Studying the influence of shading devices on indoor thermal comfort in desert and Mediterranean climates

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Abstract. Thermal comfort is regarded as the most important issue in residential buildings. To verify the thermal performance of the envelope components used for the promotional apartments in Algeria, whether they are adapted to the hot and dry southern climate, or the Mediterranean climate, and to understand the effect of fixed and combined horizontal and vertical shading devices of different dimensions (12 cm, 25 cm, and 50 cm) on the indoor thermal comfort of these apartments, two main climatic zones have been considered in this study, the first is a desert climate of (Biskra, Ghardaïa, and Ouargla), while the second is a Mediterranean climate of (Algiers, Oran, Bari, and Naples). The methodology of this research was based on a comparative approach to the outcomes of a stay in an apartment in Biskra, which was looked at as a model for other desert and Mediterranean cities, based on the operative temperature data of different scenarios obtained through several simulations, which conducted by the use TrnSys software. The findings suggest that the double-walled hollow brick envelope causes a very severe indoor thermal environment (To<29) in dwellings located in desert regions such as Biskra, Ghardaïa, and Ouargla. In addition, the findings also suggest that shading devices are more effective for apartments located in the Mediterranean region (Algiers, Oran, Bari, and Naples) than those located in the desert region. In the desert region, the use of mechanical cooling devices in the summer period is considered the most adequate solution to ensure the occupants' thermal comfort. To identify the most optimal shading device models, future research based on the parametric simulation of kinetic shading devices is needed.

Keywords: Fixed shading devices; Indoor thermal comfort; Numerical simulation; Promotional apartment; Climate.

1. Introduction
Thermal comfort is considered one of the essential parameters in the building design process [1], where it can be a key issue in building performance [2,3] because the indoor thermal conditions are rarely stable due to the interaction between the building envelope [4], climate and occupancy [5]. This is the reason why the research on optimal indoor thermal conditions of buildings has become a priority necessity, and this is to ensure the comfort of occupants and to minimize the energy consumption of
the building at the same time [6,7]. In the scientific literature, the theories of thermal comfort in workplaces during the day are widely studied [8], and even in residential environments, however, few researches have been carried out to assess the thermal comfort of residential buildings in the North African countries.

In Algeria, there are two main regions that are characterized by two different climates which are the northern region characterized by a Mediterranean climate and the southern one with a desert climate [9]. The building sector in this country consumes about 43% of total energy consumption [10], which is similar to the building energy consumption of the European Union, and the United States (40%) [11], therefore, many researchers believe that the building construction sector is the main source of greenhouse gas emissions [12]. In Algeria, the building sector consumes the largest part of energy compared to that consumed by the transport sector 36%, and industry 21% [13]. Moreover, residential buildings in the southern regions consume approximately 75-80% of the total electrical energy during the hot period, from the beginning of May to the end of September [14], because the building policy in southern Algeria is similar to that of the northern ones [9] despite having different climates. This building policy causes serious economic problems in Algeria, which has been obliged to follow an austerity policy since the beginning of 2016, due to the decline in oil prices. Therefore, this situation should not be overlooked.

The residential buildings in Algeria have become energy-intensive, because the occupant is constantly to ensure or improve the comfort of his apartment by using non-renewable energy sources, where he resorts to heating in the winter, and the air conditioner in the summer. That is why the main priorities in the design and operation of buildings must be human comfort and energy efficiency [15], where the various components of the building envelope (walls, windows, and roof) must be the key to minimizing energy demand and to ensure the indoor thermal comfort at once [16]. For this, architects must understand and control the interaction between these architectural components, and the environment (indoor and outdoor), from this, the climate is considered as an imperative factor in determining design parameters such as building orientation and building envelope [17]. This opens the need to assess the indoor thermal performance of residential buildings in Algeria to invite decision-makers to review the construction laws that require architects to use the same building materials for the different climatic zones of this country, considering the climate as a requirement, and passive design techniques as a solution [18], to improve the indoor comfort level of residential buildings, which subsequently minimizes the energy consumption of this sector.

