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Experimental Study of Thermal Comfort in Traditional Buildings in the Region of Adamawa in Cameroon

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ABSTRACT

This paper presents experimental results of a short-term thermal comfort survey performed in naturally ventilated traditional buildings in the city of Meiganga, in Cameroon during hot season. We obtained data from physical measurements (air temperature, relative humidity) using kestrel model AVM 4000. The data are collected on 23th of May 2015, 14th March 2016, and another one in January, February, March, April and May 2017. Some of our measurements of the environmental variables fell below the thermal comfort range recommended by ASHRAE standard 55 and ISO 7730 standard.
This study concludes that, during the hot season the desire for sustainable thermal comfort may not be achieved without mechanical ventilation system in some period.
KEYWORDS: thermal comfort, traditional building, local materials.

I. INTRODUCTION

Thermal comfort in traditional buildings (TB) playsan important role as well in interior environment as for the quantity of energy required by the equipment. Yet the energy used for heating, ventilation or air conditioning of buildings represents the major energy consumed by this sector **[1, 2]**. Thermal comfort is defined from the study of a representative sample of human beings. The human body needs to be shielded from the external environment in order to maintain its heat balance. This shield is the environmental envelope of the buildings where the heat exchange is conducted. The American Society of Heating, Refrigerating and Air conditioning Engineers (ASHRAE) defined it as the condition of mind in which satisfaction is expressed with the thermal environment **[3]**. But before all, define the characteristic parameters of the environment that can, under certain conditions lead to a sensational discomfort. Some essential parameters include: atmospheric temperature, humidity of the surrounding air, temperature differences sustained in time and space **[4]**. According to A. Mokhtari **[5]**, it is essentially estimated as a function of the external characteristic parameters. All buildings have to be comfortable and healthy in order to protect the occupants of the external environment, to insure an internal balance and a pleasant quality that is less dependent on the external conditions. It is as a matter of fact a general and stable state of well-being **[6]**.
To reduce the economic and environmental cost of energy consumption, investigations covering many aspects related to the thermal comfort in indoor environments have attracted authors for decades. This interest is based on the exchange relationship that is maintained between man and his environment, being it natural or constructed **[7, 8]**. A building is a siege of several thermal solicitations, both internally and externally. It concerns thermal solicitations like surrounding temperature, solar flux received by the external walls of a house, the heat given off by the occupants and equipments within a house **[9]**. The envelope of a house plays a key role in the exchange of heat between the internal and the external environment due to its thermal properties.
Based on the nature of the materials of the envelope, the heat coming from the external environment can deaden and even undergo a lag before reaching the internal environment. The thermal behavior of a building at any given time obviously depends on the construction materials and the climatic conditions of where the building is located, without forgetting architectural dispositions **[9, 10]**.
Some works have already been undertaken concerning the study of thermal comfort in traditional buildings, e.g., Agung and *et al* **[11-12]** that conducted a study of thermal behavior of traditional buildings in Indonesia and those of Nevin Aydin Gezer **[13]** and Wang Liping **[14]** who also made a study of thermal comfort in residential buildings in Turkey and Singapore respectively. They showed the influence of the studied materials on the comfort of the occupants. Lawal and al **[15]** in the works have shown how the choice of material, the orientation of the building, and the environment have contributed so much to the comfort of occupants at Ibadan, Nigeria. A

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similar study was conducted by Akeel **[16]** in a mosque at Baghdad where, he evaluated the thermal characteristics of the building's envelope.
In Cameroon, Kemajou et *al.* **[17]** made a thermal simulation over period of 24 hours in the northern part of Cameroon. Based on the experimental and numerical simulation the authors, reveals that the thermal inertia of building materials has a real impact on the temperature of the internal wall surface of building in the city of Douala in Cameroon. It shows that the building constructed of material as light as the wooden is best suited for households in hot and humid climate.
Our study will be conducted in the Adamawa region, precisely in Mbere Division where almost all the buildings have been constructed using clayey bricks; the reason why we will be studying thermal comfort in this zone. The main aim is to see how in what measure we can study thermal comfort in this zone without having anything to do with air conditioning that necessitates an immense consumption of energy.
Our project is subdivided as follows: we will start by a presentation of the geographical location of the zone of study, methodology and end with the interpretation of the results obtained. We confront our experimental results with the predictions of the international standards treating of thermal comfort. The outcomes are summarized in the last section of the paper, devoted to some concluding remarks.

2. Location and Buildings types of study area

2.1. Location

Cameroon is a country in central Africa located just above the equator, between latitudes 2° and 13°North and between longitudes 9° and 16°East. It has a surface area of 475442 Km^2 and presents different climatic nuances which, with its varied relief, summarizes the major biogeographically sets of the African continent **[18]**. The country is divided into 10 regions and the Adamawa is one of the biggest. This region, also called the Drainage basin of Cameroon, is made up of 5 Divisions amongst which we have the Mbere. The head quarter of this previous is Meiganga, located south-east of the region and between latitudes 6° and 7°north and longitudes 14° and 15°east (see **Fig.1**). More than 50% of its buildings are in local materials (walls mounted using clayey bricks); reason behind the interest to carry out a thermal comfort study in these houses. The altitude here ranges between 900 and 990m with a relatively cool climate varying between 22 and 25°C. it is an equatorial climate of the Guinean type with 4 seasons: a long dry season from December to April; a minor humid season from May to June; a dry season from July to October; and a rainy season from October to November. The relative humidity here ranges between 50 and 85% (averagely 70%) and precipitations between 900 and 1500 mm/yr.

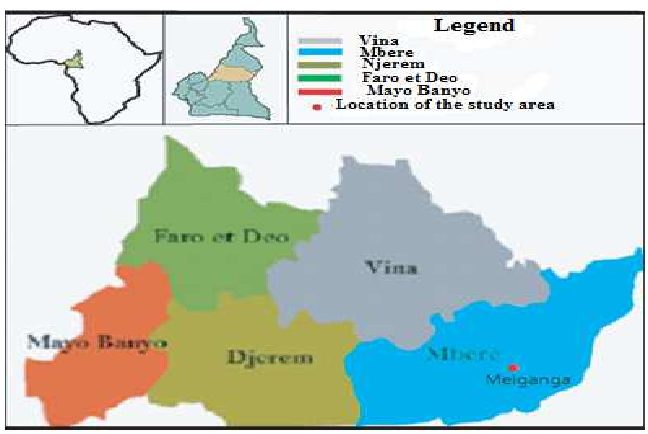

Figure 1: Map of Adamawa Region

2.2. Buildings types

From the North to the South and from the East to the West, the country has different forms of traditional houses constructed using local materials which in most cases differ from one region to another. In the Northern part of the country in general and in the Adamawa region in particular, houses are mostly constructed using mud or clayey bricks and sometimes the roofs in thatches, as present in **Fig.2**. The houses in Meiganga can take different shapes: square, rectangular and circular (Boukarou) as well as. also have modern buildings shapes.

Figure 2: Some traditional buildings at Meiganga

3. MATERIALS AND METHODS

The field test includes a measurement of environmental parameters such as temperature; relative humidity and air velocity (see **Tab.1**).

Measured parameter	Instrument	Precision °C	Note
Air temperature	Pocket Weather tracker AVM-4000	$\pm 1°C$	Manual acquisition per 60 mn
Relative humidity	Pocket Weather tracker AVM-4000	$\pm 3\%$	Manual acquisition per 60 mn

Table1: Measured parameter of outdoor, indoor and instrument

The method used here is a direct method of measurement using a climatic anemometer of the AVM-4000 type. The apparatus that was used for data collection is a pocket Kestrel 4000 climatic anemometer that permits a precise measurement of the following environmental conditions: wind speed, temperature, relative humidity, cooling index, rate of heating, air pressure, thermal stress, dew point, date and time. The resultant data are recorded in the table 1.

