International Journal of Advanced Engineering and Technology Research
ISSN: 3106-8677 (Print), ISSN: 3106-8685 (Online) | Vol. 4, No. 1, 2026

Effects of Shading Strategy on daylight illuminance and energy consumption for southern facades of Office Buildings

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Abstract: This study investigates the effects of exterior shading strategies on annual average daylight illuminance and electricity consumption for the southern façade of a two-story office building in Ann Arbor, Michigan. Using eQUEST, four cases were simulated: a baseline without shading, horizontal overhangs only, vertical fins only, and a combination of overhangs and fins. The results show that all shading configurations reduce electricity consumption compared with the baseline, while horizontal overhangs perform more effectively than vertical fins. The combined strategy achieves the lowest annual electricity consumption and the largest reduction in daylight illuminance. However, excessive shading also reduces the hours during which daylight illuminance remains above the setpoint, increasing electric lighting demand and limiting additional energy savings. The findings indicate that shading design should balance solar heat-gain reduction and daylight availability, with parameters adjusted according to climate, orientation, material, and building conditions.

Keywords: Shading strategy, daylight illuminance, energy consumption, office building, eQUEST, southern façade.

1. Introduction

Architectural shading as a connected structure between interior space and exterior space, is capable of reflecting and absorbing most part of solar radiation. It is like a filter to prevent excessive solar radiation from entering the interior space directly, and then, adjust the room temperature. Therefore, shading strategy is the most effective and popular passive design method which helps architecture save more energy.

Architectural shading system is the most required and motivated energy-saving strategy for all types of buildings such as residential houses, office buildings, schools etc. It will not only influence the energy performance of the buildings but also change the appearance of architecture, so it is an important part of the whole design process. Excess solar gain will increase interior temperature thus more cooling energy will be required to keep the temperature within comfort zone for people to stay especially during summer time, however, in cold climates area, solar gain can also be a friendly passive heating source for buildings especially for the southern façade. Consciously making decisions for shading devices during the early design period can help make a big difference for energy performance of the entire building.

There are plenty of studies focusing on energy and daylight changes brought by different shading strategies. As an article which explored the impact of shading strategy and orientation on energy performance of a building described: "The dramatic pace of developments in the building construction industry and the associated energy and environmental concerns have prompted researchers in exploring fenestration and shading systems for optimal control of solar gains and daylighting." [1] Therefore, under such background, many energy-saving related experiments especially in passive building design field such as shading design, heat storage had been done over the past ten to twenty years.

A previous study by Alshamrani and Mujeebu in 2015 had explored the impact of shading strategy and orientation on building's energy performance using Equest software as a simulation tool to make comparisons between eight cases. The scholars

came up with three main options for shading: overhangs only, fins only, overhangs with side fins. And attached them separately to south, west and east façade of a school building in Los Angeles to see the difference. [1] The very last step was to compare the energy consumption of those cases with the baseline design case (without overhangs and fins). This very clear previous study process helped to lead a clear logic through the author's study and gave a reference on how to choose effective shading strategies and how to strongly arrange, compare data results. Alshamrani's study also emphasized that south façade of a building was always known as reflecting greater influence than other facades while the north façade showed less response to any change of the parameters, [1] so the author's study mainly focuses on making changes of shading structures on south façade of the office building in Ann Arbor, Michigan.

Alzoubi had done research studying the effects of different shading structures such as vertical and horizontal structure on daylight illuminance and energy performance. "Computer simulation strategy was undertaken to correlate the illuminance level in spaces with room geometry and architectural shading elements. The Holophane model for lighting calculations was used to estimate the average illuminance level on workplace and correlate it with the expected saving energy in buildings." [2] This simulation process inspired the author to build up digital model of office building in equest and make a simulation to see the daylight illuminance difference while changing shading strategies. Results in Alzoubi's article showed that the daylight illuminance declined obviously after adding shading devices, "This is very beneficial in reducing the cooling load in summer", [2] which explained why and how shading devices can reduce solar gain and save electricity consumption. That is a very important conclusion the author can refer to when checking the daylight illuminance report to explain the

electricity-saving phenomenon.

