

The Impacts of Orientation and Building form on Internal Temperature of Visitor Center Building for Moderate and Hot Climate

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Abstract: *Passive building strategies such as building form, orientation and window ratio can have an essential impact on the indoor temperature. Building form and ordination can obtain heat gains. The designer usually designs buildings with little consideration of heat gains. This study pointed to the influence of building form and orientation in internal temperature in moderate and hot climates. In the present paper, the impact of building orientation on the indoor thermal comfort conditions expressed in terms of internal temperature is numerically investigated. This is motivated by required achievement of the thermal comfort conditions in such buildings located on hot climate regions. Moreover, the moderate climate regions are also incorporated in the present study. The numerical simulation is carried out using the TAS EDSL software to assess the optimum form model for a prefab visitor center. The result, in a moderate climate, showed that the ideal direction was obtained when the visitor center faces the south direction. Different models for building orientations have been studied and the results are presented. The results should that the internal temperature was 37.85°C for the currently model orientation and 37.71°C for the other model (known as model D), where the external temperature was 37.9°C. The worst orientations were the west direction for the case study and the east for the D model. In terms of hot climate, the internal temperature decreased by 1.0°C when west-facing. However, models with openings decreased 0.5°C. There are other passive design strategies that can be installed to models which can lead to improving the thermal comfort. The strategies can be considered for further future research.*

Keywords: *Building Design In Moderate climate, Internal Temperature, Orientation and Visitor Center Building form.*

I. INTRODUCTION

One of the concerns of the building's end-user is thermal comfort. This is to achieve a suitable and attractive place to live or work in, whether it is an administrative, residential, tourist or commercial building. The interest in tourism in the Kingdom of Saudi Arabia has been steadily increasing since the establishment of the General Authority for Tourism and National Heritage, and stimulation has increased since the announcement of the vision of the Kingdom 2030. The government will develop tourist sites according to the highest international standards. In addition to this, the Kingdom will prepare and develop historical and heritage

sites [1]. Within the tourism strategy of the Kingdom of Saudi Arabia, the Kingdom has identified the types of markets that are helping to develop the tourism sector, and the Umrah sector was identified as one of the targeted sectors. This requires equipping historical and visiting sites with capabilities for tourists [2]. This mobility prompted the Tourism Authority to work on designs for prefabricated visitor center buildings, which are fast-implemented, that meet the requirements of this sector as a first stage. Several studies have mentioned the impact of building form and orientation on thermal comfort and energy usage [3]-[4]. Several factors can have a clear impact on internal temperature of the building and that impact can positively affect energy consumption. Reference [5] has mentioned that opening materials and windows, shading, and building orientation can play a clear role on the internal temperature. In addition to that, some authors mentioned that if the building does not have an ideal orientation, that will lead to increased energy consumption [6]. Moreover, it is said that building form and details can cause deterioration of the thermal comfort of the building [7]. These factors can give an indication about their effect on building performance and the designer has to consider them during the design process [8]. This paper emphasizes the impact of building form and orientation on the internal temperature. This impact will be assessed during the summer and winter seasons. This has been done in two stages. The first stage assessed modeling the building in different forms, and then the proposed design was selected with the lower internal temperature in both moderate and hot climates. After that, these current and selected forms were oriented to south, east, west and north. The area of the study is Taif and Mecca in Saudi Arabia. The case study and result will be described in more detail in the following sections.

II. METHODOLOGY

A. Study Tool

TAS EDSL software is a commercial energy modeling program. This software helps the designer to predict the energy performance and select the optimum solution to manage it. This tool is used to assess the internal temperature of the space of the proposed visitor center building. Several researchers have considered this tool to assess building form and orientation [9]-[10]. The main features of the visitor center building have been itemized in Table II. There are several visitor center forms that have been modeled, as shown in Table III. For more details about the numerical procedure and the appropriate boundary conditions, one can see [8].

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	Layer	Width (mm)	Total U value (W/m ² .°C)			
External wall (sandwich panel)	Gypsum board - Cavity - Spray foam insulation - Container deck	150	0.375			
Ground	Sand dry - Crushed aggregate - Concrete - MGO board	1252	1.279			
Roof panel	Gypsum board - Cavity - Spray foam insulation - Container deck	150	0.379			
Glazing	Type of glazing	Width (m)	Solar absorption	Solar transmittance	Emissivity	Total U value (W/m ² .°C)
	Single	10	0.115	0.70	0.845	5.681

