CHAPTER 2: ARCHITECTURE, URBAN PLANNING AND BUILT ENVIRONMENT

Design of Weather Station and Measurement Equipment for Assessment of Buildings Energy Use in Mozambique

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ABSTRACT
The use of modeling and simulation tools for assessment of the buildings energy in Mozambique is under investigation. Thus, measurement equipment was installed in “3 de Fevereiro Building” in Maputo City, Mozambique. The measurement equipment comprises Data Logger System, Weather Station, temperature and humidity sensors. These aim to measure the climate factors around the building and indoor parameters which influence the internal environment of the buildings. This paper describes the plan design and the layout of the measurement equipment. It also presents and discusses the results of the climate parameters and the building factors for the winter season such as global and diffuse solar radiation, outdoor temperature and humidity, indoor temperature and humidity, wind speed, wind direction and rainfall. The measured results relate to a period of four months from June to September, 2009. With this field measured results it was possible to analyze a greater part of the winter climate factors. Maputo City has a subtropical climate with two seasons, a wet season from October to March (summer) and a dry season from April to September (winter). The measured results show that the equipment provides fair data which can be used for evaluating the energy of the building and for testing and validating the simulation tools of building energy.

Keywords: Design experiment, Energy efficiency, Outdoor and indoor thermal environment, Field measurements, Subtropical climate.

1.0 INTRODUCTION

Maputo City, the capital of Mozambique, is situated at 25º57´S and 32º35´E with a subtropical climate which means that it is submitted to vast solar energy with potential to increase the thermal heat inside the buildings especially in summer. On the other hand, the solar energy can be used to reduce the electrical energy used in buildings if active systems using solar energy are implemented in the buildings.

The main aim for installing the measurement equipment in “3 de Fevereiro Building” is to collect data and create database from field measurements for testing and validation modeling and simulation tools of the energy use in buildings for Mozambican climatic conditions. DEROB-LTH Program, an acronym for Dynamic Energy Response of Buildings, was selected by the author in the work related to Energy assessment Methodologies and Energy use in Buildings. This Program was tested in other tropical and subtropical countries. Espriella (1993), verified the conditions of comfort in offices in Bocota, Colombia, Fernandes (2004), analyzed the indoor temperatures in Porto Alegre, Brazil with good results and Zhiwu (1992) showed that simulations with DEROB-LTH program indicate that the results agree well with full-scale tests of the Nanning dwellings, China. The results of the field measurement from June to September, 2009 are presented in this paper.

1.1 CHARACTERIZATION OF THE BUILDING AND THE MEASUREMENT SYSTEM

The measurement equipment was installed in the "3 de Fevereiro Building" as presented in Figure 1 and Figure 2.

The building was built in the 1990s. The materials used were plastered hollow concrete block walls, concrete columns, wood framed windows with single glass, wood frame external and internal doors, concrete cement ceiling, and gypsum ceiling roof and has a floor area of 378 m^2 spread over the floors, 3 apartments on each floor. The long axis of the building is NE-SW and the main facade is south oriented. This orientation is typical in Maputo Municipality.

1.1.1 Measurement Equipment

Figure 1 and Figure 2 show the measurement equipment installed on the first floor. The ground floor has the same layout of the measurement equipment as in Figure 2 but without the solar meter sensor. The equipment allows measuring the outdoor climatic data such as the global and diffuse solar radiation, wind, rainfall, temperature and humidity and indoor parameters such as temperature and humidity.

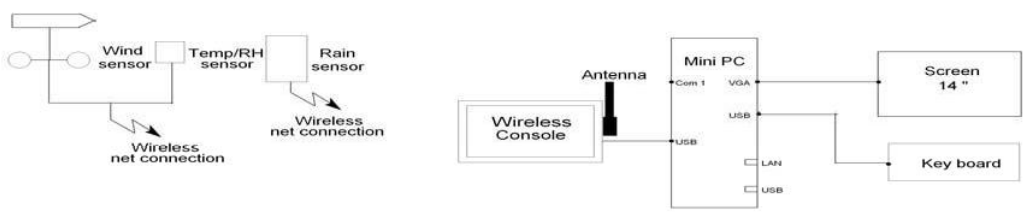


Figure 1: Weather Station system installed on the first floor.

