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Effect of Building Orientation on Energy Conservation

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Nigeria today faces serious challenge in providing adequate energy to meet the needs of her citizenry. Efforts are currently geared towards generation of more energy to ease the problem. While these efforts are commendable, it is equally desirable to explore ways of minimizing consumption of generated energy. This work has thus examined the impact of building orientation on the energy demand and thus proffers its appropriate orientation. A survey was carried out in Ibadan which is the largest metropolis city in West Africa. The orientation of built houses in various setting such as Government Reserved Areas, Public/Commercial settings and local dweller settings were studied to determine their conformity with expected standard of North-South orientation of the building length. From the study it was observed that a sizeable percentage of the buildings with the survey were placed longitudinally in the East-West direction implying that more energy may have to be expended in cooling inside the building. The defaults are more pronounced in the local dwellers. In many of the cases considered in this study, the defaults were enhanced by the road networks. This study established the need for more education on building orientation as well as road network planning. This will cut down energy consumption in cooling inside a building.

Key words: Energy demand, building orientation, local dwellers, road networks, metropolis, Nigeria.

INTRODUCTION

The present in-adequate energy generation coupled with the environmental situation has necessitated the urgent need to work towards or seek for way(s) of conserving or minimizing the consumption of this mean energy generated. Incorporating energy efficiency into all buildings has become a top priority in recent years for facility managers, designers, contracting officers and others in building business. Levermore [1]; Tzempelikos and Athienitis [2] investigated the effect of shading design and control on building cooling demand, he established 50% reduction in energy consumption due to shading design. A review work on building energy research in Hong Kong carried out by Zhenjun and Shengwei [3] also established energy saving opportunities in buildings when various research aspect and technologies discussed such as energy policy, energy audit, design, control and building performance evaluation were properly used. Another way of conserving energy is through appropriate orientation of building. The orientation of a building often is determined by site topography and/or location. However, for those sites where there is a choice, analysing the effect of orientations on energy and equipment costs can lead to a more energy-efficient building [4]. For this work, assessment of energy requirement for different orientation of buildings is studied in order to provide education and enlightenment for the general public which hopefully may lead to improved energy conservation.

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Numenclature

q_s & q_l (Btu/hr) are sensible heat and latent heat.
U (Btu/ft^2/deg F): overall heat transfer coefficient
A (ft^2): surface area for element
CLTD (deg F): cooling load temperature difference
CLF: dimensionless cooling load factor
SC : dimensionless shading factor
SHR: sensible heat release
LHR: latent heat release
$\triangle$T (deg F) is dry bulb temperature difference between indoor and outdoor air.
$\triangle$W (Pounds H_2O/pound): dry air difference in moisture content between indoor and outdoor air.
CFM: Cubic feet minute
M.H: Motor horse power
M.E: Motor efficiency

Cooling Load Analysis in Buildings

In cooling load analysis in building, the followings are always put into consideration; building characteristics, building location, orientation and external shading, weather data and selection of outdoor design conditions, selection of indoor design condition, indoor dry-bulb temperature, indoor wet-bulb temperature and ventilation rate, lighting, occupants, internal equipment, appliance and processes, and finally selection of the design. From the experience in cooling load analysis, there has been a general observation that of all these design considerations, orientation of the building seems to have a major significant impact on the final overall cooling load estimated.

Cooling load Calculation Procedure

In cooling load analysis in building, the following procedures as developed by Ashrae [5,6] and Norman [7] are employed. The procedures are hereby itemized as follows:

i. Building sunlight heat gain: This include the sunlight heat gains through the glass, the walls and the roof.
ii. Building transmission heat gain: This is the transmission heat gain through the glass and the appropriate building walls.
iii. Infiltration heat gain: This is the infiltration heat gain through the wall, door and window crack length.
iv. Outside air by pass heat load: This is the outside by-pass heat load through the ventilation and air conditioner equipment bypass factor.
v. Internal heat load: This load is generated by the occupants, machines, equipment, lighting fittings and any other heat generating devices inside the building.
(vi) **Room latent heat:** These are the heat loads released by the occupants, through infiltration and ventilation of the building.
vii. Outside heat load: This load is generated through the outside ventilation air and air-conditioner equipment bypass factor.

Cooling load classification and the accompany equations

One of the ways of classifying the building cooling load is external and internal loads classification. This class is presented along with the accompany equations.

