The Role of Cooling Degree Days on determining the insulation of building Envelop in a hot climate (Iraqi cities as an example)

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Abstract. Last decades witnessed rise in global average temperature for cities, consequently with the problem of rising needs for energy results from the growth of populations in cities. Recent studies concentrated on degree days method to calculate energy consumption for buildings, the main problem of this research is the role of cooling degree days on determining insulation of buildings envelope in a hot climate and for Iraqi cities as an example. The research aims to determine insulation of buildings envelope according to cooling degree days which reduce energy consumption; the results showed that there were differences in cooling degree days for main Iraqis cities, and there was an effect of buildings envelope insulation on cooling energy lost, the insulation for walls reduced consumption energy by 70-80%. Also, the insulation for ceiling reduced consumption energy by 65%, as compared to the same building materials without insulation.

1. Introduction

These Global temperatures had raised at the end of the 20th century and the beginning of the 21st century, the high record temperatures was one of the most prominent indicators of global warming. That affected buildings cooling energy loads especially in a hot arid climate [1]. There were many ways to calculate the energy usage for cooling and heating buildings, but the method of calculating the degree of days was one of the main types. Degree days depended on calculation temperature of the external environment, and its association with the internal temperature of buildings. The previous studies did not adequately address this indicator in Iraq, but the international studies highlighted many aspects of research and the latest of these studies. Indraganti et al. (2016) [2] examined the effect of increasing the degree days whether in cooling or heating in five different climatic zones in Saudi Arabia and for nine years with difference of the basic comparison class in the case of heating between (14, 16, 18 °C) in the case of cooling between (18, 20, 22, 24, 28 °C) and control of energy consumption (for cooling and heating) of buildings for the same cities. The study showed increase energy consumption in recent years with rising temperatures degree days. Mishra, et al., (2012) [3] studied the effect of degree days on determined the thickness of thermal insulation for walls and ceiling for buildings that minimize loss of heat through external walls, window, and ceiling, for four different climatic zones in India. The research found that optimum insulation thickness varies between 0.1446m and 0.2077 m, and energy reduction between 500.03 Rs/m² and 1014.27 Rs/m², and Payback period varies between 0.87 to 1.2374 years for External walls. Yuan, et al., (2017) [4] studied the relationship between insulation for the exterior walls of buildings and energy and CO₂ emissions in different places in China. Using life-cycle cost analysis (LCCA) and degree-days (DD) method. The research found that thermal insulation of exterior walls is more effective in Severe Cold and Hot Summer & Cold Winter climatic zones of China for both total energy cost saving and CO₂ emissions reduction per unit area of the exterior building walls. Melo, et al., (2015) [5] Studied the effects of insulation materials on energy performance for Brazil commercial
buildings. Depend on the climate of the building site. The research found that contradict the maximum limits of overall heat transfer coefficient for walls given in the ASHRAE Standard 90.1, at least for hot climates dominated by cooling energy use.

2. Degree days
Building During occupancy consumes more energy than energy for producing it. Recent studies had shown that energy consumption for buildings reached 40% of total energy consumption in the cities [6]. The consumption of buildings for energy is affected by several external environmental factors (external temperature, solar radiation intensity, relative humidity, wind, etc.), while buildings affected by its design, envelop materials and components in the calculation of consumed energy. The index of degree days is the simplest method to calculate the energy needs for buildings. It adopted by Lt-Gen. Sir Richard Strachey, during his study of the effect of daily temperature diversity across seasons on plants and seasons of growth according to their climatic zones. It defined as the sum of the differences between the hourly temperature and the base degree [7]. The degree of the base represents the degree to which the balance between the external air temperature and the temperature of the building, which does not require the building to energy for cooling or heating to achieve thermal comfort [8]. The degree days index depends on the range of temperature variations over time, thus determine both the length and duration of outdoor temperatures with the calculation of the difference between the temperature that achieves thermal comfort in the building and temperature of the outdoor air. For example, if the temperature outside in the winter 10 degrees Celsius and the temperature required to be provided in the building to achieve the human comfort of 22 degrees Celsius, this means that heating system should provide heating equal to raise the temperature inside 12 degrees Celsius. This contributes to knowledge of the energy needed to heat or cool buildings in summer. The importance of the degree of days [9]:-

- Determination of energy required for cooling and heating of buildings.
- Evaluation of thermal loss of buildings to determine the required thermal insulation and other energy saving methods.
- Control of energy consumption in buildings [10].

