International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-5, January 2020

Establishing Climate Responsive Building Design Strategies using Climate Consultant

Fabrice Mwizerwa, Mukesh Kr Gupta

Abstract: Climate responsive building has become one of the most effective approach to achieve sustainability in buildings. With the modern various innovations and diversified sophisticated technologies available nowadays in the building sector, people are tending to adopt all of this latest cutting-edge technology available on the building construction market regardless of the requirements of their building's project local climate. In this research study climate consultant software (an energy design tool) was utilized to give an appropriate understanding of Gisenyi climate and to eventually establish building design strategies matching with Gisenyi climate. The outcomes of this research work show that it is needless to adopt active or mechanical design strategies for Gisenyi climate as for this type of climate thermal comfort zone of the occupant can be best achieved through the implementation of only passive design strategies..

Keywords: Gisenyi climate, Psychrometric chart, Thermal comfort zone, Building design strategies, Climate responsive building, Climate consultant software.

I. INTRODUCTION

Being one of the most touristic places of Rwanda, Gisenyi is rapidly becoming a hub of the modern building construction techniques and home of various prestigious hotels. With this boom in the construction sector proper sustainable designing plan has to be envisaged so that these new buildings can be able to respond and match to the climate of Gisenyi and therefore making Gisenyi achieve a long term sustainable development in the building sector.
Having a monthly average temperature ranging between eighteen to nineteen degree Celsius, Gisenyi is located at an elevation of 1549 meters and its latitude and longitude coordinates are 1.677^{o} south and 29.259^{o} east respectively.
The purpose of this study is to understand the local climate of Gisenyi using the energy design tool (climate consultant software) and then establishing building design strategies appropriate to this type of climate by the help of the same energy design tool used in understanding the climate.

II. OBJECTIVE

The objective of this research study is to have a proper and detailed understanding of Gisenyi climate pattern and to eventually establish climate responsive building design strategies specific to the local climate of Gisenyi for achieving a long term sustainable development.

III. METHODOLOGY

For carrying this research work the energy design tool known as climate consultant software was utilized to understand and visualize the various attributes associated with Gisenyi climate and finally for providing the design strategies specific to Gisenyi local climate. These specific design strategies for Gisenyi climate were obtained from the psychrometric chart, which is animportant tool available for understanding and establishing thermal comfort of the occupant. Climate consultant software offers four thermal standard comfort options based on which thermal comfort of the occupant is defined. In this research work the ASHRAE standard 55 was selected for defining the thermal comfort of the occupant. The climate data of Gisenyi used in this research work were obtained from climate.onebuilding which is another source of weather data available in climate consultant software.

IV. UNDERSTANDING THE LOCAL CLIMATE OF GISENYI BY THE HELP OF CLIMATE CONSULTANT SOFTWARE

Climate consultant software is a great energy design tool which help visualize different attributes of any climate along with their graphical representation which make it even more easier to interpret and understand the climate pattern of the location under consideration. Therefore under this section variation of different attributes of Gisenyi climate such as temperature, relative humidity along with temperature and sun shade will be displayed on their respective chart for the purpose of visualizing the way they vary during different months of the year and to also further help in providing a design response. Finally the psychrometric chart will be displayed along with the required design strategies for Gisenyi region.

4.1 Weather data of Gisenyi to be analyzed

The following figure is a screenshot of all climate data of Gisenyi involved in this study through climate consultant software.

Manuscript published on January 30, 2020.
* Correspondence Author
Fabrice Mwizerwa*, Ph.D Scholar, Department of Civil Engineering, Suresh Gyan Vihar University, Mahal Rd, Jaipur, Rajasthan, India.
Mukesh Kr Gupta, Department of Center of Excellence - Renewable and Sustainable Energy Studies, Suresh Gyan Vihar University, Mahal Rd, Jaipur, Rajasthan, India.

