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Interrelation between Climatic Zone and Bungalow Building Design: CASE of Tropical Climate

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Abstract

In todays era, climate scenario is changing rapidly. People using huge amount of non renewable energy to achieve comfort condition. Global climate is becoming major problem for all countries resulting into natural and man made disasters. India categorized into six climatic zones. Climatic data of every zone differs from other. In such conditions, designing a bungalow which is achieving the human comfort conditions without using non renewable energy and catering to need of different climatic zones is important. Tropical climate conditions are temperature range is high, humidity level is very high. In such conditions, various design strategies such as building orientation, mutual shading, cross ventilation, pre – cooled winds, thermal mass (u – value), window shading devices plays an important role. Research paper focusses on various strategies that can be applied for the bungalow design in tropical climate and its result in terms of software simulation, heat gain and comfort conditions. An expected outcome of this research paper will be in terms of various strategies in terms priority that can be utilized to reduce the load on non renewable energy and also not extending the cost of construction having payback period of more than 5 years.

Keywords; *Tropical climate, human comfort, strategies, bungalow design*

I. INTRODUCTION

What is Global Climate change :

It refers to remarkable, major, long-term changes in the global climate. It occurs when these changes gives rise to new weather patterns that stay for a long period of time.

Current Scenario of global climate : The story of Earth's climate, since past has not been static. "The change and its impacts have been worse than expected" the global report warns. As per the recent studies, the earth is heading towards painful problems, soon than expected. In recent years, Forest fires, record breaking storms, droughts, floods, shift of climate zones, increase in dry climes, decrease in polar climates, rise in sea- levels, extreme seasons are seen as major climate change globally. 2015 – 2019 are recorded to be the warmest five years. Ever-rising concentration of greenhouse gas releases is judged as a primary reason for these concerns

Greenhouse gas emissions :

Behind the Global warming and climate change lies the increase in greenhouse gases. Any gaseous compound present in atmosphere which captivates infrared radiation resulting into holding and trapping heat in the atmosphere, are known as green house gases. This leads to rise in temperature in atmosphere, thus creating the greenhouse effect, ultimately leading to global warming. These heat trapping gases could be imagined as a layer of blanket, wrapped around earth. six main greenhouse gases which significantly impact the environment: namely CO2 (carbon dioxide), CH4 (methane), N2O (nitrous oxide), HFCs (hydrofluorocarbons), PFCs (perfluorocarbons) and SF6 (sulfur hexafluoride). Amongst all said components, carbon dioxide is

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considered highly leading contributor to global climate change. (Singh, 2009) 80% of carbon emissions are caused by urban human activities. This is a result of Human activities like burning of fuel while vehicular transportation, Generating power produces large amount of carbon dioxide to the environment. In addition to this, construction ventures and other industrial works are also been identified as key emission sources of carbon. Hence, global researchers are significantly concentrating on exploring alternative techniques to lessen carbon emissions. (A, 2008)

II. NEED

As it is becoming a major issue and creating harmful situations for environment. Major drawbacks of global warming are :

- Drastic variation in climatic conditions
- Unidentified amount of Rainfall
- More load on non renewable energy
- Possibilities of poor I.A.Q.
- Possibilities of Sick building syndrome
- And many more.

To cater through all these issues, it becomes important to implement green building strategies into bungalow design which will help in reducing the emission of green house gasses and many more points which affects global climate. To come up with solution, climatic zones are need to be identified and strategies must be implemented to make the design sustainable.

Climatic conditions of Tropical climate : A non arid climate is termed as tropical climate. Basic climatic conditions of such climate are :

Temperature range : 37^0 C to 18^0 C

Humidity : 55% to 91%

Rainfall : 1200 mm / year

Such climate normally found from the equator to 25 north and south latitude. In such climatic zone, the temperature remains relatively constant for whole year. In such climate, Sunlight is extreme. Such climate always observes only two seasons i.e. wet season and dry season. During the summer season, it experiences wet season in northern hemisphere and in winter season and post winter, it experiences the same season in southern hemisphere and dry season always seen at the time of low sun. (Google, 2020) The high humidity encourages ample vegetation in these regions.The diffuse fraction of solar radiation is quite high due to cloud cover, and the radiation can be intense on clear days. The dissipation of the accumulated heat from the earth to the night sky is generally marginal due to the presence of clouds. So the diurnal variation in temperature is quite low. The high humidity causes discomfort. The wind is generally from one or two prevailing directions with speeds ranging from extremely low to very high. Wind is desirable in this climate.

