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Numerical Simulation of Thermal Behavior of Buildings

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Abstract: Numerical simulation of thermal behavior of buildings was carried out with the application of Cooling Load Temperature Difference/Cooling Load Factor (CLTD/CLF) to estimate the energy required for cooling/heating of buildings. This was done to facilitate comparison of the energy being generated from a building while varying significant building parameters. Each factor contributing to space heat gain is described mathematically, considering energy balance within the system. The calculated energy should be overcome by Heating and Ventilation Air-Conditioning (HVAC) system so as to maintain the building interior design temperature and to ensure occupants thermal comfort. The effect of varying significant building parameters like orientation, window glass shade type, number of glass pane used, wall insulation, roof type and floor type on building cooling/heating load was investigated with the use of the developed software. A typical building block was used as a case study for the analysis to arrive at an intelligent decision. The software developed is simple to use, needs fewer input data compared to other software developed for similar task. All the earlier mentioned advantages are without sacrificing accuracy and reliability.

Key words: Simulation, thermal behavior, building, cooling load, heating load

INTRODUCTION

Buildings, including residential, commercial and institutional buildings account for more than one third of primary global energy demand. The building sector is the biggest energy consumer among the three energy-using sectors: transportation, industry and buildings. Global energy demand in the building sector has been increasing at an average rate of 3.5% per year since 1970 (DOE, 2006) with most of this consumption comes from heating and air-conditioning system which ensure thermal comfort of the occupants. As the thermal comfort of the occupant of a building is a very important factor that has to be considered by the building designer, it is also important to find practical solutions to engineering problems among the factors to be considered are cost, ease of use of the tool, speed and accuracy of the tool. These key criteria must be met in developing practical software for energy analysis. One very important criteria is good economic analysis of the options that exist for energy saving.

Energy use can be effectively reduced in commercial buildings through improvements in building design and construction including walls, roofs, foundations, glazing and solar control. The energy efficiency of the commercial building shell can be increased by 45% on average through improvements in design and construction compared to the existing buildings. Large reductions in residential energy use can be achieved through improved building design including correct building orientation and shading, appropriate placement of windows and the use of sunshine for lighting and heating, a high level of insulation on exterior surfaces and heat recovery systems. In Australia, a shift to an efficiency of 5 stars under the Nationwide House Energy Rating System for all new dwellings from 2000, in combination with aggressive promotion of adding ceiling insulation to the existing building stock is projected to save 18.4% of residential heating and cooling GHG emissions by 2010. For new dwellings alone the increased efficiency is in the range 50-55% (Turton *et al*., 2002).

Chowdhury *et al*. (2007) worked on numerical simulation on building performance under different low energy cooling technologies in order to reduce the energy consumption and peak demand associated with the building cooling. The simulation is based on a heat and mass balance principle and verified by measured data. Reduction of the energy consumption and maintaining a comfortable indoor thermal environment are the criteria used to identify the effect of low energy cooling technologies. It was observed that a passive cooling alternative, chilled ceiling has higher potential for energy savings of around 35% compared to the base case and pre-cooling provides a peak energy demand reduction of 28% compared to the base case.

Conceicao (2003) worked on two numerical models that evaluate respectively, the buildings thermal behavior and the human thermal comfort were presented. The first one was used in the thermal study of a building with two

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floors, located in the South of Portugal in a winter day with clean sky. The second one was used in the evaluation of thermal comfort level that an occupant is subjected when he is seated in a compartment with a window turned towards West. It was verified that at 16 p.m. when the occupant is seated near the window, uncomfortable conditions were obtained. Nevertheless, if the occupant is not subjected to direct solar radiation, the comfort thermal conditions are obtained.

Energy analysis of a building is a method of simulating annual energy use in a proposed or existing building design. The energy estimated need to be overcome by Heating and Ventilation Air-Conditioning (HVAC) System to ensure adequate thermal comfort of the occupants. Improvements made to building HVAC Systems can provide direct and indirect economic benefits. Direct benefits relate to the reduction of energy consumption and indirect benefits are related to increased productivity and reduction of medical expenses since lower energy consumption in buildings can significantly reduce the emission of carbon dioxide (CO_2). Therefore, any analysis of building HVAC System that can effectively reduce this consumption is highly valuable. In order to evaluate and reduce energy consumption in the design phase of building, Energy Simulation (ES) programs are used.

