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Thermal Performance of Typologies of School Buildings: The Side and Central Corridor Plan in the Context Climate Mediterranean in Algeria

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ABSTRACT

The architecture of the school buildings in relation to environmental quality is a major concern of sustainable development in the 21st century. The plan of the central corridor and the plan of side corridor built with baked bricks are the most practiced styles in the construction of these buildings. Today, in light of the challenges that must lead the academic space to ensure comfort conditions in respect of the environment, one wonders of the thermal performance of these conceptual models and the composition of their envelope. Based on a measurement campaign, the study allowed conducting an objective assessment of key physical parameters of thermal comfort in the climate context of an Algerian town in Mediterranean climate (Tizi-Ouzou). Moreover, bioclimatic analysis was used to identify major shortcomings related to the form and composition of the shell of the buildings and to conduct a comparative study between the two typologies.

Keywords: Thermal performance, School building, Architectural typology, Building envelope, Central corridor plan, Side corridor plan.

1. INTRODUCTION

Subjected to standard, rigid and typical design, school buildings in Algeria, with the image of much of other countries, are built following two architectural types and with the same building materials, without taking into consideration the climatic characteristics of each region. These are the plan of the central corridor and the plan of side corridor with the use of hollow brick as the main construction material for the envelope. Thus, in light of the challenges facing the school space to ensure the conditions of comfort while respecting the environment and facing the massive reproduction of these typologies, one wonders through this study on the thermal performance and the integration of these typologies with their climatic contexts to provide the conditions of thermal comfort. To identify this problem, we are enrolled in the climatic context of an Algerian city with a temperate Mediterranean climate (Tizi-Ouzou).

The study has two components. The first is an assessment of the thermal performance of these typologies. It relies on the objective quantitative method by analyzing and interpreting the results of measurement campaigns. The second part is a bioclimatic study, which will make use of our better understanding the negative aspects and defects related to the shape and composition of the envelope of each typology from a thermal point of view.

2. CASE OF STUDY

The investigation is carried out in the town of Tizi-Ouzou which is located in the north of Algeria (latitude 36 ° 42 North, longitude 04 ° 03 East). According to the Koppen World Climate Classification [1], it is characterized by a temperate Mediterranean climate. It is part of the winter H1a zone, which is characterized by a mild winter and summer E1, which is characterized by hot, humid summers with low diurnal and nocturnal temperatures [2]. The month of August is the warmest with an average temperature of 28.4 °C, while February is the coldest with an average temperature of 9.50 °C. [3].

The environment of the study concerns the school buildings of middle school and secondary school (high school) of the city of Tizi-Ouzou. The study of the architectural characteristics of the latter highlights two typologies. The side corridor plan which characterized by the linear juxtaposition of the classrooms served laterally by a passageway (fig.1 and 2). The second is the central corridor plan, which is characterized by a linear central corridor distributing on each side of the classrooms (fig.3 and 4). In addition, consultation of the plans and observations in situ made it possible to establish that the outer envelope is composed of double hollow brick walls separated by a 10 cm air gap; The exterior cladding is a cement plaster, that of the interior is made of plaster.

The investigation is carried out in four cases of study. Two of them are designed according to the typology of the

side corridor plan with all the characteristics of the classrooms are similar with the exception of their orientations. They are double oriented East / West for the 1st case and North / South for the second case. The other two cases are designed according to the typology of plan with central corridor oriented to the North and South for the first case and to the East and the West for the second case.

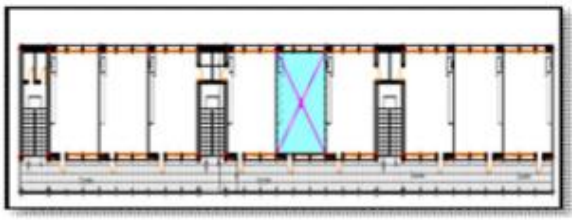

Figure 1. The side corridor plan

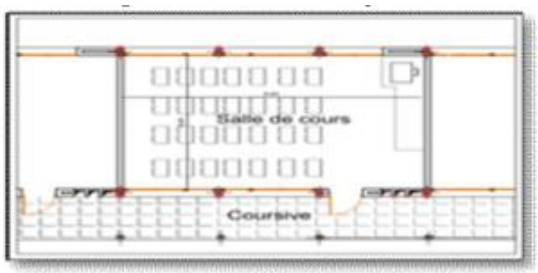

Figure2. Classroom of the side corridor plan

Table 1. Summary table of the characteristics of the classrooms of the typology of side corridor plan