WEATHER DATA SUMMARY

LOCATION: Gisenyi AP, OU, RWA
Latitude/Longitude: 1.677° South, 29.259° East, Time Zone from Greenwich 2
Data Source: ISD-TMYx 643810 WMO Station Number, Elevation 1549 m

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	489	508	519	496	471	468	491	509	529	522	506	452	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	337	348	357	338	360	371	412	393	370	363	369	265	Wh/sq.m
Diffuse Radiation (Avg Hourly)	232	235	236	233	206	204	201	220	237	239	219	249	Wh/sq.m
Global Horiz Radiation (Max Hourly)	978	1056	1034	1015	868	901	957	998	1016	1041	1029	990	Wh/sq.m
Direct Normal Radiation (Max Hourly)	828	897	736	857	726	840	836	831	799	853	804	892	Wh/sq.m
Diffuse Radiation (Max Hourly)	535	577	514	557	460	450	448	469	464	515	447	497	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	5913	6129	6237	5935	5624	5572	5860	6083	6349	6287	6117	5468	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	4078	4195	4298	4047	4299	4424	4909	4695	4447	4377	4466	3215	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	2804	2839	2838	2789	2463	2435	2402	2635	2842	2882	2654	3012	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	56763	59239	60439	57887	55079	54388	57541	59507	61777	60734	59061	52016	lux
Direct Normal Illumination (Avg Hourly)	23732	24504	25139	23204	24172	25440	27984	26941	26571	25779	25680	19432	lux
Dry Bulb Temperature (Avg Monthly)	18	18	18	19	18	18	19	19	18	19	18	18	degrees C
Dew Point Temperature (Avg Monthly)	15	14	15	16	15	14	12	13	14	15	15	15	degrees C
Relative Humidity (Avg Monthly)	81	79	86	82	83	80	65	71	79	77	83	83	percent
Wind Direction (Monthly Mode)	180	180	180	180	180	180	180	180	170	190	180	190	degrees
Wind Speed (Avg Monthly)	2	1	2	2	1	2	1	2	2	1	3	1	m/s
Ground Temperature (Avg Monthly of 3 Depths)	19	19	19	18	18	18	18	18	18	18	18	18	degrees C

Back Next

Figure 1. Gisenyi climate data

4.2 Gisenyi temperature variation

This plot gives an understanding of how the temperature of Gisenyi varies throughout a whole year.

