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BUILDING COOLING LOADS CALCULATION WITH LOCAL WEATHER DATA

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Abstract. In large buildings, an HVAC system established for the purpose of cooling consumes around 60% of the overall energy requirements.The purpose of this research is to determine the cooling load based on the local climate. A building with dimensions of 17 m x 13 m x 3.5 m was taken as a case study. In this research, The CLTD/CLF method is used to calculate the cooling loads. On the basis of the MATLAB V.2014b program, the appropriate codes were written. Meteonorm version 8.0.3 was used to collect detailed local climate data for an average of 20 years. the results showed that the high load occurs in August and July, respectively. The peak cooling load for August was on the 19th of August, which was 49.22 kW, and the peak cooling load for July was on the 21st of July, which was 46.4 kW.

Keywords: Cooling load, CLTD, Building, Weather data, HVAC.

Introduction:

At the moment, one of the most important environmental issues is energy consumption by buildings, machines, and industries, which is the primary cause of this problem. Around 72 percent of worldwide energy is consumed by households, markets, and industry. In large buildings, an HVAC system established for the purpose of cooling consumes approximately 60% of the overall energy requirements[1].

The reality of energy consumption in Iraqi buildings reveals that the majority of the energy consumed is for cooling, which is related to the nature of Iraq's environment, which is defined by a lengthy period of hot months, as well as global changes and the phenomenon of global warmingAs a result of Iraq's growing dependence and socialization, a problem has emerged in terms of increasing energy consumption rates in buildings for cooling purposes, even though most of them are far from following the principles of rationalizing energy consumption during them, and the main reason is due to the lack of systems and controls that obligate the designer or intending construction to do so, and the main reason is due to the lack of systems and controls that obligate the designer or intending construction to do so. Of course, all of this was represented in the amount of energy consumed by air-conditioning equipment, which accounted for the majority of the Iraqi family's total energy consumption. Buildings in Iraq absorb about 70% of the total energy produced in the country in (2012) [2].

In today's constructions, maintenance and operation costs, as well as selecting the correct cooling system, are critical in terms of maintaining comfortable indoor conditions while lowering the initial expenditure[3],[4]. The cooling system's capacity should be decided by the cooling load of the building. The cooling demand is incorrectly evaluated, resulting in the selection of an inefficient air conditioning system for the building, raising air conditioning expenses and reducing comfort. As a result, the dependability calculation approach must be used to compute building cooling load [5].

Several approaches for determining a building's cooling requirements due to various heat sources are being developed over time[6].

One of the most widely used and authorized approaches for estimating thermal loads in design was created by the American Society of Heating and Air Conditioning Engineers (ASHRAE). ASHRAE previously used several methods for heating and cooling load calculations, including the method of cooling load temperature difference/solar cooling load/cooling load factor (CLTD/SCL/CLF), another method is the transfer function (TFM), and another method is the total equivalent temperature difference/time average calculation method (TETD / TA) [7].

We are using the (CLTD/ SCL/ CLF) technique in this study. The right size of the HVAC (Heating, Ventilation, and Air Conditioning) system, as well as the optimum control and control of the HVAC system to save energy, must be supplied [8].

External climatic parameters, such as temperature, relative humidity, and sun radiation, are among the most important factors impacting building cooling loads and energy efficiency, because the HVAC system's performance changes when external climatic circumstances vary [9].

Cooling loads were computed in this study using local weather data. The cooling load is the amount of thermal energy that must be removed from the air at any given place to produce the desired condition (human comfort). Because the storage factor in walls and furniture varies from the cooling load to the heating load in heat gain, cooling load calculations are more complex than heating load estimates. Heat increase has no effect on the system, but it takes a long time for the system to be affected by heat gain because of the time delay, as shown in Figure 1.

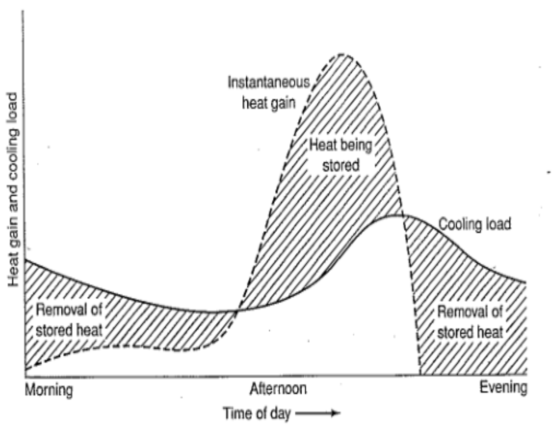

Figure 1. Heat gain and different cooling loads [10].