The best approach to analyze the thermal behavior of buildings is to estimate energy consumption in a building by calculating the cooling or heating requirements of a building during a typical design month. This in turn, requires weather data for that period, a physical description of the internal building and knowledge of the internal building loads and their variation over time. The building cooling load components are: direct solar radiation transmission load, ventilation/infiltration load and internal load. Calculation of all these loads individually and adding them up gives the estimate of total cooling load of the building. Building Energy Simulation (ES) programs are tools used for the analysis of building energy consumption and the evaluation of architectural designs. These tools are used for modeling heating, cooling and ventilating flows in a building. The modeling domain of the ES program comprises of the building envelope, Heating Ventilating and Air-Conditioning (HVAC) Systems, external and internal parameters such as weather conditions or occupancy level and indoor air represented as uniform thermal mass for a particular zone.

Until the mid 1960s, only simple manual methods were used to estimate energy usage in building (Novoselac, 2005). Two of the most widely used manual methods are the Degree Day Method and the Bin Method. The simplest method is the Degree Day Method which is based on the averaging of outdoor weather influence over a long period of time. This method was successfully used for rough estimations of heating energy requirements. For more detailed heating and cooling analysis, the Bin Method was used. This method calculates energy over several intervals (bins) of temperature using a simplified quasi-steady-state approach. Besides very limited accuracy, these simple manual methods could not provide any information about thermal comfort such as enclosure temperature and air temperature when the heating/cooling system does not research.

More detailed energy simulation methods include sophisticated models of a building and its HVAC Systems. These methods are computationally intensive and require extensive use of computers. Today, there is a larger variety of Energy Simulation (ES) programs with building system models of various complexities. Crawley *et al.* (1997) gave an overview of a report which provides up to date comparison of the features and capabilities of twenty major building energy simulation programs. The comparison was based on information provided by the program developers in the following categories: general modeling features; zone loads; building envelope and day lighting and solar; infiltration, ventilation and multizone airflow; renewable energy systems; electrical systems and equipment; HVAC Systems; HVAC equipment; environmental emissions; economic evaluation; climate data availability, results reporting; validation and user interface, links to other programs and availability. Crawley *et al.* (2008) found that even among the mature tools, there was not quite a common language to describe what the tools could do. There was much ambiguity which will continue to require additional research to resolve in the future.

Many of these programs are getting obsolete-some use simulation methods (and even code) that originated in the 1960s and designed in the days of mainframe computers, expanding their capabilities further has become difficult, time-consuming and expensive. Presently significant advances in analysis and computational methods provide an opportunity for significant improvement in these tools. Hence, the need to develop a code which will take into consideration the present day need.

Cooling Load Calculation techniques: Various methods have been presented for calculating space cooling load by ASHRAE (2007). Four methods were presented: Total Equivalent Temperature Difference (TETD) Method: this method was originally developed by

Willis carrier. Various components of space heat gain are added together to get an instantaneous total rate of space heat gain. This is converted into an instantaneous space cooling load by Time Averaging (TA) technique of immediately preceding hour. The Transfer Function Method (TFM) is similar in principle to TETD/TA Method but employs a series of weighting factors (called coefficient of room transfers functions) to apply to heat gain and cooling load values from several previous hours as well as the current hour in order to account for storage effect in converting heat gain to cooling load. The method is rigorous and complex, it require a lot of computer research. To eliminate any discrepancy between the TETD/TA and TFM, ASHRAE sponsored a research called RP-138 in 1975. For RP-138, investigators used the methodology and basic equations of TFM to generate Cooling Load Temperature Difference (CLTD) data for direct one-step calculation of cooling load from conduction heat gain through sunlit walls, roofs and conduction through glass exposure. Also developed was Cooling Load Factors (CLF) for similar one-step calculation of solar load through loads from internal source. Both CLTD and CLF include the effect of time delay caused by thermal storage, instead of two-steep procedure used by other methods described above. The accuracy of TFM has been validated in experimental effort. Due to the restrictive or limited data for the tabulated CLTD and CLF which could not account for some space geometry and building construction ASHRAE sponsored another research or project called Radiant Time Series (RTS) Method: this was based on heat balance method and it gives exact solution. It also requires computer-based solution techniques.

