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Illuminance Performance of Design Block Windows in Public Basic Schools in Tamale Metropolis - Ghana

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----------ABSTRACT----------
Illuminance is an important measure of the quantity of light falling on a surface especially in learning spaces. Design block windows are fast becoming a common window choice for schools as it is cheaper to maintain and provides more security. Scanty or no information exists on classroom illuminance for this window type especially for public basic schools.This research examined the illuminance in classrooms with design block windows per existing standards of classroom illuminance. Classrooms were measured and mapped into a variety of environmental variables and illuminance measurements taken using lux metres(LX 1330B) with only daylight at 0.72m from floor level with four parameters. Fourty percent of the classrooms studied had at any test time/condition, the recommended amount of lighting of 300-500 lux whiles 60 percent were either below or above this range. The study concluded that, more attention has to be given to the development and enhancement of passive daylighting through alternative ventilation systems like design block windows which can stay open in all conditions and under any weather.
Keywords:*Illuminance, Design Block, Lux, Passive daylighting.*

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I. INTRODUCTION

The type of ventilation used in a classroom, whether conventional windows or design block (DB) windows, has implications on the conduciveness of classroom spaces. Tanner reiterated, "Light is the most important environmental input, after food and water, in controlling bodily functions" (Tanner, 2008). Many studies have established a positive correlation between proper ventilation and pupils' work rate (Galasiu&Veitch, 2006) and have even shown access to natural light and fresh air systems can increase health, comfort,working speed, accuracy, and task performance (Chambers, 2004; Gregg & Ander, 2008).

Reports for the Ghana National Education Campaign Coalition by Sawyerr (2010) and the Ghana Center for Democratic Development (CDD-GHANA) by Amanfo&Ampratwum (2013) on the state of infrastructure in Ghanaian schools revealed that schools were being built with design blocks or honeycomb windows instead of the conventional windows. This left the classrooms hot and dark, and had implication for adequate flow and circulation of air in the classrooms especially during the afternoon shift when lessons went on till 5.00pm.

It was therefore imperative to investigate the use of design blocks used as windows in public basic schools as DB windows are constantly in a closed position and filters the amount of light that enters a space. This research also compared the illuminance in the classrooms with DB windows against standard illuminance requirements.

Generally, recommended and measured illuminance levels are given in terms of the amount of light, illuminance, falling on a horizontal work plane (Rea, 2000). This consists of a measure of the total amount of visible light present and the illuminance as a measure of the intensity of illumination on a surface.Light intensity is measured via lux, and as argued by Mott et al (2012), 500 lux horizontally on the workplane is the minimum used to create enough illumination for teachers and students to see if there is a lack of natural light available in classrooms.

Other standards also exist by other lighting institutions and authorities. As reiterated by Rea (1982, 1983); Smith & Rea (1980) as cited in winterbottom and Wilkins (2009), there is some evidence for increased discomfort at illuminance above 1000 lux and separate evidence above 2500 lux in uniformly lit rooms. Chartered Institution of Building Services Engineers (2004) provides recommended design illuminances for different types of classroom, which range from 300 lux to 500 lux.

The best lighting quality comes from the combination of daylight or natural light and artificial light according to Erwine&Heschong (2002) as cited by SanazAhmadpoorSamani&SoodehAhmadpoorSamani (2012) which is

what prevails in some schools in Ghana. Infact studies in Ghana have revealed that a greater percentage of public schools in Ghana have no or poor electric lighting (Sawyerr,2010; Amanfo&Ampratwum, 2013) with main sources of power dependent on supplies from the Electricity Company of Ghana (ECG) which is unreliable. Thus most of these schools employ passive daylighting techniques. Research has revealed that daylighting is more beneficial than artificial lighting (Hathaway et al., 1992; HeschongMahone Group, 1999)

II. MATERIALS AND METHODS

This study was performed in nineteen classrooms randomly selected from five schools in the Tamale Metropolis. Only daylightwas used as the source of lighting even in the classrooms which had supplementary artificial light. Illuminance level readings were done using Lux meters (LX 1330B) which met the climatic requirements of the geographical location of this study.

