ARIV
International Journal of Technology
Paper ID: AIJT12012020 Vol1 Issue 2 2020

An Investigation of Passive Cooling in a Building in Malaysia

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Abstract

In hot humid countries like Malaysia, a comfortably thermal environment is what people look for. To achieve such conditions, a technique called passive cooling must be the optimal choice. Many other techniques have been investigated over the years and those have been rendered almost inefficient and ineffective. Looking into passive cooling, Natural ventilation is said to be the most effective strategy in such climatic conditions. This research is based on a Four-Story office building, designed in Malaysia, meant to achieve a thermal comfort environment using Passive Cooling techniques. It was studied thoroughly, researched, in a manner that all the information regarding the methods of how to implement a passive cooling environment such as thermal comfort, climate, ventilation and insulation, etc. were explored. Later the results were calculated and analyzed by a process named convection heat transfer rates from a human body and other machined equipment. Nevertheless, the theory and calculations were made for a clear understanding.

Keywords: Natural Ventilation, Thermal Mass, Green Roof, Passive cooling, climate, insulation.

Introduction

Passive cooling is a technique that tends to use the natural ambiance of the atmosphere exclusive of the use of electricity or electrical components for maintaining a serene, healthy and comfortable indoor environment. Of the several reasons behind the recent fame of passive cooling techniques, one is the little cost of energy usage and the other is the "eco" friendliness. According to Kubota et al., (2010), Zain-Ahmed et al., (2009), and Builditsolar (2015) a small implication of one of the many passive cooling techniques can help save a lot of energy, for example, during the daytime, the use of light bulbs and tube lights for luminosity can be avoided by using windows and transparent sections of the roofs for the lightening purposes. In a similar fashion, certain available techniques can be used to maintain a pleasant and comforting temperature with little or no use of electricity.

Chan et al., (2010), Geiger (2012) and Amos-Abanyie (2013) stated that since Malaysia is located at the equator, it experiences mostly hot but humid climate throughout the year where the temperature ranges from 22°C to 34 °C with a humidity range of 70 - 90 % (General Climate of Malaysia 2011). This relatively high temperature and excessive humidity is the due reason for the residents of Malaysia to use Air-Conditioning systems for the maintenance of thermal comfort. This research will have a four-story commercial building designed for analyzing different passive cooling techniques. The location, upon research, was chosen to be Kuching as it is a highly populated city and a commercial building will fit in precisely. According to Google Books (2015) and Breesch and Janssens (2005), the overall climate of this city is further discussed below. The goal of the study is to make sure that this office building can maintain and achieve indoor thermal comfort solely based on passive cooling. To ascertain the results, a thorough research on the climatic conditions, the heat transfer rates, sizing up of the buildings and suitable materials was done.

Active vs. Passive Cooling

Theodosiou (2003) stated that active houses or buildings relatively differ in certain ways from passive housing, as they require energy sources to run the active elements, such as furnaces for heating and air conditioners for cooling. This type of housing is inclined towards quality living, providing a cleaner, healthier, and safer environment and have very little negative or zero impact on the climate and the habitat. In cases like these, a further improvement would be in the shape of solar panels to make the best of the available solar luminosity and later convert into electrical energy to maximize the power demands. Further improvements can be made by using solar thermal techniques, energy-saving gadgets, and sophisticated automated controls to improve the air quality inside a building and to control the blinds and exterior awnings for shading purposes.

On the contrary, Chowdhury et al., (2018), Tay et al., (2017) and Ahmed et al., (2017) stated that passive housing techniques are more inclined towards saving energy and reduce the overall emissions of greenhouse gases. These techniques make use of natural sources, solar and wind in particular. These strategies are improvised versions of the techniques used centuries ago.

Comparison

It is not easy to pick one of the two, on paper; Passive has far more advantages than active techniques. The focus of both the techniques is clearly in a different direction, as active housing focuses on the luxuries of life whereas the passive techniques have singular focus i.e. energy efficiency. According to Kashem et al., (2018), Touti et al., (2020) and Ahmed et al., (2019) the flip side of course is that a Passive House could be built much more economically than an Active House. The need for expensive cutting-edge technology in an Active House makes it far too expensive for most homeowners.

Khandakar et al., (2019), Kashem et al., (2017) and Kho et al., (2017) stated that active systems have relatively higher installation and maintenance costs, assuring high performances when properly operated. The maintenance and operation cause a lot of stress as the number of moving components is larger than that for a passive technique, not taking away the high sustainability factors from both the systems. Figure 1 (Kubota et al., (2010)) below gives an insight into both the systems.

