

Study of the Thermal Comfort of Autistic Children in Schools Buildings (Case study at the city of Bejaia)

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Abstract: The majority of school structures and facilities for people with reduced mobility in Algeria are marked by their lack of comfort, in particular thermal comfort, this finding is the result of poor architectural quality observed mainly in the use of certain construction materials, construction, and of the architectural devices used, which negatively influences the thermal functioning of these structures, and thus deteriorates the psychological state of its users. To face this situation, and to contribute to the improvement of the conditions of schooling of children with specific needs, the present work aims to determine the impact of the most used materials in Bejaia and the architectural devices on the thermal aspect. The article is based on the study of two schools located in the city of Bejaia. The research methodology is based on an empirical approach, first, using a questionnaire survey and through measures in situ measurements of ambient (indoor and outdoor temperatures), in order to evaluate and estimate the degree of the well-being of persons with disabilities in relation to the thermal and architectural quality of schools, and the influence of these factors on their psychological comfort. A numerical study by the dynamic thermal simulation software "ArchiWIZARD-EnergyPlus" was carried out in order to study and optimize the influence of the most used materials in Algeria and architectural devices on the thermal and energy performances as well as on the psychological comfort of people with reduced mobility in schools. The results of the research confirmed that thermal discomfort and poor architectural quality are detrimental to the psychological comfort of people (a direct relationship between physical and psychological comfort) with reduced mobility when these are not taken into account during the design. The choice of materials and architectural devices affects the level of energy efficiency as well as the thermal and psychological comfort of people with reduced mobility in school buildings.

Keywords : Thermal comfort; children; autism; schools buildings; Bejaia.

Introduction:

Architecture, like all other sciences, is confronted with the question of the existence of man, considered the main instrument that brings us closer to space and leads to architectural development, thanks to his ability to adapt to the different environments in which it lives and to its properties that other living beings do not possess (Moser, 2009). Based on research carried out in the field of neuroscience and architectural psychology, we find that the contact of man with his built environment continually influences his experience, his well-being, his activities, his sensations, and even his behavior in multiple ways (Liébard & De Herde, 2005 ; Anthes, 2009).

Therefore, man must be positioned at the heart of the design process since human-centered architecture provides solutions to problems by focusing on the context, environmental and climatic conditions, behaviors, and emotions of the occupants, this architecture always aims to positively optimize the interactions between the body and the architectural spaces as well as to design places

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that favor creativity, attention, and conviviality and which perfectly meet their requirements and above all ensure their comfort (Lavoye et al., 2015 ; Choi et al., 2016).

Comfort within a space is a complex concept to define, depending on several circumstances, on the different degrees of tolerance in the face of discomfort, but also on the plurality of the parameters that it integrates physical, physiological and psychological (Roulet, 2004 ; Moujalled, 2007). It should be noted that it also differs from one individual to another, depending on their sensory perception, an environment can be considered comfortable if it is able to provide appropriate conditions of thermal comfort, visual comfort, and air quality (Dounis & Caraiscos, 2009 ; Delzendeh et al., 2017).

The type and level of confort of a space are determined by the critères of architectural ambiance (temperature, humidity, air quality, light, noise, etc.). For example, the temperature felt inside is the key indicator of thermal comfort which constitutes one of the key stages of well-being, it is perhaps even the most decisive of the financial statements of a given construction, it is not only a summative reading of the quality of the interior atmospheres, it is also the tool which makes it possible to clearly see the quantity of energy consumed and the influence of the latter on the health and the psychological state of the occupant (Luo et al., 2016 ; Delzendeh et al., 2017). This same occupant reacts involuntarily to temperature and spends more than 80 % of its time in interior spaces (Kolokatsa et al., 2001 ; Ahmed-Memon et al., 2008). When it's hot or very cold, our heart rate quickens, our pulse is stronger, our blood pressure increases, and our cortisol levels rise, so we'll tend to feel more irritable and aggressive, but the reactions vary from individual to individual (Dounis & Caraiscos, 2009 ; Choi et al., 2016), this highlights only a small portion of the discomfort and unease that can occur when the temperature exceeds the comfort range, physiologically and psychologically, whether this either in a normal or abnormal population.

Every individual in society, regardless of their situation, age category and whether they are able to express their needs or not, has the right to live in a well-designed and comfortable space, as well as their right to education and schooling. We would like to point out that there are also space users who are not able to clearly express their needs and feelings, and who are sometimes the most affected by thermal factors people with reduced mobility (Demilly, 2014 ; Blais, 2016). The heat, humidity and air currents felt inside a space directly influence the well-being, perception and behavior that these people with reduced mobility may have in a given space (Longuepee, 2015 ; Ménaert, 2020).

Algeria has about two million people with disabilities, according to the ONS (national statistics office) of which only a minority are supported at school, while the latter is a constitutional right according to the law of OEN (orientation of education national) in structures of low architectural quality and which offer no thermal comfort; moreover, they are energy-intensive buildings par excellence. All these deficiencies lead to a deterioration of the psychological state of this fragile category. It is in this context that this research proposes to shed light on the ins and outs inherent in this category of people, which raises the following questions:

Do thermal discomfort and the absence of the architectural quality of the space have a negative influence on the psychological state of people with reduced mobility ?

Can the use of certain materials and architectural devices ensure energy and thermal performance, and improve the psychological comfort of disabled people in schools ?

This research work will deepen this subject, first of all, the relationship between building thermal and energy consumption in a building, considered the largest energy consumer in the world (Valderrama-Ulloa, 2013 ; Velazquez- Romo, 2015 ; Omrany et al., 2016). Then, it will deal with the issue of thermal comfort, psychological comfort linked to architectural quality, and also their influence on an atypical population. The purpose is to find architectural and technical solutions capable of contributing to the improvement of thermal quality and architecture while reducing energy needs and creating atmospheres more suited to the specific needs of users.

