COMPUTERISED APPROACH TO COOLING LOAD ESTIMATES FOR AIR -CONDITIONING DESIGN

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ABSTRACT

The research work provides the basic information for the design of a Central Air-Conditioning system for Kenneth Dike Library extension, University of Ibadan, Oyo State used as a case study. The software was designed, using a visual basic 6.0 (C++) programming language, to perform a thermal analysis for all the rooms of the floors in the building. The developed software called **AIRCCAD** is implemented to handle mathematical equations and engineering calculations efficiently and effectively and provide more accurate information at the very shortest possible time than manually calculated design.

Keywords: Design, Auto-Cad, Software, Air-conditioning

NOMENCLATURE

A - Surface area, m^2
CFM - litres/s
CLF - Cooling load factor, dimensionless
CLTD - Cooling load temperature differential, °C
DT - Dry bulb temperature difference °C,
DW - Difference in moisture content, kg water/ kg dry air
LHG - Latent heat gain, W/m^2 °C
SC - Shading factor, dimensionless,
SHG - Sensible heat gain, W/m^2 °C,
U-Overall heat transfer coefficient, W/m^2 °C
Q_L &Q_s - Latent and sensible heat gains, kJ

1.0 INTRODUCTION

Conditioning of air in its real sense includes treatment of air to some desired quality level for heating and cooling processes. Air conditioning can be defined to be the process or technique involved in controlling and regulating the condition of air in order to provide a comfortable environment. There are four atmospheric conditions, which affect human comfort. These are:

(i) Air temperature,
(ii) Air relative humidity
(iii) Air movement
(iv) Air purity.

The above properties are to be controlled in any air-conditioning design both for comfort and industrial purpose in which the treated air may either be cooled or heated depending on the intended purpose of the design.

Efforts have been made by many researchers to reduce the rigor involved in estimating cooling load for refrigeration or air-conditioning system. It is generally agreed that accurate calculations of the air-conditioning or refrigeration load is essential to a careful design of the system (Adeyemo, 2000). Extra effort in the design of other components cannot in any way compensate for an inaccurate calculation of the cooling load.

However, precise load estimation is not all that a simple exercise; hence there is a need to computerize the procedures to reduce the labour involved and also to avoid errors in the calculation. In space cooling load calculation, peak load time, detailed building design information and weather at selected design conditions are required. The general procedure to compute the cooling load is as given below (Adeyemo, 2000;, Porges , 1991)

(i) Calculate the peak load time

(ii) Obtain characteristics of the building. Building materials, component size, external surface colors and shapes are usually determined from the building plans and specifications.

(iii) Determine the building location, orientation and external shading. Select indoor design conditions, such as indoor dry-bulb temperature, indoor wet-bulb temperature and ventilation rate. Include permissible variations and control limits

(iv) Obtain a proposed schedule of lighting, occupants, internal equipment, appliances, and processes that would contribute to the internal thermal load.

(v) Select the time of the day and Month to do the cooling load calculation. The particular day and month are often dictated by peak solar conditions, determined from data in the standard air conditioning text books.

(vi) Calculate cooling load based on data obtained in (i) – (v).

2.0 RESEARCH METHODOLOGY

Different theories of thermal load estimation were compiled and analyzed in order to come up with an efficient method for air-conditioning design. This was followed by the development of a user friendly computer software to automatically generate cooling load estimates for air-Conditioning system based upon some input parameters.

2.1 Cooling Load Equations

The following equations have been applied to compute the various components of the cooling load such as heat gain through walls, roofs, fenestration area, infiltration, lighting, people and appliances etc. When the cooling load calculation is made will always depend on the geographical location and the orientation of the space being considered (Adeyemo, 1997 and ASHRAE, 2000). For example, peak solar loading on an east facing room may occur at 8.00 am while for a west facing room the maximum load may occur at 4pm.

The sensible heat gain through the walls, roof, and doors Q_s is calculated using Eqn. (1).

$$Q_s = U\,A\,(CLTD) \quad \dots (1)$$

where:

U - Overall heat transfer coefficient, $W/m^2\,°C$
A - Surface area, m^2,
CLTD - Cooling load temperature differential, °C

The radiative heat transfer through transparent assemblies (window) is estimated using Eqn. (2).

$$Q_s = (SC)\,(A)\,(SHG)\,(CLF) \quad \dots (2)$$

where:
SC - Shading factor, dimensionless,
A - Surface area, m^2,
SHG - Sensible heat gain, $W/m^2\,°C$,
CLF - Cooling load factor, dimensionless

Heat admission or loss through fenestration areas is affected by many factors like exterior or interior shading, solar radiation intensity and incident angle, difference between outdoor and indoor temperatures, etc. To accommodate these circumstances, Eqn. (3) was adopted to estimate the latent and sensible heat gains while Eqn. (4) was adopted to calculate the latent heat gain.