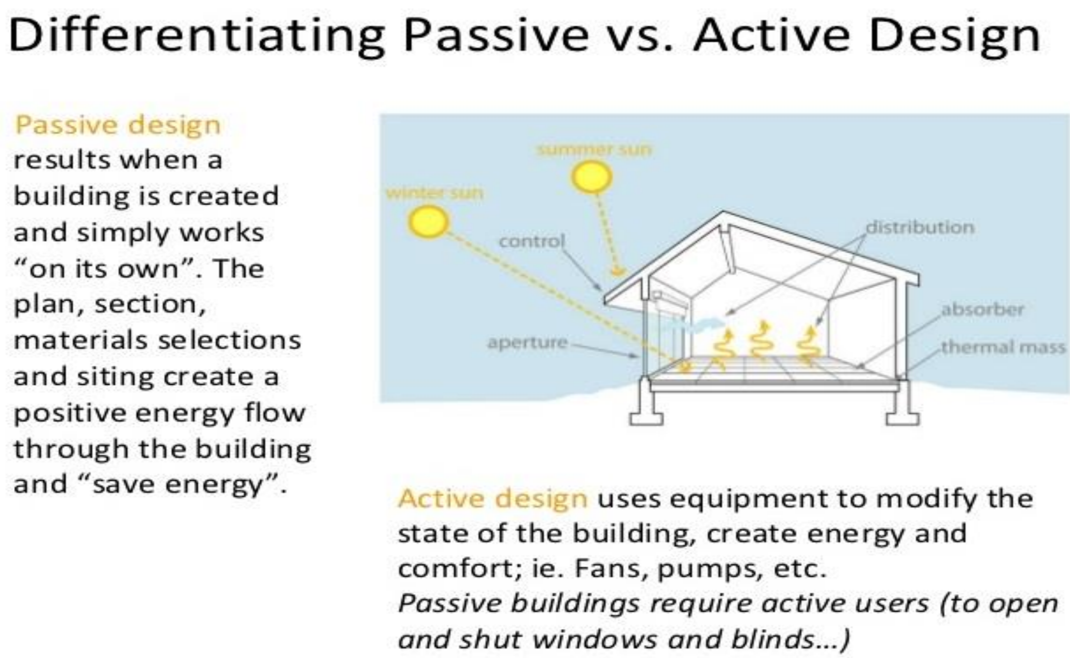

Figure 1 - Comparison Chart

Overview of the Climate in Malaysia

Malaysia is situated in South-east Asia and thus benefits from a tropical climate as it experiences a uniform temperature and consistent humidity throughout the year. During the daylight hours, the temperature rises above 32°C and falls below 20°C. Chowdhury et al., (2019), Hong et al., (2018) and Kashem et al., (2016) the only factor that makes the whole climate of Malaysia so different from other South-Asian countries is the amount of rainfall; hence the temperature or the air pressure does not play a very strong role in maintaining a consistent climate. Rainfall period usually lasts 4 months, starting from December to Match whereas the dry period lasts from June to September. The highest precipitation can be observed in the Northern and Western regions of Malaysia. Plus, the wind speed ranges from 3-7 km/h throughout the year and humidity reaches the 70% mark. Such persistence led us to choose Kuching as the location of our research (Green Building Index (2015). Table 1 shows the annual climate of Kuching and table 2 shows the global positioning and solar noon of the five cities of Malaysia (Kubota et al., (2010) and Renovation Malaysia HQ (2015)).

Table 1 - Annual Climate Stats of Kuching

Month	Mean Max. Daily Temp. (C)	Mean Min. Daily Temp.(C)	Relative Humidity	Precipitation	Rainy Days per Month	Mean Wind Speed(m/s)
Jan	28.7	23.5	88	690	26	3.98
Feb	28.7	23.7	87	429	21	3.61
Mar	28.9	24.0	88	339	21	2.84
Apr	29.3	24.1	86	288	22	2.46
May	30.3	24.0	85	267	21	2.97
Jun	31.7	24.2	84	250	19	4.23
Jul	30.6	23.8	84	195	17	4.32
Aug	31.4	23.4	83	259	18	4.85
Sep	30.4	23.7	86	242	20	3.91
Oct	30.3	23.7	86	324	24	3.63
Nov	29.3	23.3	87	330	24	3.63

Table 1 - Global Positioning and Solar Noon

Locations	Latitude(°N)	Longitude(°E)	Solar Noon
Kuala Lumpur	3.12	101.55	13:11
Penang	5.30	100.27	13:16
Johar Baru	1.48	103.73	13:02
Kota Baru	6.17	102.28	13:08
Kuching	1.48	110.33	12:36

Literature Review

The following sections will include the literature review.

First Law of Thermodynamics

Heat energy is the source of all the other forms of energy, which can go through the process of conversion. Three different mechanisms are present for the transference of the heat, which are as follows,

1) Conduction

2) Convection

3) Radiation

Conduction

According to Siddique et al., (2017) and Mubarak et al., (2016), it is a process where heat energy is transferred through neighbouring molecules of material via collisions. In other words, it can be said that it is the transfer of energy from the higher energy particles to the less energetic ones as a result of interactions between the particles. U values of the equipment used in an office building will represent the heat conduction in the building, and correspondingly, the inverse of the U-Value will give the resistivity of the equipment, more commonly known as the R-Value. These values are later compared to the value of conductivity, K-value to measure the heat transfer rate.

Convection

Chowdhury et al., (2019), Tabassum et al., (2016) and Shabrin et al., (2017) stated that convection, on the other hand, is the transference of heat through gases and liquids. It is also said that it is a combined process of conduction and advection (heat transfer through bulk fluid flow (Wiki)). The process is directly proportional to the speed of the motion of the particles, faster the motion, greater the convectional heat transfer. Hence, in the design of this particular office building higher wind speed should be attained.

Radiation

According to Kashem et al., (2020), and Nabipour-Afrouzi et al., (2018), it is the energy that comes that travels through material and space and comes from a source of electromagnetic nature, for that purpose no intervening medium is required. For the buildings such as our design, radiation is important to consider as hot objects might radiate to cooler objects.