III. DESIGN STRATEGIES

In such climatic zone, main design criteria are to reduce heat gain by providing shading, and promote heat loss by maximizing cross ventilation. Dissipation of humidity is also essential to reduce discomfort. In such climate, wind is desirable as it causes sensible cooling of body. Objectives of design for such climate are : first objective is Resist heat gain by decreasing exposed surface area, Increasing thermal resistance, Increase buffer space, Increase shading and Increase surface reflectivity. Second objective for such climatic zone is to promote heat loss by ventilation of appliances, Increase air exchange rate and decrese humidity levels.

To achieve first objective, strategies like orientation and shape of building, Roof insulation and wall insulation, Reflective roof surfaces, Balconies and verhandahs, proper designing of shading devices etc. and to achieve second objective, provision of windows or exhausts, ventilated roof construction,

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courtyards, wind towers and arrangement of openings, and adding dehumidifiers and desiccant cooling are the important strategies. (Singh M K, 2010)

IV. METHODS

As the case of tropical climate is been considered, initially the climatic data & need of such climate in terms of building design strategies are identified. The climatic data for said climate is as follows : Maximum temperature in summer – 37.1^{0}C and minimum temperature is 22.1^{0}C. Annual rainfall for such climatic zones varies from 123.10 mm to 179.49 mm. Relative humidity in summer month is 58% to 37% and during rainy season it recorded up to 85% to 78%. This whole data is collected from Indian meteorological department.

After completing data collection, further to conclude the benefits of different strategies that can be used in bungalow design for tropical climate, A base case is considered for stimulation. A small unit having 2 bedrooms, kitchen, dining, living room and patio is designed for stimulation. Following strategies were implemented to identify the interrelation between designing and climatic zone.(Singh, 2009)

To cater such climatic condition, following are various strategies which needs to be applied while designing a bungalow (ground storied structure)

a) Orientation of Building

b) Thermal mass

c) Cross ventilation

d) Mutual shading

e) Earth air tunnel

f) Shading devices

9) Stack effect.

The result of implementing these strategies in design were also analyzed in software :

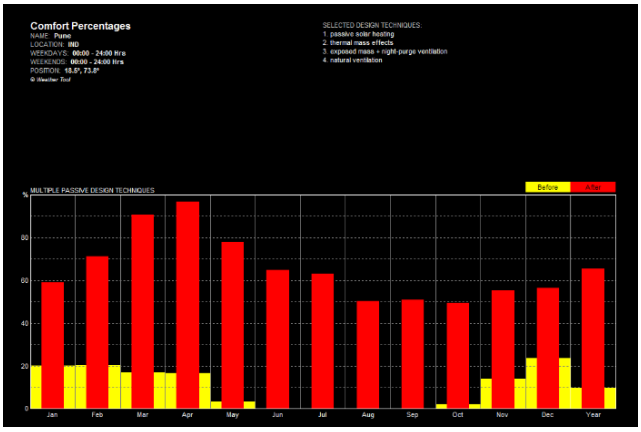

Figure i Result of Implementing various sustainable strategies with respect to Climatic zone

Implementing only two strategies i.e. passive solar heating and Natural ventilation gives more effective results in terms of benefits in money. Result graph is stated below. These strategies helps in reducing the load on non renewable energy and simultaneously as payback period is not more than 3.7 years, such strategies will play important role and also the customer will get benefited.

