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Approach Thermal Habitat Assessment in N'Djamena in Chad

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Abstract

For the earth material construction is the most used one in Chad, the object of this work is the assessment of the thermal quality of earthen adobe mixed with straw. Different simulation software analyzes the CoDyBa which is conducted to determine the behavior of this material compared to living comfort thanks to the Fanger model, which is a method of approach to thermal comfort standpoint. The study focused on two configurations on the formation of the walls of a room. The first of these configurations led to the definition of a first cell constructed earthen adobe named Batter roofing sheet aluminum and a second cell built in blocks named Batbet which had the same geometric characteristics (thickness, dimensions and side openings) and covered in the same manner as the ground cell. The different comfort indices PMV and PPD values of these two configurations of habitat were identified and were used to determine their thermal comfort rating.

Keywords

Habitat Assessment, Habitat Suitability, Building Monitoring, Climate Change, Thermal Habitat, Orientation, Solar

1. Introduction

Thermal comfort is not only a function of the individual but also depends on its habitat. Thus we will study the factors related to the individual, his vesture and activity, then the thermal qualities of its habitat. A building is never steady because:

- The outside temperature is variable;

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- Solar radiation, periodic, may be picked up by some opaque parts of envelopes or may enter directly inside through the openings;
- The establishment of a thermal power inside the building due to its operation (metabolism occupants, appliances, cooking…) is variable in time;
- The building is ventilated with an air flow (possibly variable temperature gradient variable between inside and outside).

The problem is dynamic and relatively complex, that is why simulations are necessary, through the IT tool to see the thermal behavior of walls of a social housing in a given area. Climate databases needed to run the software in use (CoDyBa) consist of information about schedules:

- The air temperature outside (T_a);
- Global solar flux received by a horizontal plane;
- The height of the sun in relation to the south;
- The relative humidity of the outside air.

So we built a base of climatic data from the meteorological data from Chad (ten-year average) [1].

2. Formatting Climate Data

Comparisons inter weather stations and global climate data processing of Chad helped define homogeneous climatic zones. To this end the influence of latitude and altitude on weather data [1] was analyzed and defined, homogeneous areas were checked in terms of humidity, rainfall and regimes the wind. So there are three climate zones [2]:

- Climate zone A: Tropical climate;
- Climatic zone B: Sahelian climate;
- Climatic zone C: Saharan climate.

As part of this study, we will choose the city of N'Djamena as "sample city" representing the climate zone B.

2.1. Meteorological Database for the Bioclimatic Design of the Habitat

To evaluate the thermal comfort conditions in housing, it is necessary to be in the most adverse weather conditions, *i.e.* when the heat input is maximum [3] [4] Thus the weather data will be determined for The hottest time of the year in the dry season for the selected climate zone. For this assessment, we will use the thermal simulation software CoDyBa buildings, which uses meteorological databases hours and hours sorting the site (temperature, humidity and sunlight, wind, …). In the absence of such information in local climatological files, it is possible to reconstruct the typical days from the average maximum and minimum averages of the meteorological data of the place.

2.1.1. Outdoor Temperature Dry and the Relative Humidity

The objective of bioclimatic architecture is to reproduce comfort conditions identical to those experienced by an individual on the outside, in the shade (under a tree), with a light breeze [3] [5] [6]. For this, the average climatic characteristics of a region (in temperature and humidity) are to be implemented in non-conditioned spaces. **Table 1** presents the most favorable climatic characteristics which could result in non-conditioned spaces. **Table 2** provides the basic external conditions in the dry season and cool season by noting:

- T_x, the maximum temperature;
- T_n, the minimum temperature;
- T_m, the average temperature;
- H_{moy}, the average relative humidity.

2.1.2. Ventilation

Ventilation is the most important parameter in evaluating the humidity in the comfort [7] [8] building is the key driver. To this end, a house may have satisfactory thermal performance if it is pointing aerodynamically in the wind direction. **Table 3** provides for zone B average speed and direction of prevailing winds.

2.1.3. Rainfall

If rainfall does not directly climate comfort, it is against directly related to the sustainability of buildings; and

Table 1. Bases of external conditions for the climate zone B.

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
T_x (˚C)	31.9	33.6	39	41.1	40	38	34.1	31.9	34.1	37.6	36.6	32.6
T_n (˚C)	14.9	17.4	22.7	25.6	26.4	25.3	23.5	22.8	23.1	22.4	19.5	15.6
T_m (˚C)	23.4	25.5	30.9	33.4	33.2	31.7	28.8	27.4	28.6	30	28.1	24.1
H_{moy} (%)	22.1	18.5	18.4	22.4	39.6	50.3	67.6	72.5	66.3	43.3	25.9	22.6

Table 2. Basic external conditions dry and cool season (zone B).

	External condition base (dry season)		Basic external condition (cool season)	
Zone	Temperatures max dry. (˚C)	Warmest month	Temperature mini dry. (˚C)	Cooler month
B (N'Djamena)	41.1	April	14.9	January

Table 3. Climatic characteristics (wind) and geographical zone B.

	Prevailing winds		Wind Speed				
Zone	Dry season	Rain season	Dry season	Rain season	Latitude	Longitude	Elevation
B (N'Djaména)	NNE	SSW	3.2 m/s	2.4 m/s	12˚07 N	15˚03 E	298 m

the works must be protected against the rain. **Table 4** shows the monthly average amount of precipitation in the area B.

2.1.4. Sunshine

Solar radiation plays an important role in thermal exchanges of bioclimatic habitat because it may represent an important, sometimes the most important, external heat gains of the building.

The heat loads in the building due to solar radiation can be reduced by the shadows cast by the projections, canopies and neighboring buildings, the construction design for natural cooling. To determine these shadows, we must know the position of the sun: its height and azimuth. **Table 5** and **Table 6** give the monthly average of the average insulation and global and direct radiation on a horizontal plane.

2.1.5. Selection of Typical Days

Given Chad's climate data available, we have selected for the climate zone B sunny days during the hottest months of the dry season and we calculated hour by hour (24 h) the average of the various parameters: temperature, relative humidity, global flows and diffuse flux, speed and direction of wind, which allowed the establishment of the day type of climatic zone B, a typical day for the month of April (**Figure 1**).

Table 7 relates to the hottest month (April) in the year of parameter values for calculating the flux stream received in the city of Ndjamena [2] [9].

2.1.6. Solar Radiation Incident

Moreover, in **Table 8**, schedules climate files on a full year have been exploited to calculate the maximum solar global radiation incident solar radiation average monthly and annual incident on the various plans for area B [2] [9].

2.2. Definition of Local Types

Local types are defined according to current construction practices in Chad. We chose local surfaces, types of walls and dimensions of current openings.

The selected configuration of the local consists of a bedroom and a separate living room by a partition. The

Table 4. Monthly average height in meters (mm).

	Zone B											
Month	Jan	Feb.	March	April	May	June	July.	August	Sept.	Oct.	Nov.	Dec.
H (mm)	0	0	0	8.40	31.36	38.72	141.94	156.33	73.14	14.64	0	0

Table 5. Average daily sunshine hours.

Zone	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
B	9.5	9.4	8.8	8.8	8.7	8.3	7.1	6.7	7.7	9.1	9.8	9.3

Table 6. Average monthly global measured and direct radiation on a horizontal plane.

Zone	Flow Wh/d	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
B	IRg	4419	4976	6549	7236	7323	6641	5193	5075	5135	5212	5090	4121
	IRd	3058	3493	4821	5450	5510	4855	3414	3276	3634	4137	3664	2764

Table 7. Parameter values used for the constitution of a typical day.