Energy Consumption of Commercial Buildings

The energy requirement as we approach the future is expanding exponentially. Currently, most consumptions in Malaysia are consumed by industrial, commercial, and residential sectors. The commercial is found to be weighing 32%, the most prominent portion in figure 2 (Kubota et al., (2010)). With the consumption of energy rising in Malaysia, the need to have these energy-efficient buildings has started to push the government in making many. The cost that results in building these passive design buildings is comparatively high with respect to the other conventional buildings, but the low operative cost offsets this effect (Safe et al., (2014), and Shaila et al., (2018),). It is of major importance knowing the desire of the country's need to build energy-efficient buildings in order to safeguard future concerns.

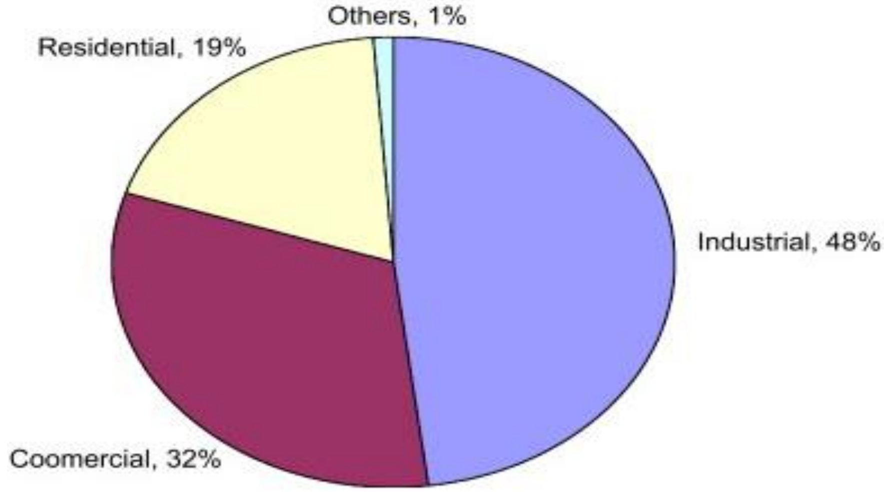

Figure 2 statistics of energy usage in Malaysia

Energy consumption is about 70-300kWh/m2 per annum that is 20-30 times than that of the residential buildings. They are also stressing on the use of renewable energy resources according to the 9th Malaysian plan. Figure 3 shows the trend of energy consumption in Malaysia from 2003 to 2006 (Kubota et al., (2010)). According to Sheikh et al., (2017), and Kashem et al., (2018), Office buildings consume about 21% of a country's total commercial use and it is assumed that almost 6090GWh is the total estimated energy used by office buildings in Malaysia.

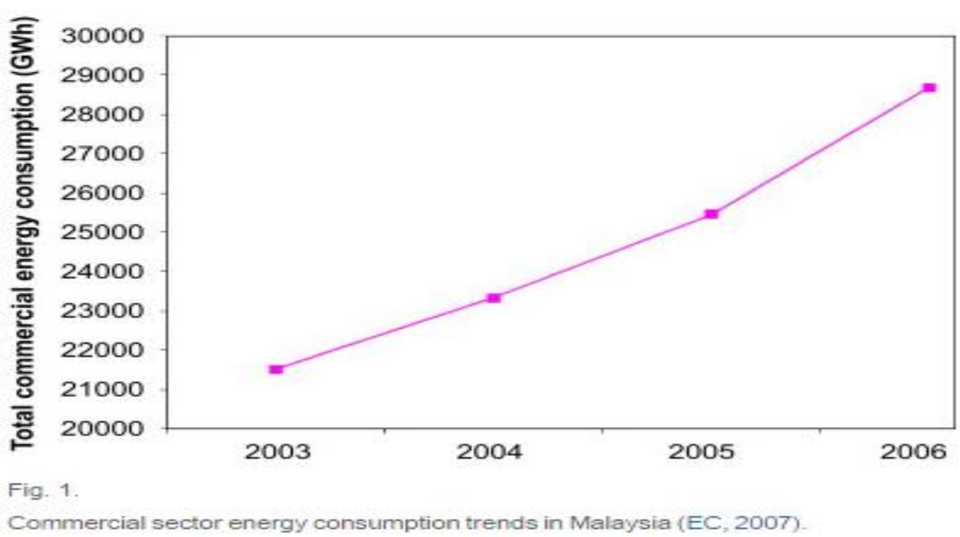

Figure 3 the trend of energy consumption

Methodology

This section is about the research pattern and methods of finding results. This section includes the explanation of the different types of techniques that can be used for passive comfort. A four-story office building was designed and then the results were used to justify our ideas. Rates of convection and other emissions were analyzed and results were deducted. In the later part of the study, Solid Works has been used to design a 4-story commercial building, and simulations were run to determine the energy usage of passive cooling techniques. For this purpose, software like ANSYS and CFD were used. Further tests were run to solidify our ideas of passive cooling techniques, which are included in the report.

Design Parameters

Conceptual Design

The climatic conditions of Malaysia are best suited for maintaining thermal comfort using passive cooling strategies. For example, the airspeed is optimum for using the natural ventilation technique, which is not only completely sustainable but also cost-effective.