External loads

i. Opaque elements located above ground (walls, roofs and doors): $q_s = U * A * CLTD$ 1

ii. Convective transfer through transparent assemblies (windows): $q_s = U * A * CLTD$ 2

iii. Radioactive transfer through transparent assemblies (windows): $q_s = A * SC * SHE * CLF$ 3

iv. Ventilation and infiltration air (sensible): $q_s = 1.08 * CFM * \Delta T$ 4

v. Ventilation heat load (latent): $q_s = CFM * \Delta W * BF * 0.68$ 5

vi. Infiltration heat load (latent): $q_s = CFM * \Delta W * 0.68$ 6

Internal Loads

i. Lighting systems: $q_s = inputlampwattage * 3.41 * CLF$ 7

ii. People: (a) $q_s = N * SHR$ 8

(b) $q_L = N * LHR$ 9

iii. Equipment and appliances:
(a) $q_s = installedwattage * CLF * 3.41$ 10

(b) $q_L = installedwattage * CLF * 3.41$ 11

iv. Motor heat load: $q_s = M.H * 2546 * ME$ 12

Case Study

Two cases shown in Figures 1 and 2 were considered for analysis in this paper, the first case considered was an industrial workshop located in Texas in United State of America, one of the leading developed Nations. The second case was the senate chamber in the Premier University (University of Ibadan) in Nigeria one of the leading developing Nations of the world. The two cases considered are sketched diagrammatically in two distinct different orientations.

Case Study 1 (Figure 1)

North Wall area = 125(12) – 15(40) = 900ft^2;

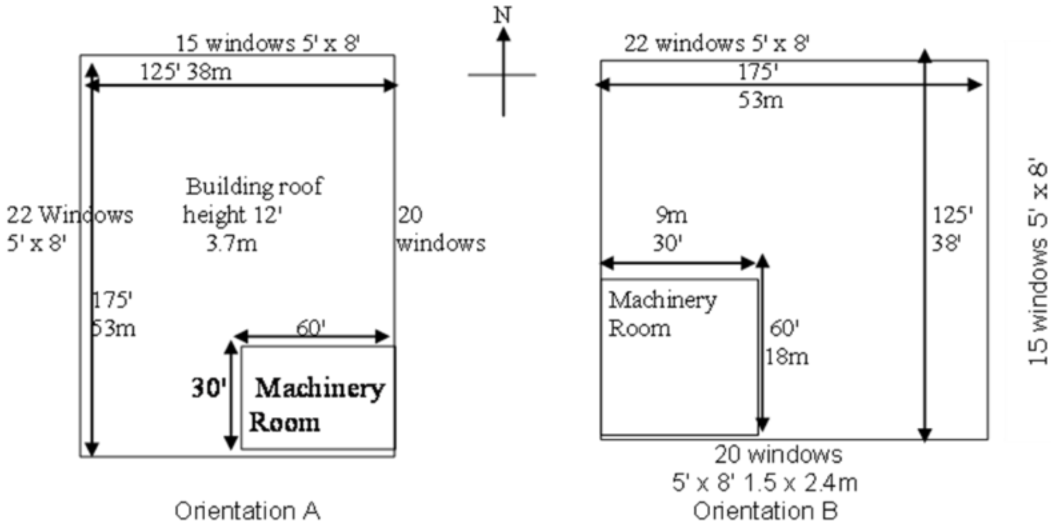

Figure 1. Plan View of a Workshop Building in Texas, U.S.A.

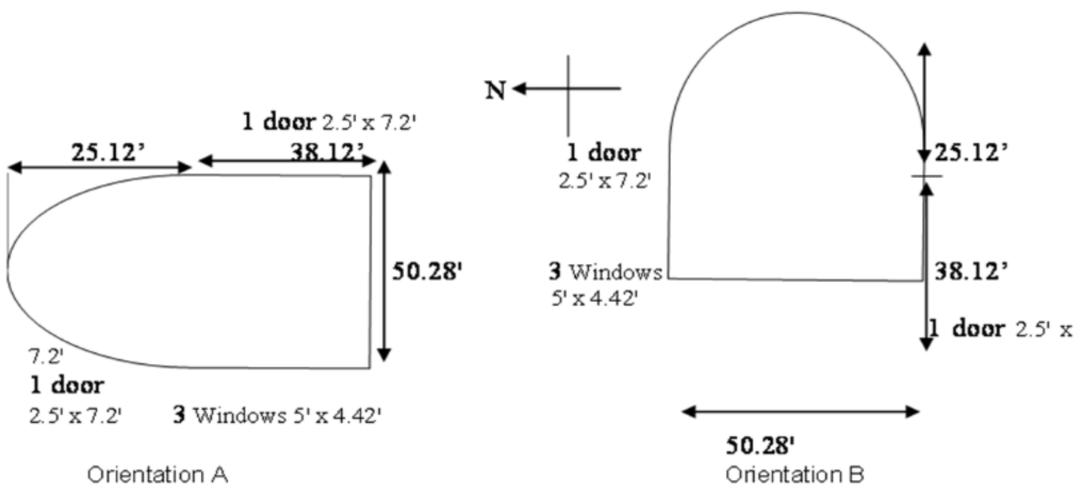

Figure 2. Plan View of a Senate Building at University of Ibadan, Ibadan, Nigeria.