Dimensions (L x w x h)	Surface	Orientation	form	Many occupants
8.60x6.75x 3.20 m^3	58.05 m^2	North/Sout East/West	Rectan-gular	Enter 26 and 32

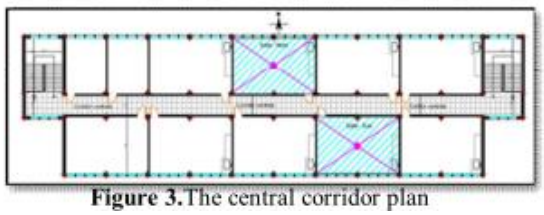

Figure 3. The central corridor plan

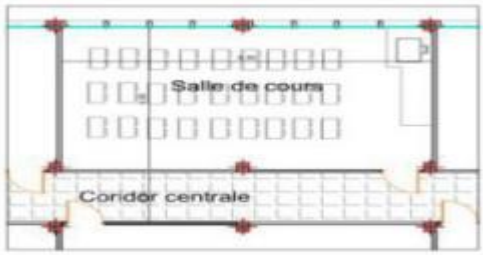

Figure 4. Classroom of the central corridor plan

Table 2. Summary table of the characteristics of the classrooms of the typology of central corridor plan

Dimensions (L X B X H)	Surface	Orientation	Form	Many Occupant
9.4x6x3.20 m^3	56.04m^2	North; South; East; West	Rectan-Gular	Enter 26 And 32

3. METHODOLOGY AND WORKING TOOLS

3.1 Objective quantitative study

In order to quantitatively evaluate the different physical parameters of the thermal environment, we carried out a measurement campaign during two periods of the year: summer and winter. In order to evaluate the capacity of the school buildings to offer a minimum of comfort under the usual conditions of work, this campaign was carried out in the presence of the pupils and without any refreshment or heating equipment. Two main parameters are measured: ambient temperature and relative humidity. The measurements are carried out in two classrooms of the typology of side corridor plan and four classrooms of the typology of central corridor plan with different orientations.

The apparatus used is a thermocouple of type K-HI 935006 and a thermo hygrometer with a probe. These are calibrated for 24 hours. The measurement interval is one hour and the probes are placed at the geometric center of the classrooms at a height of 1.1m from the floor level, as the standard recommends it [4]. The summer measurement campaign took place in September 2015, who is the hottest month of the school year. As for winter, it took place in January.

3.2 Bioclimatic study

The purpose of the bioclimatic study is to identify the main defects related to the design and the envelope of the buildings of the study cases and to know whether factors of the climatic environment are taken into account to ensure thermal comfort. Moreover, the bioclimatic analysis combined with the knowledge of the architectural and constructive characteristics of these buildings allowed us to make a comparison between the two typologies.

The bioclimatic study was based on two methods: the psychometric diagram of S. SZokolay and the paintings of Carl Mahoney. The bioclimatic diagram makes it possible to determine the zone of thermal comfort and well as the main design lines that guarantee it [5]. To learn how to apply all of these recommendations when designing buildings, we used Mahoney's tables. The application of this method to the city of Tizi-Ouzou has resulted in recommendations varying from general (location, orientation, etc.) to detail (size and arrangement of openings). These recommendations are compared with the characteristics of the buildings studied in order to achieve the above objectives.

4. DISCUSSION AND INTERPRETATION OF RESULTS

4.1 Summer measure campaign

The typology of side corridor plan is characterized by two-way of classrooms. The measurement campaign is conducted in two high schools, for two different days. In the first, the room is oriented North / South; in the second, it is oriented East / West.

Indoor temperatures in both rooms vary between 24.1 °C and 32.1 °C. The maximum difference between indoor and outdoor temperatures is 5.8 °C. By comparing these results with the comfort zone (18 °C-24 °C) defined by the psychometric diagram, we can conclude that the thermal

environment is uncomfortable for most of the time spent in classrooms.

The typology of central corridor plan is characterized by single-orientation classrooms. The measurement campaign was conducted in two colleges for two different days. The classrooms are oriented to the North and South in the first case study; East and west in the second. The interior temperatures in the four rooms range from 24.2 °C to 31.3 °C; they exceed in most cases the limit of thermal comfort.