Readings for mornings were at 7am whiles afternoon readings were done at 1pm. The working plane height chosen was 0.72 m for desk top height and measurements done using four parameters: Door closed morning (DCM), Door closed afternoon (DCA), Door opened morning (DOM), Door opened afternoon (DOA).

Average illuminance in an area was found bydividing the area into a number of equal areas as nearly square as possible by working out the room index. The illuminance at the centre of each square was then measured and the results averaged. Also,relative illuminances on the working plane which were the desks, and also walls were measured usingthe lux metres. All measurements were done with empty classrooms. This was to prevent interference,to ensure accurate monitoring and recording and also make the research economical.

III. RESULTS

Figure 1.DB 1

Figure 2.DB2

Figure 3.DB3

Figure 4.DB4

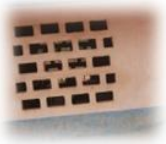


Figure 5.DB5

Figure 6.DB 6

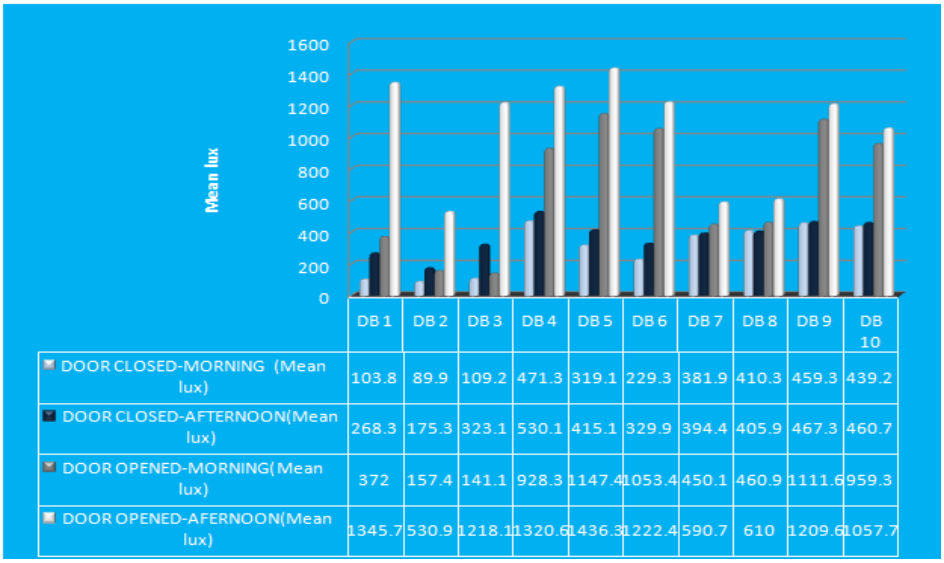
Figure 7.DB7

Figure 8.DB8

Figure 9.DB9

Figure 10. DB10

Figures 1-10 depicts the selected DB window types measured for this study. They were in varied shapes, sizes, arrangement patterns and angles. Illuminance measurements for each class was measured and summarized in Figure 11.



	DB1	DB2	DB3	DB4	DB5	DB6	DB7	DB8	DB9	DB 10
DOOR CLOSED-MORNING (Mean lux)	103.8	89.9	109.2	471.3	319.1	229.3	381.9	410.3	459.3	439.2
DOOR CLOSED-AFTERNOON(Mean lux)	268.3	175.3	323.1	530.1	415.1	329.9	394.4	405.9	467.3	460.7
DOOR OPENED-MORNING(Mean lux)	372	157.4	141.1	928.3	1147.4	1053.4	450.1	460.9	1111.6	959.3
DOOR OPENED-AFERNOON(Mean lux)	1345.7	530.9	1218.1	1320.6	1436.3	1222.4	590.7	610	1209.6	1057.7