The degree days can be divided into two main types, the degree days of heating (HDD) and the degree days of cooling (CDD), which are two indices to calculate the energy consumed for cooling and heating in buildings of different types. The degree days of heating (HDD) measure the number of degrees and periods days when the temperature of the air outside the base degree, which can calculate the amount of energy, spent for heating. Degree days of cooling (CDD) also measure the day periods when the external air temperature is above the base level, which enables the calculation of the amount of energy spent for cooling [11].

3. Degree Days calculation
There are many types to calculate degree days, depend on the factors influence in the calculation of it, as following:

- (ASHRAE) method: American Society of Heating, Refrigeration and Air-conditioning Engineers
- (UKMO) method: United Kingdom Meteorological Office
- (S-K) method: Schoenau and Kehrig’s
- Hitchin’s method
- Mean degree-hours [2]

Mean degree hours were the most appropriate type to experience the daily changes in temperatures. This depends on the highest and lowest outside temperatures [12]. To calculate the Mean degree- hours three basic factors are included, \((T_{\text{max}})\) Daily maximum temperature, \((T_{\text{min}})\) Daily minimum temperature, and a \((T_{\text{base}})\) base temperature, nominated by the user as an estimate of the outside air temperature at which no artificial heating (or cooling) is required. Base temperature is related to the degree to which thermal comfort is achieved within buildings. Previous studies have relied on the determination of the base score for the cooling and heating calculations. For example, the 18.3 °C was adopted by the United States Heating and Ventilation Organization (ASHRAE). In the United Kingdom, 15.5 °C was adopted and
15 °C was adopted in Germany are associated with varying temperatures and annual and cumulative rates in each of these states [10].

4. The relationship between the degree of days and heat transfer coefficient
The calculation of energy consumption in buildings is based on the value of thermal insulation for the buildings envelope which include (walls, ceiling, and floor). The most important indicator of insulation calculation is the total heat transfer coefficient U-Value, which represents the ratio of heat transfer across a given area with different temperatures. It is based on the properties of building materials and is measured in watts per square meter in a single Celsius degree (W / m²/°C). The relation between heat transfer coefficient, thermal loss, and the base temperature, according to the equation (1) [3]:

\[ Q = U(T_b - T_a) \]  (1)

Where
Q= thermal loss
U= heat transfer coefficient
Tb = Base Temperature (°C)
Ta = average Temperature (°C)

The relationship between degree days and the thermal loss for building envelop is expressed in the equation (2):

\[ QA = 86400DD \times U \]  (2)

Where
DD= Degree days

5. Research objectives
The main objective of this research is to contribute to the understanding the role of cooling degree days on determining the building envelope insulation in a hot dry climate. This goal can be achieved through:
1- Investigating the degree days for cooling for the main cities in Iraq for the periods of time (2010-2017).
2- Identifying the building envelope insulation according to the degree of the day of cooling which contributes to reducing the energy consumption during summer in the hot, dry climatic characteristics of Iraq.

