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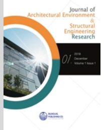

ARTICLE

Impact of glazing type and orientation on the optimum dimension of windows for office room in hot climate

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ABSTRACT

This study aims to analyse the impact of orientation and glazing type on optimum glazing size in hot climate using genetic algorithms. In winter the optimization of glazing size is obtained considering the thermal gains from solar radiation. Heating demands of the building are reduced by taking into account the free heat gains from the sun. In summer the optimization of glazing size is complex. In this case, the glazing is considered as a heat gains element. Indeed, for a hot climate, daylighting can be used as a passive strategy to reduce energy consumption. Thus an optimal window size allows avoiding problems of glare and overheating. ASHRAE proposed a Window to Wall Ratio (WWR) which is considered as the optimal glazing size that ensures minimum annual thermal loads. This coefficient neglect different parameters such as (Glazing type, the orientation and daytime). A typical office room located in Ghardaia (South of Algeria) is selected as a case study. The results show that daylight is a key factor in limiting the glazing size in hot climate. ; this study shows that the optimal window size varies with daytime. Hence, the WWR cannot be considered as optimal for the whole year.

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1. Introduction

Energy consumption of buildings has a negative impact on the environment. They are responsible for approximately 40% of the total world annual energy consumption. Most of this energy is for the provision of lighting, heating, cooling, and air conditioning. Increasing awareness of the environmental impact of CO2 and NOx emissions and chlorofluorocarbons triggered a renewed interest in environmentally friendly cooling and heating technologies [1]. Windows are generally the weakest link of buildings regarding energy conservation. Approximately one-third of the energy loss from a typical house occurs from windows [2].

In many countries, codes are regulating minimum window size to provide problems of glare and overheating. The window size is generally defined as a WWR which is related to an annual thermal loads calculation. However, this coefficient neglects several parameters that have a direct influence on thermal loads such as the orientation. Alan Pino and al [3] analyzed the thermal and luminous behavior of an office building in Santiago, for different design conditions through a year, by changing four architectural parameters that are the window to wall ratio (WWR), the outdoor solar protection devices, the type of glazing and the orientation. In winter, the window is a thermal losses element and also a source of thermal gains due to solar radiation. Taking into account this thermal gains reduce heating loads; in this case the window has an optimal size. In summer, the window is only as a thermal gains element, this means that the optimal window size is 0m². Consequently, the WWR cannot be considered as optimal for the whole year. This makes the optimization of the window size much complex for cooling-dominated climates.

The window as a thermal loads element is also a source of daylight, according to Scartzzini and al [4] daylighting strategies can contribute to curb the energy consumption of buildings, as well as the related carbon emissions, by reducing their artificial lighting and cooling needs.

In this study, the effect of using different types of glazing taking into account the daylight on optimized window dimensions of an office room (for 4 different orientations: North; South; East; West) is investigated. The Algerian standards (DTR) [5] and the Hourly Analysis Program (HAP software) are used to calculate the required hourly cooling loads (for 15th of July as an example study) for different types of glazing. Genetic Algorithm is used to determine the optimal size of the windows. The results of the hourly optimization are analyzed to evaluate the impact of a proper window optimal glazing area in a typical office room in Ghardaia city (south of Algeria) and to minimize the energy impact of windows.

2. Description of the Referenced Room

An office of an arbitrary surface area of 25.9 m², located in Ghardaia region in south of Algeria (32.49° N latitude; 3.67°E longitude), is selected for this case study. It should be pointed out that Ghardaia is located in a hot climate with specific solar radiation (Fig.1 and Fig.2).