Zone	Month	T_x at 15 pm	T_n at 3 am	Latitude	Transparency Coefficient	Specific Humidity	Insolation Fraction
N'Djaména	April	41.2˚C	25.6˚C	12˚07	0.75	0.79	0.78

*Insolation Fraction: average insolation report on the maximum duration of one day. *Transparency Coefficient: coefficient to calculate the live stream received by a horizontal plane sky "clear" (no clouds).

Table 8. Global solar radiation incident on the various plans (average in 24 h).

	Zone B		
	G monthly average (the hottest month) in W/m^2	**G annual average in W/m^2**	**G max in W/m^2**
North	68	78	156
East	161	149	162
South	65	126	218
Ouest	161	149	162
Horizontal	302	238	305

local is oriented along the east-west longitudinal axis.

2.2.1. Color Walls

We note that all exterior walls are light colored whose absorption coefficient is 0.30 (white). The absorption coefficient of the inner walls is 0.35 (beige).

2.2.2. Breakdown

Natural ventilation is ensured local with a fresh air flow that is ten times the volume of the space concerned (10 V/h) and a medium speed cited above.

2.2.3. Description of Premises

The dimensions and two selected local characteristics are as follows:

*Room

Unconditioned local presentation on the two adjacent walls to the east and south.

- Total floor space: 3.5 m × 3.0 m = 10.5 m^2
- Height: 3.40 m
- Height under false ceiling: 2.60 m
- Volume: 10.5 m^2 × 2.60 m = 27.3 m^3
- Air exchange rate: 273 m^3

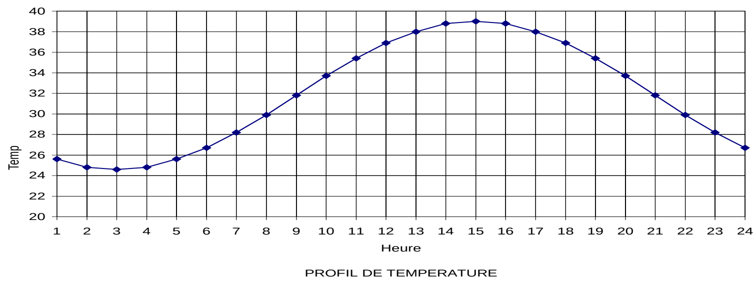
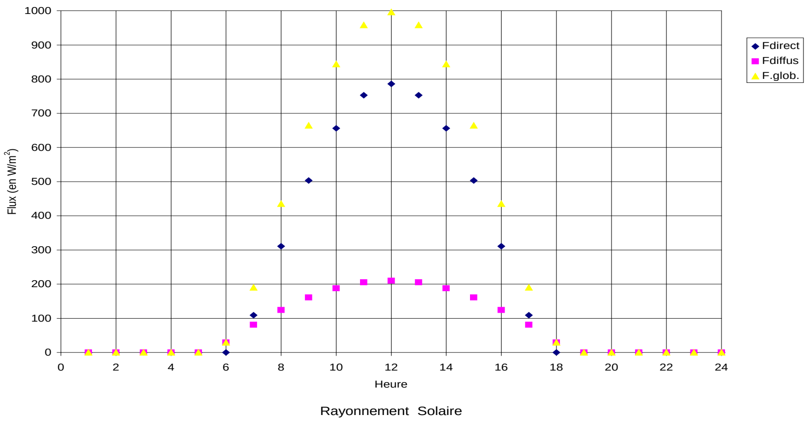
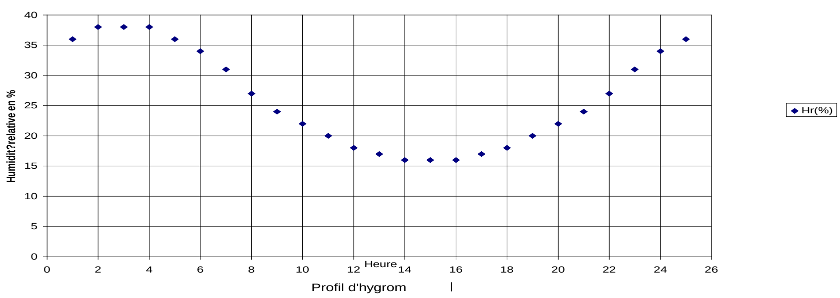
<table>
<tr><th colspan="2">DESCRIPTION OF A TYPE DAY</th><th colspan="2">N’DJAMENA</th></tr>
<tr><td>LOCALITY: N’DJAMENA
LATITUDE: 12˚07</td><td>YEAR: Over ten years
WIND SPEED: 2.4 m/s</td><td>MONTH: April
WIND DIRECTION: ENE</td><td>ALTITUDE: 298 m
Cloudiness: 4.2 octas</td></tr>
<tr><td colspan="3">
</td><td>Daily average: 33.4˚C
Maximum: 41.2˚C for 15 hours
Minimum: 25.6˚C at 3:00 PM
N.B: These values are restored by trihoraires interpolation of the data.
Source: DREM</td></tr>
<tr><td colspan="3">
</td><td>Overall Avg: 606 W/m^2
Global max: 998 W/m^2 at 12:00
Global min: 31 W/m^2 to 18 hours
Diffuse Avg: 150 W/m^2
Diffuse max: 211 W/m^2 at 12:00
Diffuse min: 31 W/m^2 to 18 hours
Source: DREM</td></tr>
<tr><td colspan="3">
</td><td>Average: 26%
Maximum: 38%
Minimum: 16%
N.B: Values reconstructed by interpolation trihoraires of data
Source: DREM</td></tr>
</table>

Figure 1. Description of a typical day of N’Djamena (month of April).

*Openings:
North Window of 1.20 m × 1 m
Clear glass transmission coefficient K = 5.8 W/m^2/˚C.
South Window of 1.20 m × 1 m
Clear glass transmission coefficient K = 5.8 W/m^2/˚C.
*Features walls:

- Exterior wall: ground brick 22 cm plus 1 cm and 2 cm ground respectively coated on both interior and exterior siding;
- Interior Partition: clay brick 22 cm + 1.5 cm of earth coated on both facings;
- Low Floor: 10 cm of heavy concrete.
- Roof: made of sheet metal, with an air gap of an average thickness of 40 cm and ceiling.

Time profiles of natural ventilation of the space concerned are presented in **Table 9**.

Table 9. Time profiles of natural ventilation of premises.

ROOM (maximum flow: 273 m^3)							
Profile week				Profile weekend			
Time	Flow %	Time	Flow %	Time	Flow %	Time	Flow %
1	100	13	0	1	100	13	0
2	100	14	0	2	100	14	50
3	100	15	0	3	100	15	50
4	100	16	0	4	100	16	50
5	100	17	50	5	100	17	50
6	100	18	50	6	100	18	50
7	50	19	100	7	0	19	100
8	50	20	100	8	0	20	100
9	50	21	100	9	0	21	100
10	50	22	100	10	0	22	100
11	50	23	100	11	0	23	100
12	0	24	100	12	0	24	100

To check the quality of the thermal comfort of our home land, we compared it to another habitat with the same construction plans but an envelope with cinderblock cement plaster.

3. Simulation

For the simulation, so we considered two configurations on the formation of the walls of this room. The first of these configurations results in the definition of a first cell in ground named BATTER roofing sheet aluminum and a second concrete cell named BATBET which has the same geometrical characteristics (thickness, lateral dimensions and openings) and covered with the same so that the earth cell.

In both configurations, the main facade is supposed to be exposed to full south; the windows are equipped with glazing usually located inside of the facade.