6. Methodology
The research studied the degree days for the main cities in Iraq (Baghdad, Basrah, Khanaqen, Erbil, and Haditha) for the periods of time (2012-2017). The calculation requires measurements of maximum and minimum outside air temperatures (T_max and T_min). According to Iraq weather history and a ‘base temperature’ T_base, for all the months of the recent years were used, to estimate cooling degree days from the following formulae:

If the minimum temperature is larger than base temperature T_min>T_base the equation (3) is applicable:

\[ CDD = \frac{(T_{\text{max}} + T_{\text{min}})}{2} - T_{\text{base}} \]  (3)

If the minimum temperature is equal or smaller than base temperature T_min<=T_base the equation (4) is applicable:

\[ CDD = \frac{(T_{\text{max}} + T_{\text{min}})}{2} - \frac{T_{\text{base}} - T_{\text{min}}}{4} \]  (4)

And the relationship between Cooling Energy Lost and Cooling degree days and the heat transfer coefficient is expressed in the equation (5) [13]:

\[ \text{Cooling Energy Lost} = \frac{(24 \times CDD \text{ Annual} \times U)}{1000} \text{ kWh/year/m}^2 \]  (5)

7. Results

7.1. Comparison of Cooling Degree Days in Iraq main cities
A comparison was made between Iraq main cities average cooling degree days, for different base temperatures 16.5, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26 °C for the periods of time (2012-2017) are
shown in Figure (1). It is obvious that cooling degree days are higher in 16.5 °C base temperature in all Iraqi cities. Also there were differences in cooling degree days for main Iraqis cities.

![Figure 1. Average cooling degree days (2012-2017) in main Iraq cities (Baghdad, Basrah, Khanaqen, Erbil, and Haditha).](image)

### 7.2. Comparison of the effect of the building envelope insulation on cooling energy lost

The common building materials in Iraqi cities which used in building envelope have different U-Value, as shown in Table 1.

| Symbol | Building envelop components | U-Value |
|--------|-----------------------------|---------|
| Wall   | W1  20 mm plaster+240 mm clay brick +20 mm cement finish | 1.429   |
|        | W2  20 mm plaster+240 mm Thermostone +20 mm cement finish | 0.723   |
|        | W3  20 mm plaster+240 mm Cement Block +20 mm cement finish | 1.515   |
|        | W4  20 mm plaster+240 mm clay brick +RSI 1.2 board insulation +20 mm cement finish | 0.516   |
|        | W5  20 mm plaster+240 mm Thermostone +RSI 1.2 board insulation +20 mm cement finish | 0.396   |
|        | W6  20 mm plaster+240 mm Cement Block +RSI 1.2 board insulation +20 mm cement finish | 0.370   |
|        | W7  20 mm plaster+240 mm clay brick +RSI 2.5 board insulation +20 mm cement finish | 0.316   |
|        | W8  20 mm plaster+240 mm Thermostone +RSI 2.5 board insulation +20 mm cement finish | 0.267   |
|        | W9  20 mm plaster+240 mm Cement Block +RSI 2.5 board insulation +20 mm cement finish | 0.253   |
| Ceiling| C1  40mm precast concrete tile+ 10mm river sands+ 20 mm tar+150 mm concrete slap+20 mm plaster | 1.1696  |
|        | C2  40mm precast concrete tile+ 10mm river sands+ 20 mm tar+25 mm polystyrene boards+ 150 mm concrete slap+20 mm plaster | 0.5931  |
|        | C3  40mm precast concrete tile+ 10mm river sands+ 20 mm tar+50 mm polystyrene boards+ 150 mm concrete slap+20 mm plaster | 0.3975  |

The effect of different building envelop materials on consume cooling energy for a main Iraq cities according to an average cooling degree are shown in Tables 2-11 according to equation (5).
Table 2. Cooling energy lost for cooling degree days 17°C.

