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Assessment of an office building glazed façade impact upon energetic consumption and environment under semi-arid climate in Algeria

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ABSTRACT/RESUME

Abstract: *The building sector is considered as a highly energy-consumption sector and a source of pollution by the emission of greenhouse gases, which raises the challenge of reducing energy consumption at the source. This energy essential to ensure the well-being in buildings, depending on the characteristics of the components constituting the building, mainly the characteristics of the envelope that can have significant consequences on its energy performance. For this one, wrong choices can lead to unexpected failures of which the impact on building energy consumption over the long term will be terrifying. In office buildings, the interest of introducing enough daylight indoors pushes designers to adopt glass as the dominant component of the envelope. Despite its advantages, this building material constitutes a weak point for heat exchange between the interior and exterior because of its low insulating capacity. The latter needs to be controlled to prevent heat loss and reduce the need for heating and air conditioning. The main objective of this work is to investigate the thermal behavior, energetic and environmental impact of a glazed façade of an office building located in the region of Oum El Bouaghi (Algeria) characterized by semi-arid climate. To carry out this study we analyzed the effect of the fully glazed external wall on thermal comfort and energy consumption in landscaped office space at the building case of study. In addition, a comparison between different glazing systems proposed for improvement is provided to find a compromise between sufficient natural lighting and acceptable thermal comfort level. Also, an environmental study was conducted to define the environmental balance of the heating and cooling loads before and after the glazing system improvement proposals. The numerical simulation is carried out on the TRNSYS V17 software whose model has been validated by the results of the in-situ measurements taken on three consecutive days of the summer period of the year 2019.*

I. Introduction

The building sector consumes about 40% of energy and contributes to greenhouse gas (GHG) emissions. Unfortunately, in the vast majority of constructions, energy efficiency is not sufficiently taken into account in buildings production, which leads to an unjustified abuse of energy consumption, especially for heating and cooling. To improve such situation, there must be given a greater priority to tools and methods that allow to optimize indoor comfort conditions at lower cost.

In recent years, various studies and research have focused on the sustainability of office buildings as well as their energy efficiency aspects. Generally, there is an agreement that such buildings consumes a lot of energy and generates significant amounts of GHGs. Sustainability requirements have developed a global reflection on energy and climate analysis.

The challenge of modern times for the environment is to achieve sustainable, comfortable and energy efficient office buildings [1].

As a general rule, buildings energy efficiency is the result of a coherent and inter-complementary process implemented for the optimization of the technical and architectural characteristics. This includes the configuration of the envelope which occupies a very important position, given to its roles of a separator between inside and outside, also as a filter that organizes indoor environmental parameters such as daylighting, heating and ventilation [2,3]. In sum, the building skin enables to create a comfortable indoor environment, independent of the conditions of the outdoor environment to meet the requirements of comfort and ensure a pleasant internal atmosphere.

The intensive use of highly glazed facades is noticeably marking office buildings since the nineties. The idea of a “clean” façade with the transparent view was pleasant to architects, owners and occupants of those buildings [4].

Nowadays most office buildings have a similar character. In a paper online published by the American institute of architects, the « open-space » office model with its panoramic views imposes the excessive use of glazing in the construction of the envelopes to give more aesthetics and more natural light inside according to the logic « more glass, more light » [5].

However, this trend has incurred in many cases discomfort indoors (summer overheating, winter excessive depredations, glare effect) demanding an irrational recourse to energy consumption. Several studies have tried to cover the question of the impact of « highly glazed surfaces» on occupants comfort and energy consumption. However, for the purpose to optimize this latter, glazed façades might often not be the most commendable solution due to glass high thermal transmittance. This is still 5 to 8 times higher than that of modern insulated opaque walls [6].

It is well proven, that once inside, solar radiations would provoke interior overheating especially during summertime and consequently would require excessive cooling and thus the energy consumption [7].

In Algeria, office buildings architecture do not do the exception of this global trend, especially that energy efficiency is in general still not taken into account in the tertiary buildings conception, leading hence to an irrational energy consumption to ensure indoor heating and air conditioning.