B. The Case Study

There are many gains that may be achieved when activating tourist programs for pilgrims. In the first place, it is to link the pilgrims and visitors culturally and socially with the Kingdom. Secondly, this kind of program can help to highlight the tourism components and advantages of the Kingdom of Saudi Arabia. In the third place, this interest helps in developing balanced and sustainable tourism that provides job opportunities and preserves cultural originality. Finally, pilgrims to the Kingdom of Saudi Arabia will have the opportunity to be introduced to the most important sites in Saudi Arabia [2]. Hence the idea of establishing visitor centers started. The proposed centers are located next to the historical sites to provide tourists with information, and this is the first stage. The design of the proposed visitor center is facing south, as illustrated in Figures 1 and 2. The total area of the visitor center is 58.56m². The building design spaces are as follows: a photo gallery, office, video showroom and toilet, as shown in Figures 1 and 2. The building material is described in more detail in Table II, which includes external wall (sandwich panel), ground, roof panel and glazing. The proposed location properties of the designed building (Taif City) and Mecca is illustrated in Table I.

Since both cities contain many historical sites and are targeted by tourists, it was chosen as a study area and to simulate this building. The main facade of the visitor center is made of glass, which might be reflected in the building's thermal performance. This will be illustrated in more detail in the following sections.

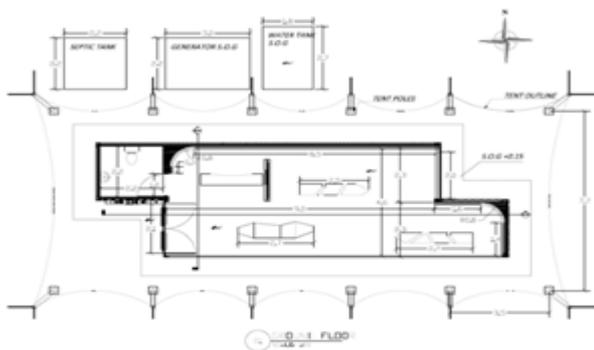


Figure 1: Ground floor of proposed visitor center [10].



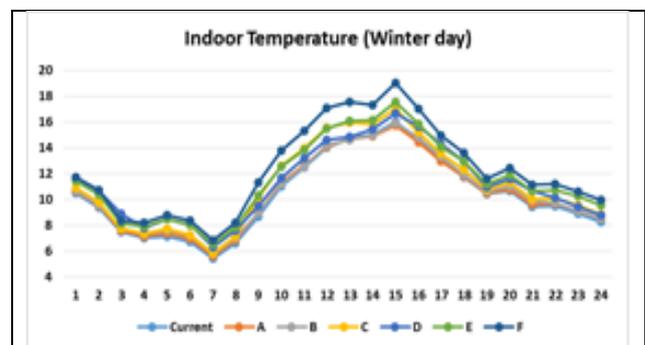
Figure 2: Visitor center perspectives [10].

Table 1. Location properties of the designed building (Taif City)

No	Property	Description
1	Location	Taif, Saudi Arabia
2	Latitude	21.44°N
3	Longitude	40.51°E
4	Elevation	1700.0 m
5	Daily lower average air temperature	10.9°C
6	Daily upper average air temperature	32.0°C
7	Average air flow speed	3.8 m/s
8	Relative humidity	46%

III. RESULTS AND DISCUSSION

The result of this study is given in two stages. The first stage has developed several forms. The result of the first stage is to select the optimum form that decreases the internal temperature. Then the proposed design has been oriented with the optimum form to south, north, east and west. This will be explained in more detail in the following sections.



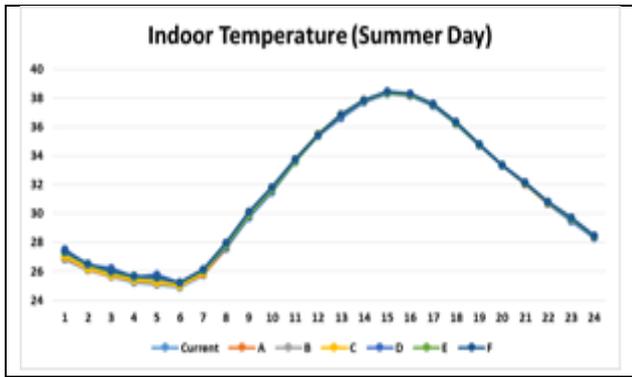


Figure 3: Indoor temperature for summer and winter days

A. Simulating forms of design alternatives

The researcher proposed several forms (A, B, C, D, E and F) beside the study model, using TAS EDSL software as illustrated in Table 3. The lowest indoor temperature was for model D during a summer day, which was 38.320C as illustrated in Figure 3 and Table III. It was a slight difference. Therefore, model D was chosen in addition to the proposed study model, since this difference may achieve positive results in the next stage of the simulation.