| Symbol | U-Value | Basrah | Baghdad | Erbil | Khanaqen | Haditha |
|--------|---------|--------|---------|-------|----------|---------|
| Wall   |         |        |         |       |          |         |
| W1     | 1.429   | 132.38 | 113.24  | 88.07 | 111.01   | 125.14  |
| W2     | 0.723   | 66.97  | 57.29   | 44.55 | 56.16    | 63.31   |
| W3     | 1.515   | 140.34 | 120     | 93.37 | 117.69   | 132.67  |
| W4     | 0.516   | 47.80  | 40.89   | 31.80 | 40.08    | 45.18   |
| W5     | 0.396   | 38.04  | 31.38   | 24.40 | 30.76    | 34.68   |
| W6     | 0.370   | 35.54  | 29.32   | 22.80 | 28.74    | 32.40   |
| W7     | 0.316   | 30.35  | 25      | 19.47 | 24.54    | 27.67   |
| W8     | 0.267   | 25.65  | 21.15   | 16.45 | 20.74    | 23.38   |
| W9     | 0.253   | 24.06  | 20      | 15.59 | 19.65    | 22.15   |
| Ceiling|         |        |         |       |          |         |
| C1     | 1.1696  | 108.35 | 92.68   | 72.08 | 90.86    | 102.42  |
| C2     | 0.5931  | 54.94  | 47      | 36.55 | 46.07    | 51.94   |
| C3     | 0.3975  | 36.82  | 31.5    | 24.49 | 30.88    | 34.81   |

Table 3. Cooling energy lost for cooling degree days 18°C.

| Symbol | U-Value | Basrah | Baghdad | Erbil | Khanaqen | Haditha |
|--------|---------|--------|---------|-------|----------|---------|
| Wall   |         |        |         |       |          |         |
| W1     | 1.429   | 122.95 | 104.7   | 80.90 | 102.81   | 116.36  |
| W2     | 0.723   | 62.2   | 52.97   | 40.93 | 52.02    | 58.87   |
| W3     | 1.515   | 130.35 | 111     | 85.77 | 109      | 123.36  |
| W4     | 0.516   | 44.39  | 37.8    | 29.21 | 37.12    | 42.01   |
| W5     | 0.396   | 34.07  | 29      | 22.41 | 28.49    | 32.24   |
| W6     | 0.370   | 31.83  | 27.11   | 20.94 | 26.62    | 30.12   |
| W7     | 0.316   | 27.18  | 23.15   | 17.89 | 22.73    | 25.73   |
| W8     | 0.267   | 22.97  | 19.56   | 15.11 | 19.21    | 21.74   |
| W9     | 0.253   | 21.76  | 18.53   | 14.32 | 18.20    | 20.60   |
| Ceiling|         |        |         |       |          |         |
| C1     | 1.1696  | 100.63 | 85.69   | 66.21 | 84.15    | 95.24   |
| C2     | 0.5931  | 51.03  | 43.45   | 33.57 | 42.67    | 48.29   |
| C3     | 0.3975  | 34.20  | 29.12   | 22.50 | 28.60    | 32.36   |

Table 4. Cooling energy lost for cooling degree days 19°C.

| Symbol | U-Value | Basrah | Baghdad | Erbil | Khanaqen | Haditha |
|--------|---------|--------|---------|-------|----------|---------|
| Wall   |         |        |         |       |          |         |
| W1     | 1.429   | 113.86 | 96.47   | 74.04 | 94.89    | 107.82  |
| W2     | 0.723   | 57.6   | 48.81   | 37.46 | 48.01    | 54.55   |
| W3     | 1.515   | 120.715| 102.28  | 78.50 | 100.60   | 114.31  |
| W4     | 0.516   | 41.144 | 34.83   | 26.73 | 34.26    | 38.93   |
| W5     | 0.396   | 31.55  | 26.73   | 20.51 | 26.29    | 29.88   |
| W6     | 0.370   | 29.48  | 24.97   | 19.17 | 24.57    | 27.91   |
| W7     | 0.316   | 25.17  | 21.33   | 16.37 | 20.98    | 23.84   |
| W8     | 0.267   | 21.27  | 18      | 13.83 | 17.73    | 20.14   |
| W9     | 0.253   | 20.15  | 17      | 13.10 | 16.80    | 19.09   |
| Ceiling|         |        |         |       |          |         |
| C1     | 1.1696  | 93.19  | 78.96   | 60.60 | 77.67    | 88.25   |
| C2     | 0.5931  | 47.25  | 40      | 30.73 | 39.38    | 44.75   |
| C3     | 0.3975  | 31.67  | 26.83   | 20.59 | 26.39    | 29.99   |
### Table 5. Cooling energy lost for cooling degree days 20°C.