Figure 11 Bar graph of mean illuminance levels of selected DB window type

Figure 11 shows descriptive statistic results of illuminance levels of selected design blocks under varied test times/conditions. The results indicated that generally the highest mean illuminance was recorded when doors were opened in the afternoon while the lowest illuminances were recorded when doors were closed in the morning.A kruskall-Wallis test results in Table 1 revealed a statistically significant difference in DB types between the different mean values of illuminance, $\chi^2(2) = 16.92$, $p < 0.05$**.**

Table 4.5 Kruskall-Wallis test of significance for DB type and test time/conditions

	DCM	**DCA**	**DOM**	**DOA**
Chi-Square	103.207	74.553	95.024	89.868
df	9	9	9	9
P-value	0.000	0.000	0.000	0.000

***Significant level at 5%**

Door closed-morning recorded a chi-square statistic of 103.207 and a p-value of 0.000 which was less than 0.05 showing a significant difference between the values recorded at door closed-morning for the various design block windows.
A chi-square statistic of 74.553 and a p-value of 0.000 were also recorded for door closed-afternoon. This also revealed a significant difference for values recorded for the various DB window types for door closed-afternoon.
A significant difference was also found for values recorded for the various DB window types at door opened-morning (95.024, p=0.00) and door opened-afternoon (89.868, p=0.000) test time/conditions.

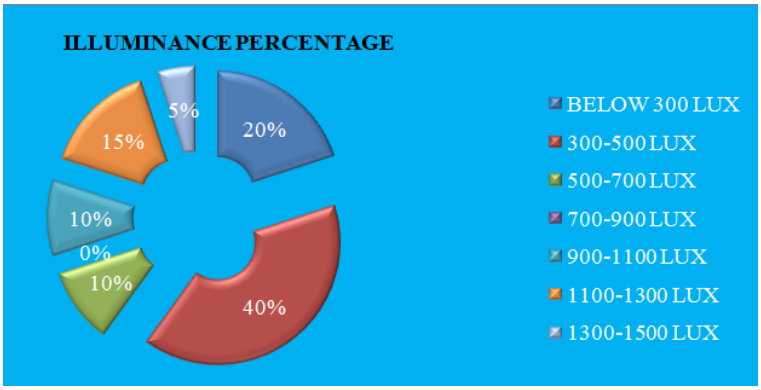


Figure 12 Illuminanceof DB windows per standard

An analysis of the various percentages of illuminances recorded by the various DB window types was presented in Figure 12. Out of all the selected and studied DB windows, 40% at any point in time had the recommended amount of lighting which was 300 lux-500 lux.
However, a substantial 20% had at any point in time, less than 300 lux of lighting within the classrooms which is below the minimum recommended illuminance level in a classroom.
Also, 15% and 5% of the DB window type classrooms studied at any point in time had illuminance levels of 1100 lux-1300 lux and 1300 lux-1500 lux respectively which was above the range at which visual discomfort will occur.
Classrooms with illuminance levels of 500 lux-700 lux were 10%, with another 10% for classes with mean illuminances ranging from 900 lux-1100 lux which was also marginally above the recommended classroom illuminance range of 300 lux-500 lux.

IV. DISCUSSION

Design block windows have had negative connotations when it comes to its ability to effectively illuminate classroom spaces in public basic schools (Sawyerr, 2010). This study however revealed that the illuminance provided for classrooms using this type of window was not entirely negative. Infact only 20% of the studied classrooms did not meet the standard illuminance requirement of 300-500 lux with only 10% also going beyond the range which would cause discomfort to students.
The illuminances of the various DB window types varied for the different parameters under which data was taken. Generally, door closed measurements for all the DB window types were relatively low whilst door opened measurements were the highest. Design block windows studied actually recorded illuminances which went beyond the level of even the highest range for classroom illuminance of 500 lux for a door closed measurement.