The relative humidity values are in both types between 28% and 71%. According to the psychiatric diagram of the city of Tizi-Ouzou, these values are included in the comfort zone.

In conclusion, the quantification of the temperature parameter shows the failure of the two typologies studied in the thermal comfort procuration during the warm period. This is supported by the rise of indoor temperatures in the same way as external ones with a small gap in most of the time. On the other hand, the temperatures of the classrooms remain quite high despite the fact that the measurement campaign took place towards the end of the warm season, with relatively moderate outdoor temperatures.

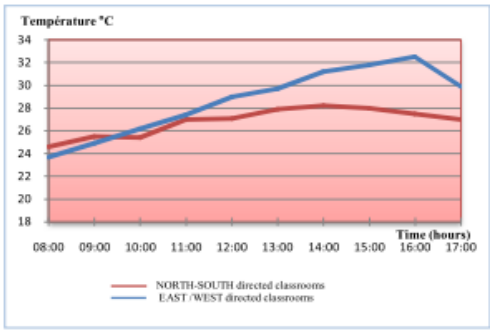

Figure 5. Variation of the interior temperatures of classrooms of the side corridor plan in summer

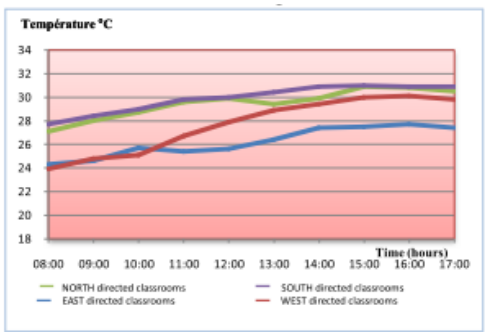

Figure 6. Variation of the interior temperatures of classrooms of the central corridor plan in summer

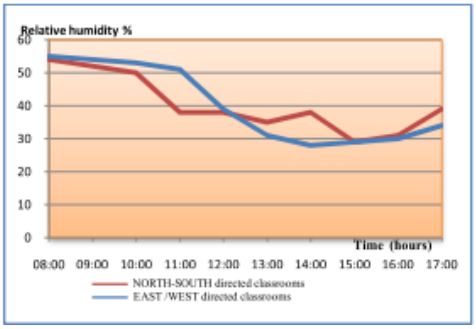

Figure 7. Variation of relative humidity of classrooms of the side corridor plan in summer

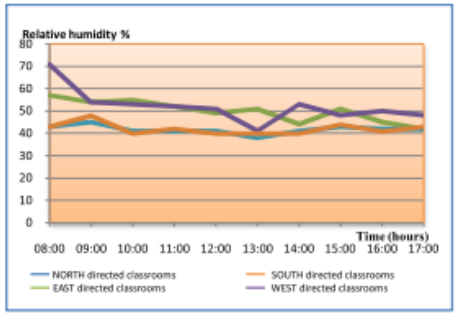

Figure 8. Variation of the relative humidity of classrooms of the central corridor plan in summer

4.2 Winter measure campaign

In the typology of side corridor plan, the measurements are carried out without heating and without the presence of the pupils. This protocol made it possible to evaluate the thermal performance of the shape and the composition of the envelope without active or passive internal contributions. The interior temperatures in the two rooms vary between 14.6 °C and 19.1 °C. In the central corridor plan type, measurements are carried out under normal working conditions while the heating is switched off. The interior temperatures in the four rooms vary between 14.1 °C and 19.4 °C. We can conclude that the temperature values do not reach the threshold of thermal comfort (18 °C) in most of the time spent in the classrooms of the two types studied and for the four orientations. On the other hand, the relative humidities are in the comfort zone and vary between 44% and 70%.

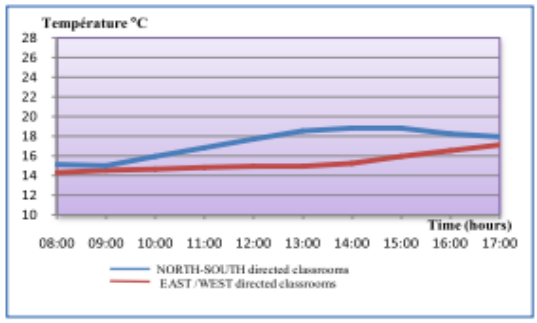

Figure 9. Variation of the interior temperatures of classrooms of the side corridor plan in winter