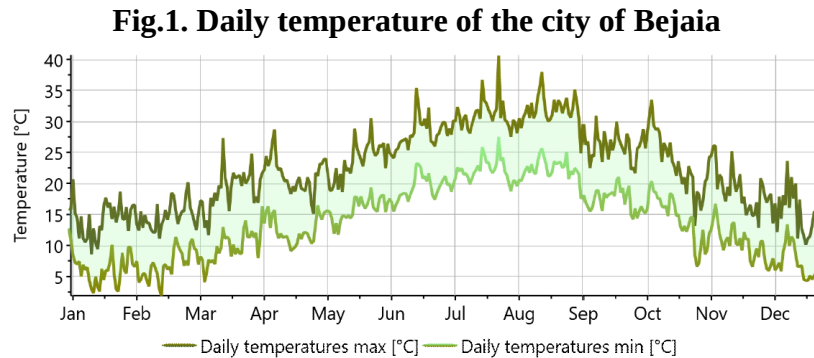
1. Research methodology

This study is based on a methodological approach adapted to the multidisciplinary nature of the subject (empirical and numerical approach).

1.1 Empirical approach

In order to identify the main problems related to thermal comfort in educational buildings intended for people with reduced mobility, field work was carried out. The empirical approach aims to assess the level of thermal comfort in an educational center in Bejaia (school of the four paths and the school of Sidi Ali Lebhar) in order to determine the influence of the choice of materials and construction devices on thermal quality by measurements carried out in situ using a thermometer as well as a qualitative study based on a questionnaire to study the impact of the latter on the psychological aspect of people with reduced mobility.

Regarding the climate, the city of Béjaïa is characterized by a Mediterranean climate a mild, dry and sunny summer and a mild and rainy winter. The figure 1 shows the daily temperature of the city of Bejaia throughout the year.



Source: Meteonorm V8.1, 2022, www.meteonorm.com

The data shown in the graph shows that the city is characterized by two seasons, a hot season (June to October) and a cold season (November to May), with higher temperatures in July and lower temperatures in January. About the case studies, the two cases studied are located in the same sector at the main entrance to the city of Bejaia with a distance of 1.7 km (Figure 2).

Fig.2. The case studies and their situation



Source: authors, March 2022

The investigation was carried out by studying two schools located in Béjaïa using an empirical approach (school of the four paths and the school of Sidi Ali Lebhar). The first case study (B1) is a primary school while the second (B2) is a psychopedagogical center for children with disabilities.

The primary school (case study B1) is located in the residential district "the four paths ", a few steps from the bus station, the Sarrasin hotel and Sonatrach in Bejaia. The Psychopedagogical Center (case study B2) is located east of "Sidi Ali Lebhar" in the urbanized area "POS 14B", near the "Aban Ramadan" airport of Bejaia.

The qualitative study by observation and the questionnaire a sample of 20 people (who work in the cases studied with an age group between 37 and 52 years) were questioned and several indicators were used in order to estimate the degree of well-being of PMR vis-à-vis the thermal and architectural quality of schools, and the influence of these factors on their psychological comfort.

The quantitative study by taking in situ temperature measurements during a representative day of the period was made with the aim of making an inventory and in order to assess the impact of building materials and architectural devices on the thermal comfort of users.

On the basis of meteorological data from the city of Bejaia, it was possible to determine the typical week "design week" and then the typical "design day" day during which measures taken for the hot and cold season (Hong et al., 1999 ; Khadraoui & Sriti, 2018). For reasons of feasibility, the measurements were taken during the coldest period, after setting the week of December 19 to 25, 2021 as the typical "design Week" week and December 19, 2021 as the typical "design Day" of the winter period. The parameters measured are the ambient temperature and the outside temperature given their direct effect on the temperature of human comfort. The measurement instrument used is a digital hygrometer thermometer model TA138 (Figure 3).

Fig.3. The measurement instrument used



Source: authors, 2022

The in situ study was carried out by measurements every two hours (dual), from 8 am to 4 pm. The results obtained were recorded in a table in order to draw the graphs and interpret them. Table 1 presents the thermal characteristics of the construction materials of the case study according to the regulations in force in Algeria.

Table 1. The thermal characteristics of the construction materials of the case study

Materials	λ (W/m.k)	C (J/kg.k)	D (Kg/m3)	Th (cm)
Cement- coating	0.80	850	1900	02
Hollow-Brick	0.39	1000	650	10/15
Plaster- coating	0.57	1080	1150	02
Air	0.047	1000	1	05
Concrete	1.75	1080	2500	10

Source: Khadraoui et al., 2018

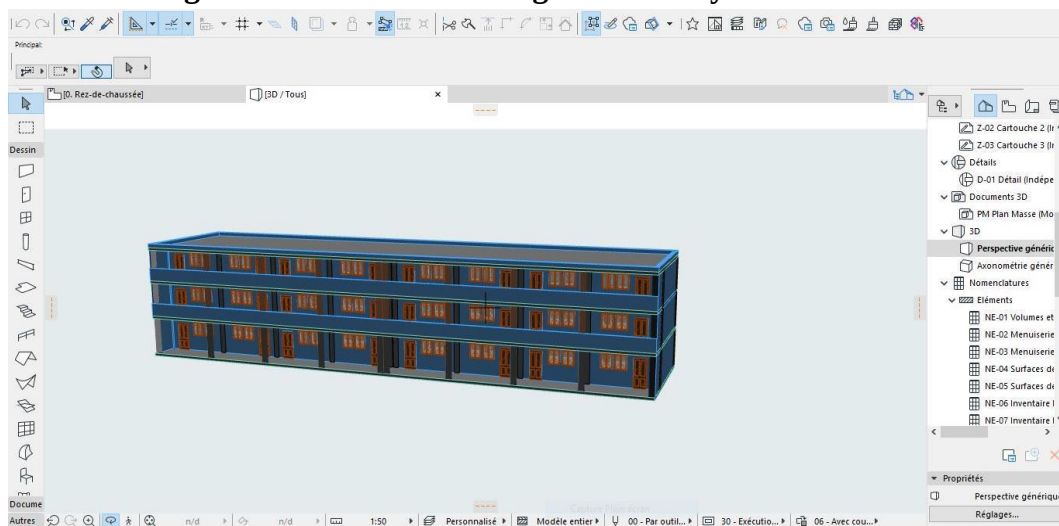
The first case study B1 is a recent construction built in 2018. The composition of the walls of B1 is identical to the normal composition according to the regulations in force in Algeria. On the other hand, the composition of the walls of case study B2 represents prefabricated elements (sandwich panels) in a degraded state after more than 30 years of existence (around 1990). The values of the thermal characteristics of the materials were also used for the study.