This research is largely built on the recommendations of RP-138 in 1975 that ASHRAE presented. There were some further recommendations which ASHRAE presented which are also included in this research. CLTD Method was finally used in this research. It various applications are as follow:

CLTD/CLF Method formulas:

- Glass cooling load is calculated as follow:

$$Q = A\ (SC)\ (SHGF)\ (CLF) \text{ for radiation} \tag{1}$$

$$Q = UA\ (CLTD) \text{ for conduction} \tag{2}$$

- Opaque surface cooling load is calculated:

$$Q = UA\ (CLTD) \tag{3}$$

- Internal loads are calculated:

$$Q_{\text{cooling load}} = Q_{\text{heat gain}} \times CLF \tag{4}$$

MATERIALS AND METHODS

Basic theory: Estimation of energy consumption of a building, involves calculation of cooling and heating requirements of the building during a typical design month or year. This in turn, requires weather data for the period, a physical description of the internal building and knowledge of the internal building loads and their variation over time.

Selection of input parameters: The few inputs required for the building energy simulation include hourly variations of ambient wet and dry bulb temperature condition as well as hourly variations of solar radiation, both of which depend on measured meteorological data for the geographical location. The solar radiation input could be explained as having an indirect impact on the air conditioner unit as it affects the space being conditioned (which surrounds the equipment) via the building construction materials such as the roof, wall, glass and floor, etc., the space being conditioned in turn affects the equipment. Thus, the building energy (or the building cooling load) is a measure of the solar radiation input into the building.

In this view, a case study (an industrial building of known specifications) in Ibadan metropolis was considered. Approximated values of ambient wet and dry bulb temperature variations were reasonably culled from daily meteorological temperature data in the absence of hourly temperature data for Ibadan location. With the use of standard calculation procedures, together with the location's weather data in respect of load due to building material specifications the variations in building cooling load were estimated. These estimates were carried out based on the design month (when the solar radiation intensity is at maximum) for the location considered. The design month is March for Ibadan.

Estimation of hourly building load: It is desired to estimate the required hourly air conditioning system capacity (building cooling load) of air conditioner equipment to serve the industrial building located (at 8°N latitude) Ibadan metropolis, Nigeria.

Building specifications: The outside walls are of type Group A wall, 8 common brick with insulation and of weight -130lb/sqft. A 6 plain-poured concrete partition wall separates the machinery room (which houses the equipment) from the conditioned space. The flat roof is made of steel sheets, covered with 1 insulation board. Internal loads are 100 people doing light assembly research; twenty five 1HP motors (each of efficiency = 0.85) running continuously at full load for the 13 h operation period of the air conditioner equipment; 20 kW of incandescent light kept on throughout the period. Design conditions for the case study are:

- Type of building-industrial building
- Location-Ibadan, Nigeria
- Elevation: 745 ft
- Average wind velocity-low, wind direction-SW
- Design month: March
- Outdoor dry and wet bulb temperature variations
- Indoor dry bulb temperature: 77°F
- Daily range: 19°F
- Latitude/longitude: 8°N/4°W
- Relative humidity: 55% at 2.5% design level

The following shows the standard calculation procedures used in obtaining the hourly building load for an equipment operating range under steady state and hourly time step considerations.

Building load computation

Sunlight heat gain {Btu/Hr}: The sunlight heat gain results from the solar radiation through the glass in windows and the materials of construction in certain part of the building walls. The East, South and West windows and walls are subjected to sunlight heat gains. North facing walls are neglected because the sunlight heat gain is usually less than the transmission heat gain.

Glass SHG: Q_{SHG} {for W, S and E} = {Window area [for W, S and E]}×Maximum radiation {through W, S and E}×Factor of shade}. Thus, the total sunlight heat gain through glass is:

$$Q_{TSHGG} = Q_{SHGGE} + Q_{SHGGW} + Q_{SHGGS} \qquad (5)$$

Wall:

$$Q_{SHG}\{\text{for W, S and E}\} = \{\text{wall area } \{\text{for W, S and E}\} \times U_{wall} \times \text{CLTDwall}\}$$

$$Q_{TSHGW} = \Sigma\ \{Q_{SHGWW} + Q_{SHGEW} + Q_{SHGSW}\} \qquad (6)$$

Roof:

$$Q_{SHGR} = \text{Roof area} \times U_{roof} \times \text{CLTD}_{roof}$$

The total sunlight heat gain:

$$Q_{TSHG} = Q_{TSHGG} + Q_{TSHGW} + Q_{SHGR} \qquad (7)$$

The transmission heat gain {Btu/Hr}: All the glass in building windows are subjected to transmission of heat from the outside to the inside as a result of the temperature difference between the outdoor and indoor dry-bulb temperatures. The transmission gain is commonly called the all-glass gain:

