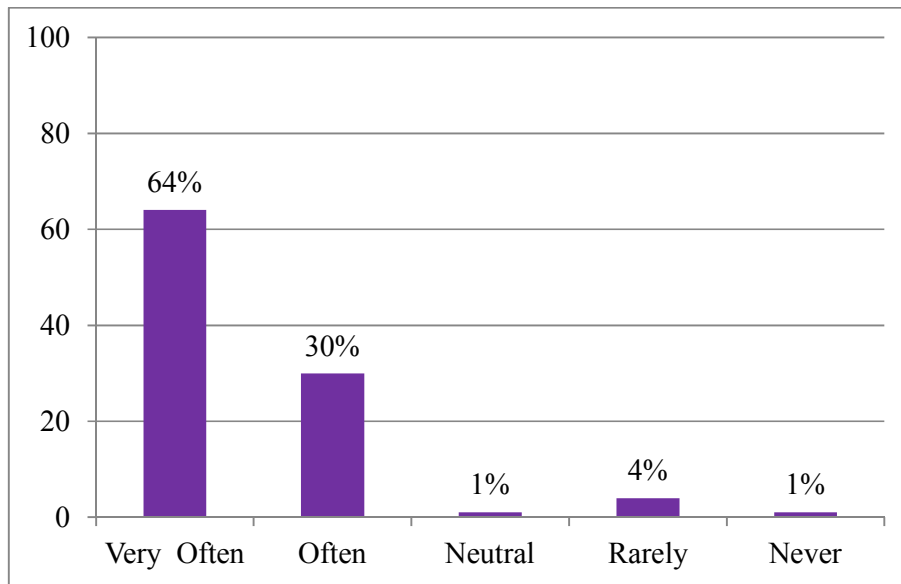


Fig. 5. Climate consideration in designing

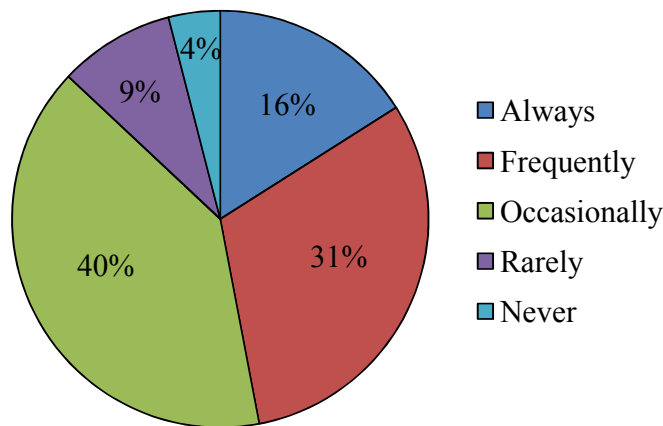


Fig. 6. Usage of design guide

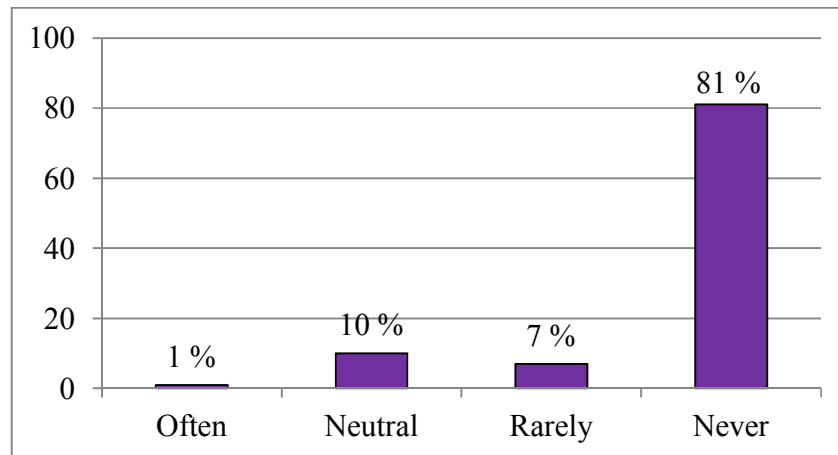


Fig. 7. Awareness about the Mahoney tables

5. CONCLUSION AND RECOMMENDATIONS

The study had the aim to find out which building type (old or new) were constructed based on climatic design principles. This was because the warm and humid climate of the Kwame Nkrumah University of Science and Technology (KNUST) necessitates that climate responsive buildings are thermally comfortable when laid down design principles are followed in the planning and construction of dwellings. The Mahoney Tables, a climatic design guide that provides decision support principles toward the design of buildings, were used to evaluate elementary perspectives of the layout, shape, structure, etc. of a climatically responsive design generate a set of reference tables as a guide to climate appropriate design and used to assess elementary perspectives of the layout, shape, structure, etc. of case study buildings. Data on level of awareness on Mahoney Tables amongst students were accrued using questionnaires.

From the case study conducted and questionnaire administered, the following conclusion can be established:

- In all, both the old and new buildings in both colleges are in the proper orientation (north–south direction) as specified by the Mahoney Tables with the exception of two blocks, one each of both the old and new blocks.
- Both the old and new blocks are all having various form of shading from horizontal fins to wide overhangs and verandas which promote energy efficient building design.

- Air flow through both the new and old blocks is effective because they are oriented to receive the prevailing winds and facilitated by the pressure differences created around the blocks. However, one block each of both the old and new buildings is oriented in the opposite direction (east–west direction) and this affects the air flow through the blocks.
- This study has revealed that the knowledge level of the Mahoney Tables by students is very little. Perhaps due to the lack of interest in designing with the Mahoney Tables. The study can therefore form the basis of literature to be used to enforce the use of the principles of the Mahoney Tables.

Based on the responses of the students about the knowledge of the Mahoney Tables, lecturers and other stakeholders needs to make the importance of such a design guide known to the students. This will help them in their training towards becoming better architects. Furthermore, the results have shown that level of awareness about the Mahoney Tables is low which calls for the increase in the intensity of awareness creation among students. Also based on the results obtained, the Department of Architecture could devise a strategy to incorporate the principles of the Mahoney Tables in student studio designs geared towards climatically responsive building.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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