The set of parameters was taken into account when taking the measurement in this study, such as the choice of space (space located at the level of an intermediate floor to avoid direct influences from the ground and the roof), measurements in natural conditions where the doors and windows are closed and the heating system is turned off (Several parameters were taken into account when taking the measurement, such as the choice of space (space located at the level of an intermediate floor to avoid direct influences from the ground and the roof), measurements in natural conditions where the doors and windows are closed and the heating system is turned off (natural conditions).

1.2 Numerical approach

Numerical simulation is one the very powerful tools, it offers a complete idea and an excellent mastery of the phenomena studied in relation to construction. Moreover, it represents a very important phase in the process of architectural design and the realization of comfortable and efficient constructions. The "ArchiCAD version 22" modeling software was used to model the digital model of the model under study (Figure 4).

Fig.4. The creation of the digital model by ArchiCAD 22

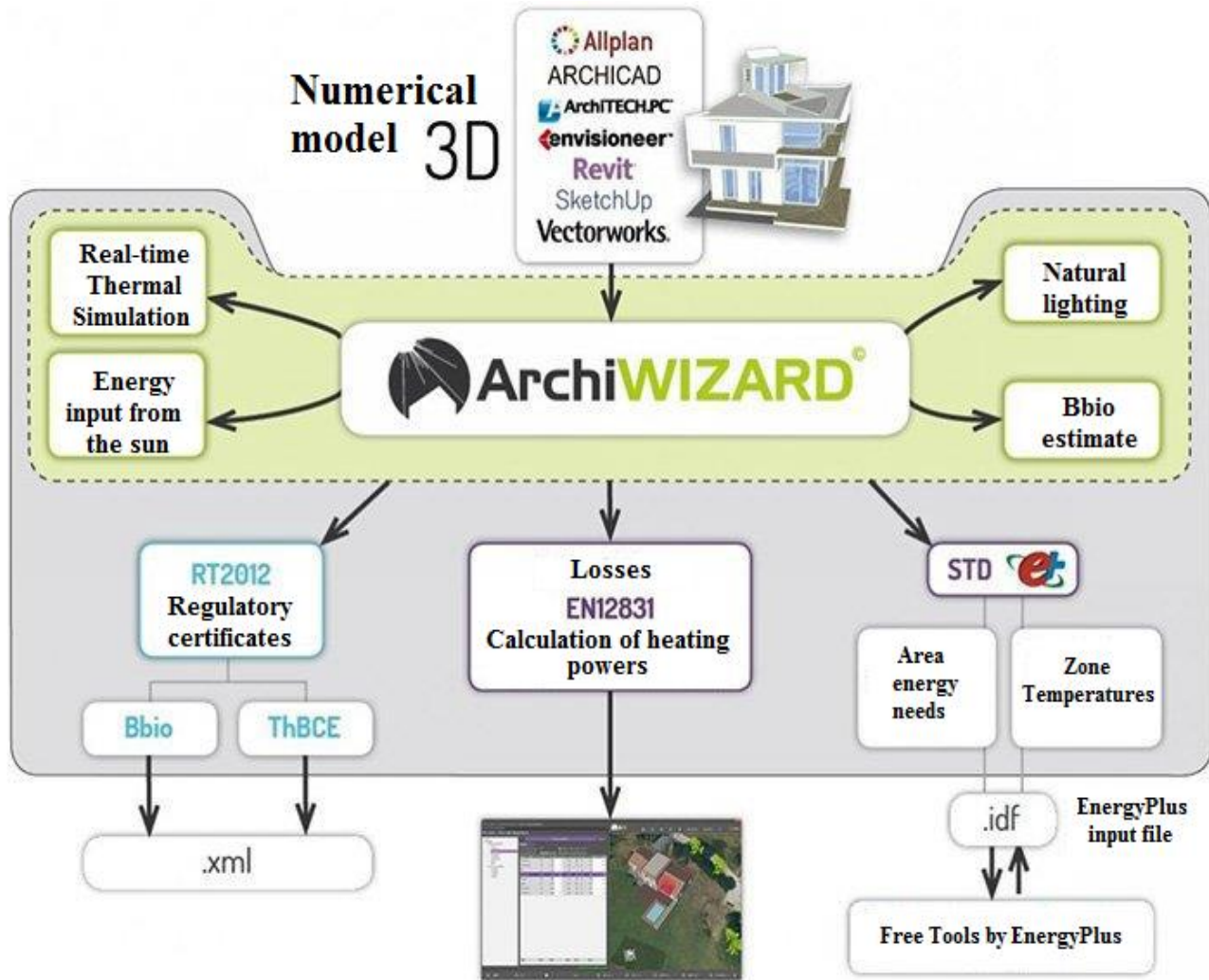


Source: authors, 2022

The digital model developed by the ArchiCAD software represents the basic shape and model most used in schools in Algeria. The objective is the creation of a simple reference model in order to compare its results with the results of other optimized models.

This research is based on a numerical study through the use of the dynamic thermal simulation software "ArchiWIZARD-EnergyPlus" in order to study and optimize the influence of certain materials and architectural devices on the thermal and energy performance of schools buildings in Bejaia. ArchiWIZARD is a very powerful Dynamic Thermal Simulation (STD) software with the EnergyPlus calculation engine. Figure 5 presents the different modules and the functionalities of the software used.

