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Influence of Orientation in Complex Building Architecture in Various Climatic Regions in Winter

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Abstract**—**It is architecturally accepted that building form and design is considered as one of the most important aspects in affecting indoor temperature. The total area of building plan might be identical, but the design will have a major influence on the total area of external walls. This will have a clear impact on the amount of heat exchange with outdoor. Moreover, it will affect the position and area of glazing system. This has not received enough consideration in research by the specialists, since most of the publications are highlighting the impact of building envelope in terms of physical heat transfer in buildings. This research will investigate the impact of orientation of various building forms in various climatic regions. It will be concluded that orientation and glazing to wall ratio were recognized to be the most effective variables despite the shape of the building. However, linear ad radial forms were found more appropriate shapes almost across the continent.

Keywords**—**Architectural building design, building form, indoor air temperature, building design in different climate.

I. Introduction

ONE of the major benefits of a building is to provide thermally comfortable environment for the users. In the recent years, there has been increased concern with respect to energy building performance by both designers and architects. Orienting building can be contemplated as an easy technique in architectural in order to achieve thermal comfort in buildings with minimum amount of energy to consume regardless of the outdoor condition of that building. This approach does not rely on mechanical means and it should to be done at the first stage of design taking into account the microclimate of the site [1]. Moreover, [2], [3] have stated that orientation is in the major substance of architectural designing knowledge. In hot regions, where temperature rises sharply, orientating building is an essential important technique [2], [4], [5]. The major apprehensiveness is that this work is considering all the regions in the world; hot, cold, moderate and tropical. Reference [3] has reported that orientation does not have substantial impact on building energy performance, and thermal insulation is the leading aspect in building fabrication and techniques. Reference [6] has stated that if the building was well oriented, this will reduce the total energy consumption by 20%. This should be underlined especially on floors exposed to sun via roof, west and east walls as they are open to sun most of time [4]. In contrast, other authors believe that orienting the building to the most appropriate way has a quite limited impact on energy building efficiency [3]. The research has investigated the implementation of orientation and thermal insulation. On top of that, [4] has revealed that the longer face of the building should be orientated to north and south.

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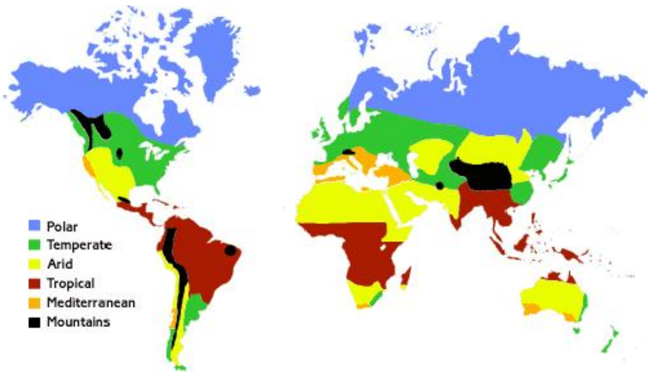

Fig. 1 Classification of world climate [1]

Thermal transmittance is a paramount element which has an influence on heat transfer in buildings [8]. Findings indicate that in hot regions, higher solar transmittance will result in worse performance. On the other hand, it is more beneficial for cold regions or cooler periods during the year. For instance, in the city of Hong Kong (cold region), the south-west orientation is the best for power generation obtained from the STPV, while south is the optimum orientation for energy performance for passive heating. In the case of Mediterranean climate, [9] has investigated the performance of single, double-glazing, and electrochromic system. It was found that electrochromic system is more suitable for west façade where south façade shows no significant difference using the same system.

II. Methodology

The present work uses the commercial energy modelling simulation TAS EDSL Software which is developed by Environmental Design Solutions Limited (EDSL) in 1989. It is considered as one of the most common used tools to predict building energy performance. The TAS version 9.4 is used to predict the Indoor Air Temperature (IAT) and the Relative Humidity (RH) of the internal space of a specified building. TAS software is used globally in many cases and applications such as [10]-[12]. The research has selected four cities located in a different climate zone across the world: Riyadh city in hot and dry, Kuala lumper in hot and humid, Rome in moderate climate, and Stockholm in cold climate. In addition, there are several architectural building shapes as presented in Table II.