The study period is the typical day consists corresponding to the hottest month (April). **Table 10** shows the data obtained for the thermal characterization. Depending on the average temperature Tm and depending on the water content w. λ The soil used is that of Djaména whose thermal characteristics are derived from the study by [9] on the variation of the thermal conductivity so for an average temperature of 33.4˚C, we obtained the following values:

Thermophysical characteristics of cinderblock used in **Table 11** obtained from the data of construction works used are:

4. Description of the Study

We consider a previously defined local which we give the geometrical characteristics in **Figure 2** and **Figure 3**.

4.1. Description of Two Configurations

Room

Creating internal loads

The internal loads are the heat flow generated inside of the building by sources other than the conditioning system if present. They therefore involved in the heat balance of the volume of air inside the thermal zone studied. These expenses are mainly due to occupants, machines and lighting are considered according to **Figure 4** [10].

We see in our study lighting and dealing with their charges is taken into account distributions made according to the following **Table 12**.

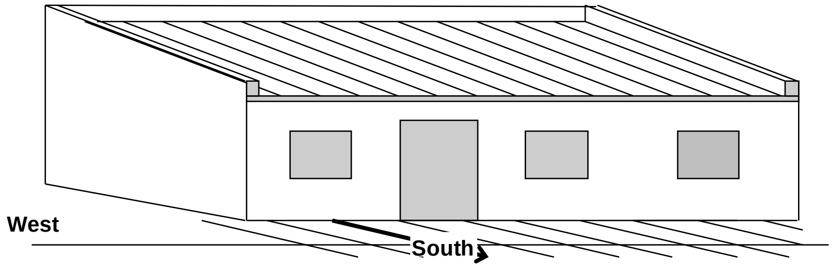


Figure 2. Overview of the study unit.

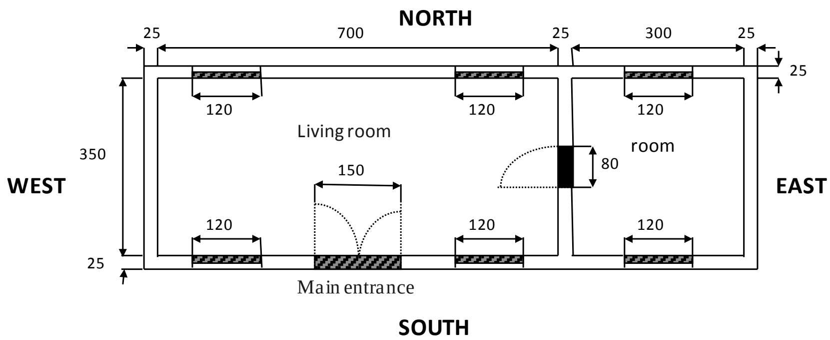


Figure 3. Plan view of the cell study.

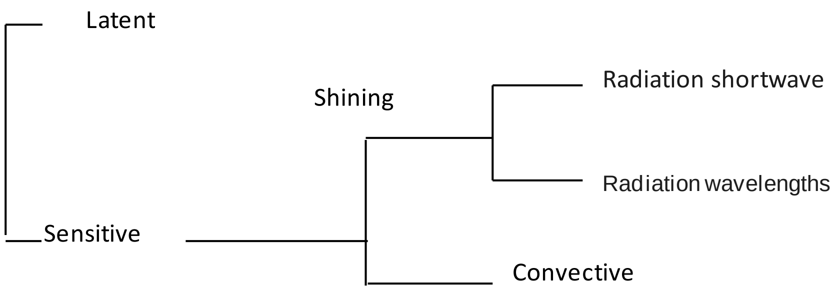


Figure 4. Schematic taking into account internal loads.

Table 10. Thermal characteristics of the land in N'Djamena.

Month	Average outdoor Temperature: T_m (˚C)	Average Relative Humidity Air: H_{moy} (%)	Average Moisture content Earth: w (%)	Apparent Thermal Conductivity: λ_{app} (W/m·˚C)	Heat Capacity: C (J/kg·K)	Density: (kg/m^3)
April	33.4	22.4	6.25	0.46	1465	1625

Table 11. Thermal characteristics of concrete block.

Properties	Thermal Resistance: R_{th} (m^2·˚C /W)	Heat Capacity: C (J/kg·K)	Density: ρ (kg/m^3)
Value	0.160	920	1400

Table 12. Internal charges.

Load type	Number	W/unit	Sensible			Latent
			% CLO	% GLO	% CONV	W/unit
Lighting	1	60	20	40		0
Occupying	1	110	0	50	50	60

These internal loads are used depending on time profiles given in **Table 13**.

Creating BATTER1 building (Earth Room)

For **Tables 14-20**, the constitution of the walls of buildings using the dimensions considered and the values of thermophysical characteristics of the different measured materials or some standard values for use by the simulation with the software "CoDyBa" retained.

Table 13. Profiles of internal loads schedules.

Eclairage Fluo.								Occupant							
Profile sensible				Profile latent (inoperative)				Profile sensible				Profile latent			
Time	%	Time	%	Time	%	Time	%	Time	%	Time	%	Time	%	Time	%
1	0	13	0	1	100	13	100	1	100	13	0	1	100	13	0
2	0	14	0	2	100	14	100	2	100	14	0	2	100	14	0
3	0	15	0	3	100	15	100	3	100	15	100	3	100	15	100
4	0	16	0	4	100	16	100	4	100	16	100	4	100	16	100
5	100	17	0	5	100	17	100	5	100	17	0	5	100	17	0
6	100	18	100	6	100	18	100	6	100	18	0	6	100	18	0
7	100	19	100	7	100	19	100	7	100	19	0	7	100	19	0
8	0	20	100	8	100	20	100	8	0	20	0	8	0	20	0
9	0	21	100	9	100	21	100	9	0	21	0	9	0	21	0
10	0	22	100	10	100	22	100	10	0	22	0	10	0	22	0
11	0	23	100	11	100	23	100	11	0	23	100	11	0	23	100
12	0	24	100	12	100	24	100	12	0	24	100	12	0	24	100
Maximum: 60 Watt				Maximum: 0 Watt				Maximum: 110 Watt				Maximum: 60 Watt			

Table 14. Characteristics of the south wall.

Layer	Material	Thickness (m)	Conductivity: λ (W/m/˚C.)	Cap.Cal: C (J/kg·˚C)	Density: ρ (kg/m^3)
1	Coated ext. ground	0.020	0.46	1465	1625
2	Bricks (ground)	0.220	0.46	1465	1625
3	Int coating. ground	0.010	0.46	1465	1625

Table 15. Characteristics of the east wall.

Layer	Material	Thickness (m)	Conductivity: λ (W/m/˚C.)	Cap.Cal: C (J/kg·˚C)	Density: ρ (kg/m^3)
1	Coated ext. ground	0.020	0.46	1465	1625
2	Bricks (ground)	0.220	0.46	1465	1625
3	Int coating. ground	0.010	0.46	1465	1625

Table 16. Characteristics of the north wall.

Layer	Material	Thickness (m)	Conductivity: λ (W/m/˚C.)	Cap.Cal: C (J/kg·˚C)	Density: ρ (kg/m^3)
1	Coated ext. ground	0.020	0.46	1465	1625
2	Bricks (ground)	0.220	0.46	1465	1625
3	Int coating. ground	0.010	0.46	1465	1625

Table 17. Characteristics of the west wall.

Layer	Material	Thickness (m)	Conductivity: λ (W/m/˚C.)	Cap.Cal: C (J/kg·˚C)	Density: ρ (kg/m^3)
1	Coated ext. ground	0.020	0.46	1465	1625
2	Bricks (ground)	0.220	0.46	1465	1625
3	Int coating. ground	0.010	0.46	1465	1625

Table 18. Characteristics of the inside door.