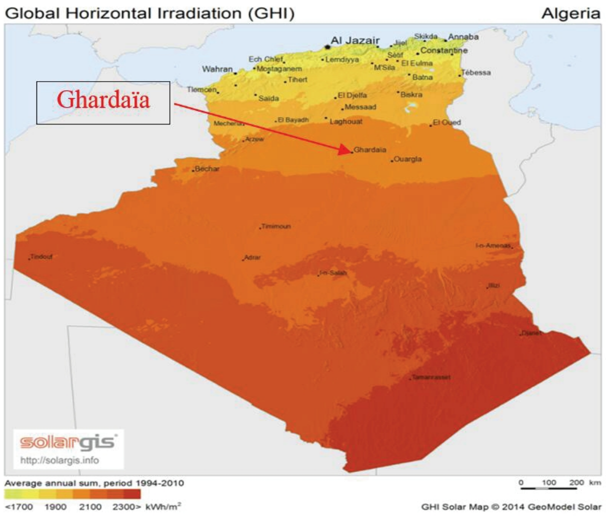

Fig 1. Solar radiation map for Algeria

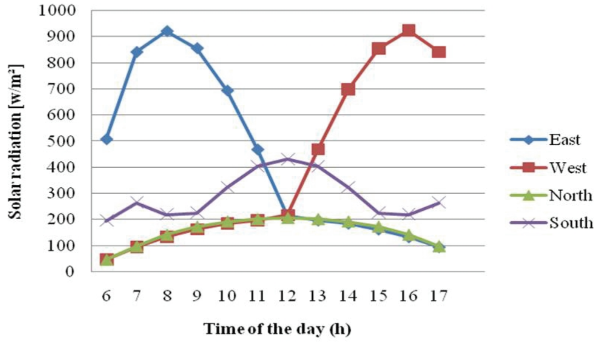

Fig 2. Solar radiation for Ghardaia region (ASHRAE method)

Figure 3 shows the schematic design of the office room. The dimension of the studied office room is 5.18 m long, 5 m wide and a height of 3 m. This model has one window placed on the external wall. Furthermore, all other opaque surfaces of the reference office room are considered as adiabatic (no heat exchanges) except the external wall. The usual external wall typology in Algeria has double wall (2 cm mortar, 15 cm brick wall, 5 cm air gap, 10 cm brick wall, 2 cm gypsum) with transmittance of 1.14 [W/m².°C]. Four orientations South, East, North and West are considered for load calculations. The optical properties of glazing are shown in Table 1. The same products have been studied by reference [6] where SF is the Solar Factor

Table 1. Glazing type characteristics

	Glazing type	SF [%]	U [W/ m².C°]	τ [%]	Thickness [mm]
Type 1	Simple glazing	0.83	5.8	0.87	4
Type 2	Double glazing classic	0.75	3.3	0.81	4(6)4
Type 3	Double solar control glazing Air	0.47	2.8	0.41	6 (12) 6
Type 4	Double solar control glazing Air	0.12	2.3	0.07	6 (12) 6
Type 5	Double glazing (Reinforced Thermal Insulation) and solar control Air	0.08	1.4	0.07	6 (16) 6
Type 6	Double glazing (Reinforced Thermal Insulation) and solar control Argon 85 %	0.37	1.2	0.40	6 (16) 6
Type 7	Double glazing (Reinforced Thermal Insulation) and solar control Argon 85 %	0.08	1.2	0.07	6 (16) 6
Type 8	Double glazing (Reinforced Thermal Insulation) and solar control Argon 85 %	0.17	1.1	0.18	6 (16) 6
Type 9	Double glazing (Reinforced Thermal Insulation) and solar control Argon 85 %	0.08	1.1	0.07	6 (16) 6

[%], U is the thermal transmittance [W/m².°C] and τ is the luminous transmittance of the glazing [%]. Furthermore, these types of glazing are as commonly used in the Algerian building construction industry.

