

Based on Revit Simulation to Propose a Green Building Design Proposal---Hotel in Merida, Mexico as an Example

Yijing Wang

School of Architecture, Tianjin University, Tianjin, China
wang_200604@tju.edu.cn

Abstract. Building energy conservation is a hot topic of concern for the whole society. Numerous governments have introduced related policies. However, specific practice is rare. Therefore, a green hotel design study is developed whose core target is to improve buildings' cooling and heating energy efficiency. First, this article is based on the hot and humid tropical climate in Merida, Mexico. Second, the study is based on 3D modeling and energy simulation by Revit, comparing the influence on cooling and heating energy consumption of three kinds of building volumes, three types of glass and different orientations. The simulation conclusion indicates that the low and enclosed building, combined with double glass with high performance, low-E coating, high visible light transmittance and low solar heat gain coefficient, which is south-facing, performs at best comprehensively. However, this proposal is just a design conception. In the future, the real building needs to be monitored, including the court microclimate, indoor environment parameters and energy consumption in order to observe the actual effect of the energy conservation.

Keywords: 3D modeling, energy simulation, green hotel design, cooling and heating energy efficiency

1. Introduction

Under the grand narrative of facing climate change and promoting sustainable development, green building has evolved from a cutting-edge conception to a core paradigm in the architectural field. Researchers aim to reduce the natural resource consumption and the influence on the ecological environment to the maximum extent by changing building forms [1], using high-performance materials [2] and connecting with the surrounding environment [3].

Merida has become a critical area to practice green building concepts because of its unique geographical environment. Merida is located in the Yucatan Peninsula of Mexico and its climate is classified as tropical savanna climate. First, the annual average temperature is high. This means that there are very few days or even no days that need heating. Second, its latitude is low so the sunlight is almost direct. The solar radiation intensity is high which is the main source of building heat gain. Third, it is adjacent to the Caribbean Sea and the Gulf of Mexico, so the air is very humid. On the one hand, the climate will hinder sweat evaporation, making people feel more stuffy and thus making people rely on air conditioning for cooling more often. On the other hand, while cooling, the air conditioning needs to spend extra energy to remove moisture. The process of condensing water

vapor into water in the air will also release heat and then increase the burden of the cooling system [4]. Forth, the temperature difference between day and night is relatively small so the effect of natural cooling at night is limited. As a result, the air conditioning needs to run for a long time. Consequently, cooling becomes the absolutely main part of the energy consumption.

Recognizing the necessity, the US government formulated and implemented the Green Building in North America [5], including the case of Mexico. This supervised framework established a clear political direction, compelling architects to seek design solutions that not only meet the regulations, but also genuinely adapt to the particular climate challenge in Merida. However, such solutions are rare.

Based on the background, this article takes a hotel program in Merida as an example, proposing a green building design proposal deeply integrating with passive design strategy, high-performance material and microclimate creation. The conclusion can provide a producible and verifiable design reference and practical paradigm for new hotels and even other public buildings whose climate is similar to that in Merida and the whole Yucatán Peninsula.

2. Site design

Figure 1 is the stick figure of the site. According to Figure 1, three characteristics are concluded. First, the area is open, without large obstructions. Second, the water body that is called Guadiana, has a regulating effect on the microclimate and can help cool the environment if used properly. Third, the surrounding road that is called Ctra. Matadero may contribute to the urban heat island effect, and the heat from traffic can indirectly raise the site temperature.

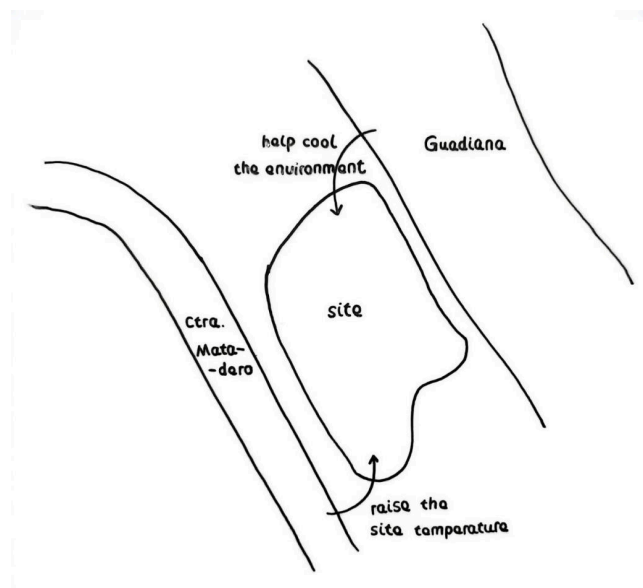


Figure 1. The relationship between the river, the road and the site (picture credit: original)

As a result, first, considering the direction of the river, the building layout adopts one or some cross-ventilation spaces, using the temperature difference between the water and the site to create airflow that removes indoor heat [6]. Second, planting trees around the site to create green buffer zone, providing shading and reducing the heat island effect.