The building that was used in this study was built with earth bricks as shown in figure**Fig.2**. Measurements were taken after an interval of one hour during a period of 24 hours. Measurements were conducted on the 23rd of May 2015 in a building made up of two rooms. However another data were conducted on the 14 March 2016 and the last one in January, February, March, April and May 2017. After each interval of one hour, the temperature and relative humidity of the building were noted. These measurements of temperature and relative humidity were noted for room 1, room 2, and externally.

The experimental data are presented in **Tab.2**.

Time (h)	Outdoor temperature (°C)	Outdoor Humidity (%)	Temperature of room 1 (°C)	Relative humidity of room 1 (%)	Temperature of room 2 (°C)	Relative humidity of room 2 (%)
1	24.5	75.6	28.2	72.4	27.4	77.2
2	24.2	71.5	27.2	72.2	27.7	74.8
3	25.7	69.2	27.5	72.4	27.5	73.1
4	24.5	72.2	27.1	74.8	26.2	75.6
5	24.2	70.6	26.8	73.1	26.4	75.1
6	24.7	68.6	26.4	71.4	26.5	69.5
7	22.9	85.6	27.4	68.1	27.1	66.7
8	26.3	76.7	26.6	67.6	26.5	71.2
9	27	73.5	27.7	73.8	27.5	70.6
10	28.7	71.1	29.2	75.7	28.9	71.6
11	30.3	64.3	30.3	70.8	30.1	71
12	31.7	61.2	31.8	66.4	31.6	70.6
13	31.8	48	31.1	64.4	31	66.4
14	31.9	54.4	30.5	66.4	30.8	70.5
15	33.5	52.3	32.1	61.4	32.1	60.5
16	34.4	49.7	33.6	55.1	32.7	64.5
17	27.9	70.1	28.9	74.2	29.1	73.8
18	24.9	73,2	28.7	68.7	28.9	69.4
19	25.7	75.6	28.8	76.1	28.9	71.9
20	22.9	87.8	28.7	73.2	28.8	73.6
21	23.4	82.4	28.3	66.9	28.3	65.9
22	24	72.7	28.2	67.3	28.1	67.7
23	22.2	75.6	28.2	67.3	28	63.2
24	21.6	75.1	26.2	76.2	27.7	66.3

Table 2: We present the experimental data during the day of 23thMay 2015

4. RESULTS AND INTERPRETATIONS

We present firstly in **Fig.3** the summary of Ngaoundere climatic conditions during a period of ten years (2007 - 2016). These curves are similarly, but in January 2008 the temperature decrease and reach a value of 10.5°C. We remarks also that, the hottest months where the average monthly temperature exceed 21°C are: February, March, April and May. Our experimental data are collected during this time.

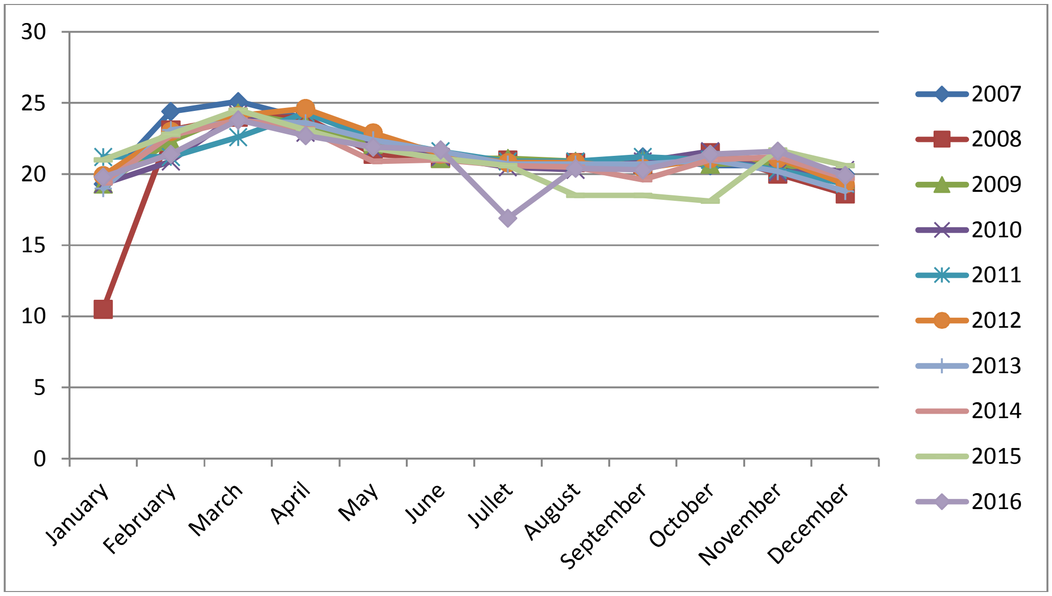

Figure 3: Summary of Ngaoundere climatic conditions (2007-2016) [19]

The average annual precipitation obtains in 2015 is 1473.3 mm, while in 2016 the average annual precipitation is 1482.5 mm with a difference of 8.9 mm. These two annual precipitations fell in the precipitation ranges of Adamawa region. We observe in this graph that, in January, February, November and December there is no rain. During this time, the climate is humid particularly in December and January and hot in February, March, April and May.

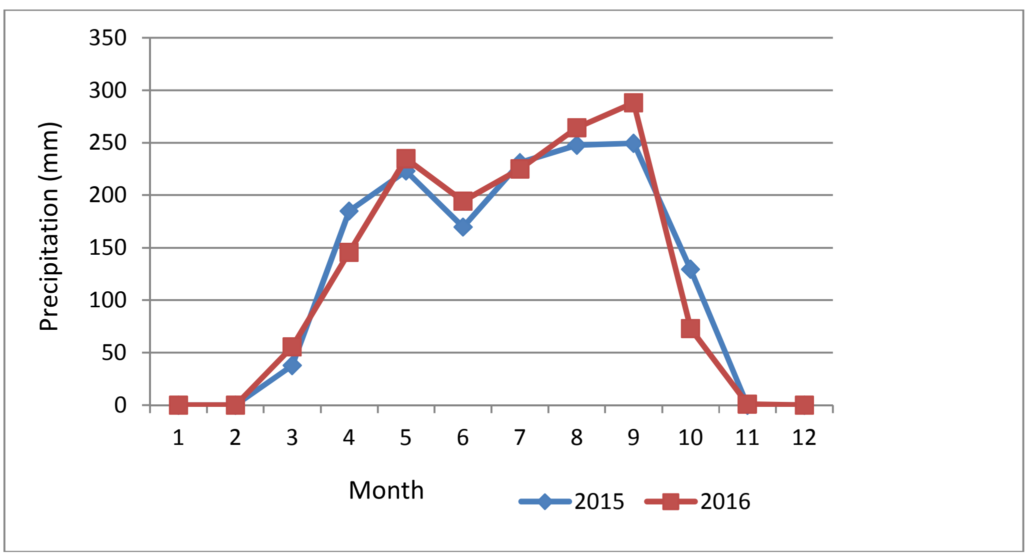

Figure 4: Annual precipitation for the year 2015 and 2016 [19]

The town of Meiganga is characterized by, an equatorial Guinean climate with 4 seasons. In **Fig.5a, b**, we present the annual temperature of the year 2015 and 2016 in Adamawa region where data are collected in the meteorological weather station in Ngaoundere airport **[19].**This curve show us that, the absolute maximum temperature in the hottest month is 33.6°C in February, and the minimum temperature in the coldest month is

11.7°C in the month of January for 2015. However in 2016 the maximum temperature here is 33.1°C in March, the difference is only 0.5°C and the minimum one is 9.8°C with a difference of 1.9°C in January like in 2015.
These data collected in Ngaoundere airport show also that, in January, February, March, April, May and November the temperature exceeded 30°C.