- Glass: Q_{THGG} = Total window area×U_{glass}×{Outdoor dry bulb−Indoor dry bulb temperature}
- Wall: Q_{TAHGW} = Wall area {North only}×U_{wall}×{Outdoor dry bulb−Indoor dry bulb temperature}
- Partition wall: Q_{THGP} = Partition area×{Partition room dry bulb−Indoor dry bulb temperature}

Thus, the total transmission heat gain:

$$Q_{THG} = \Sigma\ \{Q_{THGG} + Q_{THGW} + Q_{THGP}\} \qquad (8)$$

The infiltration heat gain {Btu/Hr}: The uncontrolled inward air leakage into a building caused by the pressure effects of wind or the effect of differences in the indoor and outdoor air density or both constitute infiltration heat gain in a building:

$$Q_{INF} = 1/2\{3\ (\text{Glass width}) + 2\ (\text{Glass height}) \times \text{Number of windows}\} \times (\text{Outdoor dry bulb-Indoor dry bulb temperature}) \qquad (9)$$

Air bypass load {Btu/Hr}:

$$Q_{BPL} = (\text{Number of people}) \times (\text{Bypass factor}) \times (\text{Outdoor dry bulb-Indoor dry bulb temperature}) \times (\text{CFM per person}) \qquad (10)$$

Internal heat load {Btu/Hr}:

- People: Q_P = (Number of people)×(Sensible heat)
- Light: Q_L = (Total light rating)×(Light conversion factor)
- Motor: QM = (Number of motors)×(Motor efficiency) ×(Motor sensible heat)

Thus, the total internal heat load:

$$Q_{THL} = \Sigma\{Q_P + Q_L + Q_M\} \qquad (11)$$

Room sensible heat {Btu/Hr}: This is the sum of sunlight heat gain, glass transmission heat, infiltration heat gain, outside-air bypass heat gain and heat gain from internal sources:

$$Q_{RSH} = \sum\{Q_{TSHG} + Q_{THG} + Q_{INF} + Q_{BPL} + Q_{THL}\} \times \{1+ \text{Safety factor}\} \qquad (12)$$

Room latent heat load {Btu/Hr}: The room latent loads result from the moisture entering the air-conditioned space with the infiltration and bypass air, moisture given off by room occupants and other moisture sources.

- Occupant: Q_{LHO} = {Number of people}×{Latent heat per person}
- Infiltration heat air: Q_{LHI} = {Window crack length} {Window infiltration rate}×(Conversion factor)×(Outdoor moisture content−Indoor moisture content)
- Ventilation air: Q_{LHV} = (Number of people)×(CFM per person)×(Conversion factor)×(Outdoor moisture content−Indoor moisture content)

Thus, the total latent heat:

$$Q_{RLH} = \Sigma\{Q_{LHO} + Q_{LHI} + Q_{LHV}\} \times \{1 + \text{Safety factor}\} \tag{13}$$

Outside heat load {Btu/Hr}:

- Latent heat:

$$Q_{OHLL} = (\text{CFM per person}) \times (\text{Number of people}) \times (\text{Conversion factor}) \times (\text{Outdoor moisture content-Indoor moisture content}) \times (1 + \text{Bypass factor}) \tag{14}$$

- Sensible heat:

$$Q_{OHLS} = (\text{CFM per person}) \times (\text{Number of people}) \times (\text{Conversion factor}) \times (\text{Outdoor dry bulb-indoor dry bulb}) \times (1\text{-Bypass factor}) \tag{15}$$

Thus, the total outside heat loads:

$$Q_{OHL} = \Sigma\{Q_{OHLL} + Q_{OHLS}\} \tag{16}$$

Grand total heat load {Btu/Hr}:

$$Q_{GTH} = \Sigma\{Q_{RSH} + Q_{RLH} + Q_{OHL}\}\ \{\text{Btu/Hr}\} \tag{17}$$

Converting this to refrigeration tonnage (i.e., tons):

$$Q_{GTH}\ \{\text{Tons}\} = Q_{GTH}\ \{\text{Btu/Hr}\}/12000 \tag{18}$$

Converting this to kJ/s or kW:

$$Q_{GTH}\{\text{KW}\} = Q_{GTH}\ \{\text{Btu/Hr}\} \times 3.5163/1200019 \tag{19}$$

It should be noted that values of Q_{GTH} {KW} represent the air conditioning load to be upset by the Evaporator component of the air conditioner model. In other words, Q_{GTH} {KW}.