By favoring the quantitative aspect and by adopting imported technologies, with any readjustment to the local environmental conditions, the tertiary sector architecture developed in the country today is at the expense of other aspects of quality, considering the "energy management" and "thermal comfort" [8].

In order to master these aspects and improve the energy efficiency indoors, the configuration of buildings envelopes need to respond to sustainable criteria that aim to maintain an acceptable thermal environment for the occupants [9].

In this context, the present work attempts to evaluate the energy consumption and thermal comfort of an office building at the University of Oum El Bouaghi, by the mean of in-situ measurements of thermal comfort parameters, togather with numerical simulations to analyze current thermal and energy performance. It is then examined the recommendations to improve indoor thermal conditions at lower cost for the study space.

II. Materials and methods

II.1. Case of study description

Larbi Ben M’hidi University is located in the north west of Oum El Bouaghi (a city in the North east of Algeria) in the highlands region. According to the Algerian building thermal regulations (DTR 3.2/4-2017) [10], the city belongs to the winter climatic and thermal zone “B” for the heating needs calculation, and to the summer zone “C”. It is characterized by a semi-arid climate. The characteristics of the chosen city are shown in Table 1.

Table 1. *Climatic characteristics of the city*

Climate zone	Dry temp (° C)	Specific humidity (g/kg)	Daytime difference (° C)	Mean Temp (° C)	Temp difference (° C)
B	37	11	15	26.5	36
C	36	11	15	29	36

This study concerns the twelve storeys office building build in 2005, dedicated to the superintendence administration. Current floors are rectangular covering each 480 square meters oriented East-west, as shown in Figure 1. The structure is in post-beam reinforced concrete and the façade, illustrated in Figure 2, contains three strips of curtain wall in strike where each band to a length of 23m and covers the height of two floors (7m). The curtain wall is composed by a glass 6mm reflective on the external side, then 12mm air gap and 5mm neutral inner glass. The transmission coefficient of this wall K = 2.9KCAL/M°C. The building is mainly occupied the day during working hours and very accessible for study. Another point that deserves to be mentioned its architecture, which reflects the constructive trend of the 2000s heavy energy consumer.

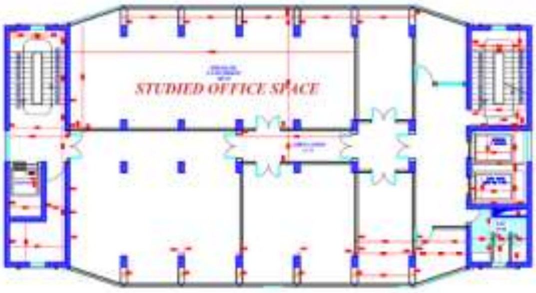

Figure 1. *Case of study floor plan.*

Figure 2. *Case of study office building.*

II.2. In-situ measurments and numirical simulation

In order to identify the main thermal problems within the study building, in-situ measurements using the (Testo VAC Smart Probe Set), shown in Figure 3, is adopted as a first step of the field investigation. The data are collected by four Smart Probe instruments allowing to register: - indoor airflow (using the hot-wire anemometer), - ambient temperature and - walls surface temperature (using the IR temperature probe) and also - relative humidity, wet-bulb temperature and dewpoint levels (by the means of a thermo-hygrometer). All the measured values are later exploited to validate the numerical model beside the operative temperature calculation with reference exclusively to the (ASHRAE 55) standard for thermal comfort criteria [11]. The numerical modelling of the office space is carried out with (TRNsys V17) software tool. More, (METEONORM 7) software generates the meteorological data adopted.

Figure 3. *Testo VAC Smart Probe Set.*

The simulation of thermal comfort in the office space is ensured by the TRNsys software. The latter makes it possible to simulate the studied local in dynamic mode. Figure 4 shows a modelling of the local under the TRNsys environment.