Layer	Material	Thickness (m)	Conductivity: λ (W/m/˚C.)	Cap.Cal: C (J/kg·˚C)	Density: ρ (kg/m^3)
1	Wood	0.040	0.160	2095	800

Table 19. Characteristics of the floor.

Layer	Material	Thickness (m)	Conductivity: λ (W/m/˚C.)	Cap.Cal: C (J/kg·˚C)	Density: ρ (kg/m^3)
1	Cement	0.100	1.750	653	2100

Table 20. Characteristics of roof.

Layer	Material	Thermal Resistance (m^2 K/W)	Thickness (m)	Conductivity: λ (W/m/˚C.)	Cap.Cal: C (J/kg·˚C)	Density: ρ (kg/m^3)
1	Sheet metal	-	0.002	70	800	7000
2	Airspace	0.180	0.400	-	100	1000
3	Wood	-	0.005	0.100	990	1200

a) Walls

1) South Wall

Type: outer wall

Azimuth: 0˚ Area: 6.6 m^2 Tilt: 90˚

Absorption coefficient (int/ext): 0.35/0.30 Thermal Resistance: 0.554˚C·m^2/W

Temperature reduction coefficient TAU: 1.00.

2) East Wall

Type: outer wall

Azimuth: 0˚ Area: 10.5 m^2 Tilt: 90˚

Absorption coefficient (int/ext): 0.35/0.30 Thermal Resistance: 0.554˚C·m^2/W

Temperature reduction coefficient TAU: 1.00.

3) North Wall

Type: outer wall

Azimuth: 0˚ Area: 9 m^2 Tilt: 90˚

Absorption coefficient (int/ext): 0.35/0.30 Thermal Resistance: 0.554˚C·m^2/W

Temperature reduction coefficient TAU: 1.00.

4) West Wall

Type: outer wall

Azimuth: 0˚ Area: 8.82 m^2 Tilt: 90˚

Absorption coefficient (int/ext): 0.35/0.30 Thermal Resistance: 0.554˚C·m^2/W

Temperature reduction coefficient TAU: 1.00.

5) West wall 2 (door)

Type: inside wall

Azimuth: 0˚ Area: 1.68 m^2 Tilt: 90˚

Absorption coefficient (int/ext): 0.35/0.35 Thermal Resistance: 0.250˚C·m^2/W

Temperature reduction coefficient TAU: 0.00.

6) Low floor

Type: floor

Azimuth: 0˚ Area: 10.50 m^2 Tilt: 180˚

Absorption coefficient (int/ext): 0.50/0.00 Thermal Resistance: 0.057˚C·m^2/W

Temperature reduction coefficient TAU: 0.00.

7) Roof

Type: floor

Azimuth: 0˚ Area: 10.50 m^2 Tilt: 0˚

Absorption coefficient (int/ext): 0.35/0.50 Thermal Resistance: 0.759˚C·m^2/W

Temperature reduction coefficient TAU: 1.00.

b) Windows

1) North Window

Number of windows: 1 | Percentage of opening: 50%
Height: 1.20 m | Width: 1 m | Depth: 0.25 m
Azimuth: 180˚ | Tilt: 90˚ | Permeability: 4
K Day/Night: 4.8 | Clear coefficient: 0.70
Window reads: glazed windows | Number of single: 1
Single Glass: transmission coefficient (0.85); absorption coefficient (0.08).

2) South Window

Number of windows: 1 | Percentage of opening: 50%
Height: 1.20 m | Width: 1 m | Depth: 0.25 m
Azimuth: 0˚ | Tilt: 90˚ | Permeability: 4
K Day/Night: 4.8 | Clear coefficient: 0.70
Window reads: glazed windows | Number of single: 1
Single Glass: transmission coefficient (0.85); absorption coefficient (0.08).

Creating BATBET1 building (Cement Room)

The data cited in the beginning of each paragraph (a1-a7) to determine the characteristics of the southern walls, East, North, West, and the inner door, the floor and roof in **Tables 21-27**.

Table 21. Characteristics of the south wall (cement).

Layer	Material	Thermal Resistance (m^2 K/W)	Thickness (m)	Conductivity: λ (W/m/˚C.)	Cap.Cal: C (J/kg·˚C)	Density: ρ (kg/m^3)
1	Coated ext. cement	-	0.020	1.150	1000	1700
2	Blocks (cement)	0.160	0.220	-	920	1400
3	Coated Int. cement	-	0.010	1.150	1000	1700

Table 22. Characteristics of the east wall (cement).

Layer	Material	Thermal Resistance (m^2 K/W)	Thickness (m)	Conductivity: λ (W/m/˚C.)	Cap.Cal: C (J/kg·˚C)	Density: ρ (kg/m^3)
1	Coated ext. cement	-	0.020	1.150	1000	1700
2	Blocks (cement)	0.160	0.220	-	920	1400
3	Coated Int. cement.	-	0.010	1.150	1000	1700

Table 23. Characteristics of the North wall (cement).

Layer	Material	Thermal Resistance (m^2 K/W)	Thickness (m)	Conductivity: λ (W/m/˚C.)	Cap.Cal: C (J/kg·˚C)	Density: ρ (kg/m^3)
1	Coated ext. cement	-	0.020	1.150	1000	1700
2	Blocks (cement)	0.160	0.220	-	920	1400
3	Coated Int. cement	-	0.010	1.150	1000	1700

Table 24. Characteristics of the west wall (cement).

Layer	Material	Thermal Resistance (m^2 K/W)	Thickness (m)	Conductivity: λ (W/m/˚C.)	Cap.Cal: C (J/kg·˚C)	Density: ρ (kg/m^3)
1	Coated ext. cement	-	0.015	1.150	1000	1700
2	Blocks (cement)	0.160	0.220	-	920	1400
3	Coated Int. cement	-	0.015	1.150	1000	1700

Table 25. Characteristics of the inside door.

Layer	Material	Thickness (m)	Conductivity: λ (W/m/˚C.)	Cap.Cal: C (J/kg·˚C)	Density: ρ (kg/m^3)
1.	Wood	0.040	0.160	2095	800

Table 26. Characteristics of the floor.

Layer	Material	Thickness (m)	Conductivity: λ (W/m/°C.)	Cap.Cal: C (J/kg·°C)	Density: ρ (kg/m^3)
1	cement	0.100	1.750	653	2100

Table 27. Characteristics of roof.

Layer	Material	Thermal Resistance (m^2 K/W)	Thickness (m)	Conductivity: λ (W/m/°C.)	Cap.Cal: C (J/kg·°C)	Density: ρ (kg/m^3)
1.	Sheet metal	-	0.002	70	800	7000
2	Airspace	0.180	0.400	-	100	1000
3	Wood	-	0.005	0.100	990	1200

a) Walls

1) South Wall

Type: *outer wall*

Azimuth: 0° Area: 6.6 m^2 Tilt: 90°

Absorption coefficient (int/ext): 0.35/0.30 Thermal Resistance: 0.071°C·m^2/W

Temperature reduction coefficient TAU: 1.00.

2) East Wall

Type: *outer wall*

Azimuth: −90° Area: 10.5 m^2 Tilt: 90°

Absorption coefficient (int/ext): 0.35/0.30 Thermal Resistance: 0.071°C·m^2/W

Temperature reduction coefficient TAU: 1.00.

3) North Wall

Type: *outer wall*

Azimuth: 180° Area: 9 m^2 Tilt: 90°

Absorption coefficient (int/ext): 0.35/0.30 Thermal Resistance: 0.071°C·m^2/W

Temperature reduction coefficient TAU: 1.00.