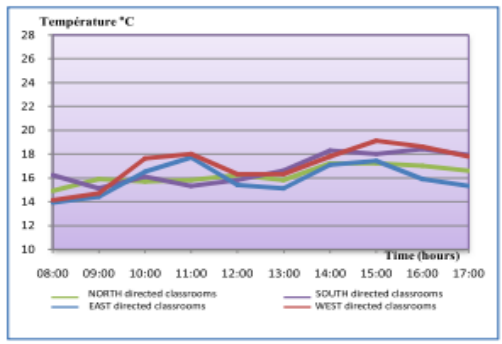

Figure 10. Variation of the interior temperatures of classrooms of the central corridor plan in winter

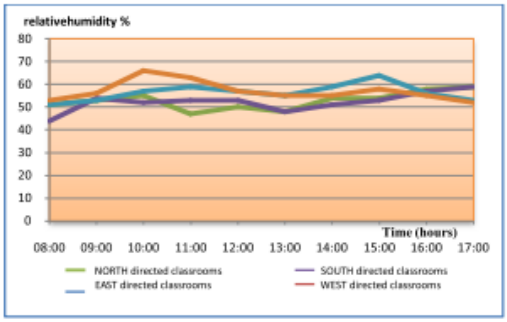

Figure 11. Variation of relative humidity of classrooms of the side corridor plan in winter

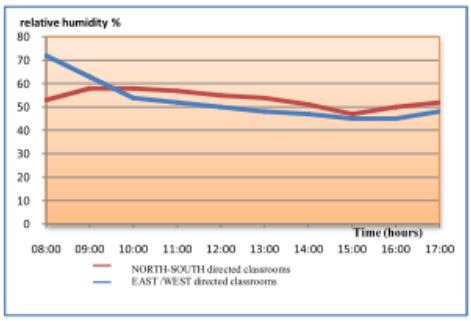

Figure 12. Variation of the interior relative humidity of classrooms of the central corridor plan in winter

4.3 Bioclimatic study

The objectives of the bioclimatic study are multiple; they can be summarized as follows:

• Confirm or invalidate the results of the measurement campaigns;

• Understand the reasons for the poor thermal behavior of each typology;

• To know to what extent the factors of the climatic environment are taken into account to ensure the thermal comfort of the studied school buildings;

• Compare between the two typologies from a thermal performance point of view.

To do so, first, we carried out a climate study of the city of Tizi-Ouzou in order to draw bioclimatic recommendations conforming to this zone. Second, we studied the architectural and constructive characteristics of the case studies (see Table 3). The two analyzes are compared to achieve the above objective.

The projection of the meteorological data of the city of Tizi-Ouzou on the bioclimatic diagram made it possible to determine three zones:

• Comfort zone;

• The under-heating zone where it is recommended to promote passive solar gains and the use of thermal mass to address problems of thermal discomfort;

• The superheat zone where it is recommended to the use of thermal mass, evaporative cooling and natural ventilation.

The application of the Mahoney tables made it possible to arrive at the recommendations necessary to achieve hygrothermal comfort in a building in Tizi-Ouzou. These recommendations as well as the architectural and constructive characteristics are summarized in Table 3.

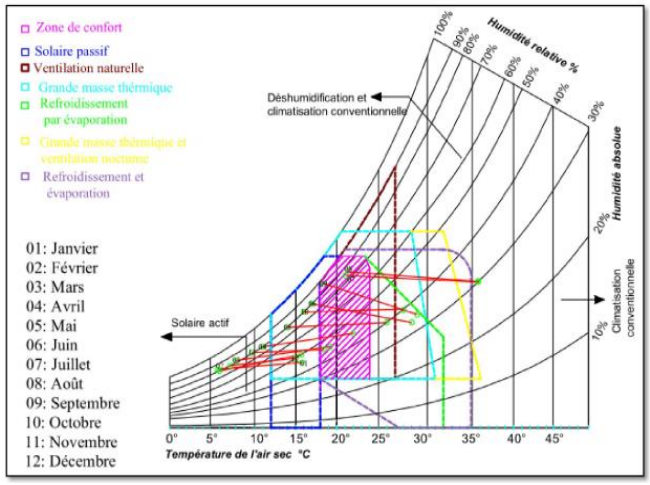

Figure.13. Bioclimatic diagram of the town of Tizi-Ouzou.