Location & Climate

The location chose is Kuching, Malaysia. This location is suitable as the population is not so much and there is ample space to carry for such experiments. The hot and humid climate of Kuching and the temperature as well, with not many major changes throughout the year, make it a feasible location for our research.

Layout and Orientation

The rectangular shape is given to our design of the building with four floors, each sizing 20mx15m. Additional 2m solar shades will be added later not only for shading but also for the generation of solar electricity. For the larger side of the building, three windows will be placed on every floor with dimensions 6mx3m.

A separate room at the North-East corner of each floor. The purpose of the room can be defined later. The size of the room will be 4mx3m and it is placed at the corner for a swift flow wind around the building. Cubicles will be installed at the center of the floors along with a few walkways. Staircase and lifts are also placed at one end of the room.

Since the maximum exposure to the wind flow is at the west side that is why the longer side (20m) will be placed at that end. The front side of the building will be placed facing south. The height of the building will be 16m that is about 12ft per floor.

Building Design

A preliminary building model has been designed by using AutoCAD software to show the external and internal look of the building. A series of pictures are given in figure 4 for better illustration.

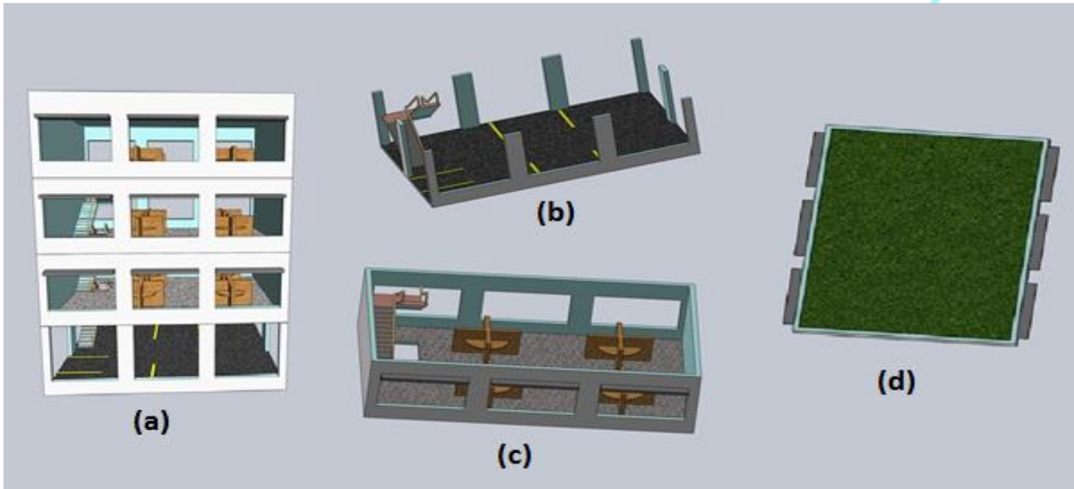

Figure 4 - Building Design. a) 4-Storey Building, (b) Parking Lot, (c) First Floor (d) Green Roof

Passive Cooling Techniques

In the research, natural Ventilation, thermal mass, insulation, and green roofing techniques would be analyzed.

Thermal Mass

One of the most crucial ingredients for the passive cooling strategies is Thermal Mass of the walls and the roofs. It often optimizes the performances of energy-conserving buildings which mostly depend on either mechanical heating or cooling strategies. For thermal mass to be at its most proficient, the material used for the construction must have a certain feature such as high heat capacity, moderate conductance, high emissivity, and moderate density.

The easiest of all the materials to access is concrete and it is indeed the best for providing thermal mass for passive cooling in commercial buildings. On top of that, it stabilizes the structure of the building along with its view. The same thermal mass is characteristically provided by the floor slab itself. These slabs have a heat sinking ability where they will absorb the internal heat emissions by the equipment used in the building, for example, photocopiers and lightings. In comparison to other concrete structures, the change in surrounding temperature is reacted gradually which serves to have preserve inward conditions amid a hot and humid atmosphere. This is then dealt with the assistance of exposed concrete which has the low radiant temperature.

To have a passive cooling in an office, peak temperatures should be reduced and in order to decrease the temperature by absorbing internal heat gains, thermal mass also delays its onset by up to six hours. An effective way, because during the afternoon's temperature is really hot and late in the evening when workers or occupants leave, the thermodynamic cycle reverses with a minimum solar gain as no heat is being generated by machines and occupants or lightning. As the evening progresses, the drop in external and internal temperature makes the ventilation more feasible removing the accumulated heat, and hence the cycle will continue the following day.

Windows & Shading

Certain products are best suitable for Louvre windows which are not only innovative but also energy efficient and sustainable. Their effectiveness is higher has the open twice as wide as a regular window and capture more wind or breeze. To make the most of the high wind velocity, windows are installed adjacently on the east and west side of the building. The double glazed Louvre window is the most effective window which can emit the emissions of the heat gains efficiently.

Double glazed windows have two panes of glass and have an inert gas, mostly argon, between them, which acts effectively as an insulator. Argon gas has certain qualities such as its highly dense and conserves energy. The heat emissions from the sunlight are significantly less during the peak hours of sunlight and it also possesses good insulation against noise. Hence, a double glazed louver window will provide the best ventilation system.