A similar study was conducted by Yassine in 2013, who also tested effects of shading devices on office buildings, but with four types of shading devices in Dubai this time. Yassine added vertical and horizontal louvers apart from fin and overhang structures. And the results showed that both horizontal and vertical louvers can save more energy than the other two structures when the scholars compared all cases together based on the energy consumption chart. [3] Athienitis and Tzempelikos were interested in controlling shading devices to reduce solar heat gain and at the same time minimize the electricity consumption for artificial lighting. [4] This balance is very important and

helps to set a range for adjusting shading parameters, which helps the author understand some differences more comprehensively while analyzing the results.

Another research conducted by Jian Yao was mainly about saving both energy consumption and cost by applying different types of shading devices, which took cost into consideration so that the project became much more realistic and therefore, helping architects make comprehensive decisions. "The results show that movable shading devices lower incremental costs by up to 50% compared with fixed ones for the same building energy efficiency for residential buildings." [5] The results from the article showed how to make decisions while the two strategies reached the same energy efficiency, and movable shading devices is a more money-saving choice than the fixed structures scholars always use while making simulation. Economic concern should be taken seriously when dealing with a practical project. In the study mentioned before, Alshamrani and Mujeebu not only did research about the shading devices, but also calculated annual energy cost. The article mentioned though the gas consumption raised after adding both overhangs and fins, the gas cost reduced compared to the base case due to a decrease in gas prices. [1] Therefore, economic evaluation needs to pay attention to the changing prices of energy sources in the whole society and designers should combine theoretical conclusion with practical experiences while making decisions in shading and glazing types.

Another interesting experiment done by Mao Jiachen and his three collegues in 2015 focused on the application of internal shading devices, which was a relatively unique research direction while most scholars were studying for optimizing external shading design for energy-saving purpose. "In real applications, external shading is difficult to use, easily damaged and prone to dirt buildup. Internal shading is more flexible, cheaper and easier to repair." [6] This sentence showed that the internal shading would also become a popular choice if it had the same effective energy-saving ability. The result proved that internal shading would reduce space cooling load and cost sharply if highly reflective materials and proper design adjustment were applied to it, which emphasized the importance of cautious design adjustment during the whole design process.

"However, there is significant scope for research on the design, type, orientation, etc., of shading devices such as overhangs and fins, and their use in different types of buildings under various climatic conditions." [1] The sentence emphasized that different locations, orientations, structural angles, and many other parameters will lead

to different results in energy performance, daylight performance and costs. Therefore, it is important to make analysis under certain specific condition and control parameters within appropriate scope which matches the tested cases well.

Above all, in this study, the author focuses on the effects of different shading strategies on the average annual daylight illuminance and electricity consumption for office buildings in Ann Arbor, Michigan. The study used equest to simulate the whole building and reorganizes the data from annual electricity consumption report and daylight illuminance report to make analysis, and then explored the relationship between daylight illuminance and energy consumption. There were 3 types of shading strategies: "only horizontal overhangs", "only vertical fins on both side of the openings", and "both overhangs and fins". All these types were attached to the south façade of the office building separately for testing.

2. Methodology

2.1. Ann Arbor

This study chooses Ann Arbor, downtown as the location for office buildings. Ann Arbor is a midwestern city located in Michigan state. The latitude of Ann Arbor is 42.3° N and the longitude is 83.7°W. Ann Arbor's climate is heavily influenced by the Great Lakes. [7]

"There are four distinct seasons: winters are cold and snowy, with average highs around 34 °F (1 °C). Summers are warm to hot and humid, with average highs around 81 °F (27 °C) and with slightly more precipitation. Spring and autumn are transitional between the two." This sentence reflected that the summers in Ann Arbor is not very hot, as the wiki website introduced, "The monthly daily average temperature in July is