| Symbol | U-Value | Basrah | Baghdad | Erbil | Khanaqen | Haditha |
|--------|---------|--------|---------|-------|----------|---------|
| Wall   |         |        |         |       |          |         |
| W1     | 1.429   | 105.25 | 88.65   | 67.76 | 87.31    | 99.59   |
| W2     | 0.723   | 53.25  | 44.85   | 34.28 | 44.17    | 50.39   |
| W3     | 1.515   | 111.588| 93.99   | 71.84 | 92.57    | 22.02   |
| W4     | 0.516   | 38.006 | 32      | 24.47 | 31.52    | 38.93   |
| W5     | 0.396   | 29.16  | 24.56   | 18.77 | 24.19    | 27.59   |
| W6     | 0.370   | 27.25  | 22.95   | 17.54 | 22.60    | 25.78   |
| W7     | 0.316   | 23.27  | 19.6    | 14.98 | 19.30    | 22.02   |
| W8     | 0.267   | 19.66  | 16.56   | 12.66 | 16.31    | 18.60   |
| W9     | 0.253   | 18.63  | 15.69   | 11.99 | 15.45    | 17.63   |
| Ceiling|         |        |         |       |          |         |
| C1     | 1.1696  | 86.14  | 72.56   | 55.46 | 71.46    | 81.51   |
| C2     | 0.5931  | 43.68  | 36.79   | 28.12 | 36.24    | 41.33   |
| C3     | 0.3975  | 29.27  | 24.66   | 18.85 | 22.02    | 27.70   |

### Table 6. Cooling energy lost for cooling degree days 21°C.

| Symbol | U-Value | Basrah | Baghdad | Erbil | Khanaqen | Haditha |
|--------|---------|--------|---------|-------|----------|---------|
| Wall   |         |        |         |       |          |         |
| W1     | 1.429   | 96.98  | 81.11   | 61.25 | 80.11    | 91.70   |
| W2     | 0.723   | 49.07  | 41.03   | 30.99 | 40.53    | 46.39   |
| W3     | 1.515   | 102.82 | 85.99   | 64.93 | 84.93    | 97.22   |
| W4     | 0.516   | 26.877 | 22.47   | 16.97 | 22.22    | 25.41   |
| W5     | 0.396   | 25.11  | 21      | 15.85 | 20.74    | 23.74   |
| W6     | 0.370   | 21.44  | 17.93   | 13.54 | 17.71    | 20.27   |
| W7     | 0.316   | 18.12  | 15.15   | 11.44 | 14.96    | 17.13   |
| W8     | 0.267   | 17.17  | 14.36   | 10.84 | 14.18    | 16.23   |
| W9     | 0.253   | 21.38  | 17.38   | 13.58 | 17.71    | 20.27   |
| Ceiling|         |        |         |       |          |         |
| C1     | 1.1696  | 79.38  | 66.38   | 50.13 | 65.57    | 75.06   |
| C2     | 0.5931  | 40.25  | 33.66   | 25.42 | 33.25    | 38.06   |
| C3     | 0.3975  | 26.97  | 22.56   | 17.03 | 22.28    | 25.50   |