In this research, we will compute cooling loads in the summer seasons based on local climatic circumstances. The goal of this research is to determine the cooling load based on local climatic conditions, determine the components of heat gain, and conduct an energy efficiency analysis of the building in order to select the appropriate air-conditioning equipment to provide human comfort in the air-conditioned space while reducing energy consumption and costs.

2. Methodology:

In this research, a building (library) with dimensions (13 x 17 x 3.5 meters) was taken, and AutoCAD version 2011, was used to draw the building plan (library) as shown in Figure 2. we will study the cooling loads calculation by using CLTD/CLF method, and using the real weather data. The MATLAB version 2014b program was based on the calculation of cooling loads, where special and appropriate software codes were created based on the MATLAB program, and the local climatic data were obtained in detail for an average (20 years), from the Meteonorm program version 8.0.3. Where the local climatic data that was obtained was entered on the MATLAB program to determine the exact cooling loads every hour, day, and month, and the results were analyzed and plotted with the Golden Software Grapher program version 17.3.454.

3. Location and specifications of the building:

Before determining the cooling load of any area or building, some essential information is required for effective HVAC system design, such as the building structure, building materials, building orientation, and climatic conditions, among other things [11].

3.1. Building constructions

The air-conditioned library's dimensions are as follows: 17 × 13 × 3.5 m in size as shown in figure 2. The dimension of each window (W) is 2 x 1 m. And the dimension of the door (D) is 2.5 x 2 m.

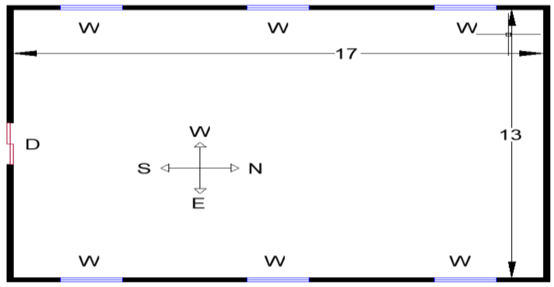

Figure 2. library plan.

3.2. Building location

The cooling load for the library located in Iraq - Kirkuk at latitude 35.47 degrees north and longitude 44.40 degrees east and the height above sea level was 331 meters.

4. Internal and external conditions:

4.1. Internal conditions:

The system's design temperature is 24 degrees Celsius, with a relative humidity of 50%, which is set by the operator.[12]

4.2. Climatic conditions (External conditions):

In this research, external information was taken from meteorological data (temperature of the dry bulb and relative humidity) as shown in Figures (2 & 3) for every hour during a year that's 8760 hours.

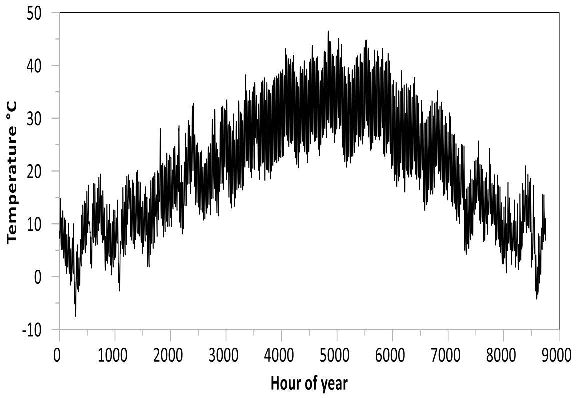

Figure 3. Dry bulb temperature.

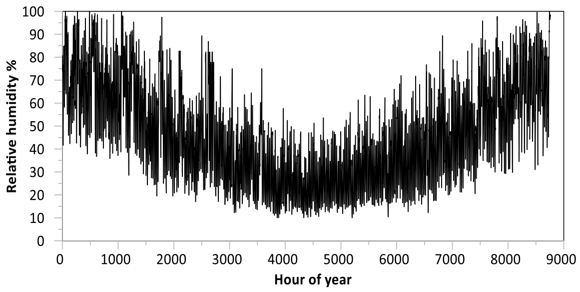

Figure 4. Relative humidity.