72.6 °F (22.6 °C)." [7] Therefore, it is significant to make full use of passive design techniques to save energy consumption so that the shading strategy can help lighten the burden of mechanical systems or become the main cooling method when mechanical systems are not necessarily in need.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °F (°C)	72 (22)	67 (19)	85 (29)	88 (31)	95 (35)	103 (39)	105 (41)	104 (40)	99 (37)	91 (33)	78 (26)	67 (19)	105 (41)
Average high °F (°C)	31.2 (−0.4)	34.9 (1.6)	45.9 (7.7)	59.6 (15.3)	70.6 (21.4)	79.7 (26.5)	83.2 (28.4)	81.2 (27.3)	74.2 (23.4)	61.4 (16.3)	47.9 (8.8)	34.9 (1.6)	58.8 (14.9)
Daily mean °F (°C)	24.7 (−4.1)	27.6 (−2.4)	36.7 (2.6)	49.0 (9.4)	59.6 (15.3)	68.9 (20.5)	72.7 (22.6)	71.2 (21.8)	63.9 (17.7)	52.1 (11.2)	40.6 (4.8)	29.0 (−1.7)	49.7 (9.8)
Average low °F (°C)	17.9 (−7.8)	19.9 (−6.7)	27.2 (−2.7)	38.0 (3.3)	48.2 (9)	57.9 (14.4)	62.1 (16.7)	61.0 (16.1)	53.4 (11.9)	42.4 (5.8)	33.0 (0.6)	23.0 (−5)	40.4 (4.7)
Record low °F (°C)	−22 (−30)	−23 (−31)	−8 (−22)	7 (−14)	20 (−7)	35 (2)	37 (3)	39 (4)	27 (−3)	19 (−7)	1 (−17)	−20 (−29)	−26 (−32)
Average precipitation inches (mm)	2.59 (65.8)	2.40 (61)	2.66 (67.6)	3.25 (82.6)	3.42 (86.9)	3.68 (93.5)	3.61 (91.7)	3.69 (93.7)	3.45 (87.6)	2.83 (71.9)	3.09 (78.5)	2.89 (73.4)	37.55 (953.8)
Average snowfall inches (cm)	16.8 (42.7)	13.4 (34)	8.6 (21.8)	2.8 (7.1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.2 (0.5)	3.1 (7.9)	13.5 (34.3)	58.4 (148.3)
Average precipitation days (≥ 0.01 in)	17.1	13.8	14.1	13.4	13.6	11.9	11.4	11.1	10.7	12.4	13.8	16.8	160.1
Average snowy days (≥ 0.1 in)	14.7	11.4	7.6	2.5	0	0	0	0	0	0.5	4.5	12.1	53.2

Figure 1. climate data for Ann Arbor, Michigan (UMich, 1981-2010)

Source: "NowData-NOAA Online Weather Data", National Oceanic and Atmospheric Administration. Archived from the original on January 29, 2014. Retrieved February 27, 2012.

2.2. Equest Software Program

The simulation part of the study was mainly operated in equest. Since equest is very easy to begin with while possesses very powerful simulation techniques. As the article, Equest…the Quick Energy Simulation Tool taught, "With equest, you will be able to provide professional-level results in an affordable level of effort." [8] The software can give scholars and designers a very comprehensive and well-organized result through the combination of a building creation wizard, an energy efficiency measure wizard and a graphical result display module. [8]

Equest is available for everybody, people can freely download it from www.energy designresources.com. It has an effective work flow and is useful for all kinds of design teams. Equest is also a very trusted tool due to two decades of continuous development and enhancement. [8] It is very convenient to make design alternatives and test results for different cases through very quick simulations. Sometimes you may omit some details during the design process, the software will help you to make framework of all parameters needed to be set up so that you will not forget any important information to adjust and finish adjustment in a very short time. The output report data is clearly organized and very comprehensive. Operators can skip all the information they don't need and go into the targeted results immediately. In this study, the author can get the annual energy consumption reports of each different case

immediately after changing parameters and is able to compare daylight illuminance level through LS-G space daylight report.