Computer program development: The program for building energy simulation has been written in FORTRAN language and the interface is designed with visual basic Version 6.0 programming Software. The VB is design to facilitate parameter input while the FORTRAN runs the program and displays the output via the note pad window. There are relevant tabs in the interface of which all required information can be entered and the results would be generated in the result file. The result file gives hourly result of cooling load for each load factor and it equally display grand total heat load both in Btu/Hr and kilowatt. In this research, a new Building Energy Simulation (BES) program was developed to enable effective testing of research hypotheses for heat transfer in spaces with unconventional Heating, Ventilating and Air-Conditioning (HVAC) Systems which have a potential to save building energy consumption while simultaneously increasing indoor thermal comfort.

Application of developed software package: Using manual techniques in the analysis of the values of building input parameters would be time-consuming and rigorous due to the complexity of data requirement involved. Hence, the need for an effective computational technique to ease the complexity and expedience of the calculation involved. For the stated reasons, the set of equations from the cooling load algorithm were programmed using FORTRAN. The program was then imported to Visual Basic thus enabling simulation of building via a user-friendly interface. The combination of the two programming languages is used to develop the building simulation software.

The results from the simulation run using the Software is presented below. Different building components properties have been compared in order to make an effective selection. The software requires general inputs such as gross building area, altitude, outside summer dry bulb temperatures and exposed perimeter length. The building itself is described by inputting the construction types letter for up to eight walls and roofs, using the wall and roof types set up in Ashrae fundamentals. Roofs with and without suspended ceiling can be differentiated. The coefficient of heat transfer (U value) and area must be input for each wall and roof.

RESULTS AND DISCUSSION

The validity of the software was checked by taking heating load calculation for a typical building block. The building block had height of 12 ft and the entire dimension shown in typical building blocks given as:

15 WINDOWS (5' X 8')
ROOF HEIGHT: 12 ft

22 WINDOWS (5' X 8')

20 WINDOWS

UTILITY OR MACHINE ROOM
(PARTITION)
60"
30"

10 WINDOWS (5' X 8')

The present software has potential of investigating the effect of significant building parameters on the heating load which may be treated as its unique feature. The tables and figures the results obtained with the software developed.

Assumptions: Building materials considered in this research are homogeneous and isotropic. Energy accumulation in HVAC components is not considered because it is significantly smaller than energy accumulation in the building structure. Besides building geometry and material properties, input data in these programs are HVAC system properties and the hourly weather data related to the location of the building. Based on these input data, the developed software program perform calculations of energy demand for heating, cooling and ventilating for a certain period of time with a span of an hour.

The effect of roof type on the building-thermal load: The effect of roof type on a building-thermal load was thoroughly investigated for the entire roof types included in the energy estimation. The finding of these investigations is shown in Table 1. The 2.5 inches, wood with 2 inches insulation gives minimum gross cooling load. Steel sheet with 1-in insulation gives maximum gross cooling load which is 46.57% more than the minimum value. A large variation can be observed in the cooling loads with different types of roof. Special care is therefore, needed for designing the most suitable roof f or an air-conditioned building. The Fig. 1 depicts the variation of building thermal load with different types of roof. The acronym R represents each roof as stated in Table 1.

