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Cooling Load Calculation Using E20 Spreadsheet and HAP Software for for the Main Entrance Glass Atrium of Shopping Mall Building

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Abstract: A complete air conditioning system has been developed to control ambient conditions such as relative humidity, temperature, and movement in an atrium shopping mall building in Batu Pahat, Johor. This study focuses on cooling load estimation of the building by using two calculation methods. The calculation considers the ASHRAE standards to ensure that valid results and data are achieved. The objective of this study is to calculate the cooling load using Hourly Analysis Program) HAP software and manual calculation. The manual calculation is conducted using E20 Spreadsheet. The building consists of four floors, and 44 shops need to be conditioned. The cooling loads on people, infiltration, lighting, ventilation heat gain, roofs, and walls can also be easily entered into the E20 Spreadsheet. At the end of this study, the result shows that the total cooling loads using two different methods are similar. The maximum difference in total cooling load between manual calculation and HAP software is 2.3 percent. Therefore, the research can be extended to many buildings such as schools, restaurants, hospitals, and others to improve the current research outcome.

Keywords: Cooling Load, E20 Spreadsheet, HAP Software, Shopping Mall Buildings

1. Introduction

Air conditioning systems have been widely used all around the world. The purpose of the methods is to provide a comfortable shopping mall environment. People in Malaysia spend most of their time in shopping malls on weekends, so it is important to have an efficient air conditioning system. An effective air conditioning system not only provides a comfortable shopping mall environment but may also cut total energy consumption because air conditioning systems consume the most energy in a structure [1]. Thus, an effective air conditioning system saves money on power and, more crucially, emits fewer greenhouse gases into the environment.

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Aesthetics and energy consumption are critical components of building construction. For example, the air conditioning system can provide thermal comfort while reducing energy usage in the building. However, these factors can impact the cost of construction, the size of plumbing, ducting, air diffusers, and the amount of power needed. For this project, the atrium building of a shopping mall was chosen. Thus, this study focuses on cooling load, which is the amount of heat energy required to be removed from some space to maintain the temperature in an acceptable and comfortable range. Thus, this study predicts cooling load utilizing CLTD (cooling load temperature difference), CLF (cooling load factor), and SCL (solar cooling load factor) for three external loads.

Buildings with atrium can be found everywhere all over the world. Nowadays, in Malaysia also, building with atriums can be found everywhere, especially in Kuala Lumpur [2]. Previous studies indicated that an atrium building is a unique construction feature that differs from the conventional slab-by-slab [3]. Other researchers also state that an atrium becomes a unique building form with a wide range of design possibilities [4].

An atrium built of glass panes might bring natural light, which is thought to produce a more pleasant inside environment than artificial lighting. Furthermore, by incorporating daylight into electrical lighting, energy usage may decrease drastically, particularly in office buildings. However, solar heat intake through the large glass surface would be enhanced at the same time. Therefore, the cooling load must be increased to avoid overheating [3]. But at the same time, energy also needs to be saved.

Additionally, the effectiveness of the air conditioning system is critical since it influences overall energy usage in shopping malls. Therefore, a poor energy-efficient cooling system would consume more power than it should, resulting in more severe electricity prices, increased greenhouse gas emissions to the environment, and more disbenefits. Therefore, this study aims to calculate and compare the total cooling load of the building using E20 Spreadsheet and HAP Software.

This project has limitations where the study focused on Batu Pahat, Johor. Therefore, the observation was conducted using specific design criteria that apply to all air-conditioning and mechanically ventilated areas. The design criteria for the maximum outside design conditions are 33.0°C DB and 27°C WB.

2. Materials and Method

The materials and methods section describes all the necessary information required to obtain the study results.

2.1 Building Profile Area

In this study, the atrium shopping mall building is located in Batu Pahat, Johor. This building has four-level and 44 shop lots that need to be conditioned. Therefore, the atrium shopping mall building shown in figure 1 is chosen for this project. The shopping mall consists of an attached atrium in front of the building. A shopping mall is a place that people like to visit. Therefore, the shopping mall needs to be comfortable for visitors. Only the zones that are highlighted in red are the atrium glass. The ground floor of the shopping mall consists of 17 shops. Next, the first floor also consists of 17 lot of shops. In addition, the second floor consists of 5 lots of offices. Lastly, the last floor has the canteen floor with a food court, kitchen, conference room and one lot of meeting room. They represent the cardinal directions. N, E, S, and W are north, east, south, and west, respectively.