The study by Sawyerr (2010)on school infrastructure challenges and the financing public education in Accra Metro, suggested that ventilation and lighting were serious issues because most Accra metro public schools were built with DB or honeycomb windows instead of the conventional windows.

Contrary to this, the DB windows studied in the Tamale Metro schools generally performed fairly well. Specifically, more than 60% of the DB windows at any of the test time/conditions had illuminances that would not harm or be discomforting to the students per recommended classroom illuminance (CIBSE, 2004; EN 12464-1). However, this research was performed in a different geographical area and might also account for the results achieved.

This study also revealed that 20% of the classrooms with DB windows had at any of the test time/conditions, less than 300 lux of lighting within the classrooms which was below the minimum recommended illuminance level in a classroom. The lowest recorded mean illuminance for this study was 89.9 lux which was over 300% below the recommended illuminance level and which also occurred for door closed--morning.

Though this mean illuminance was for door closed-morning and so it could be challenged, it could equally be argued that such a condition may arise especially when it gets dark and cloudy. Again, if for some reason, for instance it was raining in the morning, the implication would be that it would be difficult for teaching and learning to go on as students would have to strain to see or write causing them some discomfort. Teachers during the interview also corroborated this assertion as well as several other authors in their studies (Chambers, 2004; HeschongMahone Group, 2002).

Similarly, Tanner and Lackney (as cited in Tanner, 2008) also realized in their work on combination of impacts a window might have on the health of a student in a classroom that poorly lit and windowless classrooms could cause students to experience a daily form of jet lag.

On the other hand, only 20% out of the whole performed or recorded illuminances below 300 lux. This was relatively better as this implied that the DB windows if treated better could perform as well as conventional windows. Amanfo&Ampratwum (2013) in their study of classrooms with design block windows, maintained that classroom blocks which had design blocks (honeycomb blocks) for ventilation had implication for adequate flow and circulation of air in the classrooms especially during the hot afternoon classes causing classrooms to be hot and dark, especially during the afternoon shift when lessons went on till 5.00pm.

In terms of ventilation, students in the questionnaire responded on a scale of very hot to normal that DB window classrooms were very hot and this was corroborated by teachers as well. Specifically, ventilation was not a main objective of this research and information collected in this regard was to aid in determining why the new interest in DB windows thus this study cannot conclusively argue whether DB windows provide adequate ventilation or not but can maintain that the illuminance of DB windows was not conclusively negative for most test times/conditions. Also, the test times and conditions for this study were between 7am and 1pm and therefore might also account for the difference in results.

The highest mean illuminance for this study was beyond the allowable maximum of 500 lux. This caused discomfort for both students and teachers who reiterated this in the interview granted the researcher. Rea (2000, 1993) and Smith & Rea (1980) as cited in Winterbottom and Wilkins (2009), also found that that there was some evidence for increased discomfort at illuminance above 1000 lux and separate evidence above 2500 lux in uniformly lit rooms. John and Timothy (2005) also corroborated this as they maintained that insufficient lighting controls could lead to many problems worst of all health problems like eyestrain to serious musculoskeletal injuries, decreased attention span, increased body temperature and accordingly poor students and teachers' performance.

Another issue that this study uncovered on the use of DB windows was glare; especially patterned glare. The stripes and shapes of the design blocks themselves created patterns on the walls and on the learning surfaces as was observed by the researcher as the classes were studied. This was a disadvantage as nothing could be done about it as covering the DB windows meant blocking the light into the space. This was dangerous and many researchers have also concluded as this research had, that striped patterns could be responsible for visual stress as was observed by Wilkins (1995). Harle et al., (2006) even concluded that striped patterns could provoke headaches, migraines and epileptic seizures (Fisher et al., 2005; Wilkins, 1980).

V. CONCLUSION

Illuminance within design block window classrooms were measured and compared with existing standard classroom illuminance. Results revealed that 60% of the DB windows at any of the test time/conditions had illuminances that would not harm or be discomforting to the students per recommended classroom illuminance.

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