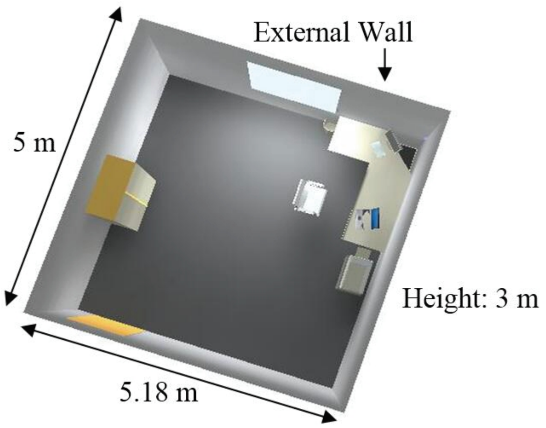

Fig 3. Schematic design of the office room

In this study, the cooling setpoint is considered equal to 26ºC. Only cooling load of the glazing, the luminaires, and the external wall are considered. For a standard office room, the internal illuminance level is equal to 500 lux. For uniform control of the illuminance Spot luminaires has been chosen with unitary luminous flux of 1300 lm and electrical power of 11.6 w.

3. Methodology for Cooling Loads Optimization

For the total thermal loads calculation, the method given by the Algerian Standards DTR [5] is used. However, the mathematical models for thermal loads calculation used in the Algerian Standards are simplified. For accuracy purposes the Carriers' method implemented by the Hourly Analysis Program (HAP) is used to recalculate the total thermal loads considering the optimal parameters obtained by the Genetic Algorithm. As the cooling loads are calculated on hourly basis, the ASHRAE [7] method is used to calculate solar irradiation intensity taking into account daytime for Ghardaia region. The objective function (Qt) to optimize is the total cooling loads due to glazing ($Q_{glazing}$), the external wall ($Q_{external\ walls}$) and the artificial lighting installation ($Q_{luminaires}$) that is:

$$Qt = Q_{luminaire} + Q_{glazing} + Q_{external\ walls}, \qquad (1)$$

While satisfying an equality constraint which is expressed as follow:

$$E_{luminaires} + E_{natural} = 500 \text{ lux}, \qquad (2)$$

$E_{luminaires}$ is the illumination level ensured by the electric lighting installation, $E_{natural}$ is the natural illumination level ensured by the daylight. The internal illuminance level (Ei) calculation in the office room was carried out using the daylight factor DF Eq.3 The daylight factor method has been adopted by the C.I.E. (International Commission on Illumination) and is therefore internationally used [8]. In the formula for Daylight Factor calculation, the Orientation Factor (OF) is fixed (average value over a year) [9]. However, in the present work the Orientation Factor was not taken as fixed. Indeed its value varies with daytime and orientation and introduced in Eq.3 to consider the case of clear sky.

$$DF = [(Ag \times \tau \times M \times \theta \times OF) / At \times (1-R^2)] = (Ei / Ee) \times 100 \qquad (3)$$

Where Ag is the glazing area of the window; t is the luminous transmittance of glazing; M is the maintenance correction factor M=90% (clean space); q is Vertical angle of visible sky from the center of the window q=90° (no obstacles); OF is orientation factor for glazing; At is the total area of room-surfaces; R² average reflectance of all room-surfaces R²=0.5 (clear interal surfaces); Ei is the required illuminance (500lux recomanded by the standards for office room) and Ee is the outside illuminanc on horizontal surface given by the method of reference [10].

The solution methodology is illustrated by the flowchart as depicted by Figure 3:

