An Investigation on Relationship between External Heat gain and Shading Device

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Abstract **Building requires large amount of energy both for cooling and heating. In fact, it has been estimated that in hot climates due to solar gain contributes maximum amount of cooling load for residential as well as non-residential buildings. While solar gain through glazed facade contributes largely to these loads. Conventionally, we use shading device for reducing the direct heat gain through the windows. The shading devices usually prevent direct radiation coming from outside of the building and entering inside the building. Design and placement of shading devices becomes more useful when it is placed on right position as per the orientation of sun. A lot of studies have presented the effectiveness of slat angles and importance of deferent shapes. This Research also focuses on the effect of external shading devices on annual cooling load and also provides a simplified calculation approach with several conditions of increasing the size of shading device in terms of percentage of window height and width from 10% to 100% and calculate the effect of shading device at each condition based on manual calculation.**

Keywords **-Passive cooling, Direct solar Radiation, SHGC, Shading Device, slat angles.**

INTRODUCTION

Building Envelop serves as a boundary between the outside environments and the inside environment. However, the inside of building is influenced by the outside weather conditions, like solar insolation, ambient temperature, wind speed, rainfall and humidity etc. To maintain the indoor thermal comfort, large amount of energy is required for heating and cooling depending on weather condition and location. In fact, due to solar gain building cooling load contributes in maximum energy consumption. Conventionally we have been using shading devices to reduce the cooling load. The main purpose of using a shading device is usually to prevent excessive radiation falling on building façade. They are installed on the exterior; the devices are able to intercept direct solar radiation before it passes through the glazing of a fenestration. Exterior shading devices such as overhangs and vertical fins have a number of advantages that contribute to a more sustainable building. The building envelope refers to the exterior façade, and is comprised of opaque components and fenestration systems. Opaque components include walls, roofs, slabs on grade (in Touch with ground), Basement walls, and opaque doors. Fenestration systems include windows, skylights, ventilators, and doors that are more than one-half glazed. The envelope protects the building's interiors and occupants from the weather conditions and shields them from other external factors e.g.: noise, pollution, etc. envelope design strongly affects the visual and thermal comfort of the occupants, as well as energy consumption in the building.

From an energy efficiency point of view, the envelope design must take into consideration both the external and internal heat loads, as well as day lighting benefits. External loads include mainly solar heat gains through windows, heat losses across the envelope surfaces, and unwanted air infiltration in the building: internal loads include heat released by the electric lighting systems, equipment, and people working in the building space.

A well-designed building envelope not only helps in complying with the energy conservation building envelope (ECBC) but can also result in first cost savings by taking advantage of the day lighting and correct HVAC sizing. The building envelope and its components are key determinants of the amount of heat gain and loss and wind that enters inside. The design features of the envelope strongly affect the visual and thermal comfort of the occupants, as well as energy consumption in the building.

Key factor which play an important role in designing the building envelope with glass are as follows:

- U-Value
- solar factor (SF)/ Solar Heat Gain Co-efficient (SHGC)Visible Transmittance (VT or Tvis)
- Air leakage
- Visual Comfort
- Relative Heat Gain (RHG)

Thermal Performance of window on the basis of U-factor and SHGC:

The overall thermal performance of windows can be evaluated on basis of the following two energy performance parameters of windows.
A. Maximum U Factor (Thermal Transmittance)
B. Maximum SHGC (Heat gain through direct solar radiation)
It has been observed that SHGC of glass has greater impact on heat gain as compared to U-value of Glass.

Example: Assume the following climatic condition.
The Outdoor solar incident energy (on 1m X 1m glass area)= 800w/m2
Temperature differential between inside and outside= 20C
SHGC of selected glass= 0.3, U-factor of selected glass= 3.0
The heat gain inside the building through SHGC of glass= 800 X 0.3 = 240W
The heat gain inside the building through U-value of glass= 20 X 3.0 = 60W
Therefore, the Total heat gain inside the building= 300W
Heat gain due to SHGC= 80% of the total Heat gain (M. Majumdar 2010)
After analysing example it observed that SHGC of glass has greater impact on heat gain than U-value of glass. While solar gains through windows contribute largely to heat gain and increasing the cooling load of the building so the useful method to decreasing cooling load by use of shading device could be useful.

Control of solar radiation through shading:

In order to control sun penetration to interior of buildings it is important to provide exterior shading as a part of the architectural envelope design. Such shading devices can be attached to the building or can be achieved by the articulation and disposition and disposition of the building floors to create overhangs.