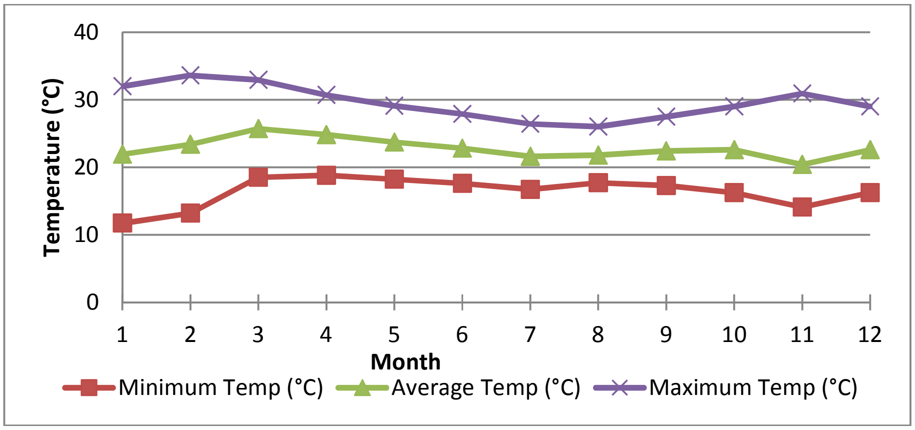

Figure 5a: Monthly average temperature, maximum temperature and minimum temperature of the year 2015

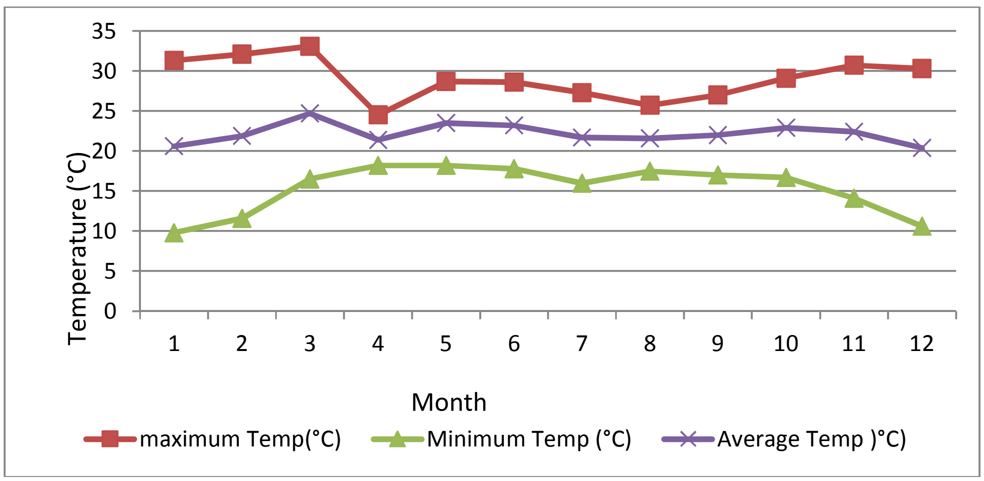

Figure5b: Monthly average temperature, maximum temperature and minimum temperature of the year 2016

4.1. Presentation of the experimental result obtained in 23thMay 2015

The results of the monitoring carried out from 23th May 2015 are presented in figure 6. Here, we present the evolution of the outdoor temperature, the indoor temperature of room 1 and of room 2. The diurnal air temperature of outdoor is higher than the indoor temperature from 1 pm to 4 pm. From 8 am to 12 am the temperature of indoor of all the rooms are almost equal to the outdoor air temperature. From 12 am to 4 pm the temperature increases. The outdoor temperature decreases from 5 pm to 7 am, the temperature difference is above 3°C with a maximum value of 6°C. From 6 pm to 12 pm, the indoor temperature of room 1 and room2 reach 28°C. During the night time, and because of the long wave radiation from ground to the sky, the indoor temperature of the two rooms increases.

Concerning outdoor conditions, the maximum temperature registered is 34.4°C at 4 pm. for indoor conditions of the two rooms, the maximum temperature is 33.6°C at 4 pm for room 1 and 32.7°C at 4 pm for room 2. The minimum is 21.6°C at 24 hours for outdoor. The minimum temperature from room 1 is 26.2°C at 24 hours and also 26.2°C at 4 hours for room 2.

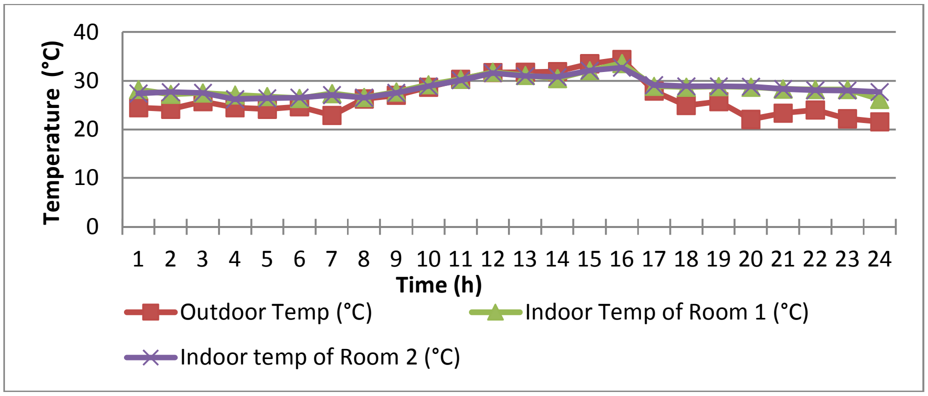

Figure6: Comparison of outdoor temperature and indoor temperature of room 1and room 2

In figure 7, we make a comparison between the outdoor relative humidity and indoor relative humidity of room 1 and for room 2 on the 23th May 2015. For outdoors conditions, the maximum relative humidity registered was 87.8%in 20 hours, the minimum was 48% and the average was 69.8%. For internal condition of room 1 the maximum relative humidity 76.2% at 24 hours, the minimum was 55.1% at 4 pm and the average was 69.8%. For room 2 the maximum was 77.2% at 1 hour, the minimum was 60.5% at 3 pm and the average was 70.02%. We note that the humidity is among the indoor environmental factors that could affect thermal comfort in a building as predicted in **Ref. [20]**

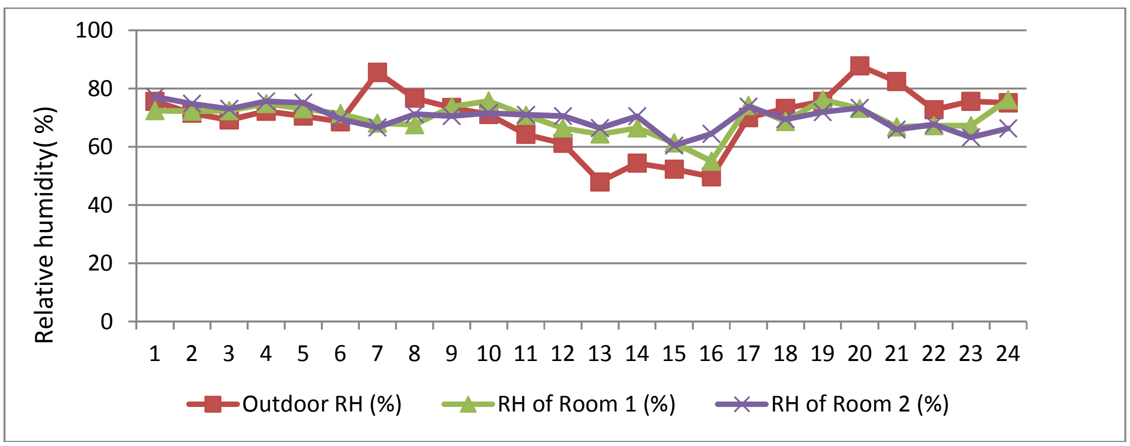

Figure 7: comparison of outdoor and indoor relative humidity of room 1 and room 2

4.2. Presentation of the experimental result obtained in 14th March 2016

Before the interpretation of these results, we gave us the table of data collection in the 14th march 2016 in two different traditional buildings one covers with roofs and another with thatch (see **Tab.3**).