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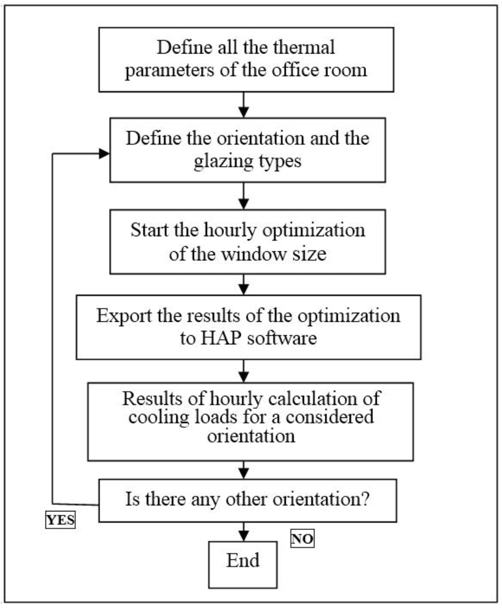
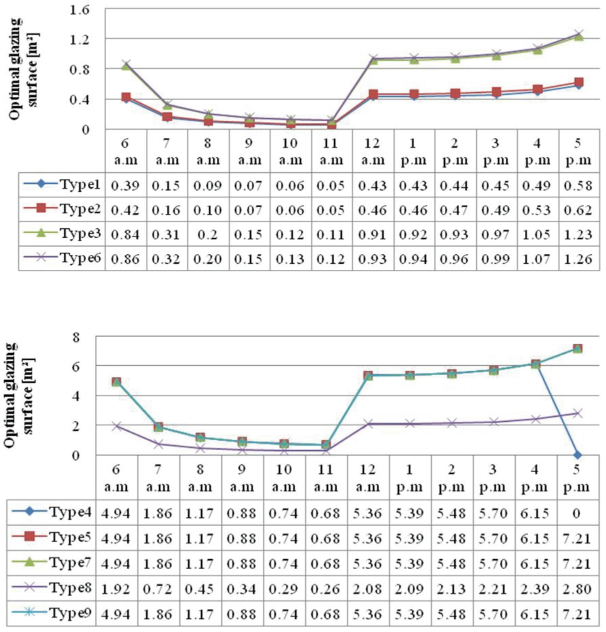


Fig 4. Structure of the proposed methodology

For the Genetic Algorithm optimization, the initial population ranges from 0 to 12 m². The number of generation is 100. The population is taken 50 individuals. The crossover and mutation fractions are respectively 80% and 10%.

4. Results

The cooling loads optimization for different type of glazing and orientations are depicted in Fig. 5, 6, 7, 8, 9, 10, 11 and 12:



	6 a.m	7 a.m	8 a.m	9 a.m	10 a.m	11 a.m	12 a.m	1 p.m	2 p.m	3 p.m	4 p.m	5 p.m
◆ Type1	0.39	0.15	0.09	0.07	0.06	0.05	0.43	0.43	0.44	0.45	0.49	0.58
■ Type2	0.42	0.16	0.10	0.07	0.06	0.05	0.46	0.46	0.47	0.49	0.53	0.62
▲ Type3	0.84	0.31	0.2	0.15	0.12	0.11	0.91	0.92	0.93	0.97	1.05	1.23
× Type6	0.86	0.32	0.20	0.15	0.13	0.12	0.93	0.94	0.96	0.99	1.07	1.26

	6 a.m	7 a.m	8 a.m	9 a.m	10 a.m	11 a.m	12 a.m	1 p.m	2 p.m	3 p.m	4 p.m	5 p.m
◆ Type4	4.94	1.86	1.17	0.88	0.74	0.68	5.36	5.39	5.48	5.70	6.15	0
■ Type5	4.94	1.86	1.17	0.88	0.74	0.68	5.36	5.39	5.48	5.70	6.15	7.21
▲ Type7	4.94	1.86	1.17	0.88	0.74	0.68	5.36	5.39	5.48	5.70	6.15	7.21
× Type8	1.92	0.72	0.45	0.34	0.29	0.26	2.08	2.09	2.13	2.21	2.39	2.80
✳ Type9	4.94	1.86	1.17	0.88	0.74	0.68	5.36	5.39	5.48	5.70	6.15	7.21

Fig 5. Variation of the optimal glazing surface for each type of glazing according to the time (East orientation)