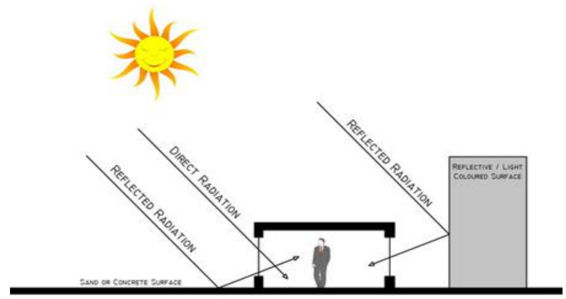

Figure 1 Source of Solar Radiation that May Required Shading

Exterior shading is greatly preferred over interior shading as it is important to keep the solar radiation/ heat from entering the building. Traditional interior blinds or drapes merely block the glare of sun, but still allow the heat to enter the interior space.

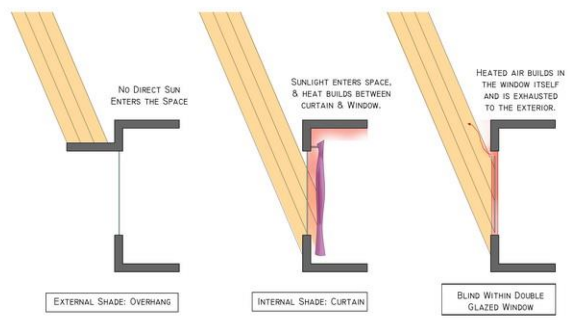

Figure 2 Benefits / Detriments of shading locations and types

Façade Treatment on Different Direction:

An understanding of solar geometry tells us that the exposure of each façade to the sun is different, and varies by orientation. Each orientation. Each orientation of the building requires a different approach to design of shading.

North Façade: North elevation (in the northern hemisphere) essentially does not requires shading because except in the summer months in the early morning and late evening, no sun penetration occurs. At this time of the day the sun angle is so low that horizontal projections would be useless as shading devices.

South Façade: South facing elevation (in northern hemisphere) allows for the easiest control of solar energy. Shading devices are normally designed as horizontal projections above the windows. The length of the projection is determined as a geometric function of the height of the window and the angle of elevation of the sun at solar noon. Such shading devices can be designed to completely eliminate sun penetration in the summer and allow for complete sun penetration during the winter when such is desired for passive heat gain.

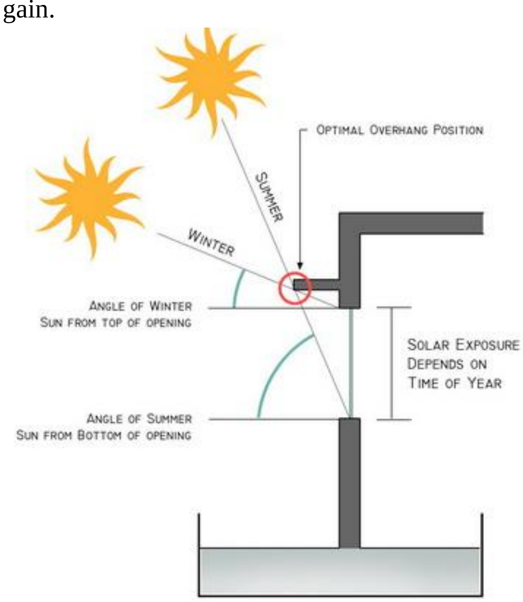

Figure 3 Basic shading strategy for a south elevation

West-East Façade: The east and west elevations are both difficult to shade "Architecturally". The sun angles in the morning and afternoon are low enough to preclude shading using overhangs. The morning sun is normally cooler and less offensive than the heat and glare of the afternoon sun.

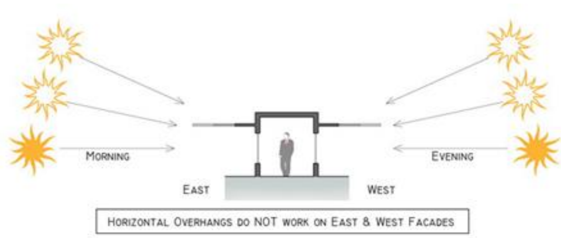

Figure 4 Shading issues with East and West Façade

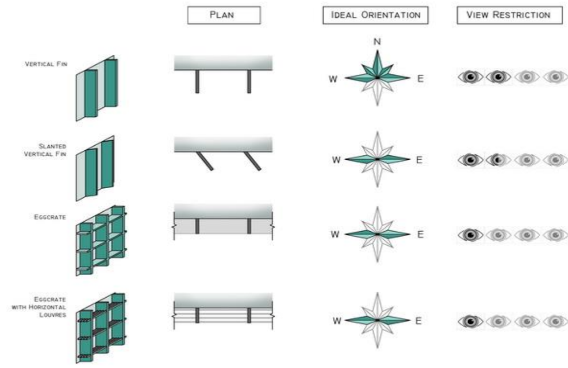

Figure 5 Shading Devices for Non-Southern Exposures

Analysis:

To find a valuable conclusion and to achieve the Aim, one sample model has created into analyzing.