B. Simulate the current and ideal alternative design forms with and without opening in moderate climate.

Both the current model and the D model were oriented to south, north, east and west. The south faces showed the lowest results for both models. However, the interior temperature for model D was 37.710C, lower than the current model which was 37.850C at 2:00pm, as illustrated in Table IV. This shows to what extent the glass ratio can affect the thermal comfort, as well as the building form. The researcher selected another day (181) to assess the internal temperature. The results for both models are lower than the external temperature. The south face for model D was 33.810C at 2:00 pm and 34.430C at 3:00pm. This shows a difference between the outside and the inside temperature of about 1.50C, and the same difference at 3:00pm as shown in Table IV. The researcher developed another form with opening for both the current design and the D model as shown in Table IV. The main result was that the west face for the current design improved the internal temperature by about 0.50C. However, the optimum face of model D was the south, which is almost the same result as the west face for the current design, as highlighted in Table IV.

C. Simulate the current and ideal alternative design forms with and without opening in hot climate.

Both models (current and D) were oriented to south, north, east and west with and without openings in a hot climate (Mecca city) as shown in Table V. The south face had the lowest result for the current model without openings. However, the west and east faces were the optimum for the D model. The interior temperature for model D was 39.020C, lower than the external temperature, which was 40.000C at 2:00pm as illustrated in Table V. This shows to what extent the orientation and building form can affect the thermal comfort. The extra openings can play a clear role on the internal temperature. This was obvious in the internal

temperature D model which was 39.820C at 3:00pm in west orientation, compared to 40.340C in south face and 40.40C for external temperature. In addition to that, at 2:00pm, the north face was 39.440C with 0.50C difference. This result can have an impact in a hot climate like Mecca. However, this result was for the prefab container building. If the building materials had been changed to local or traditional materials, this might have an impact on internal temperature.

IV. CONCLUSION

In conclusion, in moderate and hot climates, the energy consumption is increased during summertime. For that reason, thinking about using passive design strategies that can mitigate the energy consumption through relying on natural conditions can mean that the building form and orientations as passive design strategies can have a positive impact. This case study found that if the form, orientation, openings and glass ratio are carefully considered during the design process, it might be affected positively. Natural ventilation should be placed ideally on the building. This study also proved that the south direction is the optimum face for both forms without openings in a moderate climate, as illustrated in Table IV, even though the D model is better than the proposed model. Moreover, with openings the west face can be classified as an optimum face too. In a hot climate, the optimum orientation for a building without and with openings is south face and north face, respectively. For the D model, the optimum orientation for building without and with openings is east face and west face correspondingly. In general, the building orientation has showed significant effects on the thermal comfort temperature inside the buildings especially in the hot climate regions. Moreover, experimental measurements should be performed in the future work to evaluate the presented numerical results in this research.

LIMITATIONS OF THE STUDY

This study has some limitations which can be addressed after the case study is actually built. Then, the internal temperature during occupancy can be assessed. In addition to that, the model in a different city can be assessed and suitable places compared for each model.

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APPENDIX

Table- III: Building forms developed in TAS EDSL

Summer day result								
Hour	External temperature (°C)_summer day	Current	A	B	C	D	E	F
15	38.4	38.4	38.36	38.39	38.45	38.32	38.4	38.49
Winter day result								
Hour	External temperature (°C)_summer day	Current	A	B	C	D	E	F
14	13.8	14.99	14.88	14.97	15.84	15.43	16.11	17.34
15	13.8	16.03	15.75	15.9	17.02	16.64	17.54	19.01
Proposed model								