Fig.5. The different modules and features of the ArchiWIZARD software

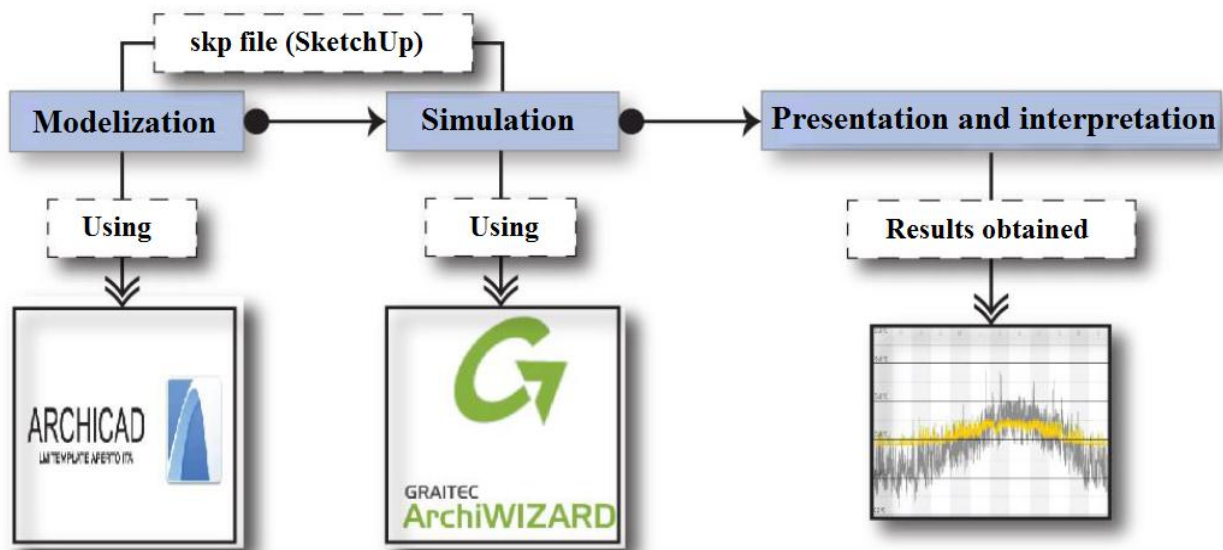
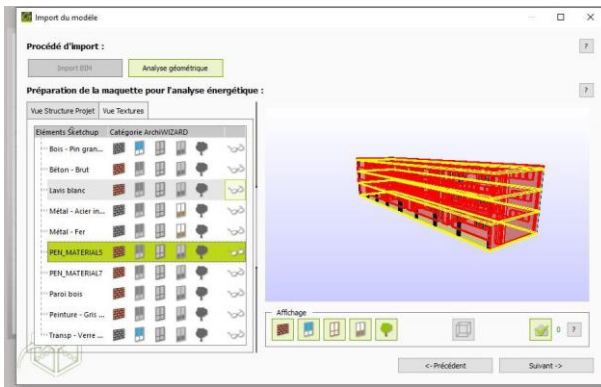
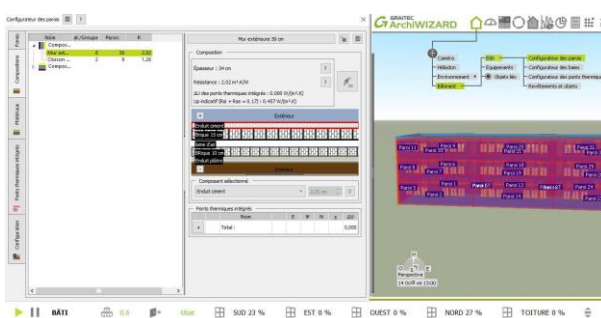
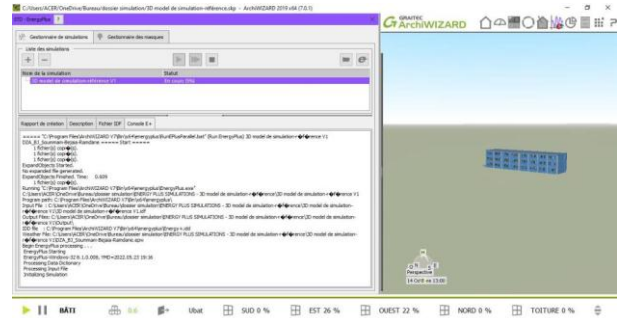


Source: GRAITEC, 2022, www.graitec.com/fr/products/archiwizard/

This software includes many additional simulation modules such as real-time energy simulation for interactive and rapid evaluation of project performance, simulation of solar and light gains, RT2012 regulatory calculation, and Dynamic Thermal simulation with the EnergyPlus.

The realization of this numerical study comprises three main parts, the first is devoted to the modeling of the geometry of the model as well as its conceptual characteristics with the software ArchiCAD, the second concerns the numerical simulation of the various scenarios and models proposed, then the last summarizes presentation and interpretation of the results obtained.

Figure 6 illustrates a summary diagram of the numerical study and the main phases of the elaborate numerical simulation.

Fig.6. The Summary diagram of the numerical study and the main phases of the simulation**Modeling and simulation process****Verification of the components of the digital model****Verification of thermal zoning****Modification of the composition of the walls****Launch of the numerical simulation**

Source: authors, 2022

ArchiWIZARD works with the EnergyPlus calculation engine, in direct connection with the digital model (3D) from different formats and software (Sketchup, Allplan, Revit, ArchiCAD). The climate file for the city of Bejaia used for the simulation is in "epw" format generated by Meteonorm V8.1 software.

Three simulation scenarios have been proposed, the first scenario (M1) is considered as a reference model (witness) to compare its results with the other models. The second scenario makes it possible to study the influence of the integration of a thermal insulator in the same wall composition (cellular glass panel insulation). The third scenario aims to study the impact of the

device of the ventilated facade on the thermal comfort and the energy performance of school buildings in Bejaia. Table 2 presents the composition of the walls of the basic model according to the regulations in Algeria.

Table 2. The composition of the walls of the basic model

Schema	Number	Material	Thickness
	01	Plaster- coating	02 cm
	02	Hollow-Brick	10 cm
	03	Air	05 cm
	04	Hollow-Brick	15 cm
	05	Cement- coating	02 cm

Source: authors, 2022

After following all the stages of the description of the characteristics relating to the construction, the immediate context, and the meteorological data of the city of Bejaia, the simulation was launched throughout the year.