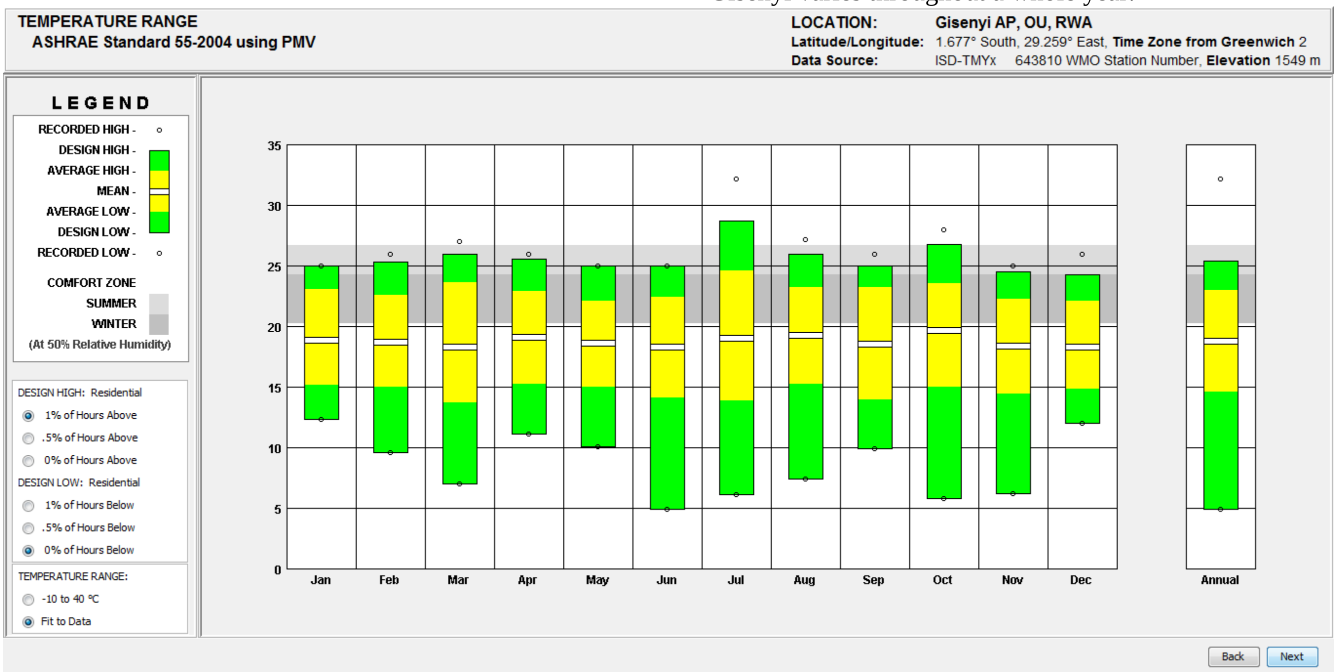

Figure 2. Gisenyi temperature variation

Retrieval Number: E6167018520/2020©BEIESP
DOI:10.35940/ijrte.E6167.018520
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Brief comments

- The annual mean temperature is very close to the comfort zone which is a good indication that in this type of climate, passive design strategies can be applied for achieving thermal comfort of the occupant.

4.3 Temperature against relative humidity

This chart is useful in terms of understanding thermal comfort of the occupant as these both variables are factors considered in establishing the thermal comfort zone of the occupant.

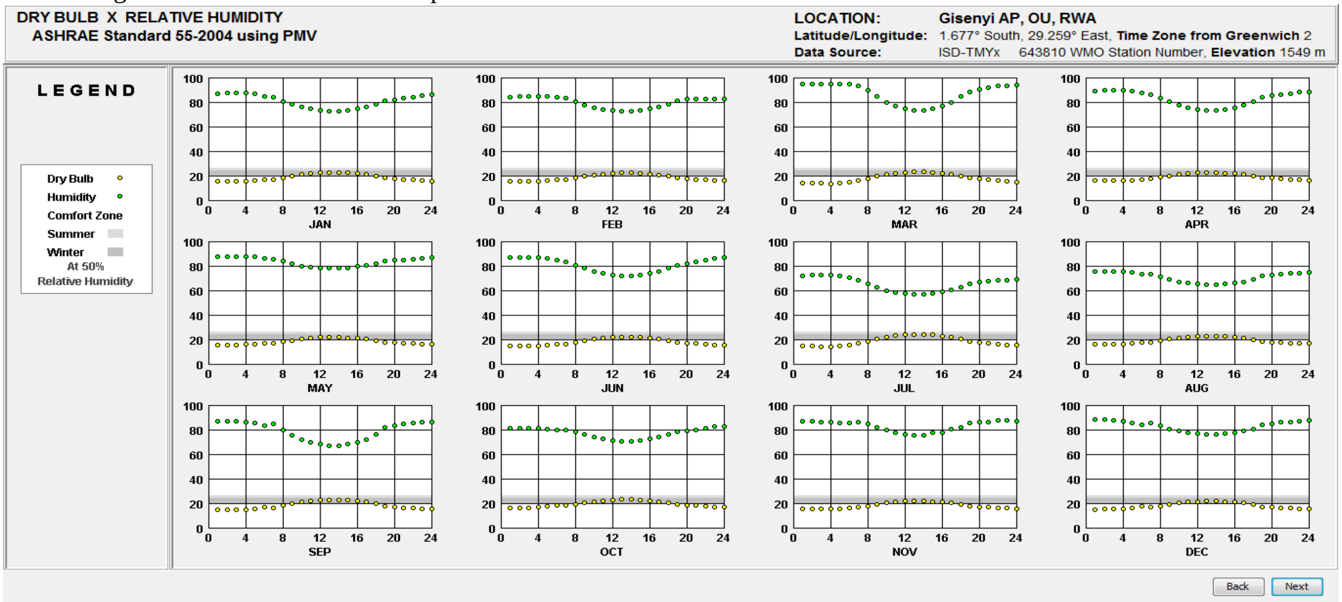

Figure 3. Temperature against relative humidity

Brief comments

- Green dots represent relative humidity and yellow dots represent temperature
- As defined on the legend which is displayed on the left side that the comfort zone should enclose an amount of relative humidity close to 50%, this type of climate shows the presence of excess moisture in the air which might require some dehumidification techniques for reducing the amount of this moisture present in the air.