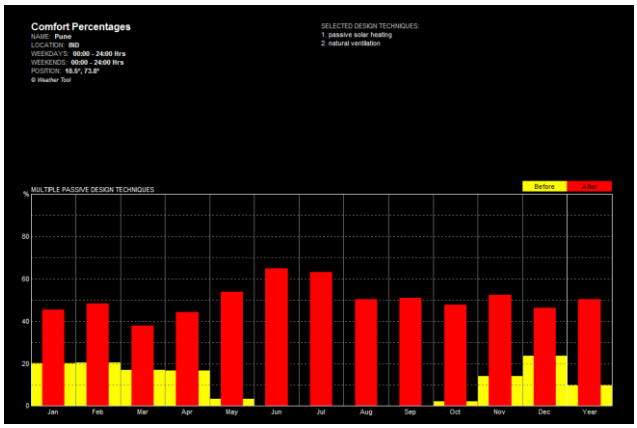

Figure ii Strategies implementation results

Figure ii indicates that, if we apply only these two strategies i.e. passive solar heating and natural ventilation then whatever are the results, they mentioned in terms of graph. Yellow bar stated the before stage analysis and red one explains the After one analysis.

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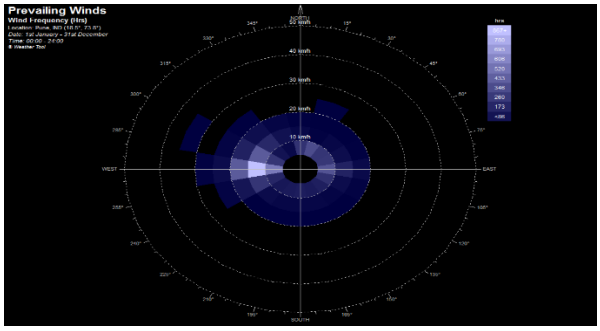

Figure iii Wind frequency status

Fig iii shows the available wind frequency in 360^0 to design the whole plan, positioning of windows and also plays an important role in achieving cross ventilation for the area.

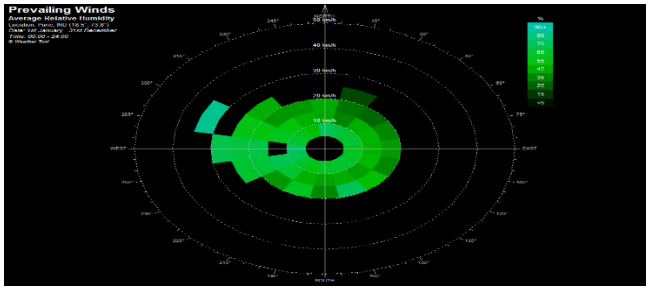

Figure iv Wind humidity status

This fig no. iv shows the available wind humidity from all the four side. This helps an architect whether to collect that wind from shown positions or not.

This fig. no. v state the available dry bulb temperature surrounding the site. This helps in designing alternative or preventive measures to achieve the thermal comfort during the hotter seasons.

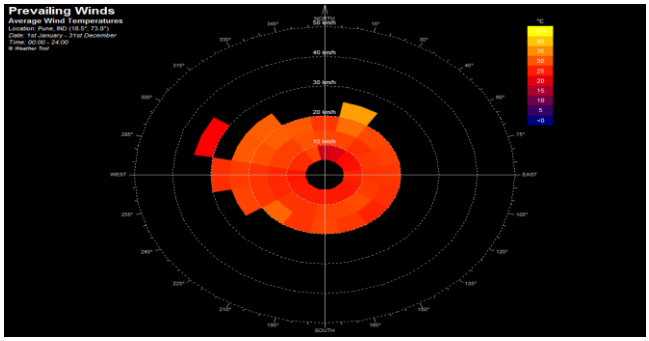

Figure v Wind temperature status

So as discussed earlier, the sketch plan of the bungalow is drawn below along with their designed orientation. Henceforth, this bungalow is taken. A basic concept plan is been designed as follow.

Figure viBungalow floor plan - Designed orientation

A) Orientation :

The various orientations were designed and analyzed with the help of Ecotect software. Following image shows the various results of conventional orientation versus designed orientation in terms of available radiations on all facades.