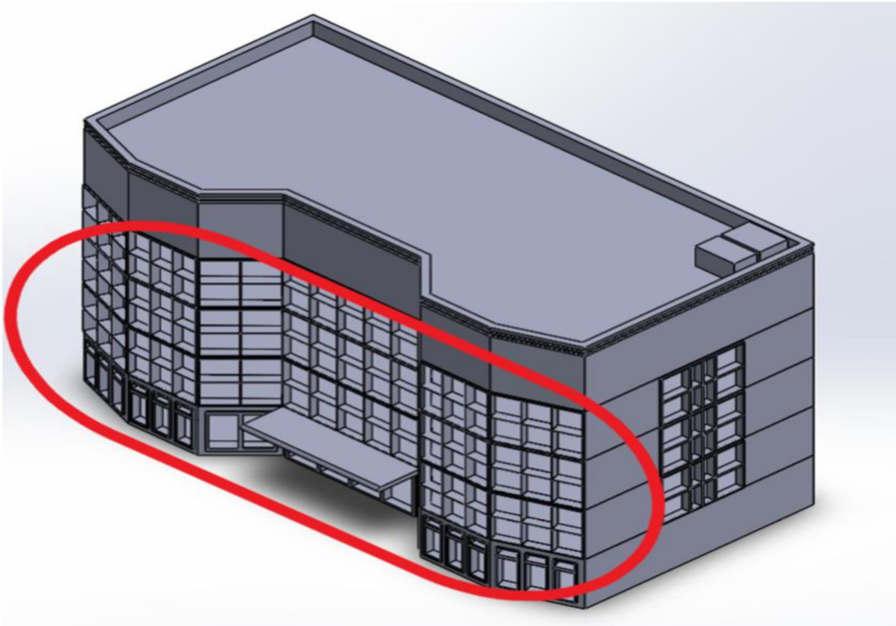


Figure 1: Shopping Mall Building

2.2 Cooling Load Calculation Method

2.2.1 E20 Spreadsheet

The cooling load temperature difference (CLTD) approach determines the sensible cooling load based on the TFM. The CLTD needed the result divided by the sensible heat gain. Cooling load calculations using the CLTD approach may be done automatically or manually for a check or preliminary estimate. The CLTD technique is a part of the TFM family of methods. The CLTD approach uses the CLTD to compute the sensible cooling load for the outside walls and roofing. A solar cooling load (SCL) component was recently included, which measures the product of the solar heat gain at that hour and the proportion of heat storage effect owing to different types of room structure and floor coverings [5]. When it comes to manual cooling load calculation, the most applied method is the CLTD/SCL/CLF method [6]. The following equation (2.1-2.4) calculates the space cooling load due to heat gained [7].

- Space cooling load due to heat gain through exterior walls, roofs, and conductive gain through the glass of atrium building shopping malls can be calculated using the equation below.

$$Q = U \times A \times CLTD_C \qquad (2.1)$$

- Space cooling load due to solar heat gain through windows can be calculated using the equation below.

$$Q = A \times SCL \times SC \qquad (2.2)$$

- Space cooling load for partitions, floors, and ceilings of the atrium building will be calculated using the equation below.

$$Q = U \times A \times TD \qquad (2.3)$$

- Space cooling load due to heat gain from people can be calculated using the equation below.