2.3. Tested Cases

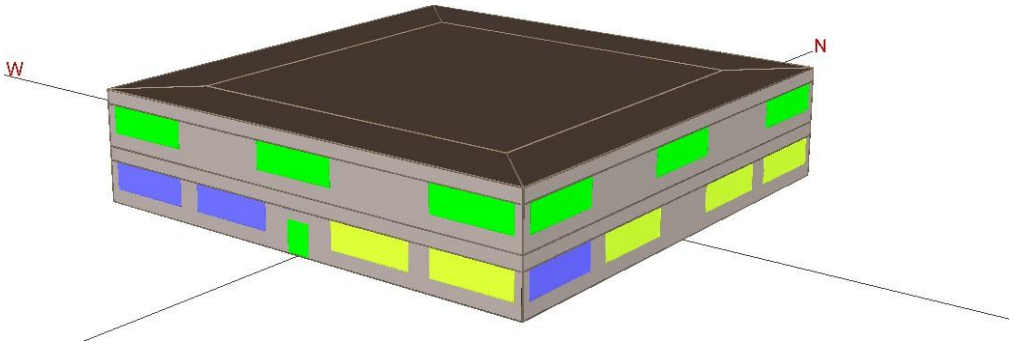
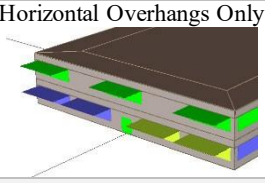
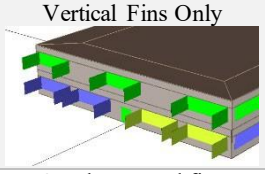
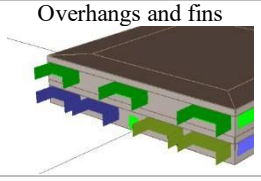


Figure 2. Base model (without shading)

As figure 2 shows, the model is a two-story office building located at downtown, Ann Arbor, Michigan State. The total building area is 25000 ft2, which has a width of 111.80ft and a length of 111.80ft. The floor-to-floor height is 12 ft and floor-to- ceiling height is 9 ft. The width of each opening is 20 ft, and the height is 6 ft. There are seven openings on each façade, doors are on the north and south side of the office building. All the windows have aluminum frames (Alum w/o Brk, Fixed). The depth of all overhangs and fins is 10 ft. For the materials of glazing, single PPG (Starphire 6mm, 5501, U=1.03, SHGC=0.9, VT=0.91) is chosen for all openings of the whole building. The model above is the base case without any shading devices. (figure2)

Table 1. test cases for different shading strategies

Case	South facade
1	Without shading (single PPG)
2	Horizontal Overhangs Only 
3	Vertical Fins Only 
4	Overhangs and fins 

In this experiment, there are four cases listed in Table 1, case one is the baseline design which has been described before, and case two shows the strategy adding horizontal overhangs to each opening on south façade, case three shows another strategy adding vertical fins to each opening on south façade. The last case four shows a strategy adding a combination of both fins and overhangs to the openings on the same façade. The main information of the office building is shown in table 2 and the simulation digital model is displayed in figure 2.

Table 2. Building specifications

Item	Specifications
Type	Office Buildings (2 floor)
Area	12500 ft2
Height	24 ft
Frame Type	Aluminum, w/o Brk, Fixed
Window	Glass and aluminum frame window; Window width=20 ft; Window height=6 ft; Window area=41.7%(floor-to-ceiling)
Overhang and fins	10 feet from the wall; Fins height=6 ft Fins width=20 ft
Heating	Furnace
Cooling	DX coils

Figure 3 shows the section and plan of the openings with different shading devices and the impact overhangs and fins leave on the distribution of daylight inside the room. The author sets two points within the ground floor space, one is in the south perimeter space, 8ft from the south façade, 25ft from the west wall. Another is located at the symmetrical position in north perimeter space. Equest software helps to measure the daylight illuminance level within south perimeter space at the ground floor and shows different illuminance level according to different shading strategy. Excel software helps to rearrange and track the most important data and then makes comparison charts based on the collected information.