4) West Wall

Type: *Inside wall*

Azimuth: 90° Area: 8.82 m^2 Tilt: 90°

Absorption coefficient (int/ext): 0.35/0.30 Thermal Resistance: 0.067°C·m^2/W

Temperature reduction coefficient TAU: 0.00.

5) West Wall 2 (door)

Type: *inside wall*

Azimuth: 0° Area: 1.68 m^2 Tilt: 90°

Absorption coefficient (int/ext): 0.35/0.35 Thermal Resistance: 0.250°C·m^2/W

Temperature reduction coefficient TAU: 0.00.

6) Low Floor

Type: *floor*

Azimuth: 0° Area: 10.50 m^2 Tilt: 180°

Absorption coefficient (int/ext): 0.50/0.00 Thermal Resistance: 0.057°C·m^2/W

Temperature reduction coefficient TAU: 0.00.

7) Roof

Type: *floor*

Azimuth: 0° Area: 10.50 m^2 Tilt: 0°

Absorption coefficient (int/ext): 0.35/0.50 Thermal Resistance: 0.759°C·m^2/W

Temperature reduction coefficient TAU: 1.00.

b) Windows

1) North Window

Number of windows: 1 Percentage of opening: 50%

Height: 1.20 m Width: 1 m Depth: 0.25 m

Azimuth: 180˚	Tilt: 90˚	Permeability: 4
K Day/Night: 4.8		Clear coefficient: 0.70
Window reads: glazed windows		Number of single: 1

Single Glass: transmission coefficient (0.85); absorption coefficient (0.08).

2) South Window

Number of windows: 1		Percentage of opening: 50%
Height: 1.20 m	Width: 1 m	Depth: 0.25 m
Azimuth: 0˚	Tilt: 90˚	Permeability: 4
K Day/Night: 4.8		Clear coefficient: 0.70
Window reads: glazed windows		Number of single: 1

Single Glass: transmission coefficient (0.85); absorption coefficient (0.08).

4.2. Simulation Results

Simulation results give us as defined configurations of the selected habitat changes per hour during 24 hours of a hot day in the hottest months, the following quantities:

- The temperature of the ambient air within the space;
- The resulting temperature of the atmosphere;
- And the local relative humidity.

We present in following **Table 28**, the results of all local defined in tables and variations of these quantities with time.

Table 28. Results of thermal simulation rooms.

Time	Room : Batter1			Cement room: Batbet1		
	T˚ air int. (˚C)	Tres. (˚C)	Hr (%)	T˚ air int. (˚C)	Tres (˚C)	Hr (%)
1	31.6	32.6	28	32.1	33.2	27
2	31.2	32.2	29	31.4	32.5	29
3	30.9	31.9	29	30.9	32.0	29
4	30.8	31.7	30	30.6	31.5	30
5	31.0	31.7	29	30.6	31.4	30
6	31.3	31.8	29	30.8	31.3	30
7	32.9	32.6	35	32.1	31.9	37
8	32.7	32.5	36	31.9	31.7	37
9	32.8	32.6	36	32.1	32.0	37
10	32.9	32.9	35	32.5	32.4	36
11	33.1	33.1	35	32.9	32.9	35
12	33.3	33.4	35	33.4	33.4	35
13	33.6	33.6	34	33.9	33.9	34
14	33.8	33.9	34	34.4	34.5	33
15	34.3	34.4	41	35.2	35.2	39
16	34.5	34.6	49	35.7	35.7	46
17	35.2	35.0	27	36.5	36.2	25
18	35.3	35.1	23	36.6	36.5	21
19	35.5	35.3	22	36.7	36.6	21
20	35.0	35.0	23	36.1	36.3	21
21	34.3	34.6	23	35.4	35.8	22
22	33.6	34.1	24	34.5	35.2	23
23	33.0	33.8	26	33.8	34.7	25
24	32.3	33.2	27	33.0	34.0	26

***Room**

In **Figures 5-8**, we have shown the resulting curves of the simulation of the two cases studied configurations, in order to observe the variation of the temperature of indoor air, the relative humidity and the resulting temperature for 24 hours.

From these curves, one notes that the amplitude of variations of these amenities (the temperature of indoor air, the relative humidity and the resulting temperature) is slightly lower for the earth construction as that of the construction cement. Indeed, during the hottest hours of the day, the thermal inertia of earth constructions tends to maintain the temperature of the indoor local air above the cement constructions.

We can say that for a hot month in Chad, it is more comfortable to live in a thermally land habitat because generally a local air temperature, relative humidity and high mean radiant temperature tend to produce a sensation discomfort in quiet air.

5. Thermal Comfort

Thermal comfort is considered the expressed satisfaction or subjective indifference to the local atmosphere. It is, indeed, based on heat exchange between the human body and environment. The comfort is even better than the heat generated by the body (metabolism) can be disengaged with less stress.

To define thermal comfort conditions, diagrams were long used moist air which are bounded on comfort zones (e.g. Givoni diagram: Annex A4). Using these diagrams sketchy faces a problem of choice: chart contour zones vary according to the authors.

To determine the thermal sensation of an individual characteristic data in a given environment, we will use a more efficient method is the model of Fanger [9] [11].

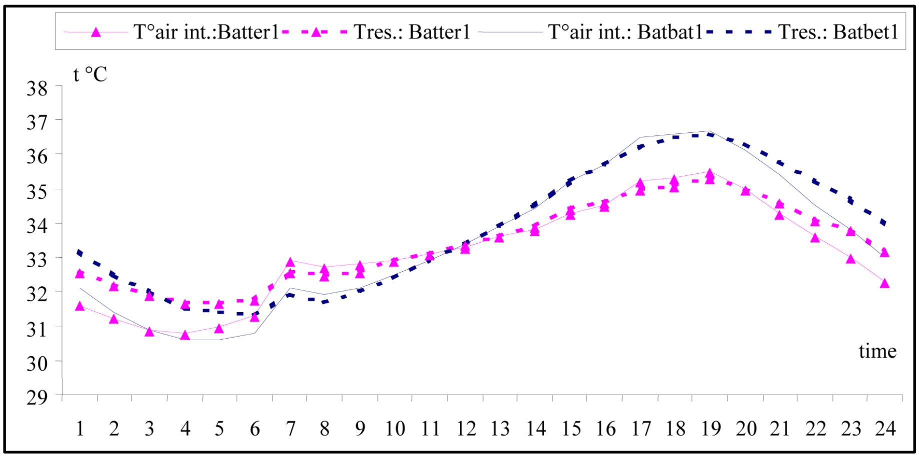


Figure 5. Variation of the resulting temperature and the air temperature inside the rooms.

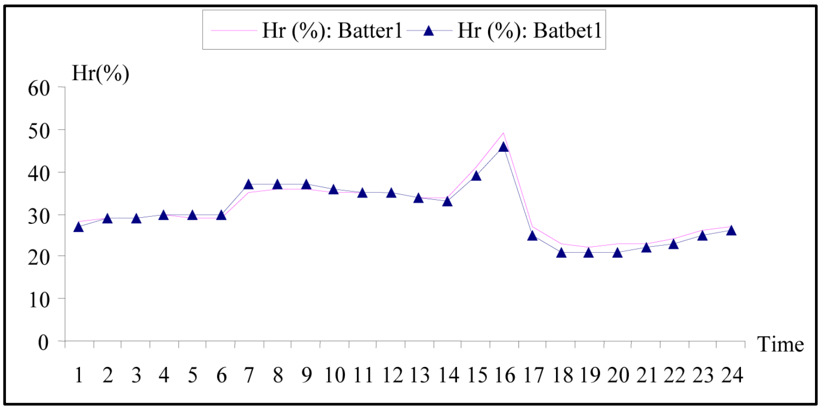


Figure 6. Variation of relative humidity rooms.