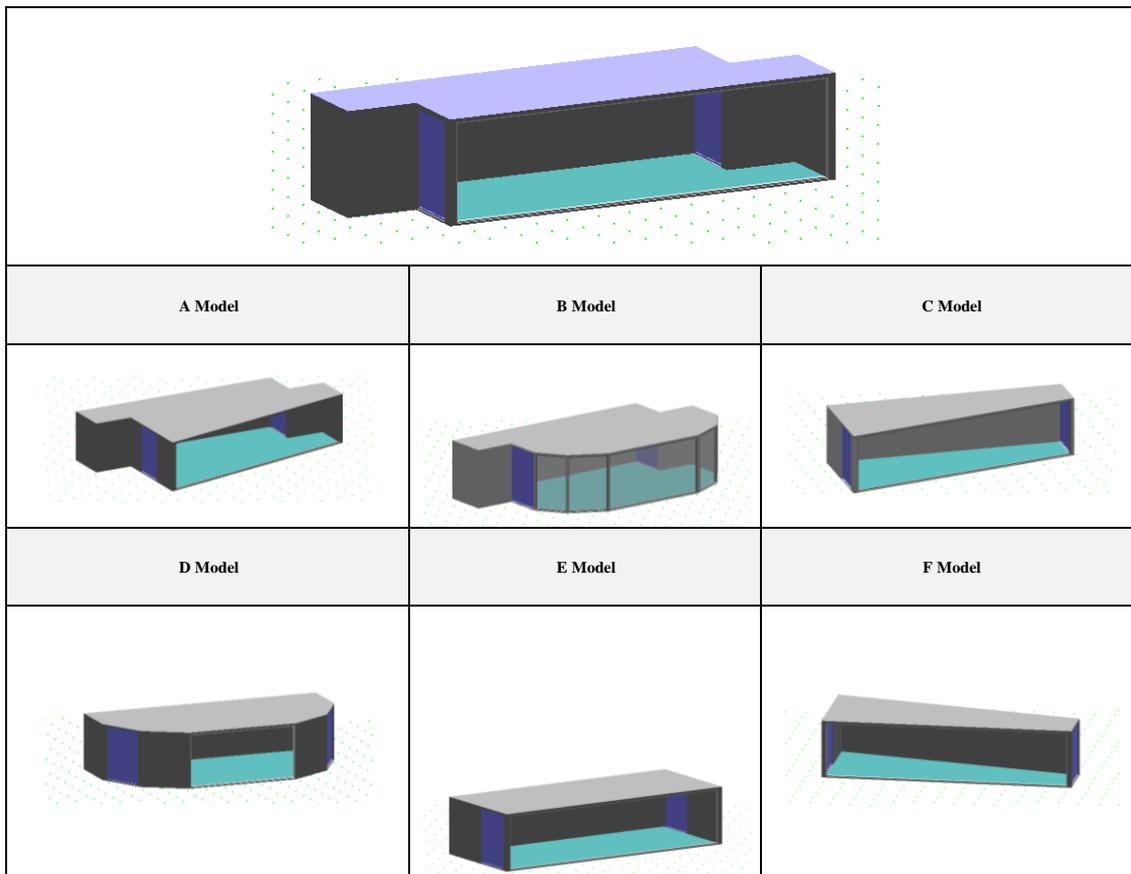


Table- IV: Building forms simulated with and without openings in TAS EDSL in moderate climate

Forms without openings									
Hour	External temperature (°C)	Current face - S dry bulb (°C)	Current - N dry bulb (°C)	Current - E dry bulb (°C)	Current - W dry bulb (°C)	D_S dry bulb (°C)	D_N dry bulb (°C)	D_E dry bulb (°C)	D_W dry bulb (°C)
212, 14	37.9	37.85	37.9	37.94	37.97	37.71	37.83	37.88	37.86
212, 15	38.4	38.4	38.44	38.44	38.6	38.32	38.36	38.38	38.43
181, 14	35.31	35.22	35.54	37.02	36.83	33.81	34.26	34.68	33.97
181, 15	35.93	35.87	36.13	36.4	38.54	34.43	34.87	34.38	35.36
Forms with openings									
Hour	External temperature (°C)	S_ Current, extra-opening	N_ Current _extra-opening	E_ Current _extra-opening	W-Current -extra-opening	S_D--extra-opening	N_D-extra-opening	E_D-extra-opening	W_D-extra-opening
181, 14	35.31	35.23	36.46	37.24	34.82	34.82	35.32	35.53	35.31
181, 15	35.93	35.82	36.32	38.54	35.42	35.43	35.44	36.69	35.93
		Current form with opening				D form with opening			
Ground floor									
Building form									

Table- IV -Building forms simulated with and without openings in TAS EDSL in a hot climate

Forms without openings									
Hour	External temperature (°C)	Current face -S dry bulb (°C)	Current - N dry bulb (°C)	Current - E dry bulb (°C)	Current - W dry bulb (°C)	D_S dry bulb (°C)	D_N dry bulb (°C)	D_E dry bulb (°C)	D_W dry bulb (°C)
181, 14	40	40.19	40.29	41.76	40.79	39.35	39.52	39.59	39.02
181, 15	40.4	40.85	40.89	41.33	41.92	39.98	40.15	39.42	39.55
Forms with openings									
Hour	External temperature (°C)	S_ Current, extra-opening	N_ Current _extra-opening	E_ Current _extra-opening	W-Current -extra-opening	S_D--extra-opening	N_D-extra-opening	E_D-extra-opening	W_D-extra-opening
181, 14	40	40.04	39.73	41.04	40.79	39.76	39.44	39.59	39.68
181, 15	40.4	40.62	40.28	41.09	41.5	40.34	40.04	39.9	39.82

AUTHORS PROFILE



Ali Alzaed was born in Saudi Arabia. He has graduated B.S in Islamic architecture from Umm Alqura University, his MSc in Advanced Sustainability of the Built Environment at University of Dundee and his PhD in environmental design (passive design). His interests are: historical and tourism building and sites in relation with sustainable dimensions, usage of recycling material as sustainable building material, passive design issues and climate change

issues