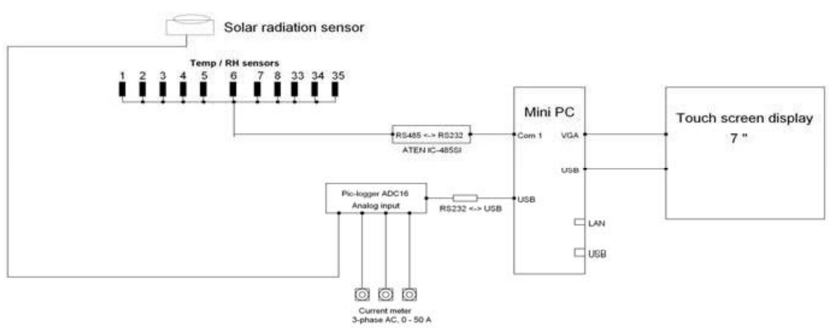


Figure 2: Measurement equipment installed in the first floor.

The East and West side of the building are the best for analyzing the thermal loads because there are directly radiated by the sun during the morning and noon periods of the days respectively. But, the owner of the building (Faculty of Engineering) allowed installing the equipment in the East side. The equipment was installed at the beginning of May, 2009.

Table 1: Measured factors and measurement equipment

Item	Measured factors	Quantity Ground floor	First floor	Sensor	Range	Accuracy
01	Global and diffuse solar radiation in horizontal surface	-	1	BF3	0 – 1250 W/m^2	Global: ±5W/m^{-2} ±12% Diffuse: ±20W/m^{-2} ±15%
02	Wind speed	-	1	WMR200	2m/s ~ 10m/s 10m/s~56 m/s	(+/- 3m/s), (+/- 10%)
03	Wind direction	-	1	WMR200	0-360º	16 positions, approx. every 14 seconds
04	Outdoor temperature	-	1	WMR200	-30ºC to 60ºC (-4ºC to140ºC	+/- 1% (+/- 2%)
	Outdoor Humidity	-	1	WMR200	25% to 90%	+/- 7%
05	Rainfall	-	1	WMR200	0 to 999mm	+/- 7%
06	Temperature in shaded volumes	-	1	SHT75	-30ºC to 60ºC (-4ºC to140ºC	+/- 1% (+/- 2%)
	Humidity in shaded volumes	-	1	SHT75	25% to 90%	+/- 7%
07	Inside temperature	9	11	SHT75	-30ºC to 60ºC (-4ºC to 140ºC	+/- 1% (+/- 2%)
08	Inside humidity		11	SHT75	25% to 90%	+/- 7%
09	Electrical current	1	1	Onset CTV-B	0 to 50 A	+/- 4.5%

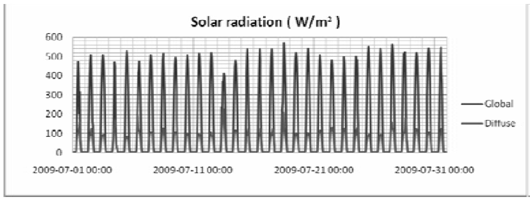
2.0 MEASUREMENT RESULTS AND DISCUSSION

The field measurement results present data (outdoor climatic elements and indoor parameters) which are important for analysis of indoor thermal loads, heating and cooling and ventilation systems for providing indoor comfort. July, 2009 measurements are used as the reference month as it is the coldest one.

2.1 Solar Radiation

Figure 3 shows the variation of the global and diffuse solar radiation in July, 2009 and Figure 4 shows the monthly maximum, mean and minimum global and diffuse solar radiation from June to September, 2009.