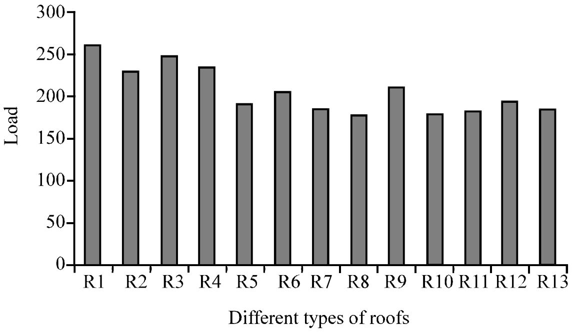

Fig. 1: Variation of building thermal load with different type of roofs

Table 1: The effects of roof type on the building thermal of load

Roof type	Peak cooling load CL (kW)	Percentage increase with minimum CL/(CL-CL3)×100/CL3
Steel sheet with 1-in (or 2-in) insulation U = 0.213 (0.124). (R1)	259.54	46.570
1-in wood with 1-in, insulation U = 0.170Btu/h.ft^2.°F. (R2)	228.44	29.000
4-in lightweight concrete U = 0.213 Btu/Hr.ft^2 °F (R3)	246.41	39.150
2-in heavyweight concrete with 1-in (or 2-in) insulation U = 0.206 Btu/Hr.ft^2.°F. (R4)	233.89	32.080
1-inwood with 2-in insulation U = 0.109 Btu/Hr.ft^2.°F. (R5)	189.98	7.280
6-in, lightweight concrete U = 0.158 Btu/Hr.ft^2.°F. (R6)	203.44	14.890
2.5-in, wood with 1-in insulation U = 0.130 Btu/Hr.ft^2.°F. (R7)	183.76	3.770
8-in, lightweight concrete U = 0.126 Btu/Hr.ft^2.°F. (R8)	178.01	0.525
4-in, heavyweight concrete with 1-in (or 2-in) insulation U = 0.0200 Btu/Hr.ft^2.°F. (R9)	209.07	18.070
2.5-in, wood with 2-in, insulation U = 0.093 Btu/Hr.ft^2.°F. (R10)	177.08	0.000
Roof terrace system U = 0.106 Btu/Hr.ft^2.°F. (R11)	181.34	2.410
6-in, heavyweight concrete with 1-in (or 2-in.) insulation = 0.122Btu/Hr.ft^2 °F. (R12)	193.45	9.240
4-in wood with 1-in (or 2-in) insulation U = 0.106 Btu/Hr.ft^2.°F. (R13)	184.91	4.420

Effect of wall thermal properties on building thermal load: The effect of wall thermal property is shown in Table 2. The gross cooling load was found to be 1.39% higher in some group of wall than the other. The differences lie on the magnitude of the overall coefficient of heat transfer and cooling load temperature difference for each type of wall. This comparatively smaller increase necessitates having a comparative economic analysis before going for particular type of wall materials. Figure 2 shows the variation of building thermal load with different type of walls. Group B: h.w. concrete wall + (finish) 12 in concrete (W6) make up the maximum cooling load.

Effect of shading on building gross thermal load: Table 3 through 5 show the effect of windows glass pane on the gross building-cooling load. The glass under consideration is single pane uncoated type. Increase or decrease in cooling load depends on the magnitude of Sunlight Heat Gain Factor (SHGF) and Shading Coefficient (SC) for each type of glass. Also affecting the cooling load is whether the internal building has interior shading or not. If the internal building has shading, there will be reduction in heat transmission through the windows, thereby reducing heat energy absorption in buildings. The results presented in the tables are just the comparison of the peak load for individual building parameter. Figure 3 and 4 show the variation of cooling load with different type of window glazing, G11 make up the maximum cooling load while G16 constitute the minimum cooling load. Table 4, 5 and Fig. 5 show the variation of different reflective single glazing window with cooling load. The 1/4 Ss on Clr 8% center glazing with

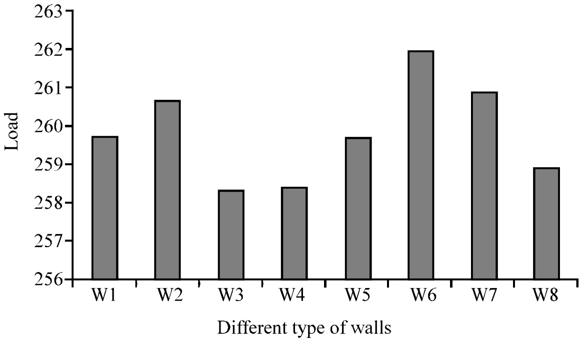

Fig. 2: Variation of building thermal load with different type of walls

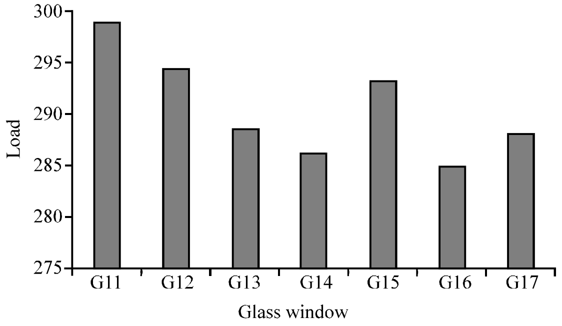

Fig. 3: Variation of building thermal load with different single pane, uncoated glass window