4.4 Gisenyi sun shading plot

Once this chart is well understood the user can provide a design response which consists of shading of windows (preventing windows to be exposed to sunlight) or keeping the windows exposed (for allowing the sun light to reach the interior of the building).

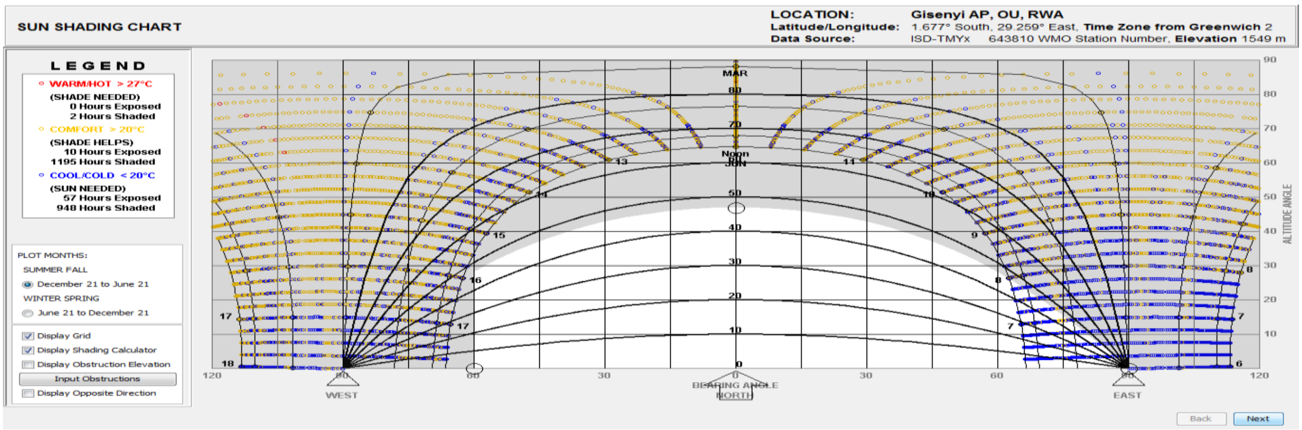

Figure 4. Gisenyi sun shading plot

Brief comments

- The red and yellow dots indicate hours of the day that require shading to prevent overheating and blue dots indicate hours where windows have to be kept exposed to sunlight to prevent cold in the interior of the building.
- The area shaded in grey that is exactly the same area that would be effectively shaded by a shading device provided by a design response.
- For horizontal shading: An angle of 45^o measured from the bottom of the window will be required to keep most of the hours in the comfort zone.
- For vertical shading: An angle of 60^o from north to west is needed.

4.5 Gisenyi Psychrometric chart

This is one of the most useful graphic tool available in climate consultant software that enable the user to identify design strategies to achieve thermal comfort. On this psychrometric chart the task of the user is to select the least number of design strategies for achieving a high level of thermal comfort. A list of sixteen design strategies is displayed on the psychrometric chart but it does not necessary mean all of the displayed design strategies must be applied to that type of climate. Selection of the least number of design strategies which will still provide a good level of thermal comfort is recommended for making climate responsive building economical. In this research work the "show best set of design strategies" feature present in climate consultant software was used to display the least number of building design strategies for Gisenyi climate.The chart below displays a suitable set of building design strategies appropriate for Gisenyi climate for a whole year and the area enclosed in blue color represents the thermal comfort zone of the occupant.