The main objective of this research is to understand the effect of shading devices on the indoor thermal comfort of apartments in different climatic zones, such as Biskra, Ghardaïa and Ouargla (Algerian desert climate), Algiers and Oran (Algerian Mediterranean climate), and Bari and Naples (Italian Mediterranean climate). It also aims to verify the thermal performance of the envelope components used in the construction of apartments in Algeria, if they are more adapted to the hot and dry climate of the south, the Mediterranean climate of northern Algeria, or the Mediterranean climate of southern Italy.

2. Methodology

This research is based on a comparative approach between different scenarios of shading devices size and climate of the apartment in different orientations such as north, south, east, and west orientation, based on a quantitative evaluation of indoor thermal comfort. For this, the collective promotional apartment [19] was considered as a case study, where the choice was on a typical living room of an apartment, oriented to the four cardinal directions, of the city 110 apartments that are located in the city of Biskra, Figure 1. The constructive system of these residences is a "post-beam" structure, of a height of 2.9 m for each floor. In addition, five cities were also considered with two different climates (desert and Mediterranean climate) to study the effect of climate on the indoor comfort level of this type of housing, and to verify the thermal performance of the components of the envelope of the promotional apartments in the hot and dry climate as those in the city of Biskra [20], where the cities of Ghardaïa and Ouargla were chosen for the Algerian desert climate, Algiers and Oran for the
Algerian Mediterranean climate, while Bari and Naples were obtained for the Italian Mediterranean climate (See Figure 1).

![Figure 1. Presentation of case studies.](image)

In this study, some shading device scenarios used in the study of Ali Ahmed [17,21], and Berkouk et al. [22,23] were combined to verify and confirm the results of these previous studies. The different scenarios of combined shading devices (vertical and horizontal) were; an apartment with no shading device (0 cm), with a device of (12 cm), and of (25 cm), and an apartment with a shading device of (50 cm) size. Furthermore, the acceptable thermal sensation of architectural spaces occupants is greatly affected by environmental factors [21], as these factors have a direct impact on the physiological state of the human being in architectural spaces [24]. Regarding thermal comfort, the temperature is considered the most important environmental parameter [5], so the indicator that was considered in this research was the operative temperature, which is expressed as the relationship between air temperature and radiant temperature, including the thermal exchanges by convection and radiation between the occupant and its environment [25], and ignoring the effect of humidity and air movements. In the scientific literature, numerical simulation is thought of among the most advanced tools for assessing thermal comfort, because it can be applied to buildings in different climates [24]. For this reason, the numerical simulation based on the study of the operative temperature as a tool for this study to evaluate the indoor thermal comfort of apartments through the use of TRNSYS software as the main research tool.

![Figure 2. Working process.](image)

The process of this work is demonstrated in Figure 2. The modeling was performed by ArchiCAD (for 2D) and Google SketchUp software (for 3D). The three-dimensional models were defined and subdivided into thermal zones by applying TrnSys plug-ins so that the volume was exported to TRNSYS studio software. It is noted that the same scenario of internal inputs was considered in TRNBuild and Multizone Building modeling with Type 56 for the different scenarios. It is also interesting to note that the same occupancy scenario was also used for the different models, where this
study was based on a five-person occupancy scenario for each apartment. Hence, the infiltration, the occupants’ metabolic energy and the thermal resistance of the clothes were fixed, respectively, at 0.8 vol/h, 1.2 met, and 1.5 clo. To avoid the air currents effect, the window closure was considered as the scenario of the window condition. The same internal gains of equipment were obtained, such as a TV of 540 KJ/h and a computer, while the lighting power was set by four lamps.