	Traditional Buildings covers with sheet metal		Traditional Buildings covers with straw		Outdoor	
Time	**T(°C)**	**HR(%)**	**T(°C)**	**HR(%)**	**T(°C)**	**HR(%)**
1	23.5	55.6	22.7	51	18.5	60
2	23.5	50.2	22.5	52.6	19.8	61.8
3	23.3	51.4	22	51.3	18.9	58.9
4	23.5	46.5	22.4	51.3	18.6	64
5	22.4	51.8	22.5	52.6	18.7	61.8
6	20.9	55.1	21.4	54.8	19.5	60.5
7	21.3	68.4	21.1	59.7	20.8	60.8
8	22.9	55.5	22.5	55.4	23.9	52.8
9	27.6	51.6	27	51.5	27.7	52.4
10	28.5	52.3	28.6	50.1	31.1	44.7
11	30.7	55.7	30.5	49.9	33	45.1
12	32.5	51.8	34.7	46.2	34.3	42.8
13	33.1	44.3	32.8	40.6	34.5	36.2
14	34.4	38	34.1	35	36	30.5
15	36.2	35.7	35.1	32.4	33.3	32.4
16	31.5	42.9	31.2	44.8	30.6	45.3

17	31.4	48	30.8	48.5	30	47.6
18	28.9	51.6	28.7	51.6	26.7	55.7
19	25.6	62.5	25.9	61.9	25.5	63.8
20	28.8	56.9	28	57.5	26.7	59.8
21	25.4	64.3	25.3	65.2	24.5	68.9
22	23.8	67.8	23.8	71	22.4	77.9
23	26.1	62.2	27.3	58.5	22.2	78.4
24	22.5	50.7	21.8	53	21.3	54.5

Table 3: Data acquisition in the 14th March 2016

In **Fig.8**, we compare internal and external temperature of two traditional houses, one covers with roofs and another with grass. Here the data were collected in 14th March 2016. In this curve, we see that the indoor temperature of the two houses the one covered with grass reaches a peak of 35.1°C at 3 pm and the other covered with grass also at 3pm reaches a temperature of 36.2°C.Similarly the indoor maximum temperature reached in the 10th march 2017 is 30.9°C at 4 pm with a minimum of 27.9°C at 22 hours. But in the day of 7 March 2017 the maximum indoor temperature was 30.2°C at 20 hours and the minimum was 26.6°C at 8 hours. However the outdoor temperature reached a peak 36°C at 2 pm. But for the traditional house covers with roof, the indoor temperature reaches a peak at 3 pm. This graph also shows that, the radiation peak time starts at 7 am and increases gradually to reach a maximum at 3 pm, and reduces gradually after that to reach starting point at 5 am. However the inner temperature increases from 7 am gradually till 3 pm.

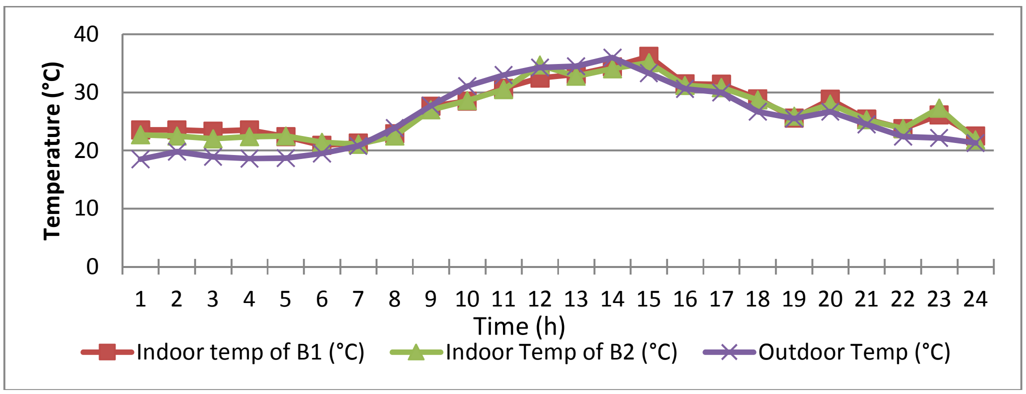

Figure 8: comparison of internal-external temperature the two difference traditional houses

Curve **Fig.9** presents the evolution of the relative humidity of the two different traditional buildings. The maximum outdoor relative humidity is 78.4%, the minimum is 30.5% and the average is 54.8%. For the house with sheet metal, the maximum relative humidity is 68.4%, the minimum is 35.5% and the average was 52.9%. For the straw one, the maximum temperature is 71%, the minimum is 32.4% and the average is 51.9%.