$$Q_s = q_s \times n \times CLF \qquad (2.4)$$

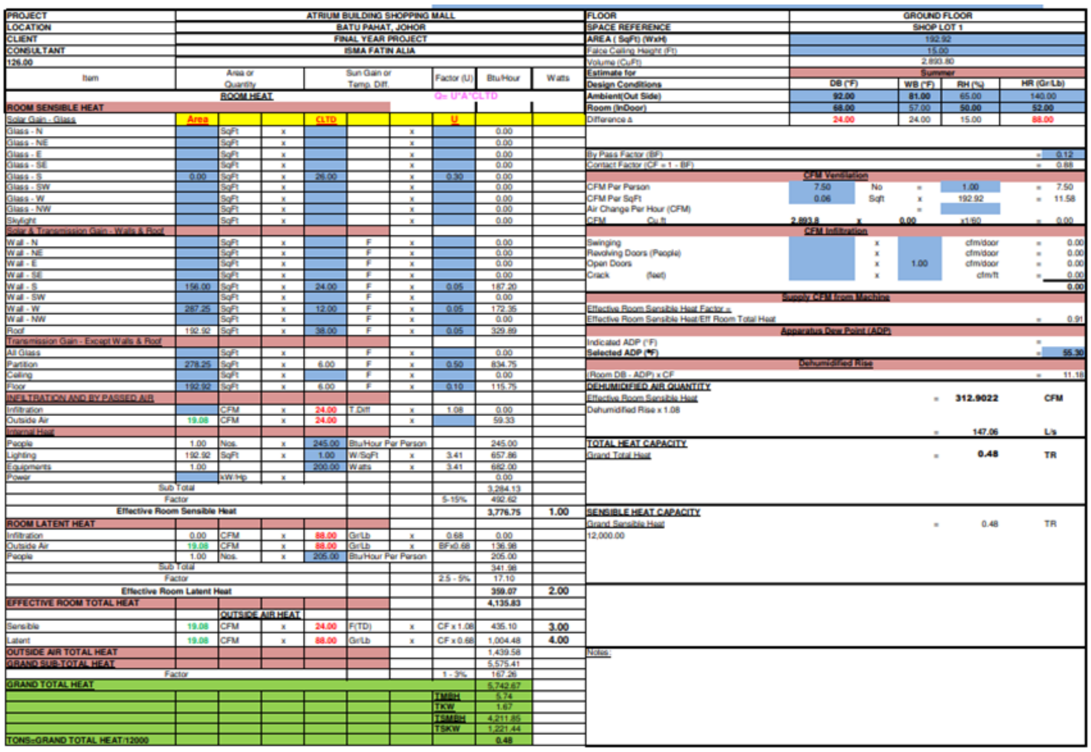


Figure 2: E20 Spreadsheet

2.2.2 HAP Software

The Hourly Analysis Program (HAP) is a computer application developed by Carrier, a firm that provides air conditioning, heating, and refrigeration solutions. This software aims to help engineers design HVAC systems for commercial buildings. It offers two tools: load estimation and system design, as well as simulation of energy consumption and cost computation [6]. The hourly Analysis Program at Carrier HAP is intended for use by practicing engineers to aid in the efficient day-to-day task of predicting loads, developing systems, and assessing energy performance. Therefore, the design of the graphical user interface and the reporting functions have received special consideration. Output reports, both tabular and graphical, give a summary and comprehensive information regarding the performance of the building, system, and equipment [8]. HAP can calculate design cooling and heating loads for spaces, zones, and coils. It also can calculate the needed airflow rates for areas, zones, and the entire system. Then it can determine the size of cooling and heating coils, the size of air circulation fans, and the size of chillers and boilers.

3. Results and Discussion

3.1 Calculation of HAP Analysis

HAP programs window only contains Johor Baharu. This study selects Johor Baharu because its weather properties are the same as Batu Pahat, that can be changed according to the specific design conditions like design temperature, relative humidity and location as shown in figure 3. The program can indicate specific space conditions like roof, people, internal and external walls as shown in figure 4. Internal load is defined as the loads of overhead lighting, task lighting, equipment, people, miscellaneous and schedule for each one to as shown in figure 5. The number of the occupants remain the same for shop lot but it is different for office lot and canteen area. External walls area is defined as number of windows, doors on walls and their component as shown in figure 6. Moreover, the roof component design and calculation are according to specific design or entire design as shown in figure 7. Lastly, the calculation of cooling load using HAP is shown in figure 8.