Mozambique has two main seasons, namely hot, normally wet season from October to March and a cooler, mostly dry season from April to September. So, from April to September it is winter with June and July presenting the low rates of the solar radiation and July the lowest month as indicated in Figure 4.



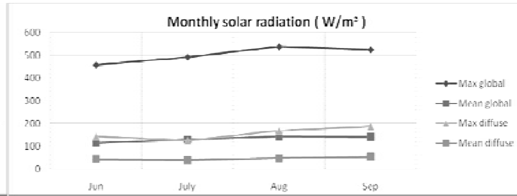


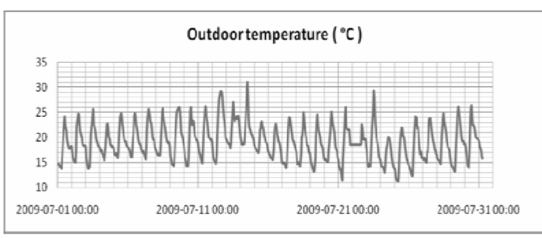
Figure 3: Global and diffuse sol. Rad., July, and 2009.

Figure 4: Monthly maximum and mean global diffuse sol. rad., June to September, 2009.

The maximum and mean solar radiation energy from June to September are presented in Table 2. The rates show that Maputo City has enough solar energy to cover the need for hot water and heating or cooling in buildings.

Table 2: Solar radiation energy.

	Solar radiation energy (KWh/m^2/Period)		Daily solar radiation energy (KWh/m^2/day)	
	Global	Diffuse	Global	Diffuse
Max.	1,475	457	12	4
Mean	*386*	*132*	*3*	*1*



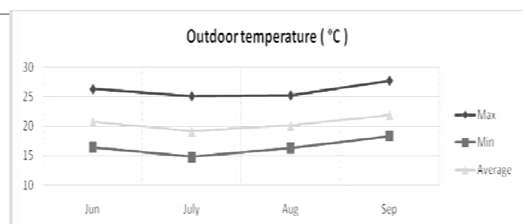
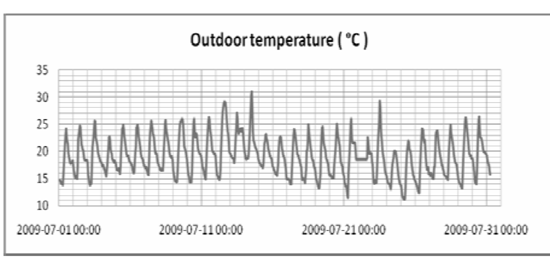


Figure 5: Outdoor temperatures of July, 2009

Figure 6: Max., Mean and min. outdoor temp.

2.2 Outdoor Temperature and Solar Radiation of the Coldest Day

Figure 5 present the measured outdoor temperature of the July, the coldest month of the winter, 2009, with low outdoor temperature and 25th July 2009 was the day with a minimum of 11.2ºC at 6:00 a.m., the lowest temperature from June to September, 2009, see Table 3.



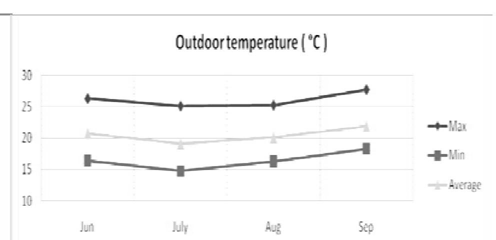


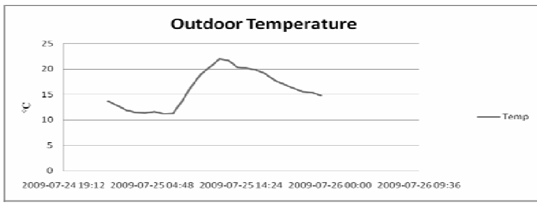
Figure 7: Outdoor temperatures of July, 2009

Figure 8: Max., Mean and min. outd. temp.