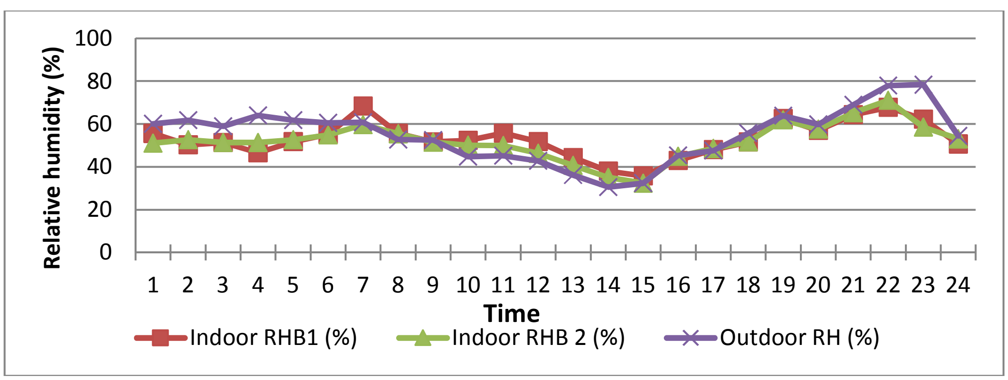

Figure 9: relative humidity of the two different traditional buildings

4.3. Presentation of the experimental result obtained in 2017

6TH January 2017					13TH January 2017				23TH January 2017				28TH January 2017			
Time	**TI**	**TE**	**HI**	**HE**	**TI**	**TE**	**HI**	**HE**	**TI**	**TE**	**HI**	**HE**	**TI**	**TE**	**HI**	**HE**
1	23.4	17.4	53.6	51.3	22.4	20.9	51.6	40.2	25	24.5	52.4	35.5	26.1	25.1	48.9	32.5
2	22.9	18.4	49.5	53.6	21.8	20.5	46.6	40.3	24.1	23.4	52.7	41.1	26.8	25.4	50	38.8
3	22.4	19.1	47.9	47.1	21.1	19.5	48.8	42.8	22.9	23	49.7	46.2	25.3	24.6	52.4	40.8
4	21.7	17.6	49.8	53.7	20.8	15.5	54.2	55.5	22.6	21.8	48.3	44.5	25.2	24.3	52.7	42
5	21.6	15.8	51.2	64.9	19.9	13.2	51.4	55.1	22.1	20.9	50.1	44.1	25	23.3	52.3	43.7
6	20.5	15.7	54.2	60.4	25.1	22.9	39.7	38.1	24.5	19.9	50.7	46.7	24.4	22.8	50.5	45.1
7	20.7	18.8	52.3	53.2	19.5	17.4	49.3	46.3	21	15.8	55.2	63.8	23.4	22.8	52.7	53.2
8	21	20.4	52.8	44.7	20	19.3	51.4	39.5	22.2	19.9	53.8	58	23.4	23	53.8	53.9
9	21.4	21.9	50.8	33.7	20	19.9	40.2	39.3	22.9	23.3	51	36.4	23.9	24.2	58.2	62
10	22	23	47.1	30.7	20.7	22.9	45.5	29.1	23.4	27.4	46.4	17.4	24.4	25	59.1	60.6
11	22.2	24.7	49.7	28.2	21	23.1	42.5	28.1	27.2	29.8	32	15.6	25	25.8	63.6	43.3
12	22.8	27.6	52.5	27.5	21.6	25.2	45.2	26.1	28.5	32.3	31.3	13.5	25.7	28.4	50.5	30.9
13	23.3	28	51.3	26.5	22.7	25.5	56.3	26.3	27.5	32.5	31.5	13.2	25.5	27.3	48.2	34.6
14	24	30.3	52.5	28.5	23	27.7	45.3	23.8	26.5	32.8	40.6	16.1	30.1	31.5	47.5	35.8
15	24.8	30.7	51	28.1	23.7	29.7	47.3	22.9	27.1	31.6	30.6	18.4	28.1	32.5	52.9	37.7
16	25.1	29.4	46.2	32.3	24.4	30.6	43.2	22.2	26.2	31.5	30.8	18.9	28.3	33.3	54.4	41.7
17	27.3	26.7	43.6	40.2	27.5	27.5	27.5	26.5	26.3	30.7	30	18	28.4	29.2	45.8	41.2
18	25.5	25.2	47.6	35.6	26.4	26.2	40.5	29.2	27	27.6	37.2	21.1	28.2	28.6	45.5	45.9
19	26.5	26.3	47.1	42.1	24.9	25.2	49.3	37.6	27.2	26.9	44.2	33.3	28.3	28.2	48.4	37.4
20	26	24.7	46.7	33.8	25.4	25.3	50.5	35.3	28.5	26.7	47.7	28.2	28.3	27.7	49.6	36.2
21	26.5	24.1	51.5	32.3	25.5	24.2	49.4	44.6	27	25.4	42.5	32.3	28.5	27.4	50.6	37.6
22	24.8	23.2	47.3	34.5	25.3	23.6	51.9	32.6	26.6	25.9	41.9	31.9	26	24.2	49.4	34.6
23	24	22.8	37.9	49.3	22.8	21.8	50.2	44.1	26.2	22.7	46.6	49	26.2	24.6	57.2	37.2
24	23.6	20.8	50.6	52.9	23.6	21.5	54.6	36.6	24.3	23.6	52.8	40.3	26.5	25.9	56.7	52.8

3TH February 2017					12TH February 2017				17TH February 2017				23TH February 2017			
Time	**TI**	**TE**	**HI**	**HE**	**TI**	**TE**	**HI**	**HE**	**TI**	**TE**	**HI**	**HE**	**TI**	**TE**	**HI**	**HE**
1	23.8	23.6	47.5	39.4	26	24.5	47.5	40.9	29	27.6	63.2	52.6	28.4	27.4	62.4	62.1
2	23.8	22.4	51.5	44.8	25.5	24.1	47.8	40.9	28.2	26.9	59.5	55.1	28.1	27	64	64.2
3	23.5	22.5	50.3	45.2	26.1	24.6	52	42.1	28.7	27	60.4	54	28.2	27.1	64.2	62.1
4	23	21.4	49.4	45.6	25	24.4	49.8	44.2	27.8	26.6	59.6	57.8	27.9	27.3	62.5	60.4
5	25.8	21.5	57.7	43.1	25	24.2	49.9	44.2	27.2	26.6	58.8	55.1	27.7	27	53.3	59.8
6	22.7	20.8	51.6	46.9	25.3	23.7	48.8	41.8	27	26.1	59.6	56.4	27.4	25.8	63.3	64
7	22.5	21.5	53.5	50.9	24.2	23.6	49.7	47.3	26.5	25.7	60.5	61.6	27.6	26.5	62.7	63.8
8	22.7	20.1	48.9	60.1	24	23.9	48.3	45.7	26.4	25.6	60.7	62.1	27.3	26.4	68.9	69
9	23	24.1	50.5	49.2	24.1	24.4	43.8	34.4	26.6	26.2	61.9	70.5	27.8	25	63.6	75.4
10	24.1	26.5	52.3	40.9	24.1	24.9	50	44.2	27	27.8	61.5	63.5	27	25.9	66.3	72.5
11	24.7	29.5	53.1	27.2	24.3	25	51.3	41.9	27.2	28.6	61.5	60.2	27.3	27.2	65.6	67.8
12	25.2	31.8	48.5	17.5	24.4	25.9	52.2	42.5	27.4	32.2	60.8	38.5	27.5	30	67.8	53.8
13	26.2	33.2	49.3	18.1	24.7	31	49.3	20.5	27.8	33.5	59.3	34.7	27.6	31	61.4	44.4
14	26.3	32.2	27.9	19.4	26.1	33.6	40.8	15	28.1	33.8	58.9	37	27.9	32.1	61	37.3
15	24.7	32.4	39.7	19.4	26.8	34	41.2	19.9	29.4	34.7	53.1	36.2	28.5	33.7	58.5	45.1
16	28.3	31.9	50.7	20.2	27.3	32.5	41.2	23.5	29.8	35.4	53.4	33	28.8	31.5	61.9	51
17	27.3	30.4	39.7	21.5	27.6	31	45	21.6	30.2	34.5	51.8	29.5	28.6	30.9	58.3	48.9
18	26.6	27.7	47.8	34.4	27.2	27.3	45.7	45.5	29.8	31.2	53.2	41.4	28.8	29	61.9	56.6
19	27	26.5	47	38.5	27.1	26.9	53.3	52.3	30.1	29.9	54.9	47.7	28.9	28.2	62.6	57.2
20	27.2	26	48.1	45.2	26.7	26.3	49.6	50.2	30	29.5	55.4	48.3	29.5	28.3	65.4	57.6
21	27.1	26.8	49.9	35.4	27.3	26.5	56.1	56.1	30.1	29.2	55.8	50.1	29.5	27.9	62	58.1
22	25.3	24.4	46.5	40	28.5	26.9	55.5	55.1	29.5	28.4	56.4	51.6	29.6	27.1	63.1	60.4
23	25.9	25	62.7	38.9	27.2	27	55	53.1	29.8	28.7	56.6	52.1	29.1	26.5	62.5	62.2
24	24.1	23.5	48	38.6	28.4	25.5	44.5	38.1	28.9	27.6	60.9	53.8	29	28.3	66.7	59.2