### Table 1. Envelope materials and their thermal characteristics [26].

| Walls / Floors          | Materials           | Thermal conductivity λ, [W/m.°C] | Thickness, [m] |
|-------------------------|---------------------|----------------------------------|----------------|
| Exterior wall           | Cement plaster      | 1.4                              | 0.015          |
|                         | Hollow brick        | 0.5                              | 0.15           |
|                         | Air blade           | 0.31                             | 0.05           |
|                         | Hollow brick        | 0.5                              | 0.1            |
|                         | Gypsum plaster      | 0.35                             | 0.015          |
| Interior wall           | Gypsum plaster      | 0.35                             | 0.015          |
|                         | Hollow brick        | 0.5                              | 0.1            |
|                         | Gypsum plaster      | 0.35                             | 0.015          |
| Low and intermediate floors | Gypsum plaster | 0.35                             | 0.015          |
|                         | Hollow body + compression slab | 1.45         | 0.2             |
|                         | Mortar              | 1.4                              | 0.04           |
|                         | Flooring            | 2.1                              | 0.06           |
| Terrace floor           | Gypsum plaster      | 0.35                             | 0.015          |
|                         | Hollow body + compression slab | 1.45         | 0.2             |
|                         | Isolation           | 0.1                              | 0.04           |
|                         | Slope shape         | 1.15                             | 0.04           |
|                         | Watertightness      | 0.04                             | 0.03           |

Regarding the integration of building materials, the external walls were considered double walls of hollow bricks (see Table 1). This constrictive system of walls consists of a first wall of bricks of 15 cm towards the outside, and another of bricks of 10 cm to the inside, with a separation of a 5 cm air gap. They are coated with cement plaster on the external side and plaster with a thickness of 1.5 cm on the internal side. In addition, the interior walls are considered simple brick walls of 10 cm, while the ceiling and planks were hollow slabs. In addition, the integration of weather data of the different selected cities (Biskra, Ghardaïa, Ouargla, Algiers, Oran, Bari, Naples) which were exported from the Meteonorm 7 software in TMY2 format was done using the TRNSYS type 109 software. Finally, the statistical study was carried out mainly by SPSS software "Statistical Package for the Social Sciences".

3. Results

3.1. Comparison of the thermal environment of different scenarios of housing with no shading devices

To verify whether the promotional housing is suitable or not in the desert climate like that of the city of Biskra, several simulations of the operative temperature have been made in Biskra, Ghardaïa, and Ouargla to take an idea on the thermal performance of the constructive system of the double wall in hollow brick used in these apartments in the desert climate of southern Algeria, and simulations were also made in Algiers, Oran, Bari, and Naples to check the effectiveness of this system in the north of the country and the Mediterranean climate in general. Table 2 shows the cumulative percentages of operative temperature hours of different desert and Mediterranean climate scenarios of different housing without shading devices. While Figure 3 shows the hour’s percentages of three comfort zones according to the operative temperature of various scenarios of these apartments. From Figure 3 and Table 2, it is observed that the values obtained from the simulated housing in cities that are characterized by a desert climate (Biskra, Ghardaïa, and Ouargla) are included between the two discomfort zones due to the heat: the discomfort zone (26<To<29), and the very discomfort zone defined as thermally aggressive (To<29), concerning the various orientations (North, South, East, and West). Where the hours’ percentages of the thermally aggressive zone are higher than those of the discomfort zone. The hours’ percentages of the very discomfort zone are between 91.75% in the south,
and 97.87% in the east, concerning the housing of the city of Biskra, while those located in Ghardaïa are characterized by hours’ percentages vary between 79.05% in the south, and 88.72% in the east, while the percentages of hours that vary between 99.95% in the south and 97.37% in the East characterize the housing located in Ouargla.