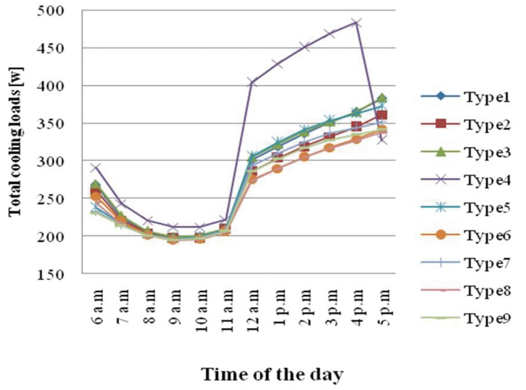
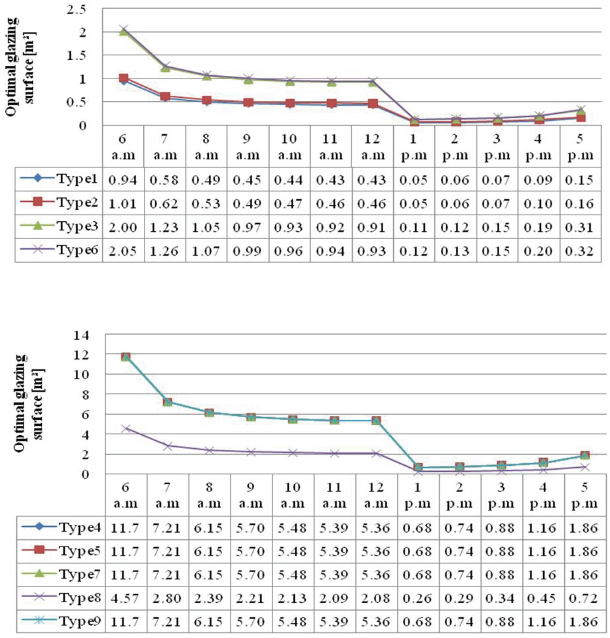


Fig 6. Variation of the total cooling load for different type of glazing (East orientation)



	6 a.m	7 a.m	8 a.m	9 a.m	10 a.m	11 a.m	12 a.m	1 p.m	2 p.m	3 p.m	4 p.m	5 p.m
◆ Type1	0.94	0.58	0.49	0.45	0.44	0.43	0.43	0.05	0.06	0.07	0.09	0.15
■ Type2	1.01	0.62	0.53	0.49	0.47	0.46	0.46	0.05	0.06	0.07	0.10	0.16
▲ Type3	2.00	1.23	1.05	0.97	0.93	0.92	0.91	0.11	0.12	0.15	0.19	0.31
× Type6	2.05	1.26	1.07	0.99	0.96	0.94	0.93	0.12	0.13	0.15	0.20	0.32

	6 a.m	7 a.m	8 a.m	9 a.m	10 a.m	11 a.m	12 a.m	1 p.m	2 p.m	3 p.m	4 p.m	5 p.m
◆ Type4	11.7	7.21	6.15	5.70	5.48	5.39	5.36	0.68	0.74	0.88	1.16	1.86
■ Type5	11.7	7.21	6.15	5.70	5.48	5.39	5.36	0.68	0.74	0.88	1.16	1.86
▲ Type7	11.7	7.21	6.15	5.70	5.48	5.39	5.36	0.68	0.74	0.88	1.16	1.86
× Type8	4.57	2.80	2.39	2.21	2.13	2.09	2.08	0.26	0.29	0.34	0.45	0.72
✳ Type9	11.7	7.21	6.15	5.70	5.48	5.39	5.36	0.68	0.74	0.88	1.16	1.86

Fig 7. Variation of the optimal glazing surface for each type of glazing according to the time (West orientation)

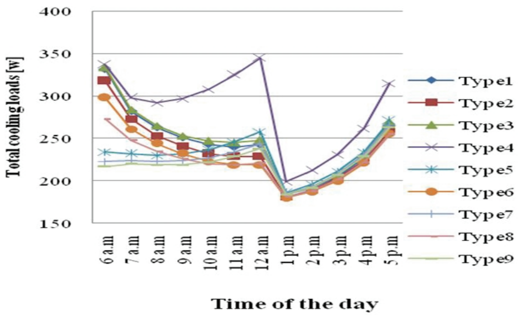


Fig 8. Variation of the total cooling load for each type of glazing (West orientation)