7TH March 2017					10TH March 2017				14TH April 2017				5TH May 2017			
Time	**TI**	**TE**	**HI**	**HE**	**TI**	**TE**	**HI**	**HE**	**TI**	**TE**	**HI**	**HE**	**TI**	**TE**	**HI**	**HE**
1	28.7	28	48	42.5	29.8	28.5	49.4	40.3	29.2	26.3	61.9	64.8	28.3	27.8	72.8	68.7
2	28.3	27.9	48.2	51.6	29.2	28.9	48.9	40.2	28.4	27.2	61.5	57.7	27.7	27.3	73.2	70
3	28.4	27.3	53.7	43.2	29.6	29.1	50.2	40.6	28.2	27.1	62.2	58.1	27.9	27.2	72.9	69.4
4	28.1	26.9	49	47.1	29.1	28.2	49.1	43.9	29.1	27	62.6	57.1	28	26.4	71.7	71.3
5	28.1	27	48.8	45.4	29.7	28.6	66.8	43.3	27.8	26.7	66.6	58.1	27.4	25.8	71.1	70.9
6	28.5	26.8	53.2	46.3	28.8	25.6	52.8	58.2	26.8	25.1	61.1	60.9	27.6	25.9	72.8	74.6
7	26.8	25.8	50.8	53.3	28.1	27.9	56.3	56.9	26.3	25.4	60.3	60.6	27	26	73.3	70.9
8	26.6	26.3	54.8	54.1	28.1	27.7	53.6	68.3	26.4	26.1	65.7	60.8	27.1	25.9	73.1	72.2
9	27.5	27.2	62.4	53.9	28.5	28.3	63.7	57.4	26.5	26.7	61.2	57.9	27.2	26.4	72.7	72.4
10	27.2	28	55.4	53.5	28.4	29.9	58	60.2	26.6	27.3	60.9	39.2	27.3	27.7	72	68.2
11	27.6	28.5	55	53.9	28.7	32	56.5	49.6	26.5	27.9	50.5	46.1	27.6	28.1	72.5	70.3
12	27.5	32	54.9	41.5	28.8	33.1	55.5	41.7	26.6	29.5	55.2	37.1	28.1	28.9	73.3	64.7
13	27.7	32.5	52.5	32.2	28.9	30.8	55.3	52	26.9	31.8	51.4	34.1	28.2	29.4	72.4	64.1
14	28	33.3	52.2	29.3	29.5	30.5	53.9	47.6	28.2	32	65.2	31.1	28.4	32.2	70.9	55.3
15	28.2	32.6	50.6	33.3	29.8	30.2	57	52.2	32.6	33.6	42.9	33.4	28.7	30	72.2	65.2
16	29.2	31.2	49	40.7	30.9	29.4	56.1	55.3	31.1	32.7	49.7	39.5	28.6	30.6	68.6	60.8
17	29.8	31.4	48.2	43.4	29.2	29.2	59.2	58. 4	28.7	30.9	52.4	42.5	28	25.9	68	98
18	29.3	29.6	48.8	45	29.1	29	59.7	58.9	29.1	29.4	55.3	38.7	27.4	26.5	66.6	68.1
19	29.4	29.6	52.3	40.6	30.1	29.5	61.5	57.8	29.1	28.5	50.2	41.7	27.7	25.2	69.9	73.8
20	30.2	29.5	54.8	40.5	29.2	27.3	58.9	58.2	28.6	27.4	51	46.8	26.5	26.1	72.8	70.7
21	29.8	28.7	54.2	45.3	28.4	25.5	59.1	65.6	28.2	27.3	51.7	44.7	27.3	26.7	77.7	71.1
22	29.8	29.1	54.9	47.9	27.9	26.6	60	61.9	28.4	25.7	54.2	54	27	26	30.7	70.9
23	29.6	28.2	53	51.8	28.1	27.2	61.3	60.5	27.5	25.9	52.6	49.9	26.5	25.7	70	71.5
24	29.2	28	50.2	42.4	30.5	27	51.5	39	29	28.2	60.9	57.1	28.1	27.6	7.2	67

In figure 10a, we present the indoor and outdoor temperature obtain the 06 January 2017. The maximum indoor temperature was 27.3°C at 5 pm, the minimum is 20.5°C at 6 hours and the average is 23.5°C.

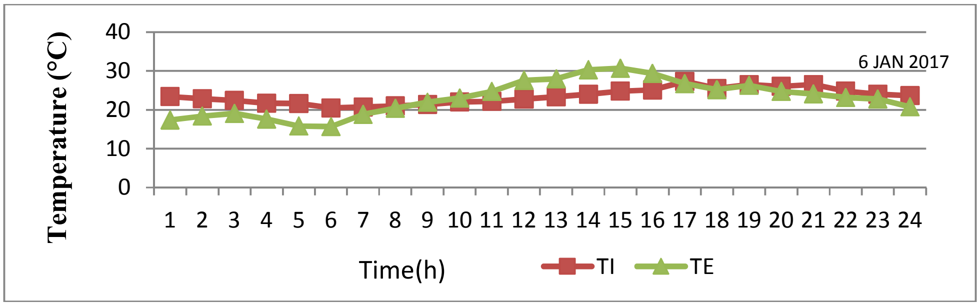

Figure 10a: comparison of outdoor and indoor temperature of the room (6 Jan 2017)

In figure 10 b we present also the outdoor and indoor temperature of the room in the date of 13 January 2017. The maximum indoor temperature is 27.5°Cat 5 pm, the minimum is 19.5°C at 7 hours and the average is 22.8°C.

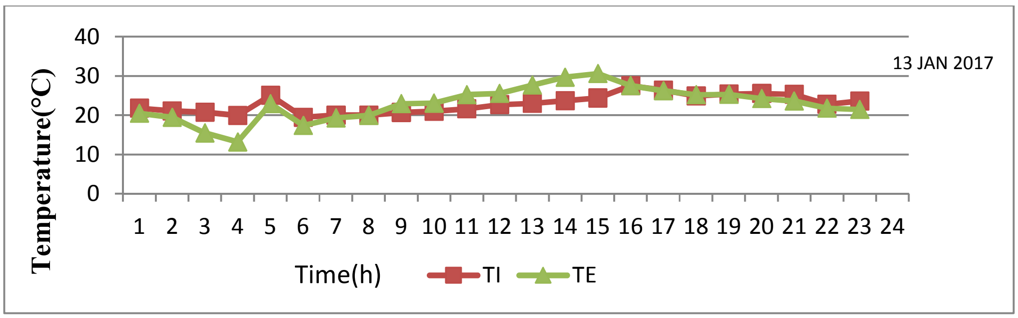

Figure 10b: comparison of outdoor and indoor temperature of the room (13 Jan 2017)

In figure 10 c we present also the outdoor and indoor temperature of the room in the date of 23 January 2017. The maximum indoor temperature is 28.5°Cat 12 hours and 20 hours, the minimum is 21°C and the average is 25.3°C.

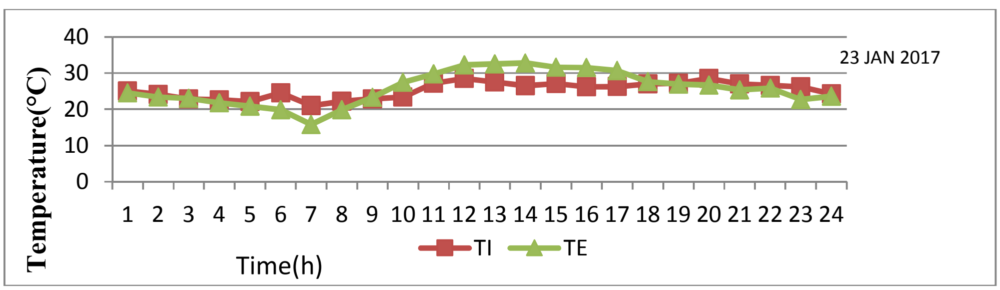

Figure 10c: comparison of outdoor and indoor temperature of the room (23 Jan 2017)

In figure 10d we present also the outdoor and indoor temperature of the room in the date of 28 January 2017. The maximum indoor temperature is 30.1°Cat 14 hours, the minimum is 23.4°C at 7 and 8 hours and the average is 26.3°C.