### Table 7. Cooling energy lost for cooling degree days 22°C.

| Symbol | U-Value | Basrah | Baghdad | Erbil | Khanaqen | Haditha |
|--------|---------|--------|---------|-------|----------|---------|
| Wall   |         |        |         |       |          |         |
| W1     | 1.429   | 89.06  | 73.90   | 55.35 | 73.15    | 84.09   |
| W2     | 0.723   | 45.063 | 37.39   | 28.0  | 37.01    | 42.54   |
| W3     | 1.515   | 94.42  | 78.35   | 58.68 | 75.55    | 89.15   |
| W4     | 0.516   | 32.161 | 26.68   | 19.98 | 26.41    | 30.36   |
| W5     | 0.396   | 24.68  | 20.48   | 15.33 | 20.27    | 23.30   |
| W6     | 0.370   | 23.06  | 19.13   | 14.33 | 18.94    | 21.77   |
| W7     | 0.316   | 19.69  | 16.34   | 12.24 | 16.17    | 18.59   |
| W8     | 0.267   | 16.64  | 13.80   | 10.34 | 13.66    | 15.71   |
| W9     | 0.253   | 15.76  | 13.85   | 9.8   | 12.95    | 14.88   |
| Ceiling|         |        |         |       |          |         |
| C1     | 1.1696  | 72.89  | 60.49   | 45.30 | 59.87    | 68.82   |
| C2     | 0.5931  | 36.96  | 30.67   | 22.97 | 30.36    | 34.90   |
| C3     | 0.3975  | 24.77  | 20.55   | 15.39 | 20.34    | 23.39   |
Table 8. Cooling energy lost for cooling degree days 23°C.

| Symbol | U-Value | Basrah | Baghdad | Erbil | Khanaqen | Haditha |
|--------|---------|--------|---------|-------|----------|---------|
| Wall   | W1      | 1.429  | 81.45   | 67.18 | 55.35    | 66.46   |
|        | W2      | 0.723  | 41.21   | 33.99 | 25.16    | 33.62   |
|        | W3      | 1.515  | 86.355  | 71.22 | 52.72    | 70.46   |
|        | W4      | 0.516  | 92.412  | 24.26 | 17.95    | 24      |
|        | W5      | 0.396  | 22.57   | 18.61 | 15.33    | 18.41   |
|        | W6      | 0.370  | 21.09   | 17.39 | 14.33    | 17.20   |
|        | W7      | 0.316  | 18.01   | 14.85 | 10.99    | 14.69   |
|        | W8      | 0.267  | 15.21   | 12.55 | 9.29     | 12.41   |
|        | W9      | 0.253  | 14.42   | 11.89 | 8.80     | 11.76   |
| Ceiling| C1      | 1.1696 | 66.66   | 54.89 | 40.7     | 54.40   |
|        | C2      | 0.5931 | 33.80   | 27.88 | 20.63    | 27.58   |
|        | C3      | 0.3975 | 22.65   | 18.68 | 13.83    | 18.48   |

Table 9. Cooling energy lost for cooling degree days 24°C.

| Symbol | U-Value | Basrah | Baghdad | Erbil | Khanaqen | Haditha |
|--------|---------|--------|---------|-------|----------|---------|
| Wall   | W1      | 1.429  | 74.31   | 60.7  | 44.41    | 60.18   |
|        | W2      | 0.723  | 37.601  | 30.71 | 22.47    | 30.45   |
|        | W3      | 1.515  | 78.79   | 64.35 | 47.08    | 63.81   |
|        | W4      | 0.516  | 26.83   | 21.91 | 16.03    | 21.73   |
|        | W5      | 0.396  | 20.59   | 16.82 | 12.30    | 16.67   |
|        | W6      | 0.370  | 19.24   | 15.71 | 11.49    | 15.58   |
|        | W7      | 0.316  | 16.43   | 13.42 | 9.82     | 13.30   |
|        | W8      | 0.267  | 13.88   | 11.34 | 8.29     | 11.24   |
|        | W9      | 0.253  | 13.15   | 10.74 | 7.86     | 10.65   |
| Ceiling| C1      | 1.1696 | 60.82   | 49.68 | 36.35    | 49.26   |
|        | C2      | 0.5931 | 30.84   | 25.19 | 18.43    | 24.98   |
|        | C3      | 0.3975 | 20.67   | 16.88 | 12.35    | 16.74   |

Table 10. Cooling energy lost for cooling degree days 25°C.