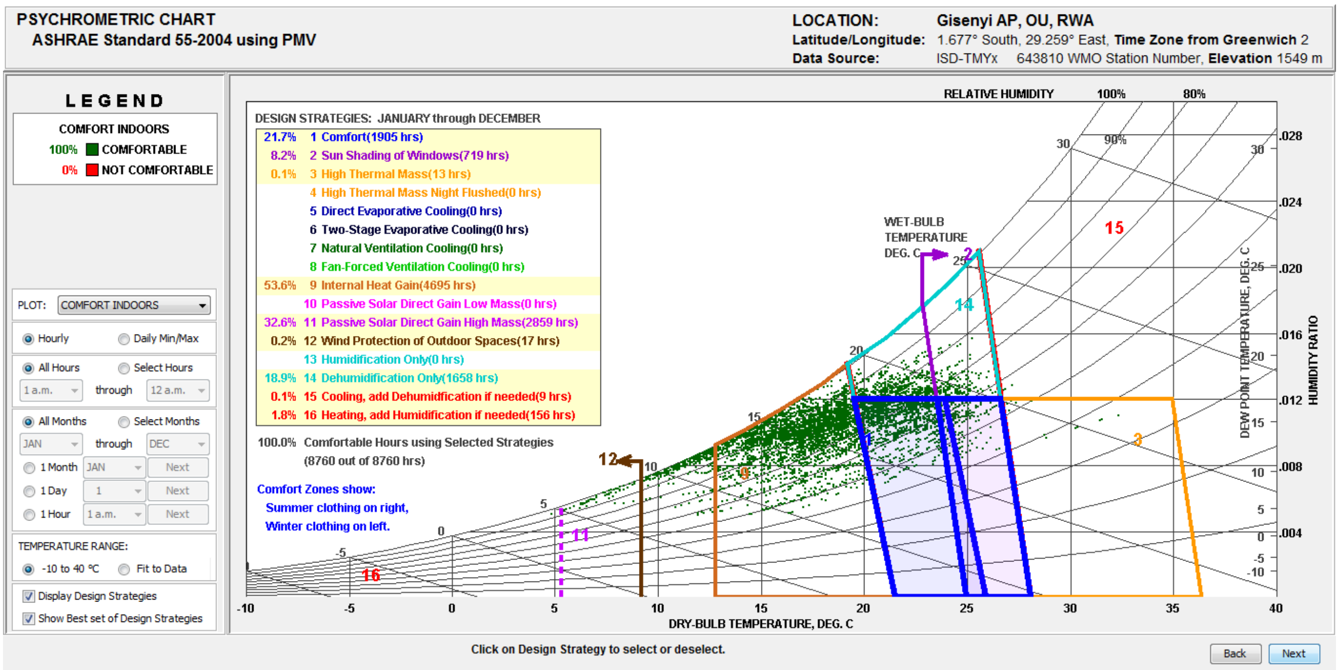

Figure 5. Gisenyi psychrometric chart

V. RESULTS AND DISCUSSIONS

From Gisenyi psychrometric chart which was obtained by analyzing climate data of Gisenyi through climate consultant software, the following building design strategies were found appropriate and required specifically for the climate of Gisenyi.

Table 1: Gisenyi building design strategies

Sr no	Types of design strategy	Required Gisenyi design strategy	Explanations
1	Passive cooling design strategy	Sun shading of windows	As seen on Gisenyi sun shading plot, an angle of forty five degrees was required for providing horizontal shading and a sixty degree angle from north to west for vertical shading. By applying this cooling design strategy of sun shading of windows, it will help in maintaining the indoor ambient temperature into the thermal comfort zone.
2		High Thermal mass	This design strategy implies that by adopting high mass construction techniques which consists of using materials that have the ability to retain or absorb heat (but to also release heat whenever required), such as blocks made of concrete, stones masonry will result in reducing the indoor temperature whenever there is a tendency of exceeding the thermal comfort zone of the occupant.
3	Passive heating design strategy	Internal heat gain	This design strategy relies more on the building design (especially the envelope part of the building) and can be much more efficient if the building is given proper insulation in order to accumulate and keep the extra heat generated from people's equipments inside the building or even from the lightning sources available in the interior of the building.
4		Passive solar direct gain high mass	This design strategy depends mostly on the orientation of the building's windows in order to capture maximum amount of solar heat. As Gisenyi is located in the southern hemisphere, this implies that building orientation has to face in the north direction to maximize solar heat gain. This building's windows orientation is also proved on Gisenyi sun shading plot (figure 4) where the sun's bearing angle is facing in the north direction.