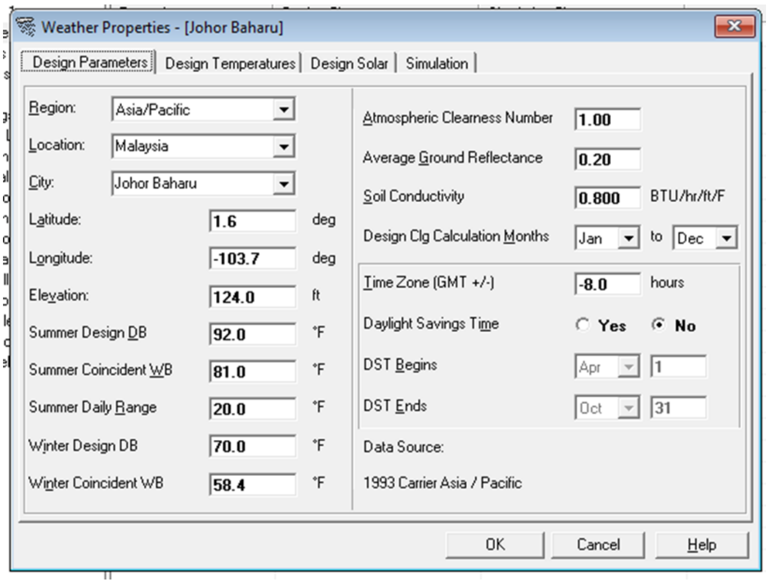


Figure 3: Input weather data for the location of the building

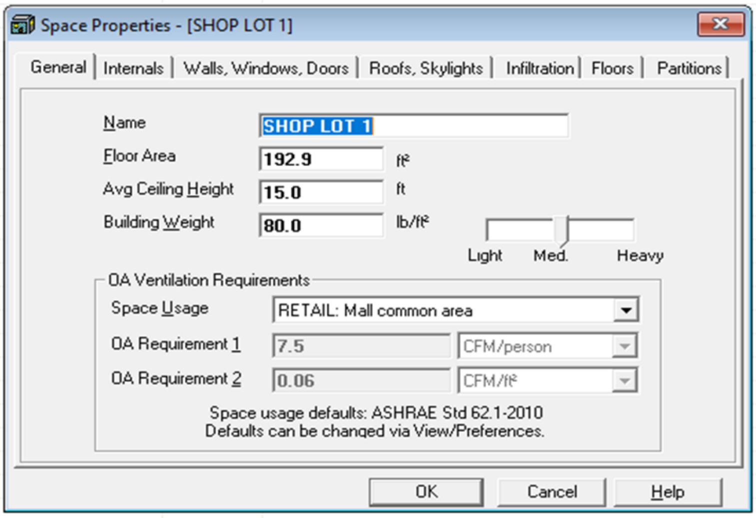


Figure 4: Input space data

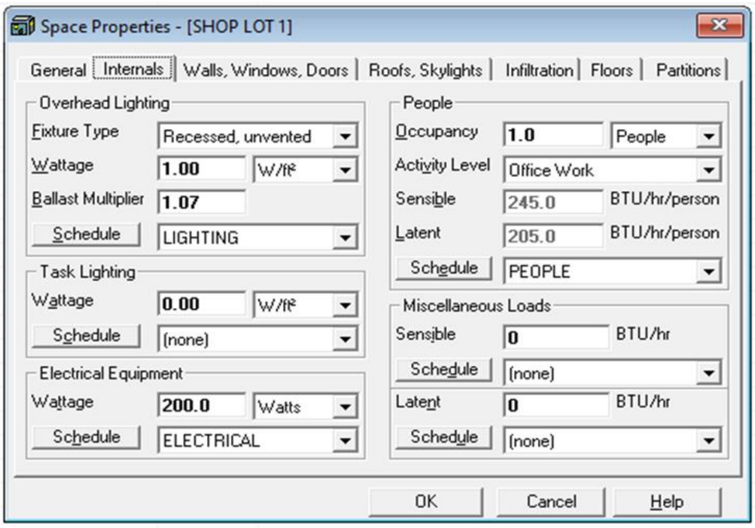


Figure 5: Input internal load

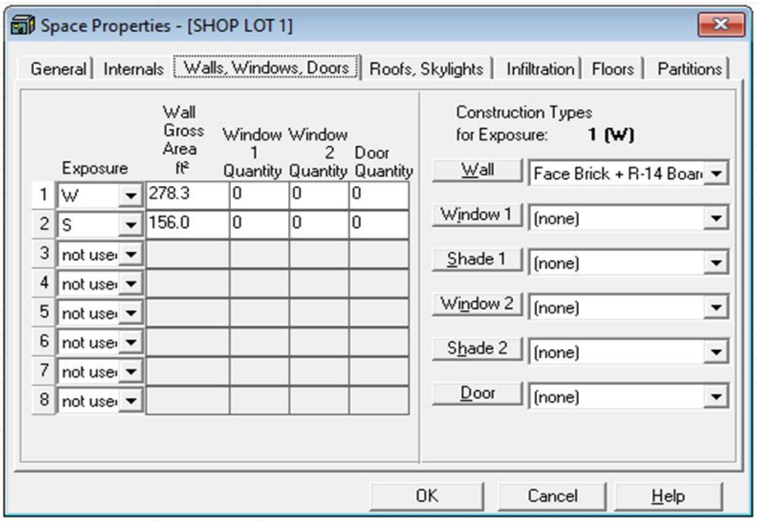


Figure 6: Input properties of walls, windows and doors

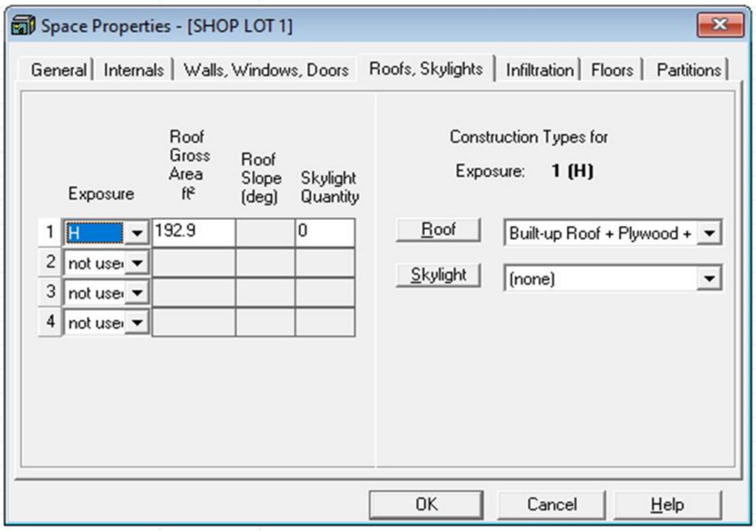
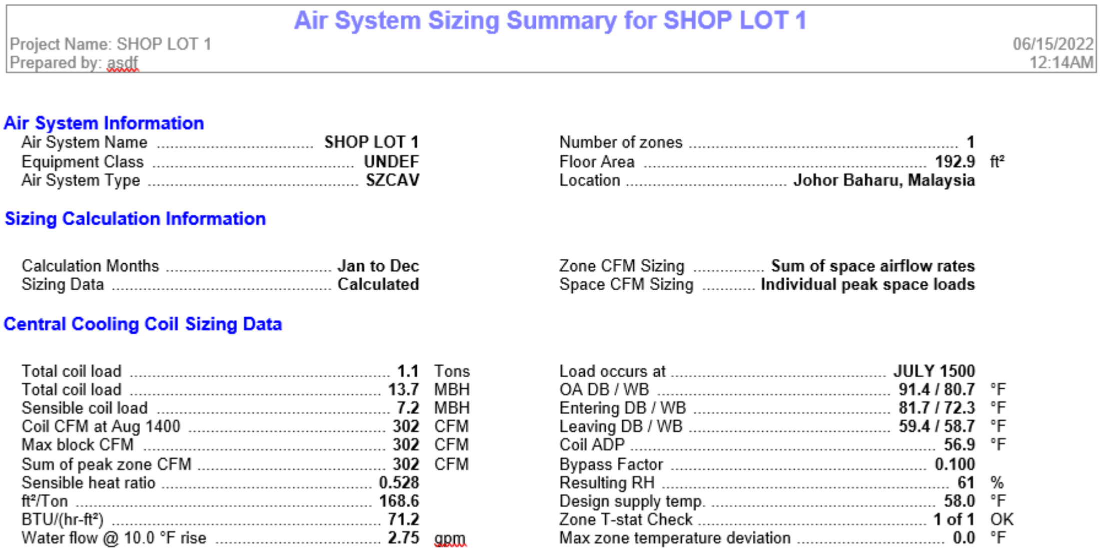


Figure 7: Input of roof properties



Air System Sizing Summary for SHOP LOT 1

Project Name: SHOP LOT 1 06/15/2022
Prepared by: asdf 12:14AM

Air System Information

Air System Name	SHOP LOT 1	Number of zones	1
Equipment Class	UNDEF	Floor Area	192.9 ft²
Air System Type	SZCAV	Location	Johor Baharu, Malaysia

Sizing Calculation Information

Calculation Months	Jan to Dec	Zone CFM Sizing	Sum of space airflow rates
Sizing Data	Calculated	Space CFM Sizing	Individual peak space loads

Central Cooling Coil Sizing Data

Total coil load	1.1	Tons	Load occurs at	JULY 1500	
Total coil load	13.7	MBH	OA DB / WB	91.4 / 80.7	°F
Sensible coil load	7.2	MBH	Entering DB / WB	81.7 / 72.3	°F
Coil CFM at Aug 1400	302	CFM	Leaving DB / WB	59.4 / 58.7	°F
Max block CFM	302	CFM	Coil ADP	56.9	°F
Sum of peak zone CFM	302	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.528		Resulting RH	61	%
ft²/Ton	168.6		Design supply temp.	58.0	°F
BTU/(hr-ft²)	71.2		Zone T-stat Check	1 of 1	OK
Water flow @ 10.0 °F rise	2.75	gpm	Max zone temperature deviation	0.0	°F