Table 3. Synthesis and comparison of the characteristics of two typologies and the bioclimatic recommendations

Criteria	Typology of side corridor plan	typology of central corridor plan	Bioclimatic recommendations
The school building			
Coefficient of form	0.54	0.34 ; 0.15	Weak
Classrooms			
Orientations	North/South; East/ West	North ;South; East; West	South; North
Surface	58.05 m²	56.04 m² ; 63.08 m²	60 m² à 62 m²
Volume	185.76 m³	180.50 m³ ; 205.00 m³	/
Ratio surfaces/raises	1.81 m² à 2.23 m²	2.24 à1.86 m² ; 2.25à 1.97 m²	1,40 à 1,50 m²
Ratio openings frontage	47%	46% ; 45%	20% à 40%
Construction materials of the opaque walls.	Hollow brick, (2h of dephasing).	Hollow brick, (2h of dephasing).	With strong thermal inertia (8heures of dephasing)
Construction materials of the glazed walls	Simple glazing	Simple glazing	/

4.3.1 Comparison of Architectural Characteristics of School Buildings and Bioclimatic Recommendations

The analysis of the building characteristics of the study cases compared to the bioclimatic recommendations confirms the poor thermal behavior of these buildings. Moreover, they allow us to conclude that the factors of the climatic environment are not taken into account to ensure thermal comfort in both types. The identified deficiencies in the design of these plans based on the bioclimatic study are summarized as follows:

In both types.

The inadequacy of the orientation of most classrooms; especially since the buildings do not have external occultation systems. Indeed, the bioclimatic study advocates the South orientation because the winter sunshine is maximum, while that of the summer is minimal with the possibility of protecting itself with a simple awning.

2. The low thermal inertia of the materials; previous studies [6], [7], [8] have demonstrated that the phase-shift time of this type of envelope is only 2 hours, and that in the climatic zone studied it is suggested that an envelope with high thermal inertia with a phase-shift time of 8 hours.

3. The absence of external solar protection; the solar protection in the classrooms are summed up as simple interior curtains that do not provide sufficient protection against the vagaries of the climate.

The typology of side corridor plan.

In addition to the deficiencies cited in the two typologies, the side corridor plan presents other deficiencies namely:

- The importance of glass surfaces; the classroom of the side corridor plan has two facades open on the outside. The calculation of the ratio of the area of the openings to the surface of the floor of the classrooms reveals that it exceeds the maximum value required by the bioclimatic recommendations. This has the effect of accentuating unwanted heat exchanges in summer and favoring thermal losses in winter. On the other hand, the central corridor plan typology is characterized by a much lower degree of openness.
- The importance of the shape coefficient; the calculation of the latter indicates that it is important for the two typologies studied. However, the typology of plan with central corridor is lower.

4.3.2. Comparison between the two typologies

On the basis of the results presented above, we note that the two typologies share several common characteristics and failures compared to the bioclimatic study. Nevertheless, the design of the central corridor plan typology is less deficient. Although it does not offer the conditions of comfort, it is better adapted to the climate context of the city of Tizi-Ouzou thanks to its more compact and less open design.

5. CONCLUSION

At the end of this study, we conclude that the problem of thermal comfort in school buildings in Algeria is the result of an unconcerned conception of the climate. The results of the investigation demonstrate the low thermal performance of the shape and composition of the envelope of the two typologies studied during the two periods with the exception of the first two hours of the morning in summer and the last two hours of the Afternoon in winter. This is supported by small temperature differences between indoor and outdoor.

Moreover, the study of the architectural and constructive characteristics of each of these typologies compared to the bioclimatic analysis of the city of Tizi-Ouzou reveal that thermal comfort and environmental quality are not taken into account in these buildings. Numerous failures, notably of the typology the side corridor plan, are listed, they can be summarized as follows.

- The composition of the envelope which does not play its protective role because of its low thermal inertia;
- The spreading shape, in particular of the typology of the side corridor plan, which generates a large thermal loss surface;
- The inadequacy of the percentage of glazed areas in relation to the bioclimatic strategies recommended for this area and the nature of the glazing (simple glazing), which increases heat exchange between the interior and the exterior;
- Inadequate orientation of most classrooms;
- The absence of external solar protection and thermal insulation.

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NOMENCLATURE

The temperature of the ambient air: it is the temperature of the fluid (air) which circulates around the individuals; its measuring unit is the degree Celsius (°C).

Relative humidity: it is the relationship between the quantity of the water contained in the air in the form of vapor, with the room temperature, and the maximum quantity which it can contain; it is expressed as a percentage (%).