In addition, the results of the scenarios of the housing estates located in Mediterranean cities (Algiers, Oran, Bari, and Naples), and which do not have any shading device, are, however, similar between them, and they are good results when compared to those located in the desert climate. Where, the percentages of hours of the comfortable zone (23<To<26) vary between 34.56% in the north and 22.10% in the west concerning the estates of Algiers; between 17.18% in the south, and 22.38% in the west for those located in Oran; between 34.56% in the south, and 25.48% in the east for the housings located in Bari; and between 34.10% in the north and 20.65% in the east, concerning those of Naples.

**Figure 3.** Percentage of comfort zone hours according to the operating temperature of different climate scenarios of various apartments without shading devices (0 cm).

**Table 2.** Cumulative percentage of hours of the operative temperature of different climate scenarios of various apartments without shading devices.

| Orientations | Operative temperature | Biskra | Ghardaïa | Ouargla | Alger | Oran | Bari | Naples |
|--------------|-----------------------|--------|----------|---------|-------|------|------|--------|
| **North**    | 23 [C°]               | 0,00   | 0,00     | 0,00    | 10,15 | 22,05| 17,89| 10,33  |
|              | 26 [C°]               | 0,00   | 0,00     | 0,00    | 44,71 | 40,62| 51,91| 44,43  |
|              | 29 [C°]               | 8,11   | 10,60    | 2,18    | 97,29 | 98,51| 98,70| 99,91  |
| **South**    | 23 [C°]               | 0,00   | 0,00     | 0,00    | 10,37 | 23,55| 17,48| 10,38  |
|              | 26 [C°]               | 0,00   | 0,00     | 0,00    | 44,61 | 40,73| 52,04| 42,95  |
|              | 29 [C°]               | 8,25   | 11,28    | 2,63    | 96,06 | 97,46| 98,29| 98,51  |
| **East**     | 23 [C°]               | 0,00   | 0,00     | 0,00    | 2,95  | 0,14 | 8,95 | 3,85   |
|              | 26 [C°]               | 0,00   | 0,00     | 0,00    | 25,24 | 21,97| 34,43| 24,50  |
|              | 29 [C°]               | 2,13   | 2,95     | 0,05    | 85,29 | 85,02| 93,72| 89,44  |
| **West**     | 23 [C°]               | 0,00   | 0,00     | 0,00    | 6,11  | 0,72 | 9,36 | 5,44   |
|              | 26 [C°]               | 0,00   | 0,00     | 0,00    | 28,21 | 23,10| 35,93| 28,53  |
|              | 29 [C°]               | 3,12   | 5,11     | 0,27    | 85,50 | 84,24| 89,14| 89,72  |

In addition, the results of the scenarios of the housing estates located in Mediterranean cities (Algiers, Oran, Bari, and Naples), and which do not have any shading device, are, however, similar between them, and they are good results when compared to those located in the desert climate. Where, the percentages of hours of the comfortable zone (23<To<26) vary between 34.56% in the North, and 22.10% in the West concerning the estates of Algiers; between 17.18% in the south, and 22.38% in the west for those located in Oran; between 34.56% in the south, and 25.48% in the east for the housings located in Bari; and between 34.10% in the north and 20.65% in the east, concerning those of Naples.
It is also observed that the values of the operative temperature simulated in the different scenarios of the apartments located in the Mediterranean cities signal slight variations of the annual percentages of hours in the different zones of discomfort due to the heat (26°C to <29°C) for the different orientations of these apartments. Where, the percentage of uncomfortable hours due to the heat of the housings located in Algiers, Oran, Bari, and Naples, reaches an average of 53.19% (± 4.78%) for those oriented to the North, an average of 52.50% (± 4.47%) for the apartments oriented to the south, an average of 61.83% (±2.63%) for the east, and an average of 58.21% (±3.79%) for the housings oriented to the west.