Table 1 Standard case specification

STANDARD CASE	
Climate	Hot & dry
City	Vadodra, Gujrat
Latitude	22° 20' n, 73° 16' e
Room type	Office
Room area (m2)	240
Room dimension	20 x 12
Occupant density	24
WWR	20%

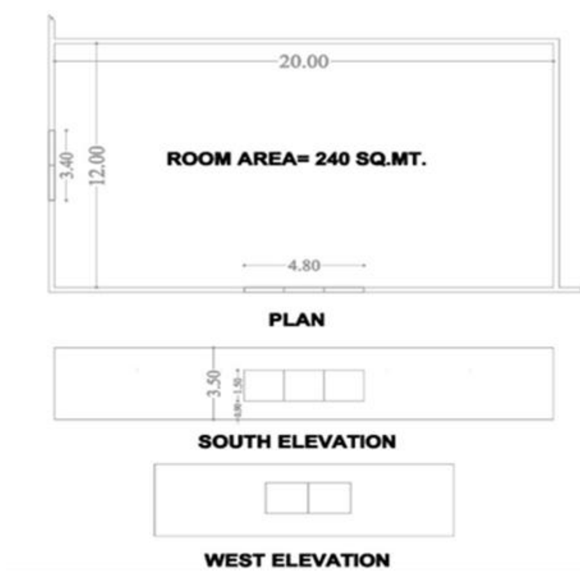

Figure 6 Plan, Elevation and Section of typical Room

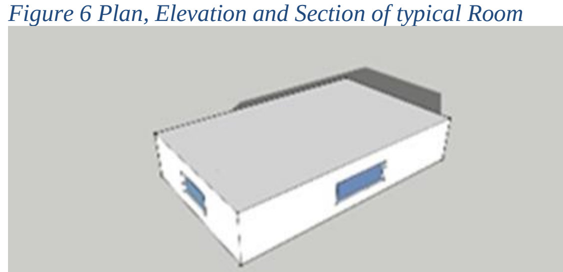

Figure 7 3D Model of Room

After calculating total heat gain of a model, its shows that external heat gain is much greater than internal heat gain, and the external heat gain has also many parameters like: Wall, Roof and Window. As we studied that window is a unique and important role in building and the environment. It affects design, thermal performance and occupant comfort drastically. Heat transfer across windows is similar to the heat transfer that takes place across walls and roofs through conduction and convection. So, U-factor of glazing is analogous to the U-factor of wall assembly. The overall thermal performance of windows can be evaluated on the basis of the following two energy performance parameters of windows.

A. Maximum U-factor (Thermal Transmittance)

B. Maximum SHGC (Heat gain through direct solar radiation)

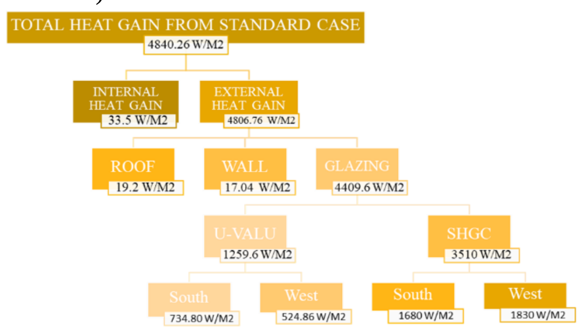

Figure 8 Total Heat Gain from Standard Case

It has observed that SHGC of glass has greater impact on heat gain as compared to U-value of glass.

Projection Factor & Multiplication Factor (M)

The SHGC requirement of a window can be affected by overhangs on a building, which reduce solar gains. The ECBC uses a term called a projection factor to determine how well an overhang shades the building's glazing. The projection factor is calculated by measuring the distance from the window to the farthest edge of the overhang and dividing that by the distance from the bottom of the window to the lowest point of the overhang demonstrates how to calculate a projection factor.