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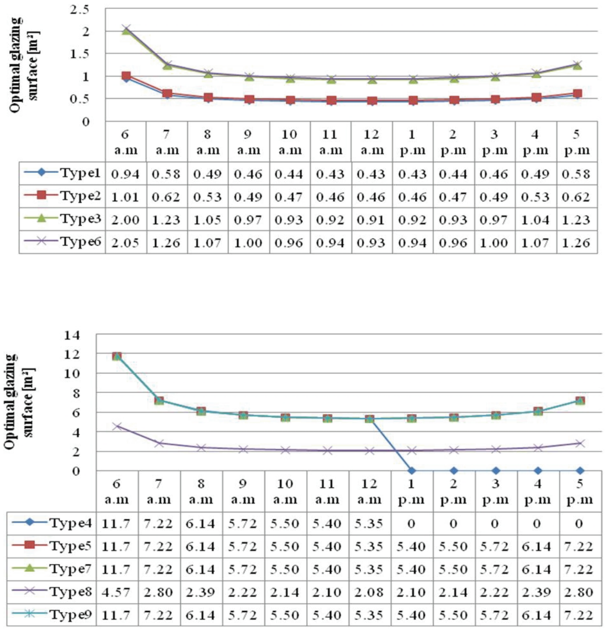

Fig 9.variation of the optimal glazing surface for each type of glazing according to the time (North orientation)

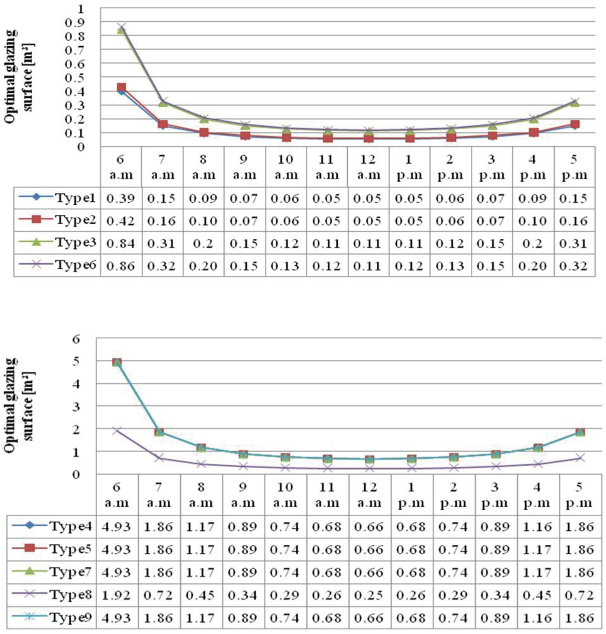

Fig 11. Variation of the optimal glazing surface for each type of glazing according to the time (South orientation)

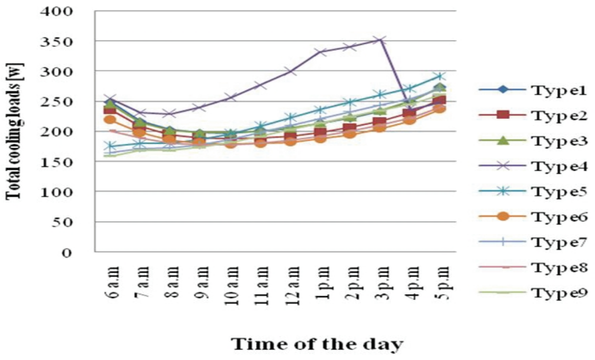

Fig 10. Variation of the total cooling load for each type of glazing (for North orientation)