5. Cooling load components

The external and interior loads make up the total cooling load for the building, among the external loads are (walls, floors, roofs, windows, etc.), and among the internal loads are (occupants, lights, equipment, etc.)[13].

5.1. Heat gain through the walls:

Heat transfer occurs through the walls from Equation (1), the wall type was considered as L.W. and H.W. Concert Block+(Finish) with 203.2mm Block, from group E, ($2\ \mathrm{W/m^2\ °C}$) is the overall heat transfer coefficient (U) for walls [14].

$$Q = UA(CLTD)_{corr} \quad \text{……….(1)}$$

U = wall design heat transfer coefficient
A = surface area (m^2)
$(CLTD)_{corr}$ = correction of cooling load temperature difference for wall, calculated by Equation (2).

$$CLTD_c = [(CLTD + LM) \times K + (25.5 - T_i) + (T_m - 29.4)] \quad \text{……….(2)}$$

5.2. Heat gain through the roof

Heat transfer occurs through the roof from equation (1), the roof description of the construction is number 8 without suspended ceiling, ($0.715\ \mathrm{W/m^2 \cdot °C}$) is the overall heat transfer coefficient (U) for the roof [14].

$(CLTD)_{corr}$ = correction of cooling load temperature difference for the roof, calculated by Equation (3).

$$CLTD_c = [(CLTD + LM) \times K + (25.5 - T_i) + (T_m - 29.4)] * (f) \quad \text{……….(3)}$$

5.3. Heat gain by conduction through the glass:

All windows are taken as single glass (3.2mm glass). Therefore, ($5.91\ \mathrm{W/m^2 \cdot °C}$) is the overall heat transfer coefficient (U) for the glass [15]. The glass area exposed to the sun's rays are divided into two directions, East (E) and West (W) direction, with ($2\ m^2$) for each glass. The heat gains conduction through the glass is determined by Equation (1).

$(CLTD)_{corr}$ = correction of cooling load temperature difference for glass, calculated by Equation (4).

$$\mathrm{CLTD_c} = [(\mathrm{CLTD}) + (25.5 - \mathrm{T_i}) + (\mathrm{T_m} - 29.4)] \quad \ldots\ldots\ldots(4)$$

5.4. Radiation through the window provides heat gain:

The glass Shading Coefficient (SC) equals one, and it is classified as a shading type [15]. SHG is solar heat gain, and CLF is cooling load factor with interior shading are taken from (ASHRAE 1981) [14]. Calculating the heat gain by solar radiation from Equation (5).

$$\mathrm{Q} = \mathrm{A} * \mathrm{SC} * \mathrm{SHG} * \mathrm{CLF} \quad \ldots\ldots\ldots(5)$$

5.5. Heat gain through the door:

A wood-panel door with a 6% glazing ratio was employed in this study. ($2.73\ \mathrm{W/m^2 \cdot °C}$) is the overall heat transfer coefficient (U) for the door [15]. The door area exposed to the external conditions in the south (S) direction, with ($5\ \mathrm{m^2}$). The heat gain through the door is calculating by Equation (6).

$$\mathrm{Q} = \mathrm{U} * \mathrm{A} * \mathrm{dT} \quad \ldots\ldots\ldots(6)$$

5.6. Heat gain from lighting

A fluorescent 1200 mm T12 bulb with a load of 40W is the type of light. The specific allowance factor (Fsa=1.38) is special to fluorescent lighting [16]. Cooling load factor is taken as maximum rate, for nighttime or weekend cooling, CLF = 1, and lighting use factor is taken as (Flu=1), and the number of lights is (N=80). Thus, the heat gain from light is calculating from Equation (9).

$$\mathrm{Q} = \mathrm{N} * \mathrm{Watt} * \mathrm{Flu} * \mathrm{Fsa} * \mathrm{CLF} \quad \ldots\ldots\ldots(9)$$