Table 2: Effect of wall thermal properties on building thermal load

Wall type	Highest cooling load, CL (KW)	Percentage increase with minimum CL (CL-CL2)×100/CL2
Group A wall:4-in face brick + (Brick) insulation or Air space + 8-in. common brick U = 0.221Btu/Hr.ft^2.°F (W1)	259.72	0.530
Group b:4-in face brick + (brick) 8-in common brick air space + 8-in. common brick U = 0.302Btu/Hr.ft^2.°F. (W2)	260.62	0.880
Group B:4-in face brick + (brick) 2-in. insulation + 4-in common brick air space + 8-in. common brick. U = 0.111Btu/Hr.ft^2.°F. (W3)	258.34	0.000
Group B:4-In, FACE Brick = (H.W concrete) 2-in.insulation + 4-in concrete U = 0.116, weight = 97(lb/ft^2). (W4)	258.40	0.023
Group B: 4-in face brick + (Clay Tile) air space or 1-in, insulation + 8-in, tile U = 0.154Btu/Hr.ft^2.°F. (W5)	259.66	0.510
Group B: h.w.concrete wall + (finish) 12-in, concrete U = 0.421Btu/Hr.ft^2.°F. (W6)	261.93	1.390
GROUP C: 4-IN FACE BRICK + (Brick) insulation or air space + 4-in. face brick U = 0.358Btu/Hr.ft^2.°F. (W7)	260.86	0.980
GROUP C:4-IN FACE BRICK + (Brick) 1-in insulation or air-space+4-in. common brick air space + 8-in. common brick. U = 0.174Btu/Hr.ft^2.°F. (W8)	258.89	0.210

Table 3: Effect of single pane glasses (uncoated single glazing) on building thermal load

Window glazing type	Peak cooling load CL (kW)	Percentage increase with minimum CL/(CL - CL3)×100/CL3
1/4 clear center glazing with interior shading (Sc = 0.94) (G11)	298.81	4.93
1/8 bronze uncoated, single, center glazing with interior shading (Shading coeff. = 0.85) (G12)	294.45	3.4
1/4 bronze uncoated, single, center glazing with interior shading (Shading coeff. = 0.73) (G13)	288.65	1.36
1/4 green uncoated, single, center glazing with interior shading (Shading coeff. = 0.68) (G14)	286.23	0.51
1/4 green uncoated, single, center glazing with interior shading (Shading coeff. = 0.82) (G15)	293.00	2.88
1/4 gray uncoated, single, center glazing with interior shading (Shading coeff. = 0.65) (G16)	284.78	0.00
1/4 blue green uncoated, single, center glazing with interior shading (Shading coeff. = 0.65) (G17)	288.17	1.19

interior shading with shading coefficient of 0.22 (G31) have minimum cooling load and 1/4 Ti on clr 30% center glazing with interior shading (shading coefficient = 0.45), (G35) make up the maximum cooling load. This results guide the designer in making choice on which window materials that can be used which amount to minimum maintenance cost.

Effect of building orientation on gross building thermal load: The effect of building orientation or the direction of transparent glass surfaces is shown in Table 6. The cooling load will be minimum when all the transparent surfaces are kept facing east. Load for other building orientations have therefore been compared with this minimum load. Percent increase in each case has also been shown in this table. It is observed that the west facing glass surfaces result into maximum cooling load which

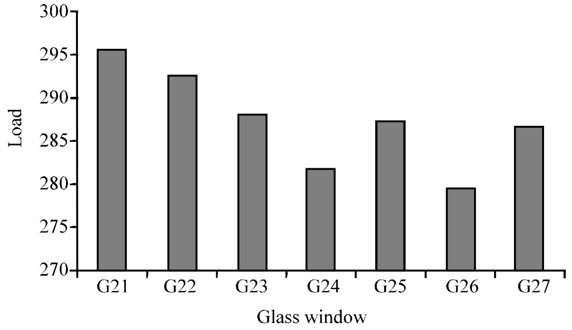

Fig. 4: Variation of building thermal load with different single pane, uncoated double glazing window

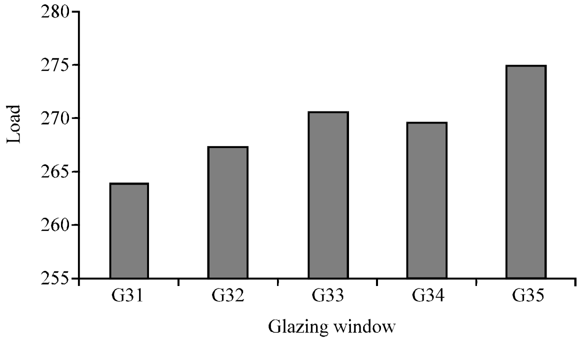

Fig. 5: Variation of building thermal load with different single pane, reflective single glazing window