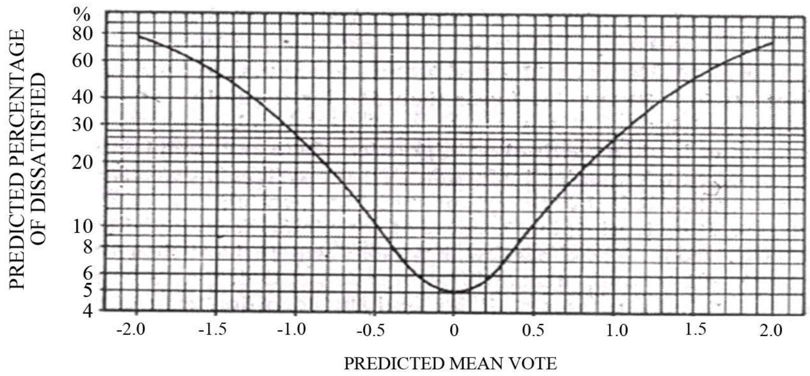


Figure 7. PPD evolution according to PMV.

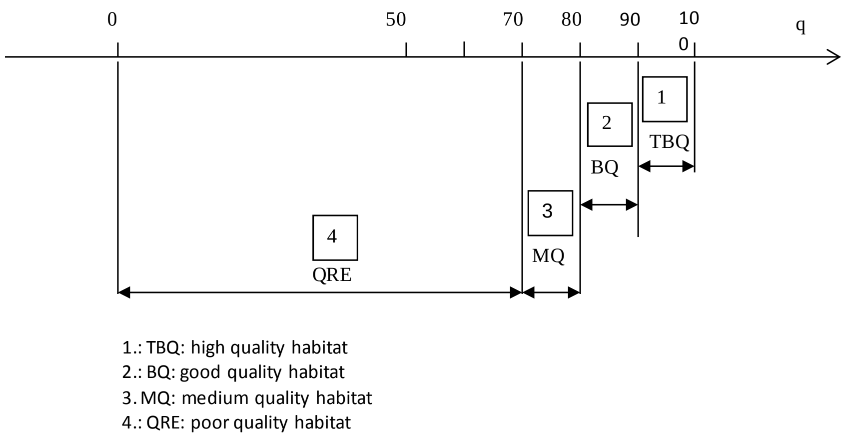


Figure 8. habitat quality characterization Scale.

5.1. The Model of Fanger

The equation of the instantaneous humidity heat balance between the human body and its environment is written [12]-[14]:

$$E_{ry} = 3.95\times10^{-8} F_{cl} \cdot A_{du} \left[\left(T_{cl}+273\right)^4 - \left(T_r+273\right)^4 \right] \tag{1}$$

$$E_{cv} = F_{cl} \cdot h_c \left(T_{cl} - T_a\right) \tag{2}$$

$$E_{ps} = \left(M-W\right) - 3.05\times10^{-3}\left[5733 - 6.99\left(M-W\right) - P_v\right] \tag{3}$$

$$E_{cr} = 0.00146M\left(34 - T_a\right) \tag{4}$$

$$E_{hr} = 1.73\times10^{-5} M\left(5820 - P_v\right) \tag{5}$$

$$E_{sd} = 0.42\left[\left(M-W\right) - 58.15\right] \tag{6}$$

avec:

F_{cl}: ratio between the area covered by the coat and the surface of the naked body

$$*F_{cl} = 1 + 0.2I_{cl} \quad siI_{cl} = 0.5Clo$$

$$*F_{cl} = 1.05 + 0.1I_{cl} \quad siI_{cl} > 0.5\ Clo$$

hc: exchange coefficient between the skin and clothing given by:

$$*hc = 2.38\left(T_{cl} - T_a\right)^{0.25} \quad si\ 2.38\left(T_{cl} - T_a\right) > 12.1\sqrt{v}$$

$$*hc = 12.1\sqrt{v} \quad si\ 2.38\left(T_{cl} - T_a\right) < 12.1\sqrt{v}$$

T_r: mean radiant temperature;
T_a: temperature of the ambient air;
P_v: partial pressure of water vapor at the temperature of the ambient air;
T_{cl}: Living the temperature determined by:

$$*T_{cl} = T_{cut} - 0.155 I_{cl}\left(M - W - E_{ps} - E_{rh} - E_{cr} - E_{sd}\right) \tag{7}$$

T_{cut}: skin temperature calculated by

$$*T_{cut} = 29.35 + 0.196 T_a - 1.064\frac{M}{58.15} \tag{8}$$

By replacing the terms of the equation:

$$Q = \left(M - W\right) - \left(E_{ry} + E_{cv} + E_{cd} + E_{ps} + E_{cr} + E_{hr} + E_{sd}\right)$$

by their value while laying $H = M - W$ and dividing by A_{du} we obtain the thermal equation of the individual who is:

$$\begin{aligned}\frac{Q}{A_{du}} &= \frac{H}{A_{du}} - \frac{1}{A_{du}}\left\{\left(M - W\right) - 3.05\times10^{-3}\left[5733 - 6.99\left(M - W\right) - P_v\right]\right\} \\ &\quad - 0.00146\frac{M}{A_{du}}\left(34 - T_a\right) - 1.73\times10^{-5}\frac{M}{A_{du}}\left(5820 - P_v\right) - \frac{0.42}{A_{du}}\left[\left(M - W\right) - 58.15\right] \\ &\quad - 3.95\times10^{-8} F_{cl}\cdot\left[\left(T_{cl} + 273\right)^4 - \left(T_r + 273\right)^4\right] - F_{cl}\cdot h_c\left(T_{cl} - T_a\right).\end{aligned} \tag{10}$$

Fanger proposed formulas for calculating each of the speaker terms in equation (10) the thermal balance of the body in a state of thermal comfort. These formulas were derived from experimental studies involving a large number of subjects (1300) and include both physical and physiological measurements and the record subjective assessments of the test subjects.

The formulation of Fanger is recognized worldwide today and has replaced the use of comfort zones in the humid air diagram.

Fanger determines the vicinity of the comfort zone a number of thermal sensation levels experienced by an individual. In a situation of comfort, thermal equilibrium is achieved without recourse to sweat: that is to say, the thermal load of the individual is zero. The feeling of comfort is translated by the following equation:

$$Q = \left(M - W\right) - \left(E_{ry} + E_{cv} + E_{ps} + E_{cr} + E_{hr} + E_s\right) = 0 \tag{11}$$

The deviation from the ideal conditions of comfort is characterized by the PMV index (Predicted Mean Vote). This index to quantify the thermal sensation, represents the average value of ratings of a sample of individuals in response to thermal stresses atmosphere.

This index is calculated from the heat balance imbalance:

$$PMV = \frac{Q\cdot C_a}{A_{du}} \tag{12}$$

where $C_a = 0.303\cdot e^{-2.1\cdot ACT} + 0.028$, *ACT*: MET activity parameter (1MET = 58.15 W/m^2)

Each level of thermal sensation is identified numerically according the following **Table 29**:

The PMV is the average value of votes, Fanger has therefore sought to know the percentage of dissatisfied thermal sensation zone. It has introduced another PPD index (Predicted Percentage of Dissatisfied). This index will help in determining rationally quality ambience of a room for a certain type of activity. The PPD is connected to the VMS by Equation (13):

Table 29. Qualification scale thermal sensation.