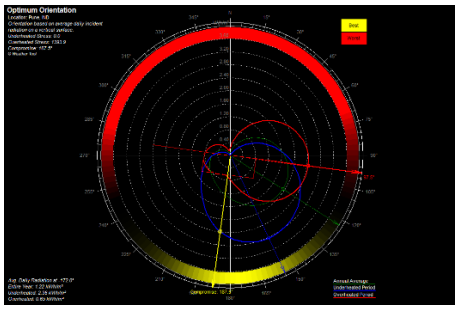

Figure vii Orientation Analysis : Results

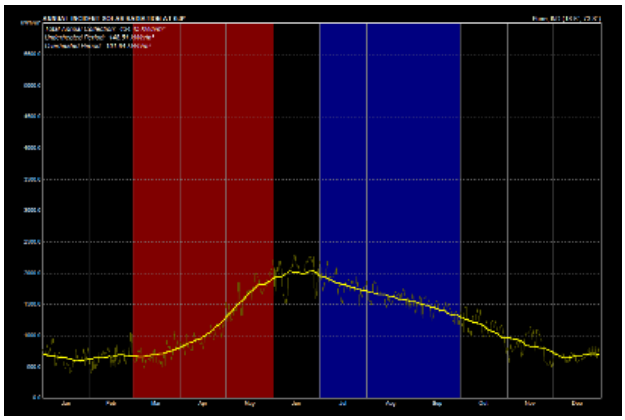

Figure viii Conventional Orientation Incident heat radiation

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Result from fig. vii & viii states that when it's a conventional orientation, the heat gain during the winter and post winter months is very low, and during summer season it is very high i.e. 2000 kWh/m^2. These conditions are against the design requirement of tropical climate. Whereas, there is a major variation in incident solar radiation if the orientation is designed properly, results of designed orientations are shown in fig ii.

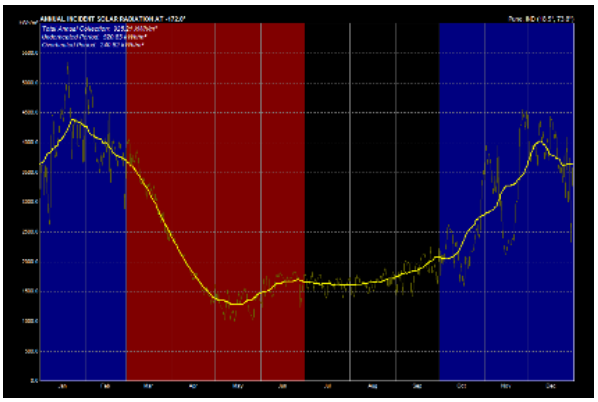

Figure ix Designed Orientation Incident heat radiation

Further, the incident solar radiation on all façade are identified and stated in table no. i

	N	NE	E	SE	S	SW	W	N W	Hz
Area	44	67.6	48	32	40	67. 8	48	32	143.53
W/sq.m.	39	19	479	26	423	31	438	14	818
Total Heat gain in watt	171 6	1284	229 92	832	169 20	210 1	210 24	448	117407

Table 1 Total Heat gain for designed orientation

This table states the maximum heat gain on all facades implementing this strategy in bungalow design is giving good results and outcome without any money.

b) Mutual Shading : This strategy plays an important role. The said strategy helps to reduce the heat gain from exterior surface. Ultimately it is minimizing the temperature, and achieving the thermal comfort without adding any extra cost. This strategy implement the benefits of surrounding structure.

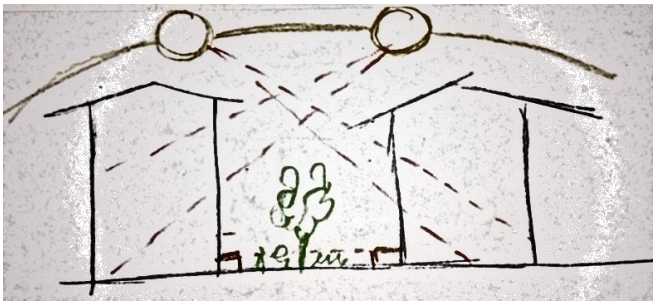

Figure x Mutual shading strategy

c) Thermal Mass : After the orientation and mutual shading, further thermal mass strategy is applied for the all facades and analysis is done for critical months. The heat gain is calculated and analyzed. The thermal mass is designed in 4 building envelopes. For the tropical climate, Basic wall section is initially considered as case 1 having U value 3.545. Case 2 section is designed similarly, only the thickness of wall is increased up to 350 mm, whose U value is 2.633. In case 3, section is redesigned, 150 mm brick wall, 75 mm cavity and 100 mm thick Internal brick wall having U value 2.094. In case 4, insulation material is used in between two 100 mm thick Brick walls, whose U value is 1.739. The construction cost for each section, U value and total heat gain is further analyzed and mentioned in following table.