5.7. Heat gain from people

There are two types of heat gain calculations for people: sensible heat and latent heat. In this research, the number of people in the room is 22 people, the cooling load factor is taken as the maximum rate (CLF=1) for designing the room. The solar heat gain (SHG) is 75 watts, and the latent heat gain (LHG) is 55 watts for each people [15]. Equation (7) determines the sensible heat gain, while Equation (8) determines the latent heat gain from humans.

$$\mathrm{Q} = \mathrm{N} * \mathrm{SHG} * \mathrm{CLF} \quad \ldots\ldots\ldots(7)$$
$$\mathrm{Q} = \mathrm{N} * \mathrm{LHG} \quad \ldots\ldots\ldots(8)$$

5.8. Heat gain from appliances

Heat gain from the desktop computer, where the room contains 22 computers, and each computer consumes 150 watts [15]. The cooling load factor is taken as the maximum rate (CLF=1) because when an air conditioner is turned off, electricity is produced. Heat gain from the computers is calculating from Equation (10).

$$\mathrm{Q} = \mathrm{N} * \mathrm{Watt} * \mathrm{CLF} \quad \ldots\ldots(10)$$

5.9. Heat gain from ventilation

Air purity is maintained by providing ventilation to the conditioned environment to decrease odor and other undesired gases. Equation (11) is used to compute the sensible heat gain, and Equation (12) is used to compute latent heat gain. The amount of air required to ventilate a room was computed by a method depending on the number of people used in this study, and it is calculated from Equation (13). The amount of air needed per person $V_{vent/P} = 8.5$ (L/S.p) [17].

$$Q_{vent\,/S} = 1.23 \times V_{vent} \times (T_0 - T_i) \quad \ldots\ldots(11)$$
$$Q_{vent\,/L} = 3010 \times V_{vent} \times (W_o - W_i) \quad \ldots\ldots(12)$$
$$V_{vent} = V_{vent/P} \times N_P \quad \ldots\ldots(13)$$

5.10. Heat gain from infiltration

Air leakage occurs as a result of air passing through cracks in the walls and around window and door openings, and thus air leakage into the rooms causes heat convection because it requires the extraction of heat from the leaking air so that its condition becomes similar to the condition of the air inside air-conditioned places. The sensible heat is calculated from Equation (14) and latent heat is calculated from Equation (15). Determining the rate of air leakage from Equation (16) based on the method of air change, The number of air changes per hour is determined by the building's quality and the number of exposed surfaces.

$$Q_{inf\,/S} = 1.23 \times V_{inf} \times (T_0 - T_i) \quad \ldots\ldots.(14)$$
$$Q_{inf\,/L} = 3010 \times V_{inf} \times (W_o - W_i) \quad \ldots\ldots.(15)$$
$$V_{inf} = (N_{inf} \times V_r)/3600 \quad \ldots\ldots.(16)$$

6. Results and Discussion

The hourly local meteorological conditions of Kirkuk, Iraq, including temperature and relative humidity, were utilized to show the distribution of temperature and relative humidity in each hour, as shown in Figures 3 and 4. Figure 2 shows the cooling loads for a specific building (library) with a length of 17 meters, width of 13 meters, and height of 3.5 meters. The cooling loads were classified into two categories, including internal and external loads, which include internal loads (people, appliances, and lighting), whose internal thermal load values are fixed by taking the cooling load factor equal to one. The external loads are different according to the hourly temperature and relative humidity. According to the heat gain analysis performed from April to October. The results will be as shown in Figure 5, which shows the cooling load per hour in the summer. Figure 6, which shows the peak cooling loads for each day, and shows that the maximum cooling loads occur in August and July respectively. Figure 7 displays the peak cooling loads for July, showing that the greatest load is 46.4 kW on July 21st. Figure 8 displays the peak cooling loads for August, showing that the highest load is 49.22 kW on August 19th. Finally, it appears that the largest cooling load occurs in August during the summer.