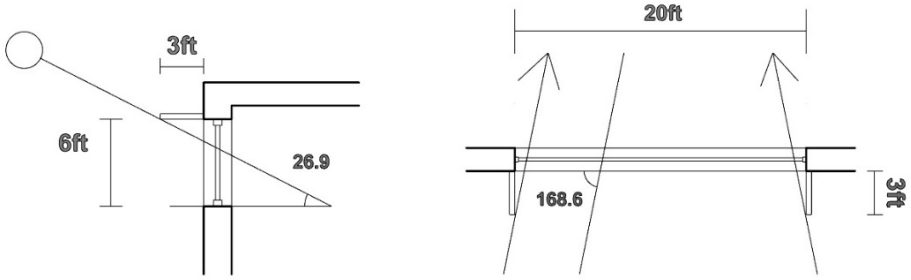


Figure 3. section/plan drawings

3. Results and Discussion

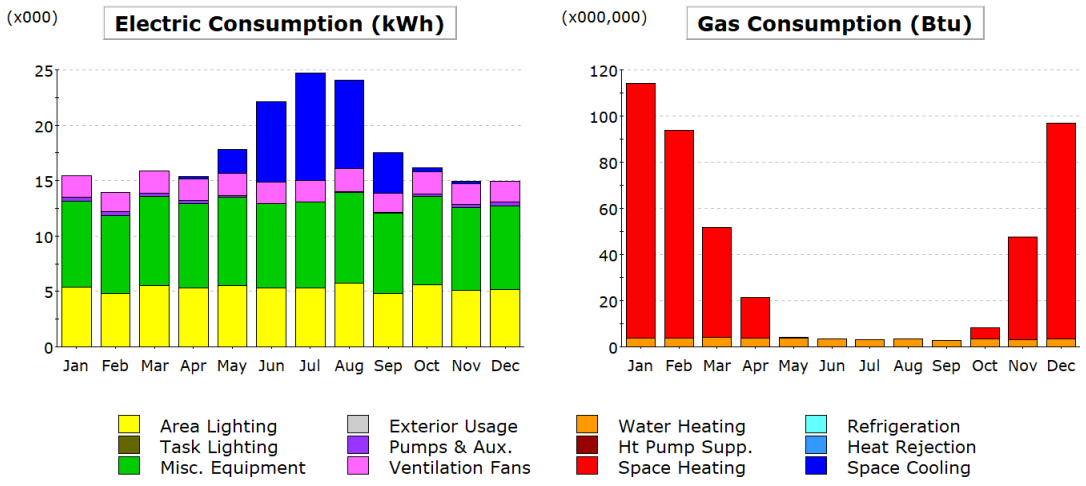


Figure 4. Energy consumption report of the base case (without shading)

From figure 4, the contributors to the annual electricity consumption are area lights, misc equipment, ventilation fans, pumps and auxiliaries, and space cooling while the contributors to the annual gas consumption are water heating and space heating.

Figure 4 shows that the peak loads appear in July and January. Misc. equipment, space cooling and area lighting consume the most electric energy compared to other

contributors. Since the electricity consumption for misc. equipment is always the same. The distribution of those contributors show that electricity is mainly consumed and can be influenced heavily by area lighting and space cooling.