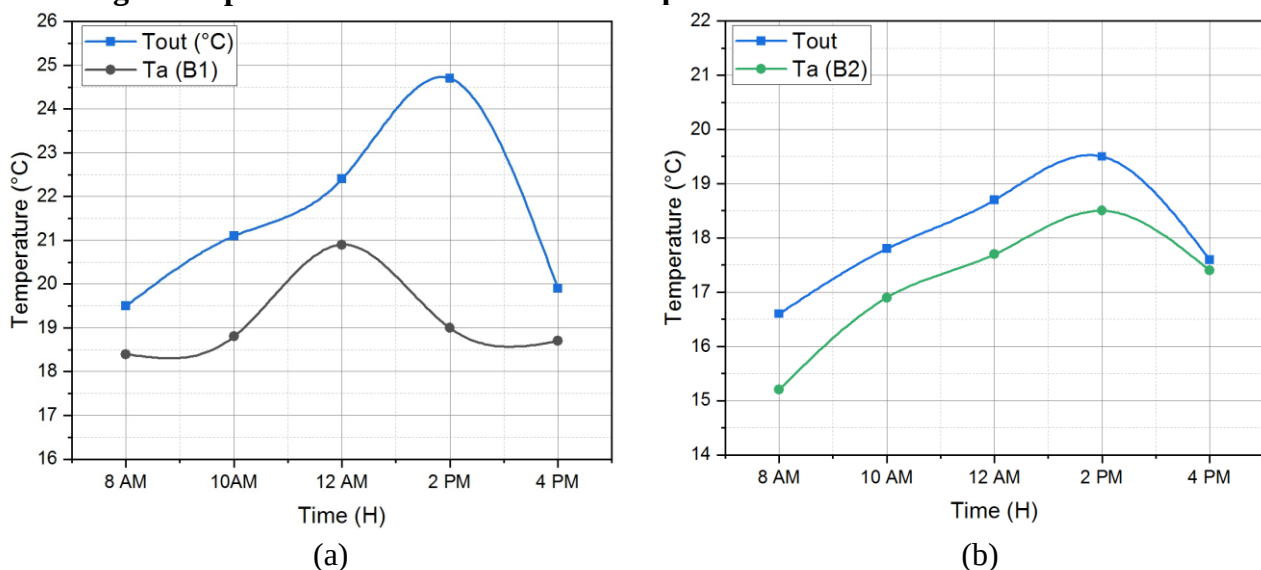
3. Interpretation of results

The results obtained are processed by the OriginLab software to draw the graphs (drawn). They are divided into two types depending on the nature of the approach used, empirical and numerical study.

3.1 Empirical Study Results

Regarding the results obtained in the field study, they are divided into two types, the results of the quantitative study, and the results of the qualitative study carried out through questionnaires. The results of the quantitative study of the in situ measurements (outdoor temperatures "Tout" and ambient temperatures "Ta") during a typical day on December 19, 2021, are shown in figure 7.

Fig.7. Graphs of outdoor and ambient temperatures measured in the case studies



Source: authors, 2022

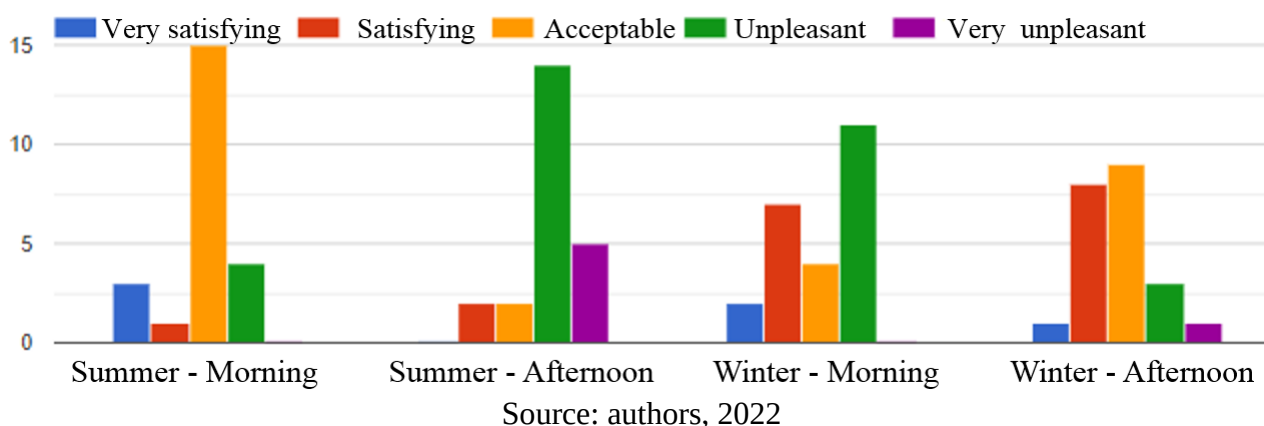
Graph (a) presents the temperatures measured every two hours in the first case study (primary school "the four paths"). The graph shows that the outside and inside temperatures develop at a stable and homogeneous rate, but with a slight difference between the two. The outside temperature fluctuates between a minimum of 19.5 °C recorded at 8 a.m. and a maximum of 24.8 °C recorded at 2 p.m., while the ambient temperature of the key space reaches its minimum value of 18.4 °C at 8 a.m. and its maximum of 20.9 °C at 2 p.m. This proves once again that the outside temperature and the climate have a direct influence on the room temperature. The ambient temperatures recorded are low compared to the outside temperatures and even they are below the thermal comfort threshold which varies between 20 °C and 25 °C, these fluctuations clearly show that the thermal functioning of this space presents a major problem, this may be generated by the inefficiency of the exterior walls, which encounter difficulties in capturing and taking advantage of the solar gains received throughout the day on the south side and in protecting themselves from the problems of the north. More specifically, the inappropriate choice of building materials used in the composition of the walls, the lack of thermal insulation and the type of facade adopted.