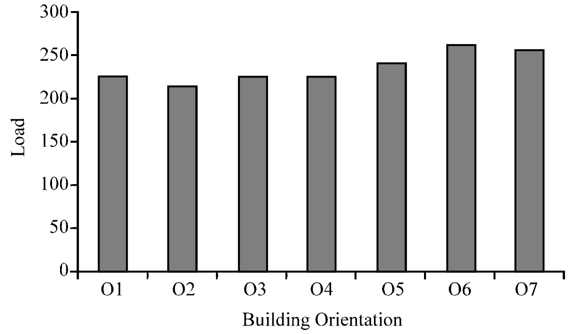

Fig. 6: Variation of building thermal load with different building orientation

Table 4: Effect of single pane glazing (uncoated double glazing) on gross building thermal load

Window glazing type	Peak cooling load Cl (kW)	Percentage increase with minimum CL/(CL-CL3)×100/CL3
1/4 Ss on Clr 8% center glazing with interior shading (Shading coeff. = 0.22) (G31)	263.99	0.00
1/4 Ss On Clr 14% center glazing with interior shading (Shading coeff. = 0.29) (G32)	267.38	1.28
1/4 Ss On Clr 20% center glazing with interior shading (Shading coeff. = 0.36) (G33)	270.76	2.56
1/4 Ti On Clr 20% center glazing with interior shading (Shading coeff. = 0.34) (G34)	269.79	2.20
1/4 Ti On Clr 30% center glazing with interior shading (Shading coeff. = 0.45) (G35)	275.11	4.21

Table 5: Variation of building thermal load with different single pane, reflective single glazing window

Window glazing type	Peak cooling load CL (kW)	Percentage increase with minimum CL/(CL-CL3)×100/CL3
1/8 Clr Clr center glazing with interior shading (Shading coeff. = 0.87) (G21)	295.42	5.71
1/4 Clr Clr center glazing with interior shading (Shading coeff. = 0.81) (G22)	292.52	4.67
1/8 Brz Clr center glazing with interior shading (Shading coeff. = 0.72) (G23)	288.17	3.12
1/4 Brz Clr center glazing with interior shading (Shading coeff. = 0.59) (G24)	281.88	0.86
1/8 Grn Clr center glazing with interior shading (Shading coeff. = 0.70) (G25)	287.20	2.77
1/4 Grn Clr center glazing with interior shading (Shading coeff. = 0.54) (G26)	279.46	0.00
1/8 Grn Clr center glazing with interior shading (Shading coeff. = 0.69) (G27)	286.72	2.60

Table 6: Effects of building orientation on gross building thermal load

Orientation with respect to sun	Gross cooling load, CL (kW)	Percentage increase with minimum (CL-CL2) ×100/CL2)
N-E facing glasses (O1)	225.20	5.08
East facing glasses (O2)	214.30	0.00
S-E facing glasses (O3)	225.24	5.08
South facing glasses (O4)	225.24	5.08
S-W facing glasses (O5)	240.56	12.25
West facing glasses (O6)	260.08	21.36
N-W facing glasses (O7)	254.95	18.96

is 21.36% higher than the minimum. In Fig. 6, it could be deduced that O6 represent the West facing glass that has maximum cooling load. Acronym O represents orientation as was shown in Table 6.

CONCLUSION

The basic features of building energy simulation have been presented in this research. Energy balance method for building simulation was used. The method of building heating/cooling load used is CLTD/CLF Method. Although, a single structure was considered in this research, it suffices to say that the analysis of building energy for more complex structure follows essentially the procedure adopted. The basic input parameters like hourly variations of ambient wet and dry bulb temperature condition as well as hourly variations of solar radiation, etc depend on measured meteorological data for the geographical location at which the simulation tool was developed.

For the case study used in this research, it could be seen obviously that the peak load occur between 13.00 and 14.00 h of the day. This is in line with the findings of Nigeria Meteorological Agency. Software developed serves as a tool for building load calculation. If the instructions guiding the use of this Software for the task at which it has been developed are properly adhered to, effective selection of materials that contribute minimum heat energy for building retrofitting can be made easily. Proper consideration of various significant parameters in a building before making a choice will reduce the cost of maintenance of building design temperature. Early consideration of best building orientation will not only increase thermal comfort of building occupants but also reduce the cost of maintaining the indoor design temperature after the building has been erected.

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