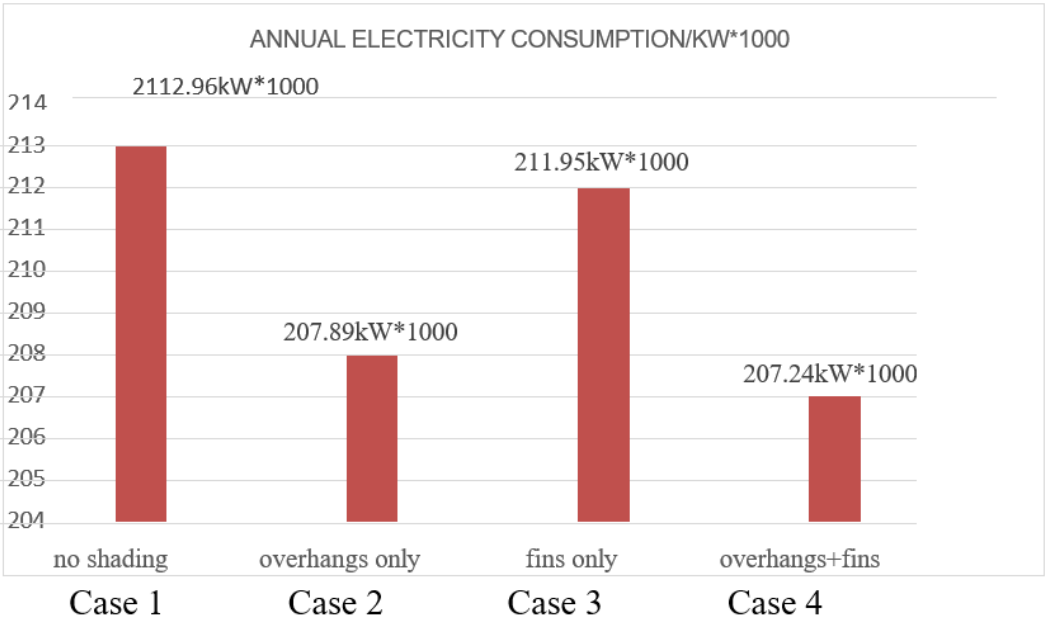


Figure 5. Annual electricity consumption

From Figure 5, electricity consumption goes down obviously after adding shading devices. Since shading devices can help to reduce the excessive solar gain especially in summers, much heat from the solar radiation has been blocked by the isolation those shading structures make. Therefore, the space cooling load will decrease if exterior shading devices are attached to the openings, which will consequently lead to an apparent reduction in electricity consumption.

From the graphic, case four has the lowest electricity consumption, which is 207240kW, case two has similar amount of consumption compared to case four, which is 207890kW, and case three consumes the most energy among these shading strategies, which is 211950kW. From the comparison, the strategy using only overhangs saves 2.38% in electricity consumption while the strategy using only fins saves 0.47% in electricity consumption. It is obvious that the strategy using horizontal overhangs saves more electricity than the one using vertical fins. As figure 3 displays, horizontal overhangs block more direct solar radiation than vertical fins do. The reason is that horizontal overhangs are attached right above the openings, extending ten feet long, they obstruct the solar radiation from the sun directly while the vertical fins are relatively weak in filtering direct solar radiation.