This is mainly derived from building form and space presented in the book of Architecture form, space and order [13]. The feature of the building envelope has been listed in Table I.

TABLE I
BUILDING ENVELOPE MATERIALS USED AND DEVELOPED IN TAS EDSL

	Layers		Width (mm)		Conductivity (W/m².°C)		Total U value (W/m².°C)
External wall	Block		100		0.85		**0.89**
Ground	Sand		1000		1.28		**0.30**
	Concrete		125.0		0.87		
	Sand dry		1000.0		0.32		
Roof	Concrete		150		0.3		**2.49**
	Concrete screed		50		0.41		
Glazing	**Type of glazing**	**Width mm**	**Solar reflectance**	**Solar absorption**	**Solar transmittance**	**Emissivity**	**Total U value (W/m².°C)**
	Single	10.00	0.070	0.115	0.7	0.845	**5.53**

TABLE II
BUILDING SHAPES EXAMINED IN DIFFERENT CLIMATES

	1	2	3	4
CE Centralized modelling design				
L Linear modelling design				
CL Clustered modelling design				
R Radial modelling design				

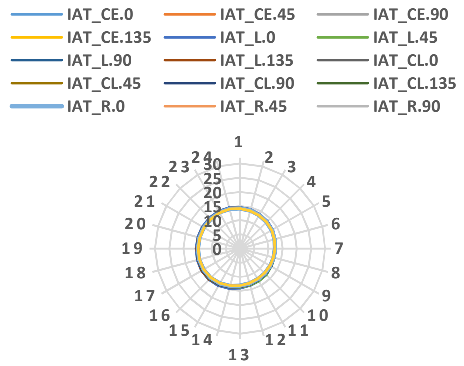

Fig. 2 IAT of designed models in Riyadh, winter

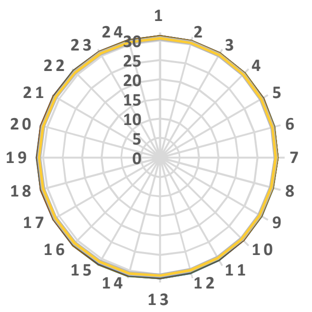

Fig. 4 IAT of designed models in Kuala, winter

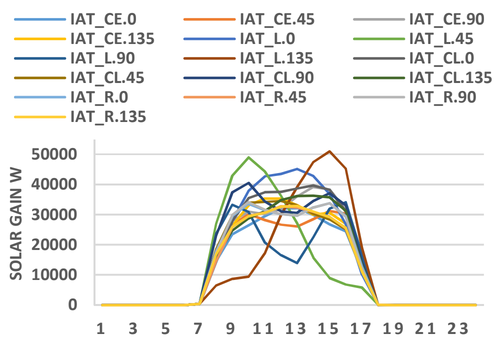

Fig. 3 SHG of designed models in Riyadh, winter

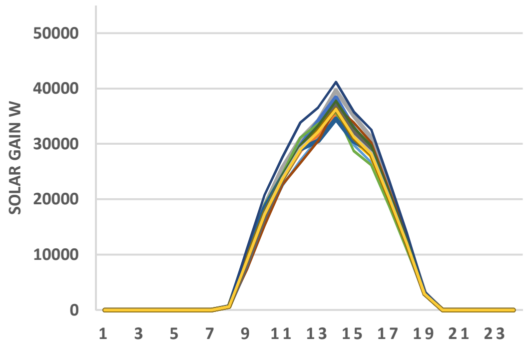

Fig. 5 SHG of designed models in Kuala, winter

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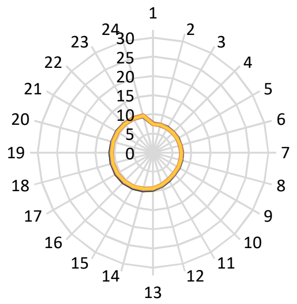