Insulation & Green Roof

The designed will two different kinds of insulation namely:

1) Wall Insulation

2) Roof Insulation

Wall insulation mainly resists the amount of heat conduction and convection. It can be achieved using different kinds of materials for example glass wool. Other wall insulation can include high emissive and reflective material for better insulation of walls. The most commonly used material for reflective insulation is shiny Aluminum. The building should be avoided by reaching an extreme temperature inside the building. Light-colored painted walls is also another way of providing insulation and less heat absorbance inside the building due to their ability to reflect solar irradiance.

Roof insulation is done by providing Green Roof to the building. It provides sustainability and reduces the emission of pollutants and other GHG's which makes it eco-friendly. The green roof is covered by extensive grass and small plants, keeping the roof clean by using the sunlight to their own benefit – photosynthesis. With regard to the Malaysian climate, it is just not about solar irradiance but also the annual rainfall which occurs almost 3 weeks in a month. In such conditions, the green roof works more ideally making it more suited towards the environment. Like other green roofs, the soil depth is kept 6m and the plants' maximum height is contained at 2-3ft. While selecting the type of plants, it is very important to select the native plants since it will be supported by the ecology of the local region. A typical arrangement on a green roof is shown in the diagram below.

Natural Ventilation

Since both these sides of the building are unguarded with huge windows, either way, air can stream. The other sides will be used as passageways for exits and entrances. Likewise, windows will be put on these two sides; however, they will not be as efficient as the other two sides. During the time of heat traps, these smaller windows will help maintain the wind stream inside the building. Below figure 5 shows the simulative work on the project regarding natural ventilation. The floor has been kept vacant and you can see the uniform streamlines going from one side of the building to the other. The velocity pattern during natural ventilation will differ in any heat source that is implemented inside the system. Disturbance inside the velocity profile is justified as you will see in the result part.

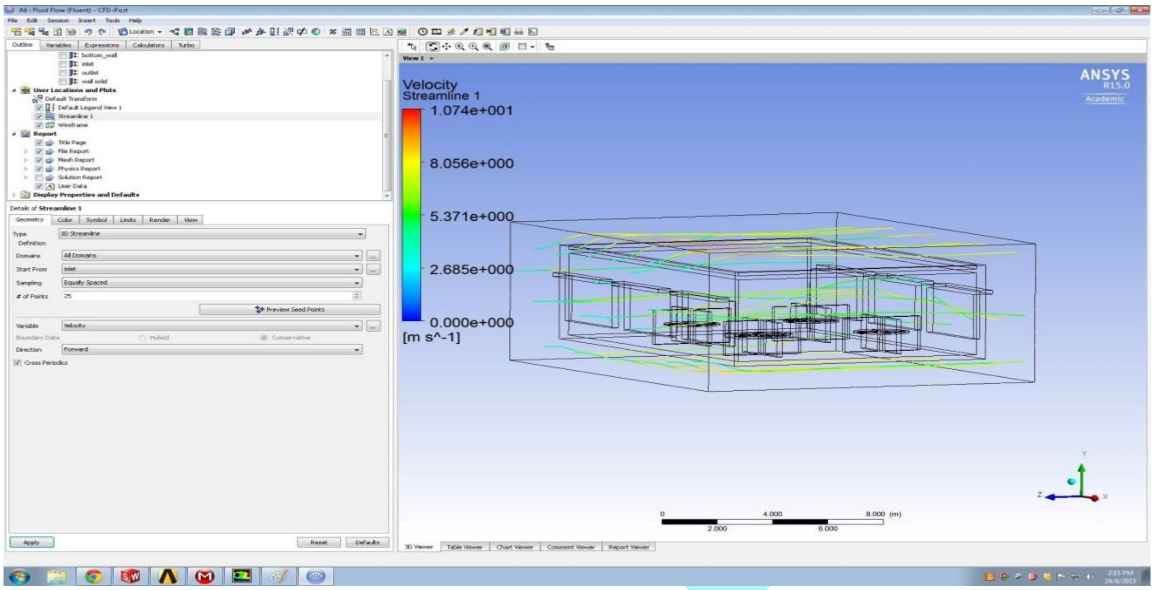

Figure 5 - Natural Ventilation ANSYS

Energy Analysis

The equation to find out the comfort temperature T_c,

$T_c = 0.31\ (T_{mean}) + 17.8$ **(1)**

Where T_{mean} is the mean monthly outside temperature. Mean temperature can be calculated by taking the average of the maximum and minimum temperature. Heat loss Q by the human body and mechanical equipment can be found by

$Q = h \times As \times (Ts - T\infty)$ **(2)**

Where, h is the heat transfer coefficient (W/m2*°C), as represents the surface area of the cylinder (m2), Ts is the surface temperature of the cylinder (°C), T∞ represents the ambient air temperature (°C). The surface area for a cylinder is given as

$As = \pi \times D \times L$ **(3)**

D: Diameter of cylinder (m)

L = Length of cylinder (m)

For a human body, it has been measured that, that diameter is 0.4m and length is 1.65m. The surface temperature of human skin is assumed to be 34 degree Celsius.