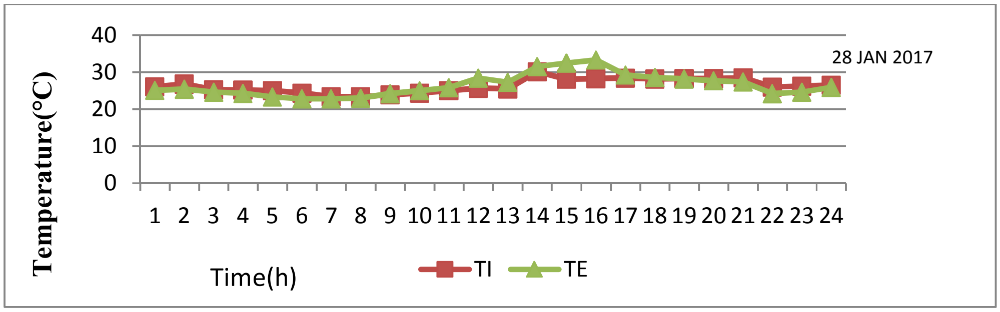

Figure 10 d: comparison of outdoor and indoor temperature of the room (28 Jan 2017)

In figure 11 a, b, c, d we present the outdoor and indoor temperature of the room in the month of February 2017. Figure 13a present us the data from 3 February 2017, the maximum temperature is 28.3°C at 4 pm, the minimum is 23°C at 4 hours and the average is 25.03°C.

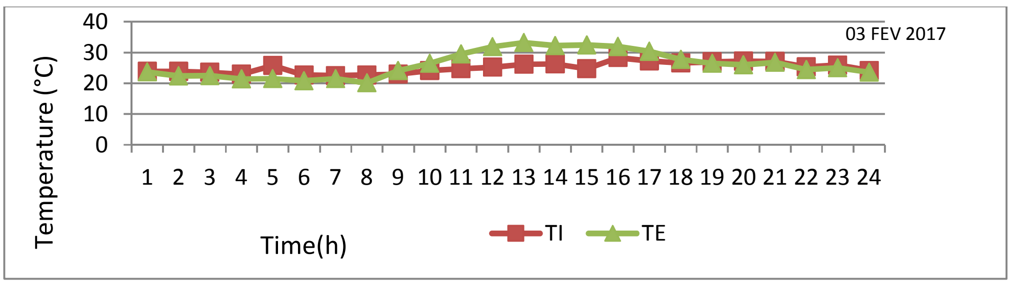

Figure 11a: comparison of outdoor and indoor temperature of the room (3 Fev 2017)

The 12th February 2017 the maximum temperature was 28.5°C at 22 hours, the minimum was 24°C at 8 hours and the average was 24.9°C as we see in figure 11b.

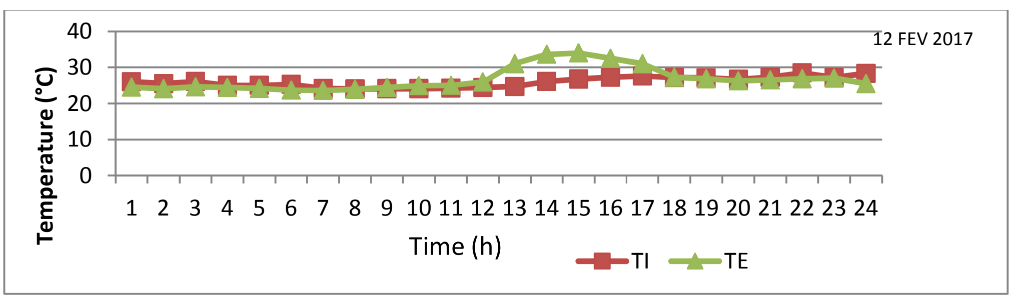

Figure 11b: comparison of outdoor and indoor temperature of the room (12 Fev 2017)

Figure 11c show the results obtain in the 17 February 2017. Here the maximum temperature was 30.2°C at 17 hours and 21 hours, the minimum was 26.4°C at 8 hours and the average is 28.4°C.

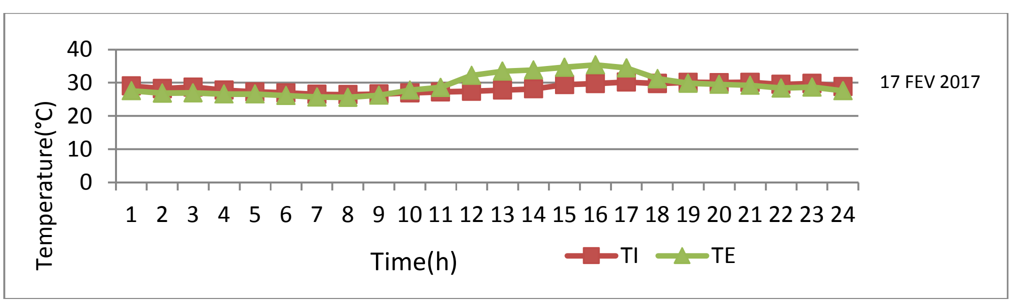

Figure 11c: comparison of outdoor and indoor temperature of the room (17 Fev 2017)

In figure 11d we present the result of 23 February 2017. The maximum temperature was 29.6°C at 22 hours, the minimum was 27°C at 10 hours and the average was 28.3°C.

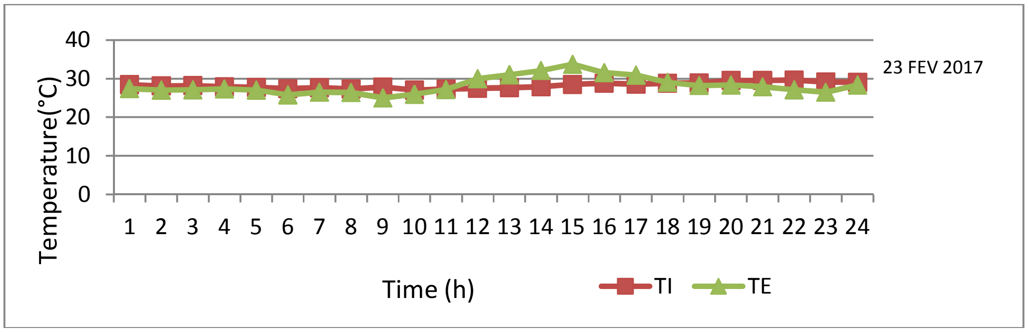

Figure 11d: comparison of outdoor and indoor temperature of the room (23Fev 2017)

In figure 12 we present the result of 7 March and 10 March 2017. In figure 12a was the evolution of outdoor and indoor temperature of the room the 7th march. The maximum temperature was 30.2°C at 20 hours, the minimum was 26.6°C at 8 hours and the average was 28.4°C.