3.2. Comparison of the thermal environment of different housing scenarios with shading devices

To verify the effectiveness of the shading devices in the different housing scenarios in different climates several dimensions of the shading devices were considered 12 cm, 25 cm, and 50 cm. Table 3 shows the cumulative percentages of operative temperature hours of different housing scenarios equipped with shading devices. While Figure 4 shows the hour’s percentages of three comfort zones according to the operative temperature of different scenarios of these apartments.

| Shading devices | Orientation | Operative temperature | Biskra | Ghardata | Ouargla | Alger | Oran | Bari | Naples |
|-----------------|-------------|-----------------------|--------|----------|---------|-------|------|------|--------|
| 12 cm North     | 23°C        | 0.00                  | 0.00   | 0.00     | 32.92   | 28.53 | 36.96| 31.98|
|                 | 26°C        | 4.21                  | 7.02   | 0.77     | 89.71   | 91.58 | 92.62| 92.67|
|                 | 29°C        | 27.26                 | 31.07  | 14.45    | 100     | 100   | 100  | 100  |
|                 | South       | 23°C                  | 0.00   | 0.00     | 32.74   | 27.7   | 35.36| 30.66|
|                 |             | 26°C                  | 4.12   | 7.15     | 87.18   | 89.56 | 91.25| 90.27|
|                 |             | 29°C                  | 26.76  | 30.84    | 14.59   | 100   | 100  | 100  |
|                 | East        | 23°C                  | 0.00   | 0.00     | 25.13   | 20.97 | 27.67| 23.72|
|                 |             | 26°C                  | 2.13   | 3.90     | 0.14    | 80.93 | 81.61| 86.04| 81.92|
|                 |             | 29°C                  | 21.34  | 24.50    | 11.23   | 100   | 100  | 100  |
|                 | West        | 23°C                  | 0.00   | 0.00     | 24.63   | 19.75 | 27.72| 23.96|
|                 |             | 26°C                  | 2.54   | 4.21     | 0.14    | 78.53 | 79.76| 84.34| 83.06|
|                 |             | 29°C                  | 21.61  | 24.51    | 11.28   | 100   | 100  | 100  |
| 25 cm North     | 23°C        | 0.00                  | 0.00   | 0.00     | 38.44   | 34.65 | 41.93| 37.78|
|                 |             | 26°C                  | 6.47   | 9.24     | 1.99    | 94.15 | 95.84| 95.73| 96.20|
|                 |             | 29°C                  | 32.33  | 34.51    | 17.52   | 100   | 100  | 100  | 100  |
|                 | South       | 23°C                  | 0.00   | 0.00     | 37.50   | 33.65 | 40.12| 35.97|
|                 |             | 26°C                  | 6.11   | 9.14     | 2.04    | 91.27 | 94.02| 94.61| 94.39|
|                 |             | 29°C                  | 31.66  | 34.28    | 17.12   | 100   | 100  | 100  | 100  |
|                 | East        | 23°C                  | 0.00   | 0.00     | 29.94   | 25.01 | 32.38| 28.22|
|                 |             | 26°C                  | 3.67   | 5.62     | 0.27    | 84.29 | 86.19| 90.21| 87.55|
|                 |             | 29°C                  | 24.91  | 27.77    | 12.95   | 100   | 100  | 100  | 100  |
|                 | West        | 23°C                  | 0.00   | 0.00     | 30.66   | 24.96 | 33.20| 30.38|
|                 |             | 26°C                  | 4.21   | 6.03     | 0.27    | 84.14 | 85.28| 89.54| 88.82|
|                 |             | 29°C                  | 26.31  | 27.95    | 13.18   | 100   | 100  | 100  | 100  |
| 50 cm North     | 23°C        | 0.00                  | 0.00   | 0.00     | 51.27   | 35.55 | 43.16| 36.36|
|                 |             | 26°C                  | 6.98   | 9.51     | 2.31    | 96.38 | 96.29| 96.74| 96.78|
|                 |             | 29°C                  | 33.75  | 35.60    | 18.53   | 100   | 100  | 100  | 100  |
|                 | South       | 23°C                  | 0.00   | 0.00     | 50.68   | 34.65 | 41.66| 37.91|
|                 |             | 26°C                  | 6.75   | 9.51     | 2.31    | 95.83 | 95.30| 95.73| 95.78|
|                 |             | 29°C                  | 33.02  | 35.20    | 18.21   | 100   | 100  | 100  | 100  |
|                 | East        | 23°C                  | 0.00   | 0.00     | 43.58   | 29.94 | 35.24| 31.20|
|                 |             | 26°C                  | 4.75   | 6.52     | 0.63    | 91.47 | 89.85| 92.26| 91.31|
|                 |             | 29°C                  | 26.99  | 29.71    | 14.21   | 100   | 100  | 100  | 100  |
|                 | West        | 23°C                  | 0.00   | 0.00     | 44.88   | 27.71 | 36.14| 32.65|
|                 |             | 26°C                  | 5.03   | 6.84     | 0.63    | 91.81 | 88.68| 92.03| 91.67|
|                 |             | 29°C                  | 27.90  | 30.58    | 14.21   | 100   | 100  | 100  | 100  |
Regarding the comfortable zone (23<To<26), it is observed that the apartments equipped with the different shading devices (12 cm, 25 cm, and 50 cm), and which are located in the Mediterranean cities (Algiers, Oran, Bari, and Naples) have higher average annual hours compared to the discomfort zones due to the heat (26<To<29) and (29<To). Where, the comfortable zone of the north-facing apartments in the cities of Algiers, Oran, Bari and Naples reaches, respectively, maximum numbers of hours of 56.79%, 63.05%, 55.66%, and 60.69%, for the 12 cm shading device scenario, Figure 4 (a). Also, for those oriented to the south, where they reached, respectively, the 54.44%, 61.86%, 55.89%, and 59.61% of comfortable hours for the scenario of 12 cm, Figure 4 (b). The apartments facing east in the cities of Algiers and Bari reached, respectively, 55.80% and 58.37% of annual comfortable hours for the scenario of a 12 cm shading device, while the percentages of 61.18% and 60.11% were obtained for the apartments in the city of Naples and that have a 50 cm shading device, Figure 4 (c). The percentages of comfortable hours that have been observed by the simulation of the apartments oriented to the west in the cities of Algiers, Oran, Bari, and Naples are similar, where they get 53.90%, 56.62%, and 59.10% for the scenario of 12 cm, while they reach 60.97% for the scenario of 50 cm, Figure 4 (d). However, it is observed by Figure 4 and Table 3 that the different scenarios of the housing located in the desert cities have the lowest average annual comfortable hours, compared with the hours of the discomfort zones due to hot (26<To<29) and (29<To), where they varied between 0.14% and 7.15% with a very low standard deviation of 2.43%, for the different orientations and the different scenarios of shading devices.