North Wall area = 175(12) – 22(40) = 1220ft^2
South Wall area = 125(12) – 10(40) = 1100 ft^2;
South Wall area = 175(12) – 20(40) = 1300 ft^2
East Wall area = 175(12) – 20(20) = 1300 ft^2;
East Wall area = 125(12) – 15(40) = 900 ft^2
West Wall area = 175(12) – 22(40) = 1220 ft^2;
West Wall area = 125(12) – 10(40) = 1100 ft^2
Roof area = (20x40)+ (10x40)+22(40)+15(40) = 2680 ft^2;
Roof area: same as orientation A
Partition area = 40x12 = 1080 ft^2;
Partition area: same as orientation A

Case Study 2 (Figure 2)

East Wall = 231'; North Wall = 231'
North Wall = 273.56'; South Wall = 231'
West Wall = 231'; East Wall = 273.56'
South Wall = 197'; West Wall = 197'
West glass = 66.01'; North Glass = 66.01'

Survey Analysis

A survey was carried out to ascertain which of the analyzed orientations is being conformed within Ibadan metropolis. In the course of survey, fifty questionnaires for each of the areas within Ibadan Metropolis were administered. The areas covered were the Government Reserved Areas (GRA) Old Bodija Estate to be specific, University of Ibadan Campus from within higher Institution/Public/Commercial areas and from among the

Table 1. Summarized Cooling Load in Sample Buildings in Ibadan and Texas.

Cases	ORIENTATION A Heat Load			ORIENTATION B Heat Load			Electrical Energy Conserved KVA
	Btu/hr.	Tonnage	Electrical Energy KVA	Btu/hr.	Tonnage	Electrical Energy KVA	
1.	759,217	63.3	74.2	726,942	60.6	71.1	3.1
2.	498,195	42	49	484,042	40.3	47.3	1.7

Table 2. Energy Estimates for Fifty Buildings in Ibadan and Texas.

Cases	Sample Nos.	Energy conserved per Unit sample KVA	Total overall energy conserved KVA
1.	50	3.1	155 KVA
2.	50	1.7	85 KVA
Globally	100	4.8	480 KVA

Table 3. Building Orientation Pattern in Ibadan, Nigeria.

S/N	Areas surveyed	No. of administered questionnaires	No. conformed with orientation A	No. conformed with orientation B	Type of Dwellers
1.	University of Ibadan	50	15	35	Elite
2.	Old Bodija Area	50	28	22	Elite
3.	Mapo & Bere Areas	50	45	5	Local
	Total for Ibadan Metropolis	150	88	60	

local dweller setting areas of the city, Bere and Mapo areas were selected.

RESULTS

The summarized results of both the cooling load and survey analysis carried out are presented in Tables 1-3.

DISCUSSION

The summary of the cooling load analysis for the two cases is presented in Table 1. This tabulated summary of the analysis shown in Table 1 can be used for fifty samples of similar buildings from each of the cities from the two different countries and see the implication of the analysis. This is also shown in tabular form in Table 2. The third column of Table 2 shows energy conserved per Unit sample in KVA; while 3.1 and 1.7 KVA of energy were saved for cases 1 and 2 respectively, a total of 4.8 KVA of energy was conserved for global sample of just 100 buildings.

In Table 3 which summarized the result of the conducted survey analysis, of all the fifty questionnaires administered for the University of Ibadan Campus Building structures, thirty-five of them were placed longitudinally in North-South direction i.e. Orientation B while the rest were placed longitudinally East-West directing i.e. Orientation A. Equal numbers of fifty questionnaires were also administered for Bodija Estate area, of these numbers about twenty-two were placed longitudinally in North-South direction while the rest were placed in East-West direction i.e. Orientation A. For Mapo and Bere areas, one of the local dweller setting areas of Ibadan Metropolis, fifty questionnaires were also administered. Out of this fifty, forty-five of them were placed longitudinally in East-West direction which is Orientation A while only five buildings were placed in North-South direction longitudinally. From this result, it is obvious that buildings orientation in A direction i.e. longitudinally East-West direction are more pronounced especially within the local dweller areas of the city. Site observation reveals that in many of the cases, the defaults were enhanced by the road networks.

Conclusion

In conclusion, from Tables 1 and 2 it is clearly revealed that, if orientation B, that is, North-South longitudinally placement of building is adhere to or selected in the orientation of the building structures in the metropolis, for fifty similar building, then, about 85KVA electrical loads will be conserved and globally about 480 KVA electrical loads will always be conserved for every 100 combination of similar building structure types. This load can be utilized in other areas either in cooling buildings or for other beneficial purposes. In addition, table 3 reveals the true picture of buildings orientation in Ibadan metropolis which implies higher energy consumption despite the fact that energy generated or supplied is insufficient and erratic in supply. It is therefore imperative that the concerned people in this area, especially in building industries, Urban and regional planners and the public to note this impact of appropriate building orientation in the energy demand and therefore make their positive contribution towards effective utilization of the available energy generated.

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APPENDIX

UNIVERSITY OF IBADAN, IBADAN, NIGERIA
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QUESTIONNAIRE ON BUILDING ORIENTATION SURVEY IN SELECTED
AREAS IN IBADAN METROPOLIS

Date: --------------------
Name and Address of the
Questionnaire administrator: -------------------------

Compass No: --
Building location Area: --

Type of the Building: ---------------------------------------
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Building Orientation: ---