PMV	Thermal sensation
+3	hot
+2	lukewarm
+1	slightly warm
0	neutral
−1	slightly chilled
−2	fresh
−3	cold

$$PPD = 100 - 95\exp\left[-\left(0.03353PMV^4 + 0.2179PMV^2\right)\right] \tag{13}$$

We can then find the values of PPD from the curve of **Figure 7**.

The function score comfort n is built from the PPD by Equation (14):

$$n = 100 - PPD$$

Either:

$$n = 95\exp\left[-\left(0.03353PMV^4 + 0.2179PMV^2\right)\right] \tag{14}$$

q that would account number of the thermal quality of habitat is based on ratings comfort n (t) corresponding to the times t studied. As part of the contribution to the development of the general laws of design assistance, taking into account the average daily need more locally because they illustrate the evolution of the quality score changes induced by the project designer. These qj daily notes, which are expressed by equation (15):

$$q_j = \frac{\left[\sum_{i=1}^{i=24} n_{i,j}\right]}{24} \tag{15}$$

sometimes will isolate a particularly typical day and observe the changes in results of the analysis comfortable conditions on a specific subsequence, thus we consider a typical day's hottest April to review by the characterization given by scale [14] and shown in **Figure 8** the two cases selected configuration.

5.2. Application of the Model of Fanger

We consider a standard user sitting at rest in the various local defined above, in April, with a light summer dress. We will evaluate the balance of heat exchanges that individual and its environment to determine the feeling of thermal comfort in each local defined above. This sensation can be evaluated from the resulting temperature very dry, which summarizes the radiative and convective exchanges. This temperature is given by the following expression:

$$T_{res} = \frac{h_{ci}T_{air.\mathrm{int}} + h_r T_r}{h_{ci} + h_r} \tag{16}$$

with: h_{ci}, exchange coefficient by convection;

h_r, radiant exchange coefficient;

T_r, mean radiant temperature;

$T_{air.\mathrm{int}.}$, Interior air temperature.

In still air and the h_{ci} and h_r coefficients are very close to where we have: $T_{res} = \frac{T_{air.\mathrm{int}.} + T_r}{2}$

The values of dry resulting temperature we are given by the simulation results.

5.2.1. Characteristics Ambience

The characteristics of the local atmosphere are determined for a day. The values of the temperature of the interior air, the resulting temperature and relative humidity are obtained by simulation. Those of mean radiant temperature and vapor pressure are derived from the values of the quantities mentioned above. **Table 30** shows the values of the characteristics of the atmosphere of rooms.

5.2.2. Individual Characteristics and Dress

For standard individual of 1.73 m height and 70 kg weight sitting at rest and wearing a light summer dress, the thermal characteristics of the person and his vesture are summarized in the following **Table 31**.

5.2.3. Evaluation of the Thermal Quality

In this section, we will evaluate the different terms of thermo hygrometric equation, given by equations (1)-(6). From these equations and results of various characteristics of the elements identified above, we will calculate the

Table 30. Characteristics of the ambiance of Room.

Time	Ground room				Cement room			
	$T_{air.int.}$ (˚C)	T_r (˚C)	$H_{r\ int.}$ (%)	Pv (mb)	$T_{air.int.}$ (˚C)	T_r (˚C)	$H_{r\ int.}$ (%)	Pv (mb)
1	31.6	33.2	28	13.53	32.1	33.9	27	13.40
2	31.2	32.7	29	13.71	31.4	33.0	29	13.6
3	30.9	32.3	29	13.48	30.9	32.2	29	13.48
4	30.8	31.8	30	13.87	30.6	31.5	30	13.72
5	31.0	31.5	29	13.56	30.6	30.9	30	13.72
6	31.3	31.3	29	13.78	30.8	30.7	30	13.87
7	32.9	31.3	35	18.15	32.1	30.5	37	18.37
8	32.7	31.4	36	18.46	31.9	30.7	37	18.17
9	32.8	31.7	36	18.57	32.1	31.0	37	18.37
10	32.9	32.1	35	18.15	32.5	31.5	36	18.27
11	33.1	32.5	35	18.35	32.9	32.0	35	18.15
12	33.3	32.8	35	18.54	33.4	32.6	35	18.65
13	33.6	33.4	34	18.31	33.9	33.4	34	18.61
14	33.8	33.7	34	18.51	34.4	34.1	33	18.55
15	34.3	34.0	41	22.93	35.2	34.7	39	22.89
16	34.5	34.5	49	27.70	35.7	35.4	46	27.72
17	35.2	34.6	27	15.84	36.5	35.9	25	15.72
18	35.3	34.8	23	13.57	36.6	36.4	21	13.27
19	35.5	35.1	22	13.12	36.7	36.7	21	13.35
20	35.0	35.1	23	13.35	36.1	36.8	21	12.93
21	34.3	34.9	23	12.86	35.4	36.4	22	13.05
22	33.6	34.8	24	12.92	34.5	36.0	23	13.00
23	33.0	34.2	26	13.55	33.8	35.3	25	13.61
24	32.3	33.7	27	13.55	33.0	34.5	26	13.55

Table 31. Characteristics of the individual and of his clothing.

Activity: Sitting at rest	Cladding: Wear lightweight summer
Metabolism (M) = 106 w	Total thermal resistance = 0.078 m^2/˚C/W
Mechanical power ext. (W) = 0 W	Isolation of the dress = 0.5 Clo

different indices PMV and PPD comfort [12] and No scoring function given by equation (14). The results of this calculation are presented in **Tables 32-34**.

***Room**

Given that ISO 7730 [15] provides acceptable thermal comfort for the following values for the PMV and PPD:

- −5 < PMV < 5
- PPD < 10%

Note that the PMV and PPD indices as they have been defined by Fanger, are global indices applying to the human body and the local in its entirety (using air temperature, radiant temperature, of humidity and air velocity) per hour. We made the calculation of average daily indices of these premises to use as a simple way to characterize thermal comfort of the subject therein. Given the results of this calculation, we can say that thermal comfort is acceptable in both configurations.

From the PMV values, we used the relation (4) to determine the score of comfort n because one of the advantages of this rating system is to avoid physical Manichaeism declaring comfortable or not comfortable atmosphere that according one is located or not in the thermal comfort zone. The system proposed by [16]-[18] allows

Table 32. Calculation of comfort indices PMV and PPD ground Room.