Ventilation and infiltration air (sensible)

$$Qs = 1.1 \times CFM \times DT \quad \dots (3)$$

Ventilation and infiltration air (latent)

$$Q_L = 4840 \times CFM \times DW \quad \dots (4)$$

where:
CFM - litres/s
DT - Dry bulb temperature difference °C,
DW - Difference in moisture content, kg water/ kg dry air

2.2 Lighting Systems, People, Equipment, and Appliances

The primary sources of heat gains are lighting systems and equipment operating within the space. The amount of heat gain in the space due to lighting depends on the wattage of the lamp and the type of fixture (Adeyemo, 2000). This is estimated using Eqn. (5). Heat gains (sensible and latent) from people are estimated from Eqn. (6) and Eqn. (7).

$$Qs = \text{Input lamp wattage} \times 3.41 \times CLF \quad (5)$$
$$Qs = \text{number of people} \times SHG \times CLF \quad (6)$$
$$Q_l = \text{number of people} \times LHG \times CLF \quad (7)$$

where:
CLF - Cooling load factor, dimensionless
SHG - Sensible heat gain, $W/m^2\,°C$,
LHG - Latent heat gain, $W/m^2\,°C$

For heat production equipment, it is necessary to estimate the power used along with the period and/or frequency of use in a manner similar to that used for lighting. For equipment having little radiant energy transmission, the CLF can be assumed equal to 1(Adeyemo, 2000). The sensible and latent heat gains are evaluated using Eqn. (8) and (9)

$$Q_s = \text{Installed wattage} \times \text{CLF} \times 3.41 \quad \ldots \quad (8)$$
$$Q_l = \text{Installed wattage} \times 3.41 \quad \ldots \quad (9)$$

where:
CLF - Cooling load factor, dimensionless

3.0 DEVELOPMENT OF AIRCAD SOFTWARE

Software development process involves the writing of the source code in the language that is understood by the computer for it to perform all the arithmetic operations. The process of software development was executed in three main stages. These are: Modular Structuring, Flow Chart Representation and Program Writing.

The program was broken down into structures. Each structure represents a pre-defined process, each of which was configured as a main subroutine. The program AIRCAD which is an interactive computer software for cooling load estimates was written using C^{++} (Visual Basic programming language). AIRCAD requires a personal computer with the following minimum configuration: Pentium 133 MMX processor, 32MB RAM, 2GB free Hard Disk, 3.5" Floppy Disk Drive, 14" Colour Monitor Visual Studio, Standard Serial Mouse and a Printer.

4.0 CASE STUDY

The building used as a case study is the Kenneth Dike library extension, University of Ibadan, Oyo State with the following parameters:

Location: Ibadan
Elevation: 745ft
Designed Month: March
Outdoor Dry bulb Temperature: 31°C
Indoor Dry bulb Temperature: 25.6°C
Outdoor Wet bulb Temperature: 25.5°C
Inside Relative Humidity: 50%
Latitude: 8°N

5.0 RESULTS AND DISCUSSION

The results generated by the software are shown on Table 1. From the results, the sensible heat (2.184E+005 kJ), latent heat (8.587E+005 kJ), ventilation heat (1.792E+005 kJ) and total heat (3.044E+005 kJ) were determined accurately. Also, the refrigeration tonnage (5.9712E+002 kW) was estimated with very little error. All these calculations are for upper ground floor, lower ground floor with all the rooms located within each floor of the building. These results compared favourably with the ones computed manually. A comparison of the time spent by the computer assisted design using AIRCAD software with that of the fastest long (manually) generated solution shows that AIRCAD will design and draft in few (about 25 seconds) what a competent engineer will do in about one hour.

Table 1: Summary of the Floors Heat Load

FLOOR	EFFECTIVE SENSIBLE HEAT	EFFECTIVE LATENT HEAT	EFFECTIVE TOTAL HEAT	TOTAL VENTILATION
BASEMENT	30677	20041	50718	10022
LOWER GROUND FLOOR	257288.13	107847	365135.13	204510
UPPER GROUND FLOOR	283960.776	89604	380122	170024
EFFECTIVE TOTAL HEAT	571925.906	217493	794579	384556
GRAND TOTAL HEAT	1173973.5135Btu/hr = 1,238,542.056 kW/hr			
REFRIGERATION TONNAGE	98.23 TONS			

6.0 CONCLUSIONS AND RECOMMENDATIONS

The study was able to develop a user friendly, menu driven and portable software named AIRCAD for cooling load estimates for central air-conditioning system design. The result was found to be accurate and the calculated cooling loads were within the accepted standard for engineering calculations. With the developed AIRCAD software, the user is able to design at an extremely fast rate. The software was found to increase productivity in the design function by over three hundred folds above manual. AIRCAD software is therefore recommended for use in our industries, as this will improve their productivities.

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