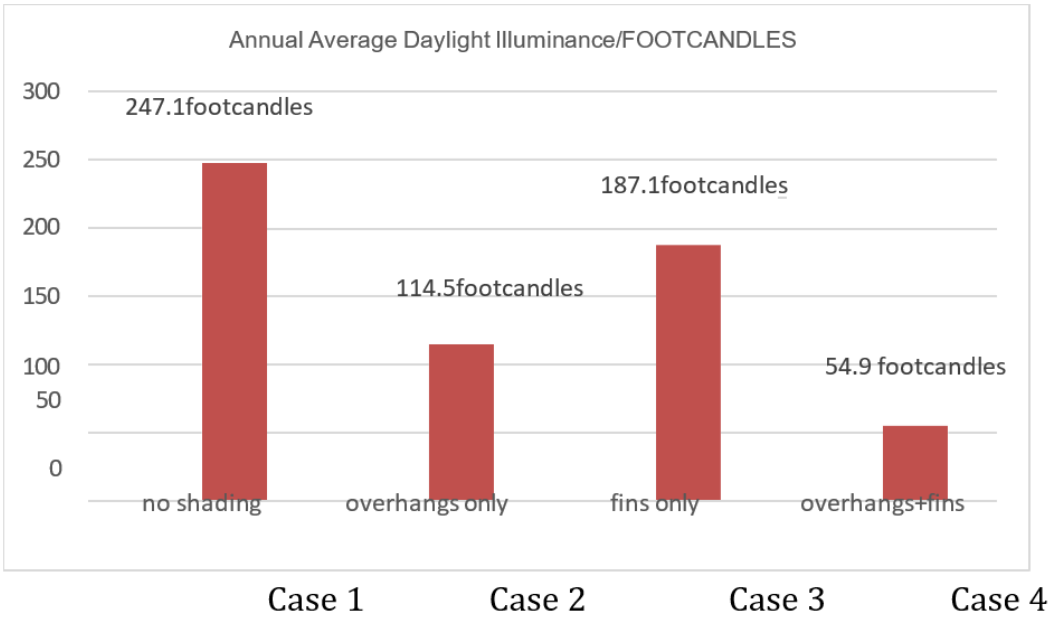


Figure 6. Annual average daylight illuminance

Figure 6 can help explain why adding shading devices will save a lot of energy. If you add shading structures to openings, the average daylight illuminance level will decrease sharply. This result makes sense because when daylight illuminance level goes down, the solar radiation or the interior heat gain will reduce, which can reduce space cooling load. As mentioned before, space cooling load is a main contributor to electricity consumption, so it helps save a lot of electricity. As

figure 7 shows, adding overhangs will reduce 53.7% of the daylight illuminance compared to the base case without shading, adding fins will reduce 24.3% of the daylight illuminance, which accounts for the reason why case two consumes less electricity than case three. The sharpest reduction is the last case using both overhangs and fins, which reduces 77.8% of the daylight illuminance compared to the base case.

From Figure 5 we can see that the strategy using a combination of overhangs and fins saves the most amount of electric energy compared to other cases. It has a saving of 2.7 % in electricity consumption annually. Though this strategy saves the most amount of energy, its electricity consumption amount does not make much difference compared to the "overhangs only" strategy. This is a very strange phenomenon because as figure 7 shows, the reduction of daylight illuminance of case four is a lot more than case two. However, case four doesn't save much more electricity than case two.