Case	Surface area	U Value	Radiation	Heat gain	Construction cost
1	522.93	3.545	289	535 744	140/- per sq.ft.
2	522.93	2.633	289	397 916	210/- per sq.ft.
3	522.93	2.094	289	316 459	350/- per sq.ft.
4	522.93	1.739	289	262 809	785/- per sq.ft.

Table 2 U value and Construction cost

Hence it is observed that even the construction cost of 4th building section is higher, it helps in reducing / increasing heat gain during summer and winter months respectively. Even the construction cost is higher, it gives the benefit in energy saving modes. So the calculated payback period for this kind of

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section is from 3 years 5 months 13 days to 4 years 1 month 24 days.

d) Cross ventilation : As this climates basic need is to achieve cross ventilation to reduce additional humidity available in atmosphere. This strategy reduces the load on non renewable energy i.e. electrical energy, There is need to create positive and negative spaces in or areas near bed room, living room i.e. habitable rooms. This is needed just because we already know that, wind travels from negative pressure to positive pressure at the day time and vice versa during night time.

e) Earth air Tunnel : This strategy plays important role to maintain the thermal comfort without increasing load on non renewable energy. This method based on the rule that the temperature below 3 M. of the ground level in the earth is always constant and ranges between 18^0 C to 22^0 C. So the wind catcher is located in set back areas and wind is allowed to pass through it. This tunnel is further taken down below the ground level and run horizontally 3 M. below the ground level. When wind passes through the same, it is been cooled down and then allowed to pass to the various rooms.

f) Shading devices : This strategy must be utilized with précised drawings and analysis. Such analysis helps in designing various sized shading devices along with its benefits. As shown below, following are the alternatives tried for designing shading device for this bungalow and the results were found are displayed :

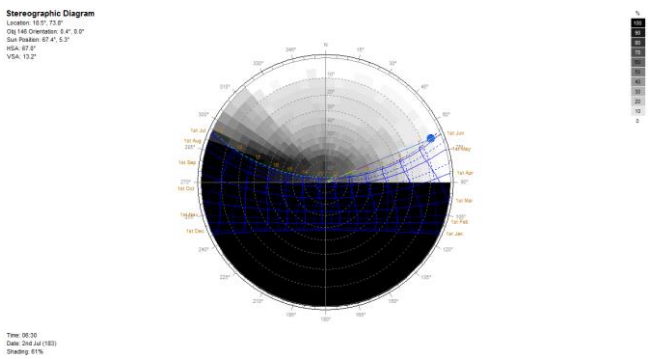

Figure xi North South Shading device 300 mm long Shade analysis

This image is stating that if we design the 300 mm wide shading device, it will provide the shade only during winter season and will allow sun to enter in for the summer season which will increase the heat in the structure.

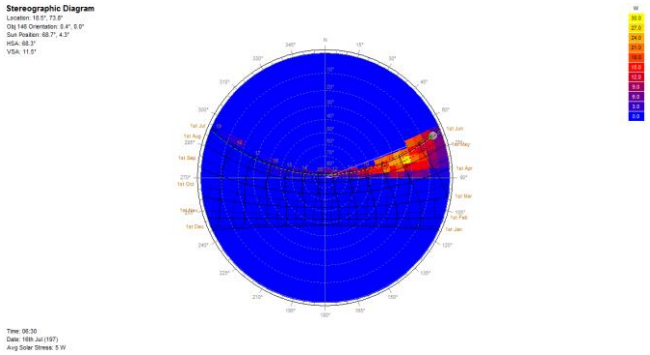

Figure xii North South Shading device 300 mm long Incident heat analysis

And will allow maximum solar radiation in summer month which will be against the sustainability. It proves that designing 300 mm wide shading device will increase the load on non renewable energy to achieve comfort conditions in the interior.