Fig. 6 IAT of designed models in Rome, winter

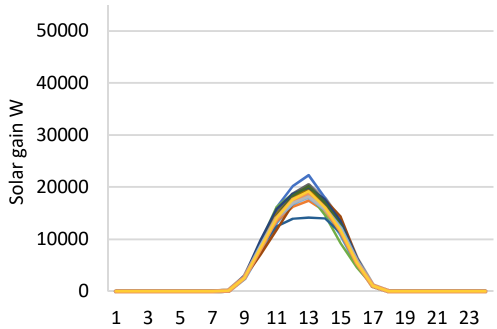

Fig. 7 SHG of designed models in Rome, winter

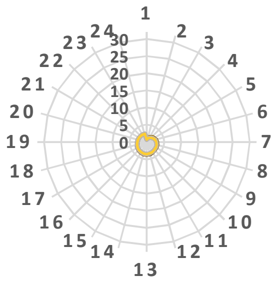

Fig. 8 SHG of designed models in Stockholm, winter

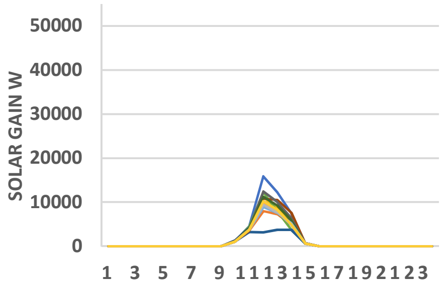

Fig. 9 IAT of designed models in Stockholm, winter

III. Discussion and Findings

In hot regions of Riyadh, linear concept with a long access that is facing north and south was the best form and orientation combination. This supports the finding of [7]; there in an increase of about 0.5 ºC when the axis of the building is facing east and west (90º). As a result, in hot regions, the axis of linear building concept should always be facing north-south although other studies revealed that triangle shape was found the best among the basic shapes [14]. However, the case study of the later reference was carried out in the hot and humid climate which might not be the same as the hot and dry climate. The hot and humid climate has relatively similar temperature swing of outdoor condition. With respect to hot and arid regions, it was found here with average performance compared to other complex shapes, especially when applying orientation. Clustered shapes are also expected to provide same features as centralised shapes. This is because they both have the huge centre elements which dominate the configuration. As radial shape has a fan-shape which rotates on itself, there is no major change expected in orientation. However, it was noticed that radial shape has an appropriate influence on the indoor air temperature. It can be concluded that linear and radial shapes are the most appropriate for the hot and dry region. However, it is important in the configuration of linear shape to allocate the building facing north and south. With respect to tropical regions, since Kuala has a similar climate as Riyadh where 'hot' climate is the dominate feature of these regions, it was found that linear shape facing north and south is the best. However, as this region has limited temperature swing in between day and night, limited impact was resulted due to using different shape configuration as well as various orientation. On the other hand, linear configuration with north and south facing in Rome was not found as effective as the case in Riyadh city. This is due to the amount of solar radiation combined with outdoor temperature. It was noticed that the impact of building shape/orientation has limited influence in Rome. However, it is recommended to use any type of building, but it has to be highlighted that external envelope has to be facing south or west orientation in order to be exposed to the sun for passive heating. In cold regions, linear shape is recommended with external wall facing east and west to maximise absorption of solar radiation. It can be noted that, in cold region, size and ordination of glazing system has the leading impact for passive design.

IV. Conclusion

This research has investigated the impact of complex architectural forms orientation on indoor air temperature in various climatic regions. It was revealed that, in hot regions, linear building forms are recommended if long axis is facing north-south. It was found here with average performance compared to other complex shapes, especially when applying orientation. Similarly, clustered shapes are also expected to provide same features as centralised shapes. Because they both have a dominating huge centre element. As radial shape has a fan-shape which rotates on itself, there is no major change expected in orientation. However, it was revealed that radial shape has appropriate influence on the indoor air temperature. Orientation and glazing to wall ratio are found to be the leading variables regardless of the shape of the building. However, linear and radial shapes were found to be the best shapes in any sort of climate. These forms provide flexibility in controlling the solar radiation to align more or less glazing system as required based on the location of the building.

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