Projection Factor = The ECBC provides a modified SHGC requirement where there are overhangs and / or side fins, which are a permanent part of the building. This may be applied in determining the SHGC for the proposed design. An adjusted SHGC, accounting for overhangs and / or side fins, is calculated by multiplying the SHGC of the unshaded fenestration product by a multiplication, a separate M, Factor shall be determined for each orientation and unique shading condition. (ECBC, Energy conservation building code user guide 2009)

ECBC has provided the values of M-Factor for various projection factors

Overhang "M" Factors for 4 Projection Factors					
Project Location	Orientation	0.25 - 0.49	0.5 - 0.74	0.75 - 0.99	1 +
North latitude 15° or greater	N	0.88	0.8	0.76	0.73
	E/W	0.79	0.65	0.56	0.5
	S	**0.79**	**0.64**	**0.52**	**0.43**

Table 2 SHGC "M" Factor Adjustments for Overhangs

Vertical Fin "M" Factors for 4 Projection Factors					
Project Location	Orientation	0.25 - 0.49	0.5 - 0.74	0.75 - 0.99	1 +
North latitude 15° or greater	N	0.88	0.8	0.76	0.73
	E/W	**0.8**	**0.72**	**0.65**	**0.6**
	S	0.79	0.64	0.52	0.43

Table 3 SHGC "M" Factor Adjustments for Vertical fins

HEAT GAIN WITHOUT SHADING DEVICE ON SOUTH WINDOW									
								Total heat gain W/m2	
Wall surface	Type of glass	U-value	Temperature Different between inside and outside C'	Heat gain through U-value of glass	SHGC	Outdoor solar incident energy (on 1m x 1m glass area) W/m2	Heat gain through SHGC of glass	U-Value x window area(7sqmt)	SHGC x window area(7sqmt)
SOUTH	Improved aluminum single clear glass	6.44	16.3	104.972	0.75	320	240	734.804	1680
								2414.804	

Table 4 HEAT GAIN without shading device on south window

HEAT GAIN WITHOUT SHADING DEVICE ON WEST WINDOW									
								Total heat gain W/m2	
Wall surface	Type of glass	U-value	Temperature Different between inside and outside C'	Heat gain through U-value of glass	SHGC	Outdoor solar incident energy (on 1m x 1m glass area) W/m2	Heat gain through SHGC of glass	U-Value x window area(7sqmt)	SHGC x window area(7sqmt)
SOUTH	Improved aluminum single clear glass	6.44	16.3	104.972	0.75	488	366	524.86	1830
								2354.86	

Table 5 Heat Gain without shading device on South Window

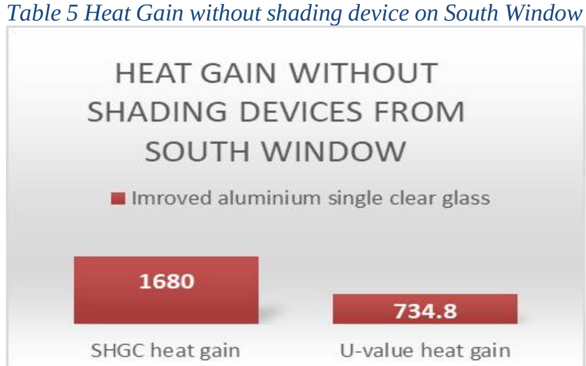

Figure 9 Heat Gain from south wall without shading device

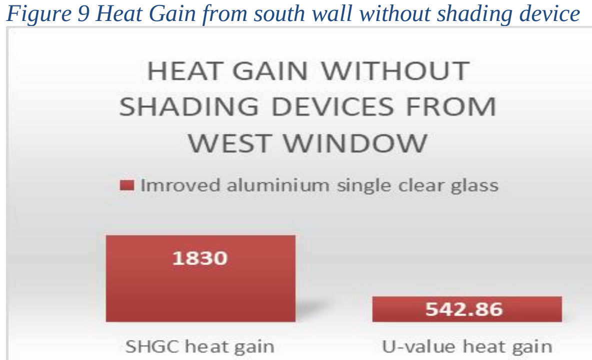

Figure 10 Heat gain from west wall without shading device

So, after calculating the projection factor at different projection sizes projection will increase in terms of percentage of window height/ width like from 10% to 100% according to need of shading type. Than account the PF to multiplying with ECBC multiplication factor "M" to determine EFFECTIVE SHGC.