Figure 4. *Local modeling under V17.TRNsys environment.*

III. Results and discussion

III.1. Validation results

Figure 5 illustrates the temperature of the studied room obtained by in-situ measurements and provided by modeling. The measured temperatures are in good agreement with the simulation. Indeed, the difference between the two values varies during this day of 0.01 and 1.61°C, which represents an error of 6%. The indoor air temperature ranges from 26.4°C in the morning to 30.3°C in the afternoon. The orientation of the local (South-West) leads to an increase in temperature during the afternoon (maximum temperature obtained at 16:00h). However, the outside air temperature varies between 19.9°C (8 am) and 31.2°C (15 pm).

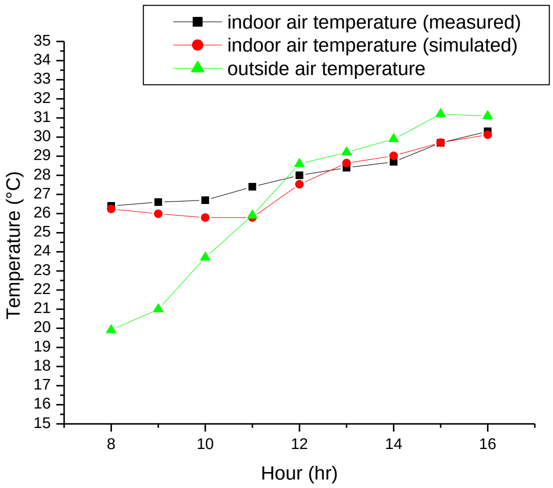

Figure 5. *Measured, simulated and outdoor air temperature.*

III.2. Office indoor thermal comfort assessment

In order to verify the thermal comfort in the studied office space, we used the operative temperature as comfort level indicator; it allows taking into consideration the indoor air temperature and the average radiant temperature of the surfaces of the indoor space. By definition, the operative temperature is the average between the indoor air temperature and the radiant temperature of the interior surfaces of the room. The ASHRAE defines the operative temperature range for a thermal comfort sensation for the winter of 20-23.5°C and in the summer of 23-26°C [12].

Figure 6 shows the variation of the operative temperature of the indoor space between November and February. The glass surface gives the possibility of increasing the amount of solar radiation entering the room. On 2879 simulated hours, 1067 hours are in the thermal comfort zone (ie 37% of thermal comfort). However, low emissivity double-glazing (as shown on the same graph) presents good thermal comfort values. Indeed, over the simulated period, only 34 values were obtained under the comfort zone which represents 1.2%. It is obvious that this type of glazing is better suited to this type of climate.

During the summer period, which extends between the month of May and September, no value is in the thermal comfort zone for both types of glazing, as shown in Figure 7. The double glazing leads to operative temperature values lower than that of the low-emissivity double glazing. The intense access of solar radiation to the room considerably increases the operating temperature of the office. The need for an air conditioning system increases with the heavily glazed rooms.

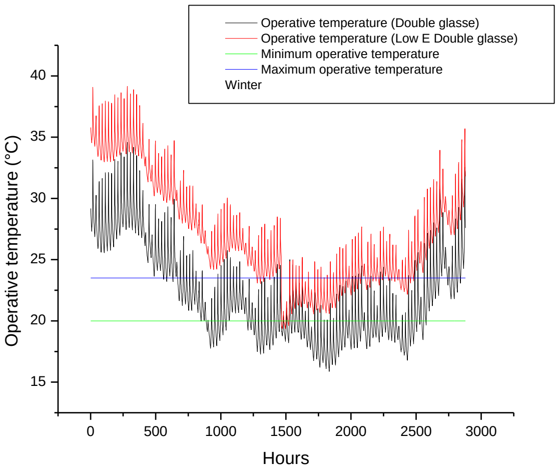

Figure 6. *Variation of the operative temperature of the office during the winter*