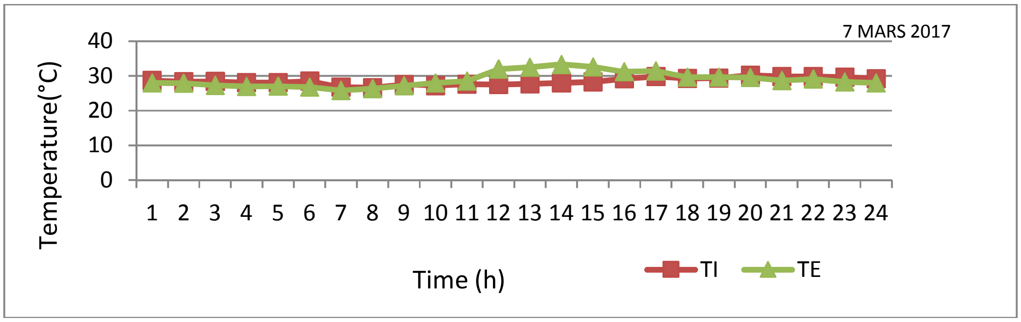

Figure 12a: comparison of outdoor and indoor temperature of the room (7 March 2017)

In figure 12b was the evolution of outdoor and indoor temperature of the room the 10th March. The maximum temperature was 30.9°C at 4 pm, the minimum was 27.9°C at 22 hours and the average was 29.1°C.

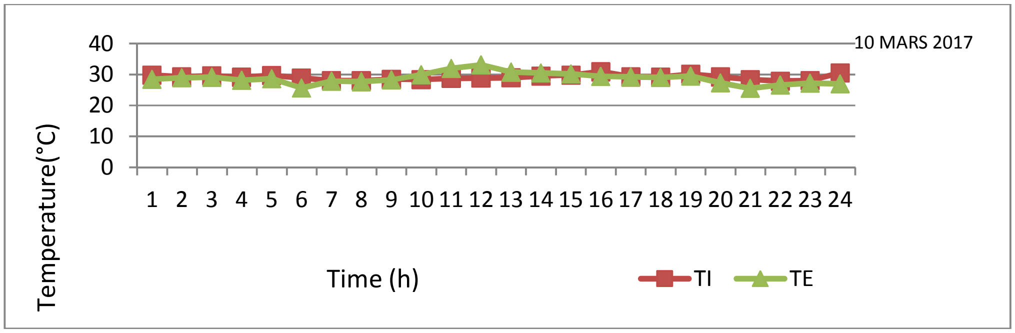

Figure 12b: comparison of outdoor and indoor temperature of the room (10 March 2017)

We present in figure 13 the results obtain in 14 April 2017. The maximum temperature was 32.6°C at 3 pm, the minimum was 26.3°C at 7 hours and the average was 28.1°C.

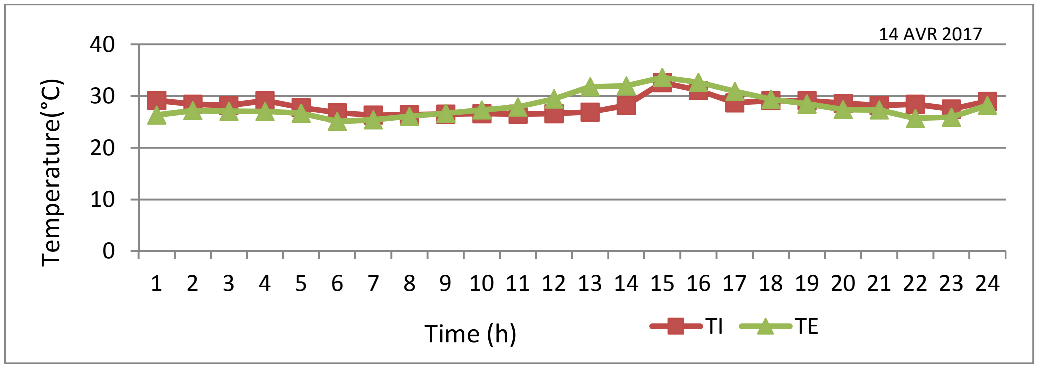

Figure 13: comparison of outdoor and indoor temperature of the room (14 April 2017)

Curve 14 presents us the result of the 5 May 2017. Here the maximum internal temperature was 28.7°C at 3 pm, the minimum was 26.5°C at 20 and 23 hours and the average was 27.6°C.

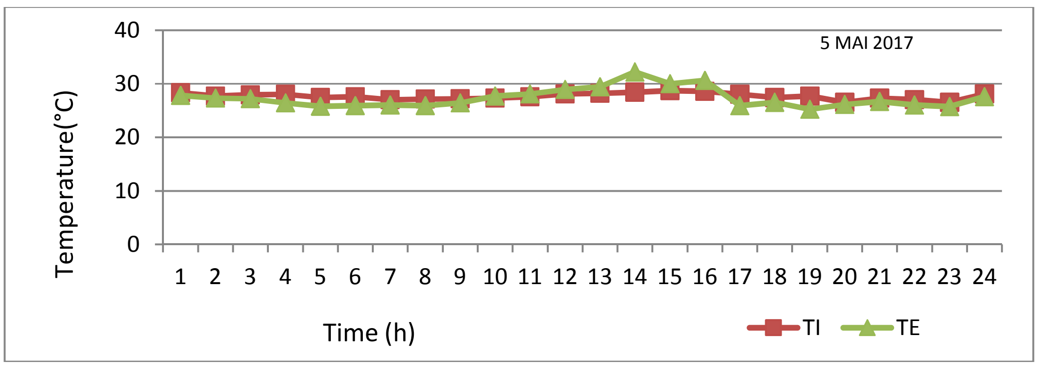

Figure 14: comparison of outdoor and indoor temperature of the room (5 May 2017)

Therefore, in the table below we present the interval of comfort made by several researchers **[21]**. According to this table we note that our experimental values found are located in the comfort zone according to some authors. But according to the ISO standard 7730 and ASHRAE, some of our results are not in the comfort zone. Humphreys et al. present also a result of field studies in United Kingdom, Indian, Irak and Singapore. It is noted that temperatures well above 30°C are not considered uncomfortable in some cases **[22]**.

Parameter	Piece 1	Piece2	Sapien et al	ASHRAE	ISO 7730-7784
T_0(°C)	27.78-29.51	26.40-28.00	26.00-29.50	23.0-26.0	23.00-26.00
RH (%)	55.58-69.90	67.80-77.60	<90	50.0	30.0-70.0
V_a (m/s)	0.19-0.24	0.14-0.28	0.5-1.0	<0.15	<0.4

Table 4: Interval of comfort quote by some researchers **[21]**

5. CONCLUSION

This work dealt with the study of thermal comfort in traditional buildings at Meiganga in the area of Adamawa in Cameroon, Central Africa. The results obtained in this paper show that the internal temperature for all data collected in these traditional rooms during the night varies between 19.9°C – 30.5°C. The data are collected without openings the windows. This temperature rise is due to the fact that the amount of heat absorbed by the walls during the day is transferred inside houses. We also observed that material selection, openings, orientation and provision of vegetation around buildings contribute immensely to the thermal comfort of occupants of traditional buildings in the town of Meiganga. It has also shown that thermal comfort is enhanced by incorporation of ceiling and provision of shading can prevent excessive solar heat penetration. The comparison of the results of 2016 and 2017 show us that, concerning indoor conditions, the maximum temperature registered during the night is 30.5°C at 24 hours the 10 march 2017. But in 2016, the maximum temperature is 28.8°C at 20 hours for houses with sheet metal and 28°C also at 20 hours for the houses with straw.

Another aspect of this study is to provide thermal comfort for the occupants and reduces energy consumption. The majority of traditional buildings have small Windows. For reduce the indoor temperature we can propose to occupants to increase the size of windows with can provide good infiltration of ambient air and reduce the indoor temperature.

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