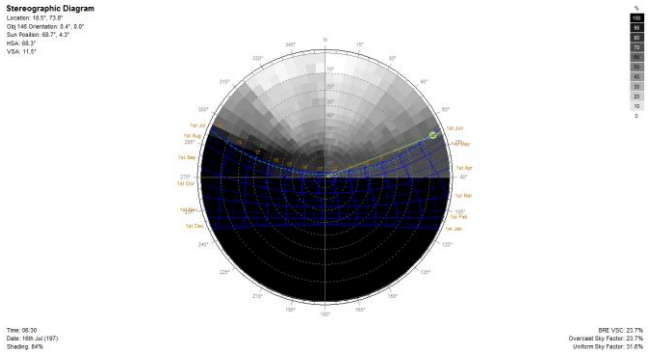

Figure xiii North South Shading device 450 mm long Shade analysis

Now, if the length of shading device is increased to 450 mm, still it is not serving the purpose completely. It also going to disturb the daylight which will again be the problem.

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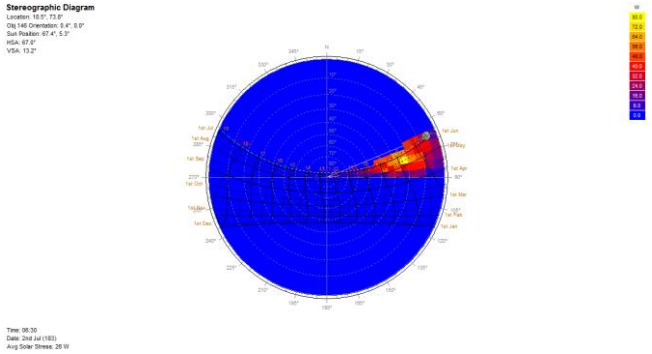

Figure xiv North South Shading device 450 mm long Incident heat analysis

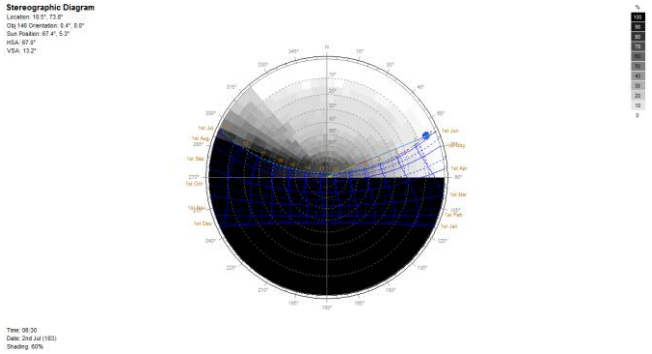

Figure xv North South Shading device 350 mm Box Shade analysis

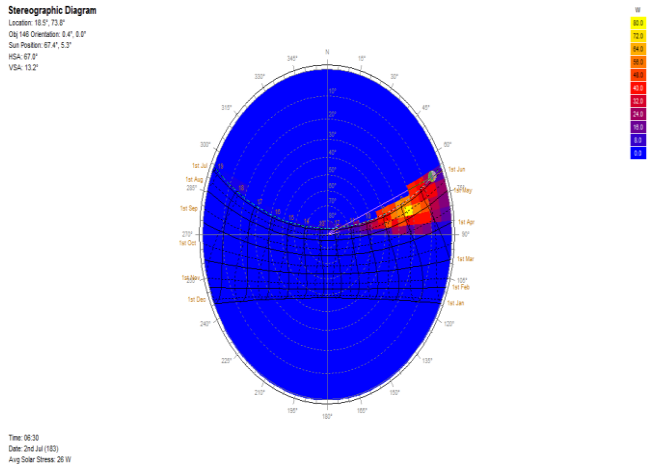

Figure xvi North South Shading device 350 mm box Incident heat analysis

Above images shows North and South shading devices design and incident heat radiation and shadow analysis for two different sized shading devices. Following images shows the same data for East and West façade. This data helps in reducing the heat gain.