| Symbol | U-Value | Basrah | Baghdad | Erbil | Khanaqen | Haditha |
|--------|---------|--------|---------|-------|----------|---------|
| Wall   | W1      | 1.429  | 67.35   | 54.53 | 39.40    | 54.08   |
|        | W2      | 0.723  | 34.7    | 27.58 | 19.93    | 27.36   |
|        | W3      | 1.515  | 71.411  | 57.81 | 41.77    | 57.33   |
|        | W4      | 0.516  | 24.322  | 19.69 | 14.22    | 19.52   |
|        | W5      | 0.396  | 18.66   | 15.11 | 10.92    | 14.98   |
|        | W6      | 0.370  | 17.74   | 14.11 | 10.20    | 14      |
|        | W7      | 0.316  | 14.89   | 12.05 | 8.71     | 11.95   |
|        | W8      | 0.267  | 12.58   | 10.18 | 7.36     | 10.10   |
|        | W9      | 0.253  | 11.92   | 9.65  | 6.97     | 9.57    |
| Ceiling| C1      | 1.1696 | 55.13   | 44.63 | 32.25    | 44.26   |
|        | C2      | 0.5931 | 27.95   | 22.63 | 16.35    | 22.44   |
|        | C3      | 0.3975 | 18.73   | 15.16 | 10.96    | 15.04   |
Table 11. Cooling energy lost for cooling degree days 26°C.

| Symbol | U-Value | Cooling energy lost in kWh/year/m² |
|--------|---------|----------------------------------|
|        |         | Basrah | Baghdad | Erbil | Khanaqen | Haditha |
| Wall W1 | 1.429   | 60.77  | 48.37   | 34.70 | 48.39    | 57.27   |
| W2     | 0.723   | 30.74  | 24.63   | 17.56 | 24.48    | 28.97   |
| W3     | 1.515   | 64.24  | 51.63   | 36.79 | 31.30    | 40.72   |
| W4     | 0.516   | 21.94  | 17.58   | 12.53 | 17.47    | 20.68   |
| W5     | 0.396   | 16.84  | 13.49   | 9.61  | 13.41    | 15.87   |
| W6     | 0.370   | 15.73  | 12.60   | 8.98  | 12.52    | 14.82   |
| W7     | 0.316   | 13.43  | 10.76   | 7.67  | 10.70    | 12.66   |
| W8     | 0.267   | 11.35  | 9.09    | 6.48  | 9.04     | 10.70   |
| W9     | 0.253   | 10.75  | 8.62    | 6.14  | 8.56     | 10.14   |
| Ceiling C1 | 1.1696 | 49.74  | 39.85   | 28.40 | 39.60    | 46.87   |
| C2     | 0.5931  | 25.22  | 20.21   | 14.40 | 20.08    | 23.77   |
| C3     | 0.3975  | 16.90  | 13.54   | 9.65  | 13.46    | 15.93   |

The results showed that different wall materials (clay brick, Thermostone, and cement block) with RSI 2.5 board insulation and 26 °C base temperature were more efficient in energy consumption for cooling for all tested Iraqi cities, and concrete ceilings with 50 mm polystyrene boards insulation was and 26 °C base temperature were more efficient in energy consumption for cooling for all tested Iraqi cities.

8. Conclusion
The cooling degree days can be used by the designers to predicate cooling energy consumption for building envelop in a hot climate. In this study average cooling degree days was investigated for years (2012-2017), in main Iraq cities (Baghdad, Basrah, Khanaqen, Erbil, and Haditha) with base temperatures of 16.5, 17, 18, 19, 20, 21, 22, 23, 24, 25, and 26 °C were chosen to calculate cooling degree-days. The higher base temperatures 26 °C related to lower cooling degree days in all Iraqi cities and better cooling energy consumption. Also, calculations were made to show the effect of building envelope insulation on energy consumption according to cooling degree days for different base temperatures to determine the most efficient in energy consumption. The most important factor affected by energy consumption was the insulation on walls that reduced energy consumption to 70-80% as compared with the same wall materials without insulation. Also, the insulation on ceiling reduced energy consumption to 65% as compared with the same ceiling materials without insulation.

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