Graph (b) illustrates the temperature values measured every two hours in the second case study (psychopedagogical center in "Sidi Ali Lebhar"). By comparing the graphs of the outside temperature and those of the ambient temperatures of the two key spaces of our 2nd case study, it appears that these values are more or less equal and that the evolution of the ambient temperatures follows that of the outside temperature. The outside temperature reaches its minimum of 16.6 °C at 8 a.m. and its maximum of 19.5 °C at 2 p.m. with an amplitude of 2.9 °C, just like the ambient temperatures which reach their minimum at 8 a.m. 15.2 °C and their maximum at 2 p.m. with a value of 18.5 °C. The amplitude which varies between 1.8 °C and 3.3 °C is always under the effect of the external climatic conditions and the composition of the walls. The internal temperatures measured are lower than the external temperature measured and are always outside the range of thermal comfort, this is mainly due to the deterioration of the condition of these spaces and the composition of the external walls which have completely lost their characteristics thermal, as well as the uncontrolled movement of air that is blown inside.

After interpreting the results obtained, the different effects of climatic conditions as well as the choice of materials and certain elements of the facade (composition, insulation, etc.) influence the thermal functioning of buildings and the interior thermal comfort of users. from space. Each element plays an important role in determining these, which is why everything must be taken into account during the architectural design.

Regarding the results of the qualitative study, the processing of the results was carried out after the calculation of the percentages of the responses. Figure 8 illustrates the results obtained from the thermal satisfaction of workers under natural conditions.

Fig.8. Worker thermal satisfaction under natural conditions

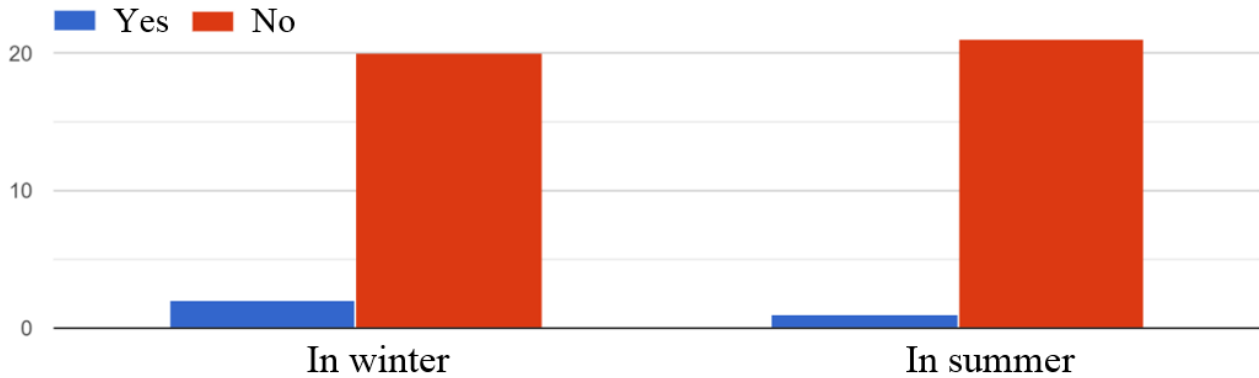


A total of 65.21 % of employees have an acceptable thermal satisfaction with their environment during the morning in summer and this in natural conditions, while 60.87 % are not at all satisfied (an unpleasant level) with the level of comfort thermal that their environment offers in summer

during the afternoon period. The results obtained during the winter period and in natural conditions are basically divided into two large categories during the two periods of the day, where 47.82 % are not at all satisfied with the thermal conditions of their environment in the morning, while the afternoon are satisfactory with a percentage of 34.78 %.

Figure 9 presents the results of the satisfaction of people with disabilities with the existing thermal conditions inside the classroom, without heating or air conditioning.

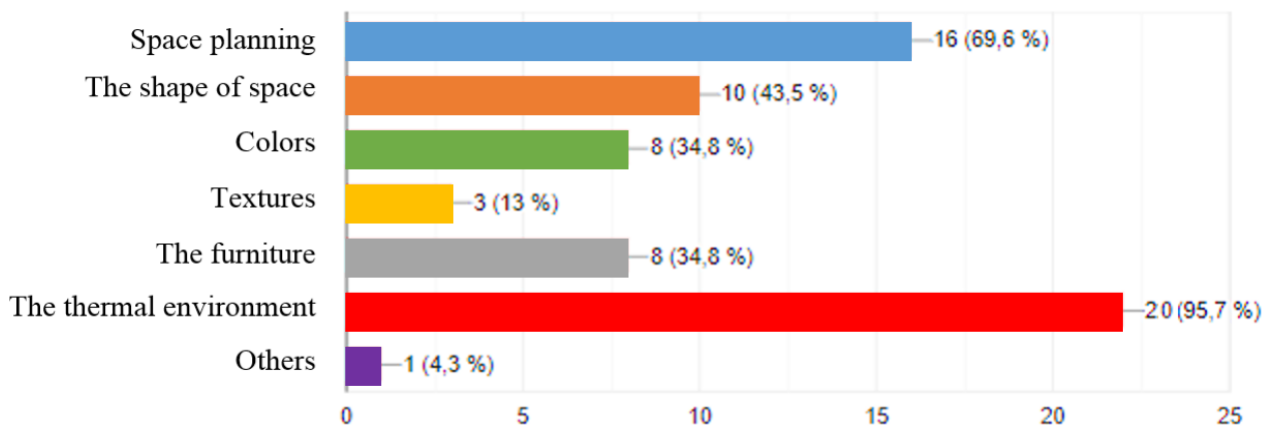
Fig.9. Satisfaction of people with disabilities with thermal conditions in the classroom under natural conditions



Source: authors, 2022

Disabled people do not show thermal satisfaction with their environment in natural conditions (without heating or air conditioning), this has been confirmed by the extremely high percentages of dissatisfaction with a percentage of 86.95 % in winter a percentage of 98.65 % in summer. The results of the qualitative study obtained by observing and analyzing the behavior of children on the factors influencing the architectural quality of spaces are shown in figure 10.