3. The overview of three building design proposals

3.1. Design 1

This building consists of many small rooms connected by a long and intricate corridor and some small cross-ventilation spaces. The footprint of the building is 569.84 m² and the height is 4 m. The building only has one floor. So the building is called a low and linear building. The specific design is shown in Figure 2.

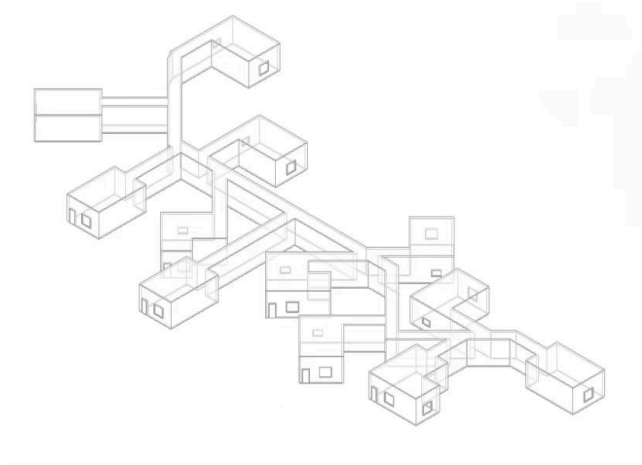


Figure 2. Design 1: a low and linear building (picture credit: original)

3.2. Design 2

The building consists of three long and wide volumes. These volumes form a total enclosed space. The footprint of the building is 1063.02 m² and the height is 4 m. The building only has one floor. So the building is called a low and enclosed building. The specific design is shown in Figure 3.

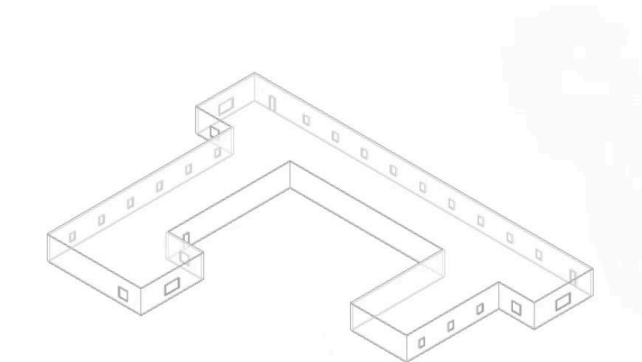


Figure 3. Design 2: a low and enclosed building (picture credit: original)

3.3. Design 3

The building consists of many long and wide volumes. These volumes pile up vertically. The footprint of the building is 2019.92 m² and the height is 20 m. The building has five floors. So the building is called a vertical and concave building. The specific design is shown in Figure 4.

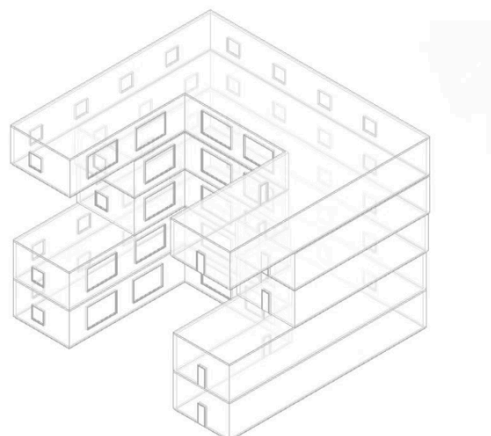


Figure 4. Design 3: a vertical and enclosed building (picture credit: original)

4. The impact of glass on district heating and cooling

4.1. The type of glass

Table 1. Comparison of the type of glass affecting district heating

the type of building/ the type of glass/ the largest change of the percent/ district heating (GJ/m ²)	a low and linear building	a low and enclosed building	a vertical and concave building
Double glass-clear	0.00314	0.00028	0.00140
Double glass-low radiant heat climate, low solar heat gain coefficient	0.00326	0.00032	0.00133
Double glass-high performance, low-E coating, high visible light transmittance, low solar heat gain coefficient	0.00342	0.00037	0.00141
	8.94%	32.14%	6.02%