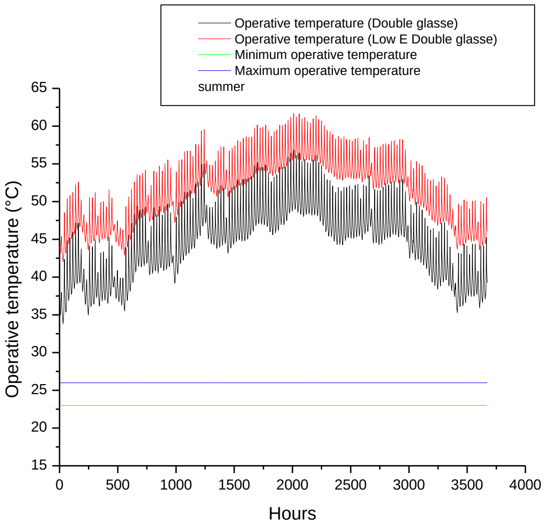

Figure 7. *Variation of the operative temperature of the office during the summer*

III.3. Energy consumption evaluation

The preceding analysis has shown that the use of double-glazing leads to a situation of thermal discomfort and consequently to the use of heating and air-conditioning systems. In order to propose the best type of glazing “adapted” to this climate, we estimated the energy consumption of the premises with three different glazing types, namely: double glazing (real case), double glazing low emissivity, double glazing low emissivity with summer protection. The simulation results, presented in Figure 8, show that the low-emissivity double-glazing can cover all the heating needs with almost zero consumption. In this case, the protection is carried out only for the summer. A reduction in heating requires from 520 kWh for the real case (double-glazing) to 32 kWh for the improved case (ie 94% reduction). However for summer period, double glazing with low emissivity has the highest cooling consumption and this is due to this thermal characteristic (low U coefficient) which prevents the heat from leaving the room to the outside and therefore its cooling. The increase compared to the real case is 4%. For this, the application of sun protection leads to a huge reduction in needs estimated at 49%.

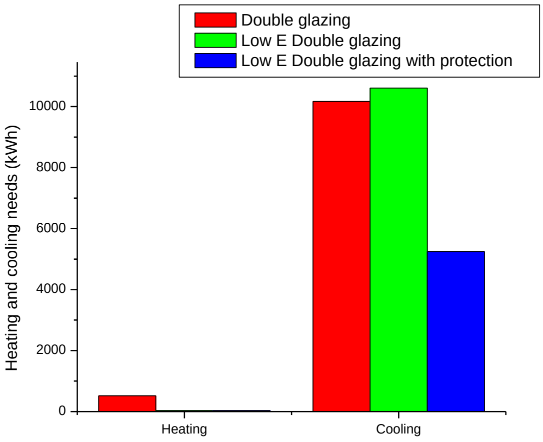

Figure 8. *Energy consumption with different types of glazing*

III.4. Environmental impact evaluation

The choice of the type of glazing has an impact on the building's energy consumption and therefore on its environmental balance. Indeed, for every kWh of electricity consumed, 0.68 kg of CO_2 is released to the atmosphere [13]. Figure 9 illustrates the variation in the amount of CO_2 for the use of each type of glazing. It is obvious that the use of single glazing leads to the ejection of the largest amount of CO_2. In the case of study, this is estimated at around 2423 kg while it decreases to 1196 kg of CO_2 according to the results of the simulation proposal (even double glazing with low emissions).