Fig.10. Factors influencing the architectural quality of spaces



Source: authors, 2022

The thermal environment is a very important factor because it is responsible for determining the thermal quality of these classes with a percentage of 95.7 %, comes directly in second position the layout of the space with a percentage of 69.6 %, then the architectural form with a percentage of 43.5 %. Colors and furniture are in fourth position with an identical percentage of 34.8 %, and at the end textures have a low percentage of 13 %. The results obtained clearly demonstrate the real impact of the choice of materials and certain architectural elements (façade, insulation) on the thermal functioning of buildings and on the interior thermal comfort of space users. The interpretation of the results of the qualitative study confirms that the state of the establishments

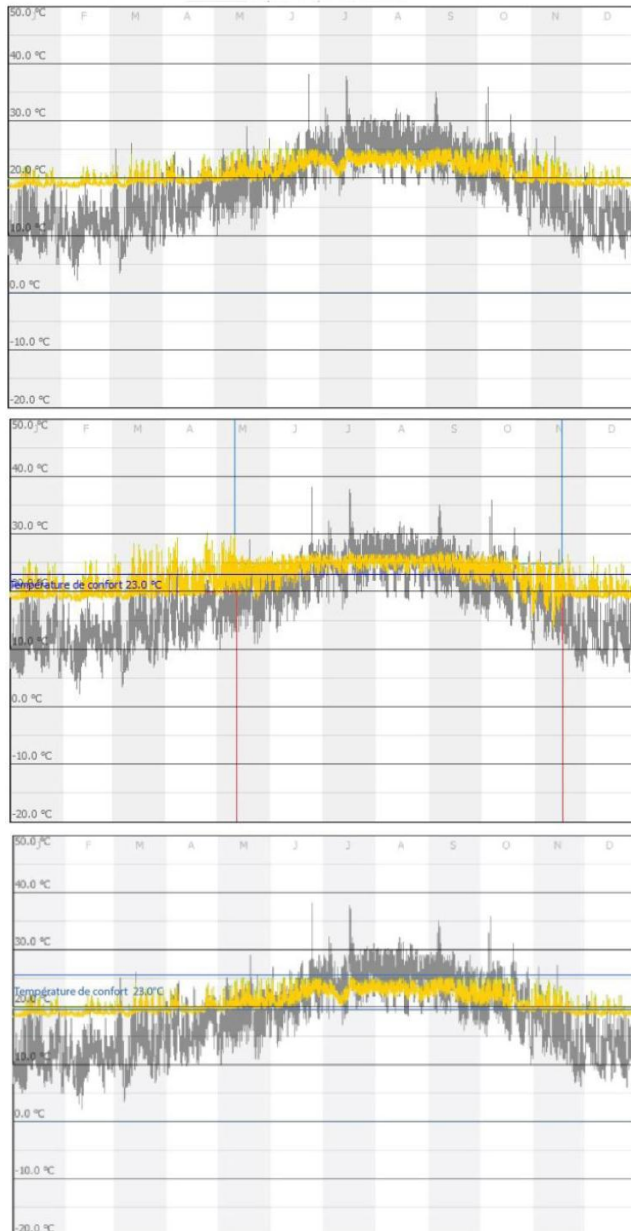
accommodating disabled people are characterized by the lack of thermal comfort which influences the psychological of the children.

3.2 Numerical Study Results

The dynamic thermal simulation results obtained in the three scenarios (models) are shown in figure 11.

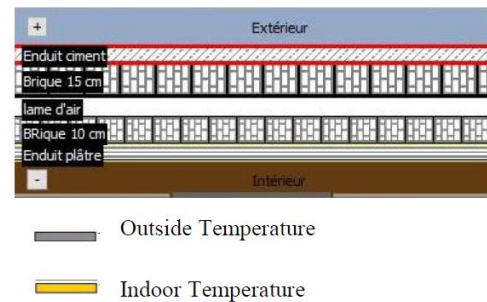
Fig.11. The results of the dynamic thermal simulation obtained in the three scenarios

STD dynamic thermal simulation results

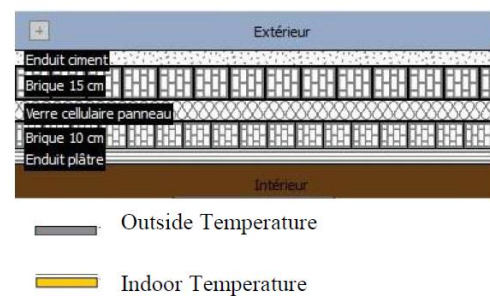


Scenarios

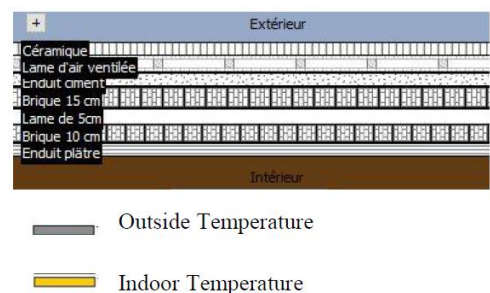
First scenario : M1



Second scenario : M2



Third scenario : M3



Source: authors, 2022

The graph of the first scenario with ventilated (M1) indicates that the outside and inside temperatures evolve in a stable and homogeneous way, with a slight difference between the two. The outside temperature varies between a minimum of 5 °C recorded in January and December for the winter period and a maximum of 38 °C recorded in June and July, while the ambient temperature within the key zone reaches its minimum value of 18 °C always in January and December and its maximum of 26 °C in July and August. The simulated ambient temperatures are