The heat transfer coefficient can be calculated from the equation given below

$$Nu = \frac{(h * D)}{k}$$

$$\mathbf{Nu_{cyl}} = \frac{(h*D)}{k} = 0.3 + \left[\frac{\left(0.62 * Re^{\frac{1}{2}} * Pr^{\frac{1}{3}}\right)}{\left\{1 + \left(\frac{0.4}{Pr}\right)^{\frac{2}{3}}\right\}^{\frac{1}{4}}} \times \left\{1 + \left(\frac{Re}{282000}\right)^{\frac{5}{8}}\right\}^{\frac{4}{5}} \right] \quad \mathbf{(4)}$$

Re: Reynold number

Pr: Pandlt number

Reynolds number can be calculated by using the given formula.

$$\boldsymbol{Re} = \frac{(V_{\infty} * D)}{\nu} \quad \mathbf{(5)}$$

The above steps will be followed again to determine the heat transfer by the mechanical equipment present in the office such as the photocopier machine and laptops. In this case, the surface temperature is assumed to be 36 degree Celsius and the shape to be rectangular with a standard dimension (length=0.75m and width = 0.6m). For the laptop, the assumed length is 0.35m and width is 0.3m.

Solar Heat gain through windows $Q\ solar = Area\ of\ the\ window * Solar\ intensity * Transmissivity$ (6)

The heat taken away by the wind $Q = 0.025 * Area\ of\ the\ window * Wind\ velocity$ **(7)**

Computational Analysis

The computational results were run on simulation software is known ANSYS workbench 15.0 version. The results are not based on a whole building design due to the restriction in ANSYS of not allowing more than 512000 cells, the simulation and results are based on the third-floor analysis. The first part was followed by a vacant area and then a fully furnished model. The building model was created in Solid Works as shown previously, then saving in a different file format named IGS. After saving it in other file types, the geometry was imported in ANSYS shown by the picture.

The fluid fluent module then undergoes to Mesh analysis part, where the designed model was meshed into small elements. Fine meshing analyses were conducted for better results. Below the table summarizes the meshing analysis.

The meshing module was then ready to go for the Setup module. The outside model was edited to bricks and the fluid was set as default i.e. air. Energy Equations were switched on with no-slip conditions. In the solution method tabs numbers of iterations were defined as 300 and simulations were run to get our calculations ready. Once the calculations were done, the setup module showed a graph design for 300 iterations. The velocity factor was set to 4.5m/s, although our research suggested that average velocity in Malaysia is nearly around 4m/s but since the calculations were based on the third floor as velocity is in proportion with height. With no-slip conditions and pressure defined as zero Pa for the outlet.

The gravity and specific operating density were fixed while running simulations for both vacant and with heat-generating equipment's and occupants, and were defined as -9.81m/s2 and 1.179kg/m3 respectively. The values defined had to be the same as guided by ANSYS Customer Training Materials.

The pressure equation was set to second-order, and momentum and energy equations were set to Third-order MUSCL. They were set to high order to get as accurate and better results. For solution initialization, hybrid initiations were used for efficient and required output, which emphasize on the setup of the simulation with no additional information.

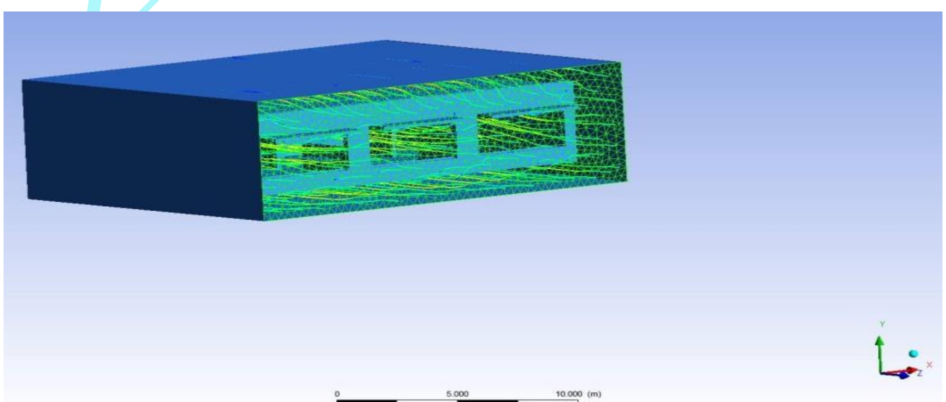

Figure 1 - Floor Definition

The following figure shows the velocity inside the floor without the enclosure and showing different patterns with no stagnation point