Table 2. Comparison of the type of glass affecting district cooling

the type of building/ the type of glass/ the largest change of the percent/ district cooling (GJ/m ²)	a low and linear building	a low and enclosed building	a vertical and concave building
Double glass-clear	1.88	1.07	1.24
Double glass-low radiant heat climate, low solar heat gain coefficient	1.81	1.03	1.13
Double glass-high performance, low-E coating, high visible light transmittance, low solar heat gain coefficient	1.77	1.01	1.06
	5.85%	5.61%	14.52%

So, Table 1 and Table 2 can indicate that Glass 3 and Design 2 are the best choices. Although district heating increases, district cooling is the major factor that needs to be considered in Merida.

4.2. The advantage of Glass 3

First, two core concepts need to be explained. The first one is the solar heat gain coefficient [7]. It is the proportion measuring the energy of solar radiation entering the rooms through glass. A lower value means a stronger ability to hinder the solar energy. In Merida, it is the most important parameter. Reducing the solar heat gain coefficient can directly and effectively decrease the air conditioning's cooling burden.

The second one is the heat transfer coefficient [8], which is also called the U-value. It is the rate at which heat is conducted through glass due to the temperature differences between the interior and exterior. A lower value means better performance of heat insulation. In Merida, a lower U-value can not only prevent heat from transferring from the outside, which is beneficial for cooling, but also prevent the heat loss from the inside, which is beneficial for heating. But in Merida, the benefit of preventing heat transfer from the outside is largely offset by the negative effect of high solar heat gain coefficient (SHGC).

Second, by comparing the data, the performance of three types of glass will be ranked. The first one is the double clear glass. It has a high SHGC and a high U-value. It is like the greenhouse, which allows a lot of solar radiation to enter the room. At the same time, its ability to heat insulation is relatively poor. It is the most incompatible option in Merida. It will make the indoor temperature increase rapidly causing the hard work of the air conditioning, so the district cooling is its highest. Meanwhile, because of its poor ability of heat, the indoor temperature increases significantly, reaching 24 °C or even higher. At that time, not only is the heating system unnecessary, but it is also sometimes necessary to open windows slightly for heat loss. The record of district heating is extremely low. This heat is from the sun.

The second one is the double glass which is used in a low radiant heat climate and has a low solar heat gain coefficient. It has a medium SHGC and a medium U-value. This kind of glass is designed for hot climate decreasing SHGC. It can prevent solar heat energy from entering the rooms. Its low-E coating is probably applied to the inner surface of the outer glass, whose major function is to reflect solar infrared radiation. In Merida, compared with the clear glass, it obviously decrease the solar heat gain, so the district cooling begins to decrease. At the same time, its U-value is higher than that of the clear glass, so the indoor temperature rises limited to around 20 °C. Some people may feel a little cold under this temperature. But because its U-value is not the best, the indoor heat will dissipate quickly at night. This may require more heating energy consumption.

The third one is the double glass which has high performance, low-E coating, high visible light transmittance, and a low solar heat gain coefficient. It has a low SHGC and a low U-value. It is the best configuration for hot climate. It uses more advanced low-E coating which is probably applied to the outer surface of the inner glass. It can not only reflect solar infrared radiation effectively, but also achieve the lowest SHGC. It can also achieve a very low U-value by filling with inert gas. In Merida, its district cooling is the lowest because it prevents the most major heat sources, solar radiation, to the largest extent. Its district heating is highest because its very low U-value is like a cotton-padded jacket, tightly wrapping the building. It prevents heat from transferring from the outside. During the daytime, because there are no free solar heat, the indoor temperature probably rises to 19 °C slowly. At this time, residents may feel a little cold, so they adjust the air conditioning to 22 °C artificially. The heating system begins to work, consuming energy to heat actively. At night, because of the effect of the glass which is like a cotton-padded jacket, the heat generated by the heating system, appliances and humans will dissipate slowly. This is a good situation, while during the daytime, more active heating energy has been consumed.

5. The advantage of Design 2

The greatest benefit of the enclosed building is that the building is not an object exposed to the environment and creates an internal courtyard which can form a self-adjusting microclimate [9]. The microclimate is like a buffer zone. It improves the relationship between the building and the harsh external environment significantly. Figure 5 shows the shade when the height angle of the sun is high.