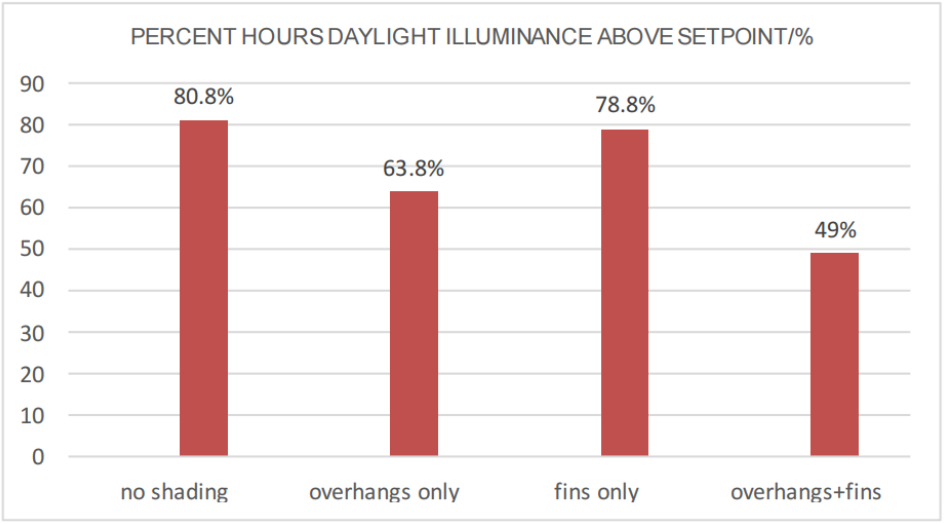


Figure 7. Percent hours daylight illuminance above setpoint

Figure 7 shows that though adding shading devices will reduce space cooling load and consequently save electric energy, too much shading will increase electricity consumption in area lighting. In case four, the hours during which daylight illuminance above setpoint only count for 49% of the whole time period. Therefore, case four will consume more electricity than other cases for electric lighting use, it saves electricity for space cooling but not for electric lighting. So that is why case four has the lowest daylight illuminance but saves relatively less electric energy because of the sharp reduction of illuminance. Too much shading will influence daylight quality, which also causes a lot of energy consumption if parameters or combinations of shading devices are not controlled within an appropriate scope.

4. Conclusion

Above all, for Ann Arbor office buildings, on southern facades, adding shading devices is a very effective electricity-saving passive design technique. Annual electricity consumption goes down sharply after the application of shading devices. Using horizontal overhangs saves more electric energy than using vertical fins while a

combination of both two structures will save the most electric energy.

Daylight illuminance is a significant element which will directly influence the amount of energy consumption. A high level of daylight illuminance will bring excessive solar gain to the interior space especially in summers, shading devices are very effective structures to help obstruct direct solar radiation and consequently reduce the daylight illuminance. And then, the space cooling load will go down, which makes electricity consumption for cooling decrease. An interesting result shows that the strategy using only overhangs and the one using both overhangs and fins consumed very similar amount of electricity while the daylight illuminance level of each is totally different. It can be explained by the fact that the area of shading devices is so large that it influences the normal daylight quality inside the room, which means that too much shading will raise the electric lighting consumption and thus influence the entire energy consumption.

Therefore, further study may be conducted to focus on exploring a strategy which will block the most amount of solar radiation while minimizing the lighting consumption. A scope for parameters of shading devices should be identified in order to optimize shading strategy and balance the electricity consumption of each contributor. Different experiments have different results depending on climate, location, material, orientation, etc. We should simulate specific models based on specific environmental background, adjust all the parameters based on a reasonable scope and make cautious decisions comprehensively during the passive design process.

References

[1] Alshamrani, O., & Mujeebuu, M. A. (2016). Effects of shading strategy and orientation on energy performance of school building. *Journal Architecture & Planning*, *28*(1), 129–141.

[2] Alzoubi, H. H., & Al-Zoubi, A. H. (2010). Assessment of building façade performance in terms of daylighting and the associated energy consumption in architectural spaces: Vertical and horizontal shading devices for southern exposure facades. *Energy Conversion and Management*, *51*, 1592–1599.

[3] Farah, Y. (2013). *The effect of shading devices on the energy consumption of buildings: A study on an office building in Dubai*. The British University in Dubai (BUiD).

[4] Athienitis, A. K., & Tzempelikos, A. (2002). A methodology for simulation of daylight room illuminance distribution and

light dimming for a room with controlled shading device. *Solar Energy*, *72*(4), 271–281.

[5] Yao, J., & Yan, C. (2011). Evaluation of the energy performance of shading devices based on incremental costs. *World Academy of Science, Engineering and Technology*, *5*(5), 394–396.

[6] Ye, Y., Xu, P., Mao, J., & Ji, Y. (n.d.). Experimental study on the effectiveness.

[7] Wikipedia contributors. (2018, December 21). *Ann Arbor, Michigan*. Wikipedia, The Free Encyclopedia. https://en.wikipedia.org/w/index.php?title=Ann_Arbor,_Michigan&oldid=874518235

[8] U.S. Department of Energy. (n.d.). *eQUEST … the QUick Energy Simulation Tool*. http://www.doe2.com/download/equest/eQUESTv3-Overview.pdf