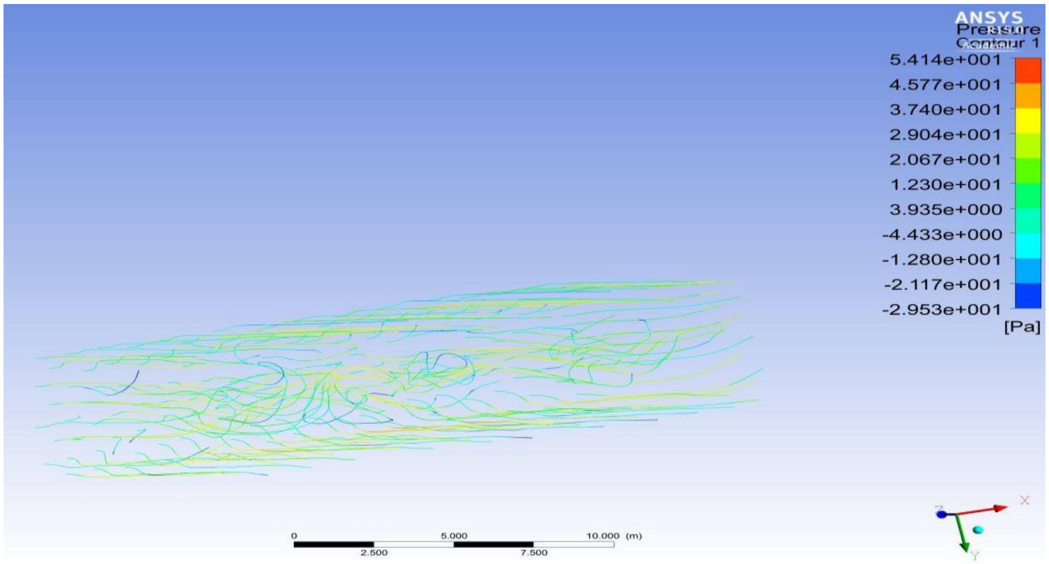

Figure 2 - Wind Dimension

During the implementation of boundary condition inside the setup sector, following properties of Air and Brick has been applied. With the brick, using our technique of thermal mass opted with a lower thermal conductivity as it suits best for passive buildings and air has general properties as listed down in table 3 below.

Table 3 Properties of Air and Brick

Properties	**Air**	**Brick**
Temperature, T (°C)	26.2	-
Density, ρ (kg/m³)	1.179	1920
Specific Heat, Cp (J/kg·K)	1007	790
Thermal Conductivity, k (W/m·K)	0.0256	0.9
Dynamic Viscosity, µ (kg/m·s)		-

With the velocity contours and streamlines, simulative results of pressure contour were also obtained. The following figure will show you the pressure generated in inlet and outlet, also shows the pressure contour distribution inside the floor.

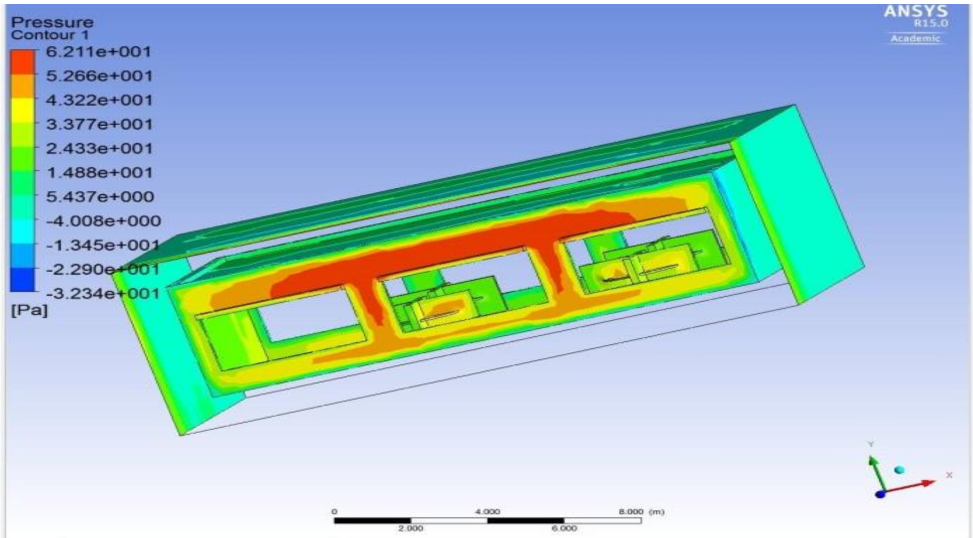

Figure 3 - Pressure Contours in the Building

During the vacant model simulation, the temperature was defined as room temperature which is 300K. As it was mentioned in the simulation, there will be no heat source inside the floor, ANSYS kept the temperature constant. The following figure shows the temperature volume rendering.