First, it has a positive impact on the district cooling. On the one hand, the enclosed building itself is like a barrier, providing substantial shade for the internal courtyard and the building's façade facing the courtyard. It significantly reduces the direct solar radiation received by the core area and facades of the building which is the largest heat gain source in tropical regions. In contrast, all facades of the linear building are exposed to the sunlight, and although the concave building has self-shading, its huge total areas of walls and roof still absorb numerous radiant heat.

On the other hand, most of the ground of the courtyard is covered by the shade of the building. Its temperature is greatly lower than the external ground. The dense cold air settles at the bottom of the courtyard, forming a cold well, which is called the cold well effect [10]. When the cool air of the courtyard enters the room through doors and windows, it is equivalent to providing pre-cooled fresh air, decreasing the room's cooling burden directly.

Second, it has a positive impact on the district heating, though the demand is rare. On the other hand, in Mexico, temperature may decrease slightly at night in winter occasionally. The enclosed form can resist cold wind effectively and decrease the heat loss because of air infiltration.

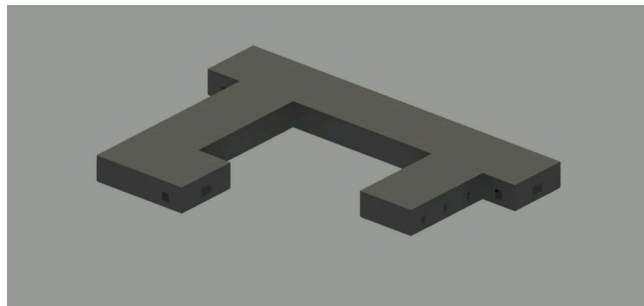


Figure 5. Shade when the height angle of the sun is high (picture credit: original)

On the other hand, in winter, when the height angle of the sun is small, sunlight can penetrate deeper into the courtyard. The enclosed form can capture and store solar energy greatly. After the ground and walls absorb heat, the heat is released slowly at night providing free heat for the surrounding building spaces. Figure 6 shows the shade when the height angle of the sun is low.

In contrast, the layout of the linear building is scattered, which is easy for heat loss. The concave building's volume is large so the air volume that needs to be heated is also large and the hot air easily gathers in the high altitude above the area of human activities, which results in waste.



Figure 6. Shade when the height angle of the sun is low (picture credit: original)

6. Orientation

When the building is north-facing, the district heating is the lowest while the district cooling is the highest. Because in the northern hemisphere, the northern façade cannot receive any solar heat. The

indoor temperature is affected by the heat dissipation of indoor occupants and equipment, so the indoor temperature is the most stable and nearly never exceeds its setting temperature. The heating system only needs to replenish a little heat according to the heat loss so its active heating energy is the lowest. Table 3 list the comparison of the orientation affecting district heating.

However, in humid regions like Merida, a large part of air conditioning's energy is used for removing moisture. Rooms facing north do not have solar heat, so they can not remove moisture easily. Its air conditioning needs to be individually controlled and constantly to deal with this huge, humid burden.

Table 3. Comparison of the orientation affecting district heating

the type of building/ orientation/ the largest change of the percent/ district heating (GJ/m2)	the low and enclosed building with Double glass-high performance, low-E coating, high visible light transmittance, low solar heat gain coefficient
north	0.00037
east	0.00038
south	0.00038
	2.70%

Table 4. Comparison of the orientation affecting district cooling

the type of building/ orientation/ the largest change of the percent/ district cooling (GJ/m2)	the low and enclosed building with Double glass-high performance, low-E coating, high visible light transmittance, low solar heat gain coefficient
North	1.008
East	1.007
south	1.005
	0.30%

Table 4 lists the comparison of the orientation affecting district cooling. When the building is east-facing, it is the transition zone of heating and cooling. Because in winter mornings, the eastern facade receives strong solar radiation, which can provide heat so the district heating will increase compared to north-facing buildings.

However, in summer mornings, intense sunlight from the east will heat rooms rapidly, causing the air conditioning to operate at high capacity. But after mornings, there is no intense sunlight from the east. East-facing rooms will have opportunities to dissipate a part of the heat.

However, on this site, if the building is east-facing, it will directly face the river, and air conditioning will consume abundant energy to remove moisture.