**Figure 4.** Percentage of operative temperature hours of different housing scenarios equipped with shading devices: (a) North, (b) South, (c) East, (d) West.
Concerning the very uncomfortable zone due to the heat (29<\(T_0\)), it is observed that the scenarios of the apartments located in the Mediterranean area have no hours in this discomfort zone all the year 0.00%, this means the effectiveness of the shading devices for the apartments located in this region. On the other hand, it is worth noting that the apartments equipped with different shading devices and located in desert cities have the highest average hours in this discomfort zone (29<\(T_0\)), compared with other zones (23<\(T_0\)<26) and (26<\(T_0\)<29), despite the fact that the shading devices cause a slight decrease in the number of hours of discomfort due to the heat, while increasing the scope of these devices from 12 cm to 50 cm. Where, the apartments oriented to the north of the city of Biskra, Ghardaïa and Ouargla reached, respectively, the maximum percentages of hours of the very uncomfortable zone with 72.74%, 68.93% and 85.55% for the scenario of 12 cm, and 65.67%, 65.49% and 82.48% for the scenario of 25 cm, and 66.25%, 64.40% and 81.47% for the scenario of 50 cm, Figure A2 (a). Also, similar results were observed for apartments facing the other orientations (South, East, West). For the South orientation, the percentages of hours of this area uncomfortable housing located in Biskra, Ghardaïa and Ouargla were, respectively, 73.24%, 69.16%, and 85.41% for the scenario of 12 cm, and they were 66.98%, 64.80% and 81.79% for the scenario of 50 cm, Figure A2 (b). While for the east orientation, the percentages of hours of the discomfort zone were, respectively, 78.66%, 75.50%, and 88.77% for the scenario of 12 cm, and they were 73.01%, 70.29%, and 87.79% for the scenario of 50 cm, for the housing located in Biskra, Ghardaïa and Ouargla, Figure A2 (c). While for the western orientation, the hours' percentages of 78.39%, 75.49% and 88.72% were observed for the scenario of 12 cm, and 72.10%, 69.42%, and 85.79% for the scenario of shading devices of 50 cm of the apartments located in Biskra, Ghardaïa and Ouargla, respectively, Figure A2 (d).