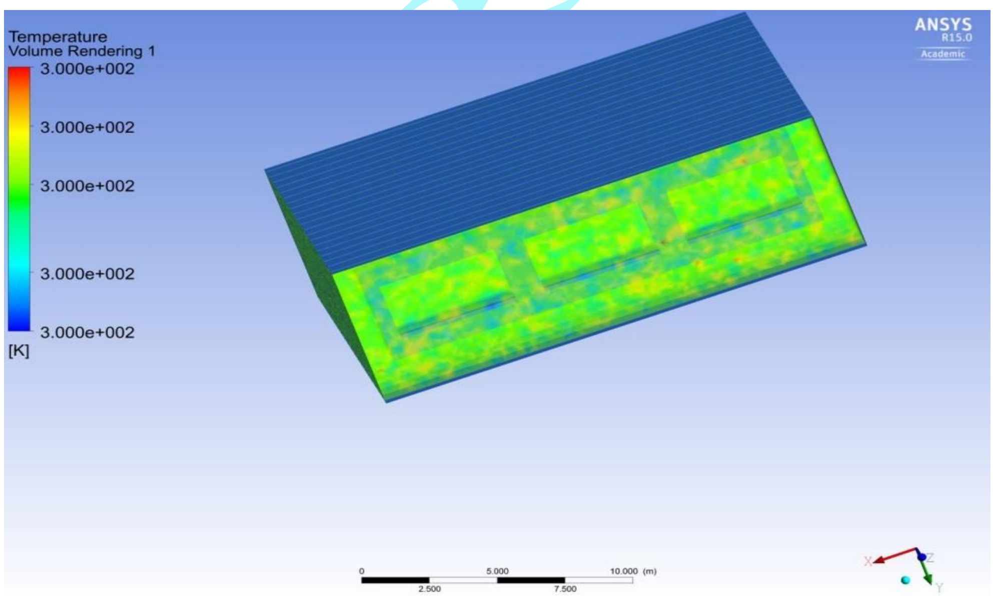

Figure 4 - Temperature Rendering

The following figure best describes the no-slip condition. It was operated the same way for the whole building design and showed zero velocity relative to the boundary. The model turned blue which guaranteed and provides a satisfying value. This means the fluid velocity at all fluid-solid boundaries is equivalent to that of the solid boundary.

Case study of a Passive design building

A case study of a Passive design building named Energy Commission Diamond Building has been illustrated in Table 3

Table 2 - Case Examples

Building name	Energy Commission Diamond Building
Building type	Low rise
Sector	Commercial
Building Size (storeys)	8 storeys
Project Description	The Diamond Building is the first building design to enhance green building features. BEI of the building is about 85kWh/m2/year. A special feature is the inverted pyramid concept, which creates extensive shading of the building. It also enhances the use of daylight. The cost-effective diamond building received GreenMark Platinum rating based on passive design and green building features.
Building Features	This building is inspired by the original form of the diamond, which form symbolizes transparency, value, and durability; characteristics that represent the Energy Commission's role and mission as a regulatory body. The diamond shape is found to be the most aerodynamic and effective form to prevent air infiltration through the advantage of a tilted facade. The Atrium has been designed to optimize daylight utilization with reflective panels and an automatic roller blind system responsive to the intensity as well as the angle of the incident sunlight. In addition to providing a high-quality indoor environment, a good outdoor environment is also provided through extensive landscaping and a sunken outdoor garden
Material used	Low VOC materials
Reference	http://www.st.gov.my/

Cost Analysis

A case example of a building in Malaysia is considered for a cost comparison with our building. Since the sample building is a 6 to 7 story building and its total cost is about RM. 55,084,000. Therefore, the total cost will be reduced to half for a 3-story building. 27,542,000. Therefore, the entire cost becomes RM 2, 92,633. This cost is an approximation for the proposed model; however, the cost might vary when this will be implemented in the real world.

Discussion & Analysis

The results for the heat gain are shown below along with the calculations for one floor.

Calculations for one floor:

Total Floor area = 15*20 = 300 square metre.

Heat Gain by a photocopier machine

Assumed a rectangular-shaped object

Area, A= L * W = 0.638 * 0.489 = 0.31m2; Velocity = 3.98 m/s; Re = 15.6 * 104

Nu= 291.36; H= 122.052 W/m2*k

Hence, Q= 355.66 W

Since there are assumed to be 2photocopier machines so Q= 2*355.66=711.32W

Heat Gain by a human body

Assumed a cylindrical shaped body

Tf= 31.35*C; Re = 9.89 * 104; Nu = 213.325; H= 14.17 W/m2*k;

Area is calculated by As = π × D × L

Area = 2.07m^2

"Qconv = h "×" As "×" (Ts – T∞)"

Therefore, Q= 150.2W

It is assumed that the number of occupants in each floor is supposedly 8 then;

Q becomes= 8*150.2= 1201.6W

Q solar = Area of the window*Solar intensity*Transmissivity

Area of the window = 18squaremetre (see the above table)

Solar intensity is found to be = 1380 (W/m2)

For double-glazed windows, with shadings and frames = 1.2 W/m².K

Hence, Q solar = 29.81 KW

The heat has taken by the wind:

Q = 0.025 x A window x Velocity wind

The velocity is = 3.98;

Q= 1.8W

Recommendations

After the outcome of our results, few recommendations have been made. The objectives stated are limited to a specific number of people as the initial cost of the building is very high and not everyone can afford it. The payback period decreases due to low operational costs. More techniques can be implemented to produce an ideal design if the model could be modified and used for more real-world scenarios. Making use of passive design structures keeps the environment clean and safe, hence it is more stressed to use for existing residence to make use of the technique. More applications can be added by making use of renewable resources; Solar panels, wind turbines, and hydro-electric turbines could be used to generate electricity for the use of small mechanical components such as fans to be used with passive cooling techniques to achieve better indoor conditions, for example, solar panels for the generation of electricity, which can prove cost-effective for future purposes. Aluminum and timber roofs could be replaced by cheaper materials such as roof tiles with the high thermal capacity to absorb large amounts of heat. White paint could be applied to reflect a large chunk of the solar heat gain. For better implementation, such rules and guidelines could be regulated into government laws for ease on a large urban scale.

Conclusion

In this research, the appropriate design for a building near a beach in Kuching has been designed, by applying information on climate, building materials, and thermal comfort, to provide a comfortable indoor environment in a hot and humid climate. In the beginning, based on the objectives, literature was gathered, which was followed by the methodology. After that, results and calculations followed which were later analyzed and discussed. Further work will be conducted by CFD on the design proposed for more accurate results and more comprehensive insight.

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