Table 3: Maximum and minimum temperatures (monthly peak outdoor temperature)

Month	Day	Time (h)	Out. Temp. (^{0}C)		Month	Day	Time (h)	Out. Temp. (^{0}C)	
June	23-06-09	13:00	Max.	30.3	Aug.	09-08-09	14:00	Max.	30.4
	27-06-09	07:00	Min.	11.3		09-08-09	06:00	Min.	12.9
July	14-06-09	12:00	Max.	30.3	Sep.	08-09-09	14:00	Max.	35.8
	25-07-09	06:00	Min.	11.2		13-09-09	04:00	Min.	16.1

Figure 9 shows the graph of the outdoor temperature on 25th July 2009, the coldest day in winter and Figure 10 shows the global and diffuse solar radiation on the same day. The maximum value of the global solar radiation was 527.8 W/m^2 occurred at 12:00 and the diffuse was 87.2 W/m^2 at 13:00.



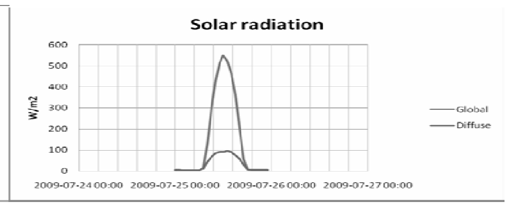
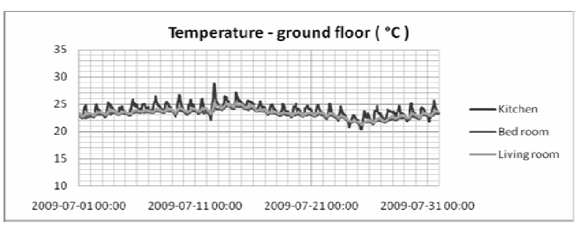


Figure 9: Outdoor temperature of the coldest day of the winter, 2009.

Figure 10: Global and diffuse solar radiation coldest day of winter, 2009.

2.3 Temperature Inside of the Building

Figure 11shows the indoor temperature of the ground floor and Figure 12 shows the indoor temperature of the first floor. The kitchens of the apartments are located in the north side, the hottest position in terms of solar gains. The temperatures in these rooms are higher than the rooms placed in the south side of the building. In both flats, the temperatures of the living room and bed room are very similar due to the fact of the two volumes having the same location (south side), the same characteristics, the same solar radiation and the same casual gains.



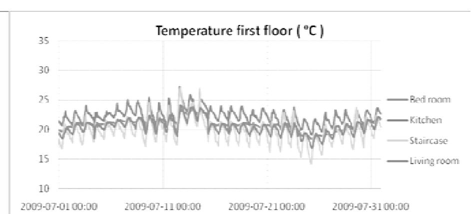


Figure 11: Indoor temperatures on the ground floor, July, 2009.

Figure 12: Indoor temperatures on the first floor July, 2009.

From June to September the maximum indoor temperature on the ground floor was 25.3ºC in September and the minimum in the first floor was 19.2ºC in July.

2.4 Meteorological Instrument

WM200/WM200A anemometer was used to measure the wind speed and its direction around the building. This instrument was installed outside of the building in the south side. Analyzing the Figure 13 related to the wind, it can be concluded that the wind is southerly.

Table 4 Maximum, mean and minimum indoor temperatures in the apartments.

	Indoor temperatures (ºC) Ground Floor				Indoor temperatures (ºC) First Floor			
	June	July	Aug	Sep	June	July	Aug	Sep
Max	24.8	23.8	24.0	25.3	23.2	20.4	22.3	24.4
Mean	24.5	23.4	23.7	24.9	22.3	20.4	21.4	22.9
Min	24.2	23.0	23.3	24.4	20.4	19.2	20.4	20.4

Table 5: Maximum, mean and. min wind speed, for the months of the June to September.