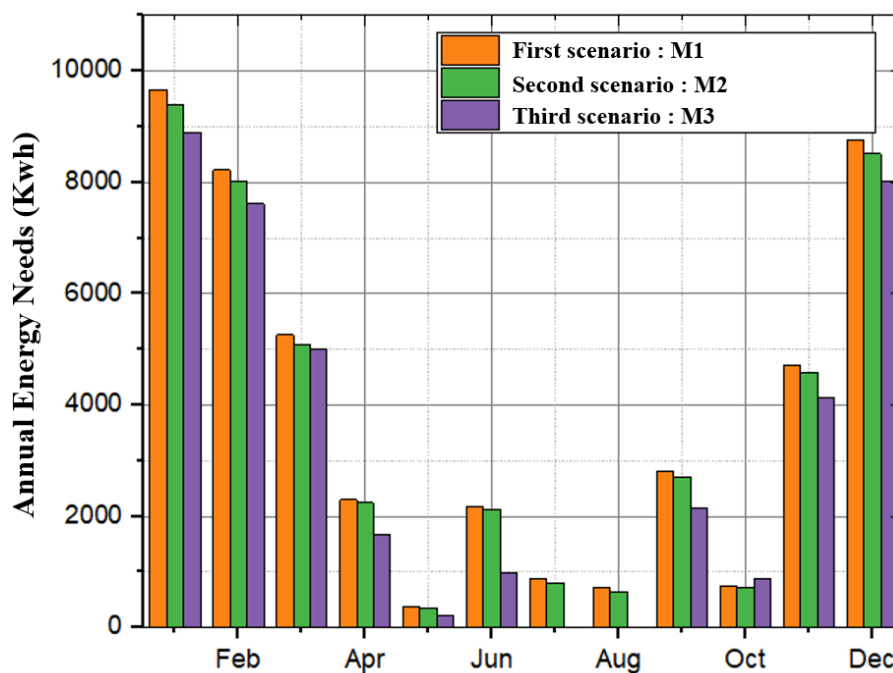
higher than the exterior temperatures and are beyond the thermal comfort threshold which varies between 20 °C and 25 °C, this fact confirms that the ordinary composition of the exterior walls does not exhibit good thermal functioning , and finds difficulties in valuing the thermal inputs received during the summer period and in protecting itself during the winter period, all this with the presence of hollow bricks having a high thermal conductivity of 0.48 (W/m.k), and the blade of air with low thermal transmission.

Concerning the results of the second scenario (M2) with insulation, from January to the beginning of May and from the beginning of November to December the ambient temperatures recorded after the simulation are within the thermal comfort zone varying between 20 °C and 25 °C , since in this case the simulated ambient temperature inside the classroom is 23 °C. On the other hand, the period between mid-May and the beginning of November is still outside the comfort zone, with temperatures slightly exceeding 25 °C. These results demonstrated that the insulation integrated in the middle of the composition of the exterior wall positively influenced the thermal functioning of the exterior wall, since it presented optimal comfort during the winter period.

About the results of the third scenario (M3) with ventilated facade, the results appearing on this graph confirmed our prediction concerning the device of the ceramic ventilated facade, the ambient temperatures recorded after the simulation are all within the thermal comfort zone varying between 20 °C and 25 °C while throughout the year, and the simulated ambient temperature inside the classroom is set at 23 °C. We can therefore say that the device of the ventilated facade has ensured human thermal comfort and has improved the thermal functioning of the exterior walls and of the building in general compared to the reference model and that of the insulation.

Figure 12 presents a comparison of the annual heating and cooling energy needs between the three simulated scenarios.

Fig.12. The annual heating and cooling energy needs of the three simulated scenarios



Source: authors, 2022

This figure compares the energy needs of the three simulated scenarios highlights that, compared to the other scenarios, the initial scenario, similar to the real project, will have to consume too much energy for the temperatures to be maintained between 20 °C and 25 °C throughout the year, using heating and air conditioning equipment. It should be noted that the heating needs are estimated at 40237 KWh and approximately 7151 KWh for the air conditioning needs for a single year. The

second simulated scenario consumes less energy than the first and even its heating needs have decreased by a value of 1119 KWh equivalent to 2.79 %, and cooling by a percentage of 3.88 %. This small improvement in the energy behavior of the exterior walls and of the building is due to the presence of the "cellular glass panel" insulation. The third scenario of devices of the ventilated facade without external insulation is the most efficient in terms of energy compared to the other two, it made it possible to reduce the estimated energy needs with a percentage of 5.14 % in winter and 41.67 % in summer, a very appreciable value, we also find that the months of July and August have become independent in terms of energy.

The results of this simulation confirm that the choice of construction or insulation materials and that of the architectural devices at the time of design, without forgetting the consideration of their characteristics, the way in which they are placed and the climatic data of the city in question, directly lead to negative or positive impacts on the thermal and energy efficiency of school buildings, and therefore on the thermal and psychological comfort of children regardless of their situation, without neglecting the influence exerted on the environment. The right choice of certain materials and devices can guarantee a high level of energy efficiency as well as thermal and psychological comfort.

Conclusion

The study of the thermal building is a key step in the effective design of the architectural project, succeeding in this step not only ensures the thermal comfort of users and rationalizes energy consumption, but also ensures the psychological comfort of space users. People with reduced mobility, in particular autistic children, represent a very fragile and neglected category in urban and architectural spaces, in particular in school buildings. This article aims to study the thermal and psychological comfort of autistic children in school buildings located in Béjaia (Case study at the city of Bejaia), based on an empirical approach (qualitative and quantitative) by taking measurements, observation, and questionnaires as well as a numerical study by dynamic thermal simulation with the use of the "ArchiWIZARD-EnergyPlus" software.

The empirical study confirms that the state of the buildings welcoming people with reduced mobility in Béjaia is, unfortunately, more complex than one might think, not only a glaring lack of compliance with standards but also an overall lack of all means of well-being and comfort in all the plans. As part of this research, we wanted to address two significant problems in this type of building, namely thermal and psychological comfort. This constitutes the first initiative in the process of the improvement of at least the critical space of these buildings which requires thermal renovation studies to ensure thermal comfort in its buildings given its importance on the thermal and psychological state of children.

The results obtained confirm the total lack of thermal and psychological comfort conditions in the cases studied and demonstrate the importance of the influence of the thermal and architectural environment on the psychological comfort of people with reduced mobility. The appropriate choice of construction materials for the project envelope and the various devices and insulation of the facades guarantee the children's thermal comfort and ensure the buildings' energy efficiency and the psychological comfort of children. A good thermal and architectural environment inside this space will be very beneficial for their psychological state and ensure the smooth running of educational activities within these buildings.

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