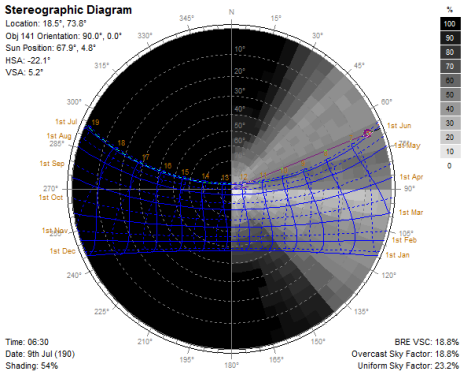

Figure xvii East West Shading device 300 mm wide Shade analysis

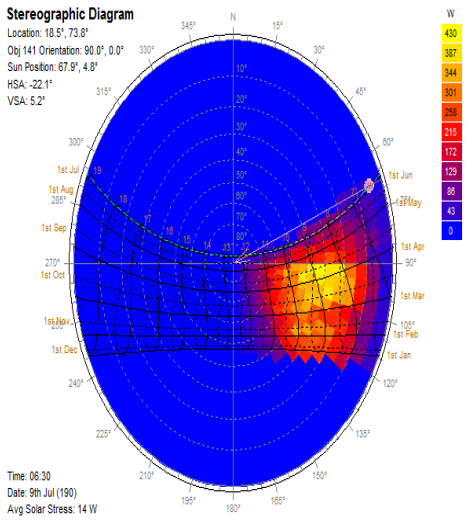

Figure xviii East West Shading device 300 mm wide Incident heat analysis

Further, Instead of going for traditional shading designs, a new shading device is designed which is inclined at 27^0 and whose length is 470 mm from the exterior wall façade. This device is found very useful for the selected climate. It's results are as follows :

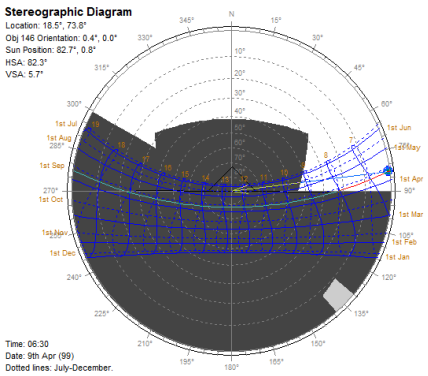

Figure xix

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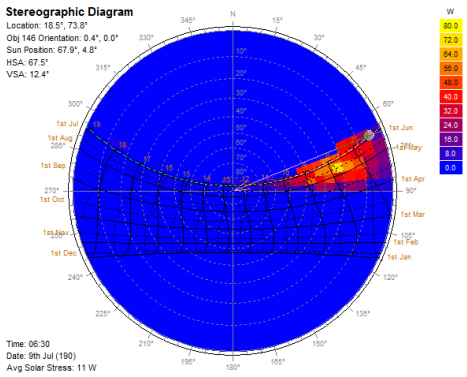

Figure xx North South Shading device 470 mm long sloping Incident heat analysis

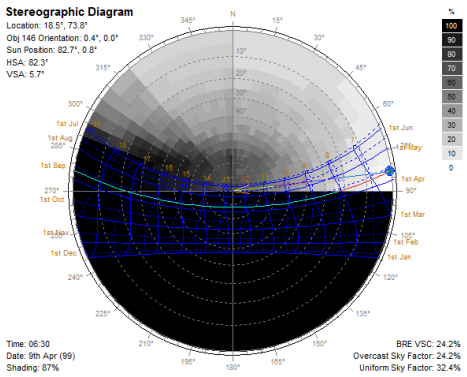

Figure xxi North South Shading device 470 mm long sloping Shade analysis

So designing such shading device helps in reducing the heat gain from window by 38%. And the construction cost for traditional shading devices and designed devices is increased by 17% only. But the advantages are very more. These results are valid for said case study only.

V. CONCLUSION :

- Bungalow building design is interralted with the micro climatic data
- Design changes as per the climatic zone.
- Such designs helps in reducing green house gasses emissions and also helps in controlling global climatic issues.
- Mentioned design strategies can be implemented in bungalow design to make it sustainable.

The construction cost is increased by 47% due to implementation of these strategies but the maximum payback period for this is not more than 5 years 13 days

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