Wind speed (m/s)				
	June	July	Aug	Sep
Max	6.4	7.1	7.5	9.7
Mea	3.5	3.9	4.2	5.8
Min	1.0	1.2	1.6	1.5

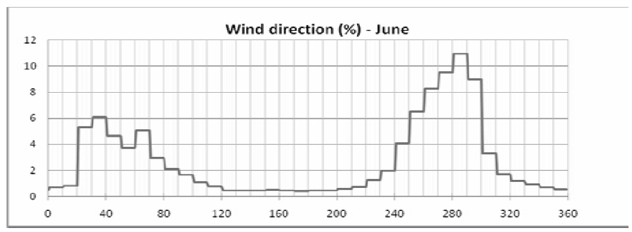


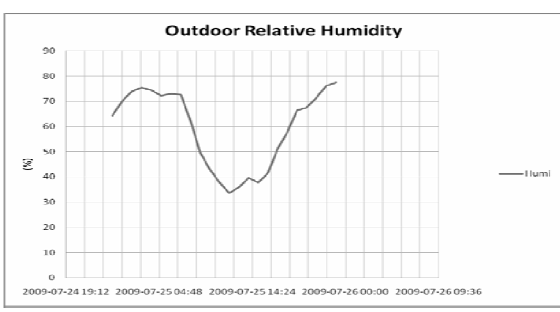
Figure 13: Wind direction in June, 2009

2.5 Rainfall

The objective of measuring the rainfall is to provide a database of the rainfall on the site of the building. This information is useful for preventing the harmful phenomena caused by the moisture in the structure of the buildings. If the quantity of rain is known it is possible to take certain precautions for eliminating the harmful effects of the moisture caused by the rain. The rates of the rainfall from June to September are presented in Table 6.

2.6 Outdoor Relative Humidity

Figure 14 illustrates the outdoor relative humidity during July and Figure 15 represents maximum, mean and minimum outdoor humidity from June to September, 2009.



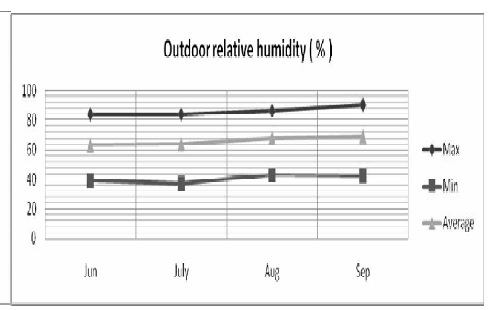


Figure 14: Relative humidity of the coldest day of the Winter.

Figure 15: Maximum, mean and minimum outdoor relative humidity.

2.7 Comparison of the Site Measurements and Maputo Airport Meteorological Station Data.

The Table 6 presents the data from field measurement and the outdoor data from Maputo Airport Meteorological Station for comparison.

Table 6: Data of the outdoor temperature, rainfall and relative humidity

		Outdoor temperature (%)			Rainfall(mm)	Relative Humidity (%)		
		Max.	Mean	Min.	-	Max.	Mean	Min.
	Meas.	26.3	20.7	16.4	9.5	83.9	63.4	39.2
June	MAMS	25	18.5	14.2	26	-	66	-
	Meas.	25.1	19.1	14.7	2	83.8	64.0	36.8
July	MAMS	25	18.2	13.9	12	-	66	-
	Meas.	25.3	20.1	16.3	-	86.2	68.1	42.8
August	MAMS	25.7	19.1	15.0	12	-	65	-
	Meas.	27.7	21.9	18.3	-	90.3	69.5	42.4
September	MAMS	28.4	20.6	16.0	35	-	65	-

Meas. = Measured and MAMS = Maputo Airport Meteorological Station.

3.0 CONCLUSIONS

The measurement equipment installed in the apartments can be considered effective and reliable as it can provide data on building parameters and the weather climatic elements which can be used for assessment of energy use in buildings as well as for testing, validation and calibration, modeling and simulation tools of building energy use.

Analyzing the data from the measurement equipment it can be concluded that it provides fair results since the comparison of these data with the one from other weather stations, such as Maputo Airport Meteorological Station presents similar trends.

Further work will consist of measuring several variables for testing the functionality of the DEROB-LTH.

4.0 ACKNOWLEDGEMENTS

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