5		Wind protection of outdoor spaces	Implementing this design strategy would help in preventing outdoor cold winds which could affect and disturb the indoor thermal comfort of the occupant. This wind protection of outdoor spaces is considered as a design strategy because the standard thermal comfort model used in this research work (ASHRAE standard 55), assumes that the thermal comfort zone of the occupant relies partially on the outdoor conditions as the windows are free to be closed or opened.
6		Dehumidification only	This design strategy reinforces again the relationship of temperature against relative humidity chart seen above (in figure 3), where the presence of moisture in the air throughout the whole year was significantly above the accepted range (50 % relative humidity for comfort zone). Therefore in this type of climate even though the indoor temperature is within the thermal comfort range, dehumidification techniques once applied would significantly improve occupant's satisfaction.
7	Active or system design strategy	Cooling along with dehumidification if required	This active design strategy might be required during period when the outdoor temperature is well above the accepted thermal comfort range and the surrounding air is also too humid. In this scenario lowering the temperature and removing the presence of moisture in the air would provide better thermal comfort to the occupant.
8		Heating along with humidification if required	This heating and humidification active design strategy might be required in times when the outdoor temperature is well below the accepted thermal comfort range and also the surrounding air is too dry. In this situation increasing the temperature and providing additional moisture in the air would much better improve the thermal comfort zone of the occupant.

VI. CONCLUSION

After analyzing Gisenyi climate through climate consultant software and acquiring the understanding of its pattern, it was found that most likely passive design strategies would apply best to this type of climate as seen on its psychrometric chart. The active or system design strategies of Gisenyi as shown on the psychrometric chart are very insignificant and they stand as optional strategies in case they might be required. Finally Gisenyi climate is one of the more comfortable climate based on its different graphical representations seen in section four of this paper, which infers that the thermal comfort of the occupant can be achieved through the implementation of only passive design strategies, thus saving extra money which would otherwise be spent on purchasing and installing unnecessary mechanical devices to provide thermal comfort of the occupant.

ACKNOWLEDGMENT

This research work was supported by the research and development cell of Suresh Gyan Vihar University, Jaipur (India).

REFERENCES

1. Khalid, A. (2016). Design Strategies and Guide lines for Tropical Coast of Pakistan, Using Climate Consultant. European Journal of Sustainable Development, 5(3), 505-512.
2. Osman, M. M., & Sevinc, H. (2019). Adaptation of climate-responsive building design strategies and resilience to climate change in the hot/arid region of Khartoum, Sudan. Sustainable Cities and Society, 47, 101429.
3. Bhattacharya, Y., & Milne, M. (2009, May). Psychrometric chart tutorial: a tool for under-standing human thermal comfort conditions. In 38th American Solar Energy Society Conference, Buffalo (pp. 11-16).
4. Milne, M., Liggett, R., Benson, A., & Bhattacharya, Y. (2009, December). Climate Consultant 4.0 develops design guidelines for each unique climate. In American Solar Energy Society Meeting.
5. Milne, M., Liggett, R., & Al-Shaali, R. (2007, July). Climate consultant 3.0: A tool for visualizing building energy implications of climates. In proceedings of the Solar Conference (Vol. 1, p. 466). American solar energy society; american institute of architects.

AUTHOR'S PROFILE

Fabrice Mwizerwa, Ph.D scholar in the department of Civil Engineering, Suresh Gyan Vihar University, Mahal Rd, Jaipur, Rajasthan 302017 (INDIA). mwizeretu@gmail.com

Mukesh Kr Gupta, Center of Excellence - Renewable and Sustainable Energy Studies, Suresh Gyan Vihar University, Mahal Rd, Jaipur, Rajasthan 302017(INDIA). Mukeshkr.gupta@mygyanvihar.com