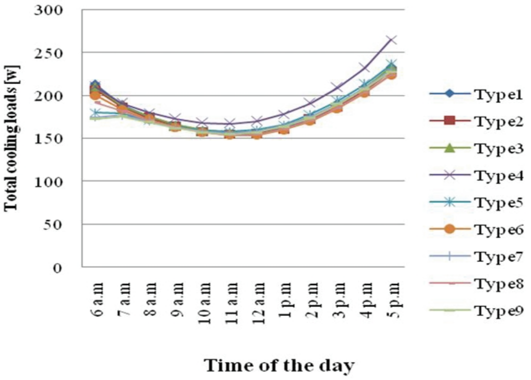

Fig 12. Variation of the total cooling load for each type of glazing (South orientation)

5. Discussion

From previous work, it has been found that the optimal glazing surface calculation was related only to orientation, glazing types. However, in this study orientation, glazing types, daytime and clear sky have been considered. From the obtained results it can said that:

For East Orientation, the optimal glazing size decreases for all glazing types (6 a.m to 11 a.m). This is due to the high solar radiation intensity. From 12 a.m to 5 p.m, the optimal glazing size increases (the external wall is in shade). The glazing types 1, 2, 3 and 6 give the minimum of optimal glazing area than glazing types 4, 5, 7, 8 and 9. The glazing type 4 gives a maximum of total cooling loads compared to all the other glazing types, which means that this glazing type is not adequate for this orientation.

At 5 p.m the optimal glazing size for glazing type 4 is equal to 0 m² (in relation to a minimum cooling load). This can be justified by the fact that the heat transmission from the glazing is higher than daylighting transmission, because the glazing has a high thermal transmittance and a low luminous transmittance.

For West Orientation the optimal glazing size increases for all glazing types (6 a.m to 12 a.m) at this time the glazed area is in shade. From 1 p.m to 5 p.m, the optimal glazed size decreases, this is due to the high solar radiation intensity. The glazing types 1, 2, 3 and 6 give a mini-

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mum of optimal glazing area than glazing types 4, 5, 7, 8 and 9.

The glazing type 4 gives a maximum of total cooling loads compared to all the other glazing types, which means that this glazing type is not adequate for this orientation.

For North orientation, the optimal glazing surface is the largest compared to all the other orientations. For this orientation the glazing area is in shade all the daytime. The glazing types 1, 2, 3 and 6 give a minimum of optimal glazing area than glazing types 4, 5, 7, 8 and 9. From 1 p.m to5 p.m, the optimal glazing size for glazing type 4 is equal to 0 m², this can be justified by the fact that The heat transmission from the glazing is higher then daylighting transmission, because the glazing has a high thermal transmittance and a low luminous transmittance.

The glazing type 4 gives a maximum of total cooling loads compared to all the other glazing types, which means that this glazing type is not adequate for this orientation.

For South orientation, the optimal glazing size is the lowest compared to those obtained considering the other orientations. In this case the glazing is permanently exposed to the sun. The glazing types 1, 2, 3 and 6 give a minimum of optimal glazing area than glazing types 4, 5, 7, 8 and 9.

The glazing type 4 gives a maximum of total cooling loads compared to all the other glazing types, which means that this glazing type is not adequate for this orientation.

It is shown from the above analysis that the optimal glazing size depends on daytime, solar radiation intensity, orientation and glazing types.

The optimal glazing size increases when the luminous transmittance of the glazing decreases while giving a minimum of cooling loads.

Finally, it can be said that for hot climate, glazing with high thermal and luminous performances should be used in the construction industry.

6. Conclusion

This study evaluates the influence of daylight on optimized glazing size in an office room in hot climate. Unlike the Wall to Window Ratio (WWR) method for glazing surface calculation, this study shows that the optimal window size depends on daytime, orientation, the glazing type and solar radiation intensity. In fact, the glazing type and room orientation have a large effect on cooling load when optimum dimension of glazing is considered under a clear sky. The results show also that daylight is a key factor in limiting the glazing size while having a minimum of cooling loads. Indeed, the choice of an adequate glazing type allows reducing cooling loads and increasing the window size. This result indicates that there is a significant effect of daylight on optimizing window size to reduce the energy consumption of an office room located in a hot climate.

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