When the building is south-facing, the district cooling is the lowest while the district heating is the highest. Because in winter, south-facing windows can introduce sufficient solar energy, improving the indoor temperature obviously. When the indoor temperature exceeds the setting value, the system needs to consume energy for cooling so that the district heating is at its highest. In summer, because of the high angle of the sun, it is difficult for direct sunlight to penetrate rooms. Southern façades receive the least solar radiation. So its district cooling is the lowest. Introducing water bodies to the courtyard to form a small pool can decrease the temperature and avoid extra moisture.

7. Conclusion

Based on Revit modeling and energy simulation analysis, this study proposes a green hotel design proposal suitable for the hot-humid climate of Mérida, Mexico. By comparing the impact of three

building volumes, three glass types, and different orientations on cooling and heating energy consumption, some findings can be concluded.

The low enclosed building (Design 2) performs best in terms of energy efficiency. Its enclosed form provides substantial shading, reducing solar heat gain on façades and core areas, while the internal courtyard facilitates a "cold well effect," supplying pre-cooled fresh air and significantly lowering cooling loads.

Regarding glass, the double glass which has high performance, low-E coating, high visible light transmittance and low solar heat gain coefficient (Glass 3) proves most effective. Its low SHGC minimizes solar heat entry, drastically reducing cooling energy—the dominant demand in Mérida.

A south-facing orientation yields the lowest cooling consumption due to minimized direct solar radiation in summer.

The site design—introducing water bodies into the courtyard and planting trees around the building—creates airflow that removes indoor heat and provides shading and reduces the heat island effect. So if designers need to build hotels or other public buildings whose climate is similar to that in Merida and the whole Yucatán Peninsula, the conclusion can provide a design reference.

The limitations of this study is that, first, the conclusion completely relies on the static simulation of Revit, without considering the actual impacts on human behaviors, changes of equipment efficiency and differences of the local construction process. Second, it has not economic and feasible analysis related to the initial investment cost, local availability of materials and complexity of operation and maintenance. In the future, the real building needs to be monitored in order to observe the actual effect of the energy conservation.

References

- [1] Sharma, S. (2024) Green Materials & Construction: a Step towards Sustainable Environment. AIP Conference Proceedings, 3050 (1), 030009.
- [2] Wang, Z.H. (2023) A Survey of Factors and Life Cycle Assessment in Selection of Green Construction Materials. Journal of Computational Intelligence in Materials Science, 16(1), 0.
- [3] Alfouly, M. and Hamacher, T. (2025) Evaluating Urban Form Influence on Solar Exposure and Corresponding Building Energy Demands. European Geosciences Union General Assembly 2024, EGU24, 15532.
- [4] Oladosu, T.L., Baheta, A.T. & Oumer, A.N. (2021) Desiccant Solutions, Membrane Technologies, and Regeneration Techniques in Liquid Desiccant Air Conditioning System. International Journal of Energy Research, 45(6), 8420–8447.
- [5] Molina. & Mario, C. (2008) Green Building in North America. Paper 3a. Institutional Efforts for Green Building : the Case of Mexico / Centro Mario Molina. Montréal, Québec : Commission for Environmental Cooperation.
- [6] Kirschner, V., Moravec, D., Macků, K., Kozhoridze, G. & Komárek, J. (2024) Comparing the Effects of Green and Blue Bodies and Urban Morphology on Land Surface Temperatures Close to Rivers and Large Lakes. Land, 13(2), 162.
- [7] Samuelson, H., Srivastava, C. & Baniassadi, A. (2025) Optimizing Window Solar Heat Gain Coefficient for Energy and Carbon Performance in a Changing Context of Electrification and Decarbonization. Energy Reports, 13, 1450-1466.
- [8] Malyarenko, V., Alyokhina, N. & Orlova, S. (2023) Methodology for Determining Heat Losses through Translucent Construction. Problems of the Regional Energetics, 83-98.
- [9] Zhang, Z., Hui, H. & Song, Y. (2025) Response Capacity Allocation of Air Conditioners for Peak-valley Regulation Considering Interaction with Surrounding Microclimate. IEEE Transactions on Smart Grid, 16(2), 1155-1167.
- [10] Karim, S.M.S., Kaplan, M.L., Lin, Y.-L. (2025) Urban Impacts on Convective Squall Lines over Chicago in the Warm Season—Part II: a Numerical Study of Urban Infrastructure Effects on the Evolution of City-scale Convection. Atmosphere, 16(6), 652.