4. Conclusion and Discussions
This study consists in examining the thermal performance of the envelope components used in the construction of promotional apartments in Algeria and verifying if they are adapted to the desert climate or the Mediterranean climate. A comparative study was made in this research between the results obtained by the simulation of the operative temperatures of an apartment in Biskra, which was looked at as scenarios for the other desert cities (Ghardaïa, and Ouargla) and Mediterranean cities (Algiers, Oran, Bari, and Naples). Where the models were considered as without shading devices (0 cm), and with shading devices of different sizes (12 cm, 25 cm, and 50 cm).

Findings from this research suggest that the indoor thermal environment of apartments that have no shading devices, located in desert cities (Biskra, Ghardaïa, and Ouargla), is defined as thermally aggressive (\(T_0\)<29), where, in which it is not possible to expect the conditions of comfort and health, as well as the occupants, maybe in danger [27] as a result of high indoor temperatures. This explains why the double-wall hollow brick construction system is not suitable for hot and dry climates. In addition, the different scenarios of apartments located in Mediterranean cities (Algiers, Oran, Bari, Naples) report slight variations in the percentages of annual hours in the different zones of discomfort due to heat (26<\(T_0\)<29).

Moreover, the findings show, on the one hand, that apartments equipped with different shading devices (12 cm, 25 cm, and 50 cm) and located in Mediterranean cities have the highest comfort zone (23<\(T_0\)<26), compared to the zones of discomfort due to heat (26<\(T_0\)<29) and (29<\(T_0\)), and on the other hand, that the inhabitants of the Mediterranean apartments do not spend time in a very uncomfortable situation (29<\(T_0\)), because the annual percentage of hours in this zone is 0.00%. From this, we can deduce that the shading devices are effective for housing located in this region. In contrast, the findings show that compared to the number of hours (26 <\(T_0\) <29) and (29 <\(T_0\)) in uncomfortable areas due to heat, the annual averages of comfort hours in different scenarios of housing located in desert cities are the lowest, and although shading devices cause a slight decrease in the number of hours of discomfort due to heat while increasing the reach of these devices from 12 cm to 50 cm, the average hours of the discomfort zone (29<\(T_0\)) in the desert apartments scenarios are the highest. This explains that except for the use of a cooling mechanical system during summer, there is no other solution that can ensure thermal comfort in the desert region [28].
This study is limited in the evaluation of the effect of a single type of composite shading devices (horizontal and vertical) of different dimensions on a living room of an apartment, regarding the different orientations, however, it should be noted that to have a comfortable indoor thermal environment, it is imperative to use the right type of shading devices in the correct period and disposition [29]. Based on the findings of this study, it is believed that future research on data evaluation of parametric simulations of kinetic shading devices is needed to search for the most optimal designs of shading devices for each climate.

5. References

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