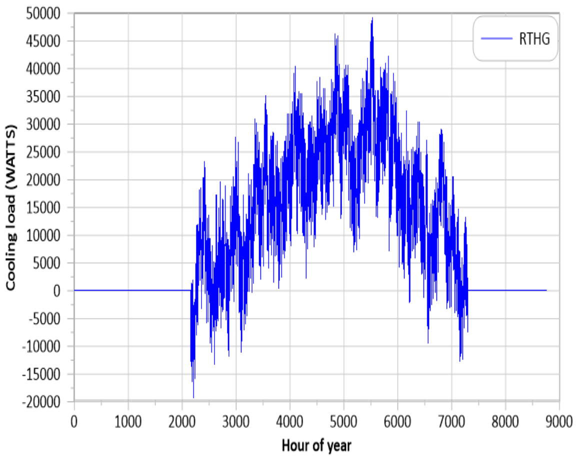

Figure 5. Cooling load hourly.

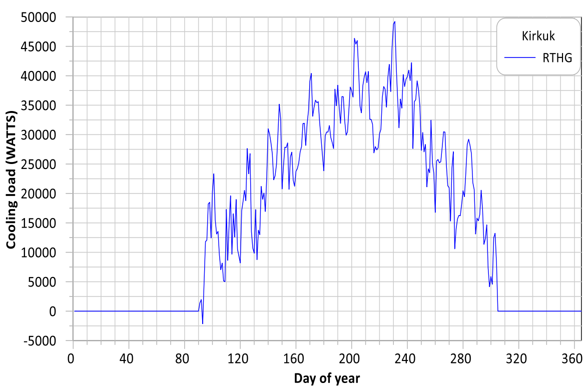

Figure 6. Peak daily Cooling loads.

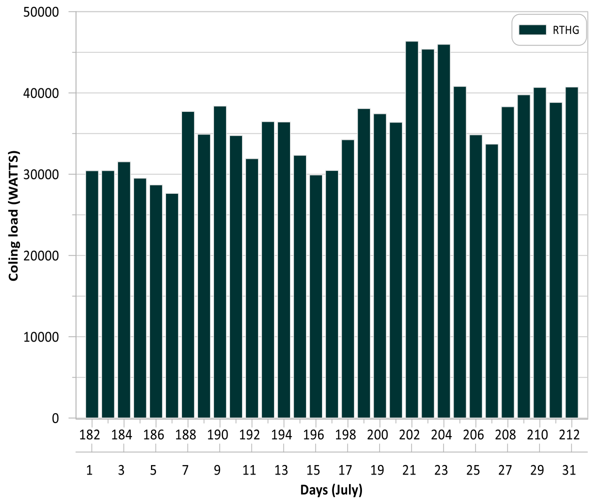

Figure 7. Peak Cooling loads of July.

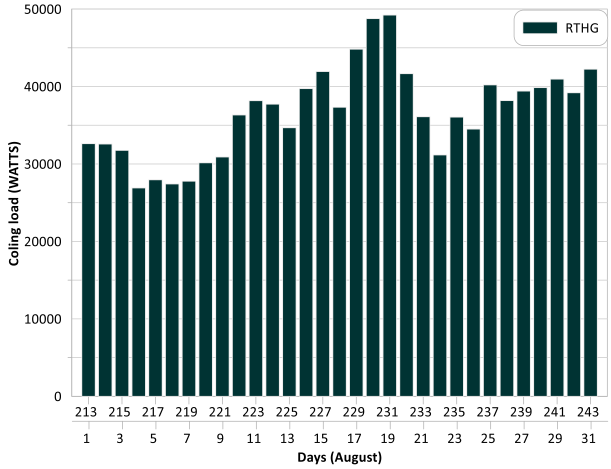

Figure 8. Peak Cooling loads for August.

7. Conclusion

According to the presented results of calculating the cooling load by the program (MATLAB), it appears that it has superior ability in calculations with high accuracy, so it is possible to show realistic and accurate results during hours during days, and possible to show high load during the months in which the calculation is made, depending on the climatic conditions that are the subject of this research. According to the results of a heat gain investigation conducted from April to October, the highest load occurs in August and July, respectively. The peak cooling demand for August was 49.22 kW on August 19th, and the peak cooling load for July was 46.4 kW on July 21st. This means that the peak cooling load for the summer is on August 19. This supports using it to calculate the cooling load, indicating a suitable way to install appropriate cooling systems and equipment with high accuracy, which has a return on that investment, as well as leading to good green building design and energy efficiency.

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