Time	Gound room								
	E_{ry}	E_{cv}	E_{ps}	E_{cr}	E_{hr}	E_{sd}	Q	PMV	PPD
1	11.66	13.12	94.95	0.37	8.16	20.10	−42.35	−0.65	13.91
2	14.40	14.39	95.01	0.43	8.13	20.10	−46.46	−0.71	15.75
3	16.43	15.34	94.94	0.48	8.17	20.10	−49.45	−0.76	17.19
4	18.81	15.67	95.06	0.50	8.10	20.10	−52.22	−0.80	18.61
5	20.76	15.02	94.96	0.46	8.15	20.10	−53.46	−0.82	19.27
6	22.08	14.08	95.03	0.42	8.11	20.10	−53.82	−0.83	19.46
7	24.95	9.17	96.38	0.17	7.30	20.10	−52.07	−0.80	18.53
8	24.66	9.81	96.48	0.20	7.24	20.10	−52.50	−0.81	18.76
9	24.00	9.50	96.51	0.19	7.22	20.10	−51.51	−0.79	18.24
10	19.95	9.17	96.38	0.17	7.30	20.10	−47.07	−0.72	16.04
11	18.61	8.54	96.44	0.14	7.26	20.10	−45.09	−0.69	15.12
12	15.58	7.91	96.50	0.11	7.23	20.10	−41.43	−0.64	13.53
13	15.19	6.95	96.43	0.06	7.27	20.10	−40.01	−0.62	12.95
14	12.15	6.33	96.49	0.03	7.23	20.10	−36.33	−0.56	11.54
15	9.07	4.91	97.86	−0.05	6.41	20.10	−32.30	−0.50	10.16
16	8.08	4.45	99.33	−0.08	5.53	20.10	−31.41	−0.48	9.88
17	7.35	1.79	95.67	−0.19	7.73	20.10	−26.45	−0.41	8.45
18	6.47	1.38	94.97	−0.20	8.15	20.10	−24.87	−0.38	8.05
19	5.04	0.73	94.83	−0.23	8.24	20.10	−22.71	−0.35	7.54
20	5.13	2.33	94.90	−0.15	8.19	20.10	−24.49	−0.38	7.96
21	4.84	4.53	94.75	−0.05	8.28	20.10	−26.45	−0.41	8.45
22	6.29	6.75	94.77	0.06	8.27	20.10	−30.24	−0.47	9.52
23	5.40	8.68	94.96	0.15	8.15	20.10	−31.45	−0.48	9.89
24	8.54	10.90	94.96	0.26	8.16	20.10	−36.91	−0.57	11.75
				Average				**−0.61**	**13.36**

Table 33. Calculation of comfort indices PMV and PPD cement Room.

Time	Cement room								
	E_{ry}	E_{cv}	E_{ps}	E_{cr}	E_{hr}	E_{sd}	Q	PMV	PPD
1	6.52	11.53	94.92	0.29	8.18	20.10	−35.53	−0.55	11.25
2	11.37	13.76	95.06	0.40	8.10	20.10	−42.79	−0.66	14.10
3	14.75	15.34	94.94	0.48	8.17	20.10	−47.77	−0.73	16.37
4	20.15	16.30	95.01	0.53	8.12	20.10	−54.20	−0.83	19.67
5	21.81	16.30	95.01	0.53	8.12	20.10	−55.86	−0.86	20.59
6	25.45	15.67	95.06	0.50	8.10	20.10	−58.86	−0.91	22.32
7	28.68	11.71	96.45	0.29	7.26	20.10	−58.50	−0.90	22.10
8	30.00	12.34	96.39	0.32	7.30	20.10	−60.45	−0.93	23.27
9	27.03	11.71	96.45	0.29	7.26	20.10	−56.84	−0.87	21.14
10	24.33	10.44	96.42	0.23	7.28	20.10	−52.80	−0.81	18.91
11	19.95	9.17	96.38	0.17	7.30	20.10	−47.07	−0.72	16.04
12	16.59	7.60	96.53	0.09	7.21	20.10	−42.12	−0.65	13.82
13	13.16	6.01	96.52	0.02	7.22	20.10	−37.03	−0.57	11.80
14	8.02	4.43	96.51	−0.06	7.23	20.10	−30.21	−0.46	9.51
15	4.52	2.05	97.84	−0.19	6.42	20.10	−24.75	−0.38	8.02
16	1.43	0.64	99.34	−0.26	5.52	20.10	−20.77	−0.32	7.12
17	−0.02	−2.34	95.63	−0.39	7.75	20.10	−14.73	−0.23	6.07
18	−4.38	−2.75	94.88	−0.40	8.21	20.10	−9.65	−0.15	5.46
19	−5.08	−3.06	94.90	−0.42	8.19	20.10	−8.63	−0.13	5.37
20	−6.06	−1.18	94.77	−0.32	8.27	20.10	−9.57	−0.15	5.45
21	−4.57	1.05	94.81	−0.22	8.25	20.10	−13.42	−0.21	5.88
22	−3.40	3.90	94.79	−0.08	8.26	20.10	−17.56	−0.27	6.52
23	−1.88	6.14	94.98	0.03	8.14	20.10	−21.52	−0.33	7.28
24	1.99	8.68	94.96	0.15	8.15	20.10	−28.04	−0.43	8.88
Average								**−0.54**	**12.79**

for the shade between two architectural proposals, one leading to slightly uncomfortable atmosphere and the other very uncomfortable atmospheres. The distinction is made on the footnote that establishes quality deviations at a given time on the sequence of study. Even a short study sequence provides a series of notes that can be considered as such because it would become difficult to read, which brings us to use parameter synthesizing these results as the average of those notes whose quality index q will result.

The results of this calculation are shown in the following **Table 34**.

The results show us that whether we are in a building or land in a cement building for this hot day in April, we have a quality index q such that: $80\% < q < 90\%$. Depending on the scale of **Figure 8**, the two habitats are considered good thermal quality.

It is important to note that the number q is not a comfort index [19]. It characterizes the building in relation to the thermal fields that are created during the climatic sequence and the reaction of the user. It is not intended to make finely account statements comfort of a user, but rather to give an image a posteriori the conditions under which it perceived the atmosphere. The indices comfort them and have to assess the physiological reactions to environmental factors.

In conclusion, we can say that although the PPD in the land habitat is slightly higher than that in the cement housing, land habitat has almost the same thermal performance as the cement and with habitat very good

Table 34. Calculation notes of comfort and quality of local heat.

Time	Ground room			Cement room		
	PMV	***PPD***	***n***	***PMV***	***PPD***	***n***
1	−0.65	13.91	86.09	−0.55	11.25	88.75
2	−0.71	15.75	84.25	−0.66	14.10	85.90
3	−0.76	17.19	82.81	−0.73	16.37	83.63
4	−0.80	18.61	81.39	−0.83	19.67	80.33
5	−0.82	19.27	80.73	−0.86	20.59	79.41
6	−0.83	19.46	80.54	−0.91	22.32	77.68
7	−0.80	18.53	81.47	−0.90	22.10	77.90
8	−0.81	18.76	81.24	−0.93	23.27	76.73
9	−0.79	18.24	81.76	−0.87	21.14	78.86
10	−0.72	16.04	83.96	−0.81	18.91	81.09
11	−0.69	15.12	84.88	−0.72	16.04	83.96
12	−0.64	13.53	86.47	−0.65	13.82	86.18
13	−0.62	12.95	87.05	−0.57	11.80	88.20
14	−0.56	11.54	88.46	−0.46	9.51	90.49
15	−0.50	10.16	89.84	−0.38	8.02	91.98
16	−0.48	9.88	90.12	−0.32	7.12	92.88
17	−0.41	8.45	91.55	−0.23	6.07	93.93
18	−0.38	8.05	91.95	−0.15	5.46	94.54
19	−0.35	7.54	92.46	−0.13	5.37	94.63
20	−0.38	7.96	92.04	−0.15	5.45	94.55
21	−0.41	8.45	91.55	−0.21	5.88	94.12
22	−0.47	9.52	90.48	−0.27	6.52	93.48
23	−0.48	9.89	90.11	−0.33	7.28	92.72
24	−0.57	11.75	88.25	−0.43	8.88	91.12
q_j		**86.64**			**87.21**	

architectural design we can improve thermal comfort.

6. Conclusions

The study of bioclimatic comfort and thermal simulation has enabled the assessment of the thermal quality of ground adobe mixed with straw. The simulation analysis by the software CoDyBa confirmed the interesting behavior of earth materials. Fanger's model is a method of approach in terms of habitat comfort, supports the conclusion that the earth mixed with straw is a good thermal performance material.

Despite all the attention on building envelopes of land adobes habitat mixed with straw, the better quality thermal comfort can be achieved by taking into account the architectural parameters.

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