Figure 8: Cooling Load by HAP

3.2 Comparison of Cooling Load Calculation

Table 1 shows data about a summary of cooling load estimation of the shopping mall building using manual calculation and HAP Software without glass. Table 2 gives an overview of the cooling load estimation of shopping mall buildings using two different methods with glass. Comparing the two methods, the shopping mall that uses glass for the south orientation and the mall building with all walls will also be compared. Thus, the total cooling load for using glass is much higher than using all walls. It is because having more glass will lead to more solar radiation. The result between manual and HAP calculation is slightly different. The cooling load (without glass) using the E20 manual was 86.9, higher than the HAP software. It was 73.3 TR when using HAP software. The difference between E20 and HAP results was 7.8%. The total cooling load (with glass) was 87.7 TR using the E20 manual method and 73.6 TR using HAP Software. The difference between E20 and HAP Software is identical to the previous one. According to [6], the researcher state that the difference between of two calculation was 8.8%, where the values are approximate.

Table 1: Total Cooling Load for All Floors (without glass)

Floor Area	Cooling Load Calculation using E20 (TR)	Cooling Load Calculation using HAP (TR)	Percentage Different
Ground Floor	22.3	18.7	1.9%
First Floor	23.6	19.9	1.9%
Office Floor	13.6	11	2.4%
Canteen Floor	27.4	23.7	1.6%
Total	86.9	73.3	7.8%

Table 2: Total Cooling Load for All Floors (with glass)

Floor Area	Cooling Load Calculation using E20 (TR)	Cooling Load Calculation using HAP (TR)	Percentage Different
Ground Floor	22.5	18.9	1.9%
First Floor	23.8	19.8	2.0%
Office Floor	13.7	11.1	2.3%
Canteen Floor	27.7	23.8	1.6%
Total	87.7	73.6	7.8%

4. Conclusion

This study calculated the cooling load using the atrium retail mall building in Batu Pahat, Johor. This study has achieved its objectives after the end of the investigation. It compares cooling load calculation methods utilizing E20 Spreadsheet (manual calculation) and HAP Software by the ASHRAE-55 Standard. Both approaches frequently use cooling load estimation calculations but provide significantly different results. The primary findings that can be made from the current study are that the overall cooling load for the shopping mall building without glass and with glass by hand is 86.9 TR and 87.7 TR, respectively, whereas required 73.3 TR and 73.6 TR based on HAP software. The difference between the two types of buildings, the total cooling load is slightly different. The shopping complex with glass will attract the public attention even though the glass cost is higher. The HAP program may calculate the load for any building design. The difference in cooling load between the two approaches was caused by the fact that the values were randomly entered into the HAP program. While using the E20 manual approach, the values taken from the ASHRAE Handbook were accurate for the area. HAP values were approximations. Exact values were obtained after manual computation. As a result, HAP may have fewer tones of refrigeration (TR). Overall, the E20 and HAP software outputs were within an acceptable range of the cooling load needed for a commercial center.

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References

[1] Chua, K. J., Chou, S. K., Yang, W. M., & Yan, J. (2013). Achieving better energy-efficient air conditioning - A review of technologies and strategies. In Applied Energy (Vol. 104, pp. 87–104).

[2] Yunus, J., Ahmad, S. S., & Zain-Ahmed, A. (2010). Analysis of atrium's architectural aspects in office buildings under tropical sky conditions. CSSR 2010 - 2010 International Conference on Science and Social Research, 536–541.

[3] Hung, W. Y. (2003). Architectural Aspects Of Atrium. In International Journal on Engineering Performance-Based Fire Codes (Vol. 5, Issue 4).

[4] Ibrahim, N. (2001). Atrium is required in shopping complex / Norsuriany Ibrahim.

[5] AlHarbi, F., AlRomaih, A., AlHudaithi, S., AlHusayyani, A., AlQadhi, T., Alsagri, A. S., Alateyah, A. R., & Basha, S. S. (2019). Comparison of cooling load calculations by E20 and HAP software. Universal Journal of Mechanical Engineering, 7(5), 285–298.

[6] Bhatia, A. (2001). Cooling Load Calculations and Principles Credit: 6 PDH.

[7] Shan K. Wang,(2001) "Handbook of Air Conditioning and Refrigeration", second edition.

[8] Comparison between Hand Calculation and HAP programs for estimating total cooling load for Buildings. (2016). ZANCO Journal of Pure and Applied Sciences, 28(4).