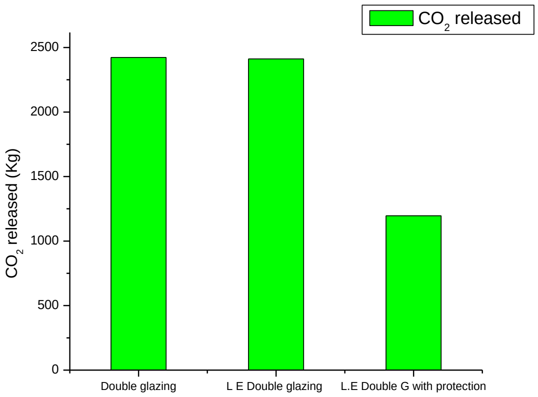

Figure 9. *Quantity of CO2 emitted to the atmosphere for each type of glazing*

IV. Conclusion

The use of entirely glazed facades especially in office buildings is widespread in Algerian cities regardless of their geographical location. However climate diversity from temperate Mediterranean in the north to hot and arid south causes confusion. In fact, if a need for natural lighting can be used as an argument for such architectural trend, other serious interior environmental problems are just highlighted. Then, the use of such a construction tool must be adopted taking into account a set of criteria. For instance, an accurate estimation of the effective energy consumption necessary to unsure thermal comfort (heating and cooling) cannot just be omitted. In this sense, the main objective of this investigation was to assess the influence of glass surfaces in an office building (located in a semi-arid climate) and the internal thermal comfort incurred as well as consumption energy required. A series of measurements is carried out in order to validate the model developed under the Trnsys 17 environment. The results obtained in this work (part of a PRFU research project [14]) allow put forward some statements:

- The evaluation of the thermal comfort in the studied room shows that it is possible to reach a thermal comfort during 37% of the winter period. However, the recourse to an active heating system remains necessary.
- Thermal discomfort is recorded throughout the summer period, which leads to the conclusion that such types of walls are not too suitable in a semi-arid climate.
- The double-glazed low emissivity with argon is best suited for a semi-arid climate in winter. However, it leads to an increase in air conditioning needs during summertime.

- Sun protection applied to low-e double glazing provides a good design alternative to significantly reduce the need for air conditioning.
- The amount of CO2 emitted into the atmosphere is considerable and can be reduced by using suitable glazing such as that proposed in the simulation.

V. References

1. Delzendeh, E.; Wu, S.; Lee, A.; Zhou, Y. The impact of occupants' behaviours on building energy analysis: A research review. *Renewable and Sustainable Energy Reviews* 80 (2017), 1061-1071.
2. Champetier, J.; Vidal, T. Anatomie de l'enveloppe des bâtiments. *Le Moniteur Paris* (1997).
3. Hegger, M. Construction et énergie: architecture et développement durable. *Presses polytechniques et universitaires romandes.* (2011).
4. Poirazis, H. Double Skin Façades for Office Buildings: Literature Review. *Lund: Division of Energy and Building Design, Lund Institute of Technology, Lund University.* (2004).
5. American institute of architects AIA (2019) https://www.aia.org/articles/195656-how-office-design-trends-are-influencing-ex. visited on 22/09/2019.
6. Marco, S.; Motuzienė, V. Energy Efficient Glazed Office Building Envelope Solutions for Different European Climates. *Mokslas - Lietuvos Ateitis* 4 (2017) 47-81.
7. Freewan, A. Impact of External Shading Devices on Thermal and Daylighting Performance of Offices in Hot Climate Regions. *Solar Energy* 102 (2014) 14-30.
8. Douidi, M. Le verre et le confort thermique dans les édifices administratifs moderne. Cas d'Oran – Algérie. *Centre de Recherche en Anthropologie Sociale et Culturelle* (2012) https://www.ouvrages.crasc.dz/pdfs/2012-amnagement-urbain-fr-douidi.pdf visited on 31/08/2019.
9. Gou, Z.; Siu-Yu Lau, S. Post-occupancy evaluation of the thermal environment in a green building. *Facilities* 31 (2013) 357-371.
10. DTR C 3.2/4 Document technique reglementaire: Reglementation thermique du bâtiment. *Ministere de l'habitat, de l'urbanisme et de la ville. CNERIB* Alger (2017).
11. ANSI/ASHRAE. Standard 55-2017 Thermal environmental conditions for human occupancy. *American National Standards Institute, American Society of Heating, Refrigerating and Air-Conditioning Engineers* (2017).
12. Taleghani, M.; Tenpierik, M.; Kurvers, S.; Dobbelsteen, A. A review into thermal comfort in buildings. *Renewable and Sustainable Energy Reviews.* 26. (2013) 201-215.
13. APRUE, GIZ. Guide pour une construction eco-energetique en Algerie. *Ministere de l'energie* Alger (2014).
14. Projet de recherche et de formation universitaire: Les structures rafraichissantes et leur influence sur le comportement thermique du bâtiment, 2018-2021, N00N02UN250320180003.

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