EFFECTIVE SHGC FOR SOUTH WALL:

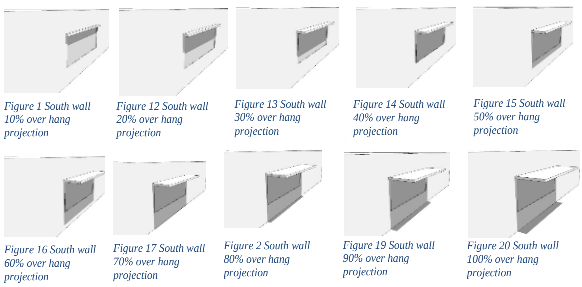

Figure 1 South wall 10% over hang projection
Figure 12 South wall 20% over hang projection
Figure 13 South wall 30% over hang projection
Figure 14 South wall 40% over hang projection
Figure 15 South wall 50% over hang projection
Figure 16 South wall 60% over hang projection
Figure 17 South wall 70% over hang projection
Figure 2 South wall 80% over hang projection
Figure 19 South wall 90% over hang projection
Figure 20 South wall 100% over hang projection

Figure 10 Effective SHGC for South wall Horizontal projection and shading on vertical façade

HEAT GAIN WITH SHADING DEVICE ON SOUTH WALL									
% of Shading device	U-value	Temperature Different between inside and outside C'	Heat gain through U-value of glass	effective SHGC	Outdoor solar incident energy (on 1m x 1m glass area) W/m2	Heat gain through Effective SHGC of glass	Heat gain W/m2		Total Heat gain W/m2
							U-Value x window area(7sqmt)	SHGC x window area(7sqmt)	
10%	6.44	16.3	104.972	0.75	320	240	734.804	1680	2414.804
20%	6.44	16.3	104.972	0.75	320	240	734.804	1680	2414.804
30%	6.44	16.3	104.972	0.5925	320	189.6	734.804	1327.2	2062.004
40%	6.44	16.3	104.972	0.5925	320	189.6	734.804	1327.2	2062.004
50%	6.44	16.3	104.972	0.5925	320	189.6	734.804	1327.2	2062.004
60%	6.44	16.3	104.972	0.48	320	153.6	734.804	1075.2	1810.004
70%	6.44	16.3	104.972	0.48	320	153.6	734.804	1075.2	1810.004
80%	6.44	16.3	104.972	0.39	320	124.8	734.804	873.6	1608.404
90%	6.44	16.3	104.972	0.39	320	124.8	734.804	873.6	1608.404
100%	6.44	16.3	104.972	0.39	320	124.8	734.804	873.6	1608.404

Table 6 Heat Gain with shading device on south wall

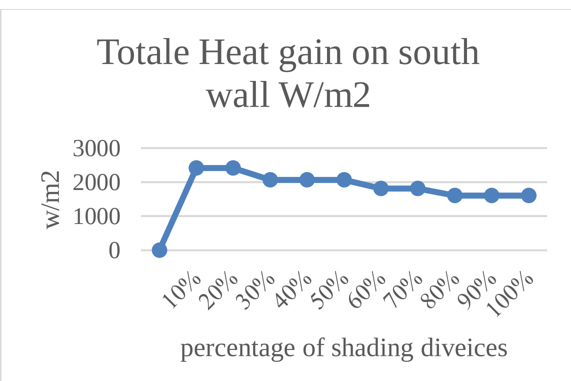

Figure 11 Heat Gain graph with after installation shading device on south window

HEAT GAIN WITH SHADING DEVICE ON WEST WALL									
% of Shading device	U-value	Temperature Different between inside and outside C'	Heat gain through U-value of glass	Effective SHGC	Outdoor solar incident energy (on 1m x 1m glass area) W/m2	Heat gain through Effective SHGC of glass	Heat gain W/m2		Total Heat gain W/m2
							U-Value x window area(5sqmt)	SHGC x window area(5sqmt)	
10%	6.44	16.3	104.972	0.75	488	366	524.86	1830	2354.86
20%	6.44	16.3	104.972	0.75	488	366	524.86	1830	2354.86
30%	6.44	16.3	104.972	0.6	488	292.8	524.86	1464	1988.86
40%	6.44	16.3	104.972	0.6	488	292.8	524.86	1464	1988.86
50%	6.44	16.3	104.972	0.54	488	263.52	524.86	1317.6	1842.46
60%	6.44	16.3	104.972	0.54	488	263.52	524.86	1317.6	1842.46
70%	6.44	16.3	104.972	0.54	488	263.52	524.86	1317.6	1842.46
80%	6.44	16.3	104.972	0.4875	488	237.9	524.86	1189.5	1714.36
90%	6.44	16.3	104.972	0.4875	488	237.9	524.86	1189.5	1714.36
100%	6.44	16.3	104.972	0.45	488	219.6	524.86	1098	1622.86

Table 7 Heat Gain shading device on west wall

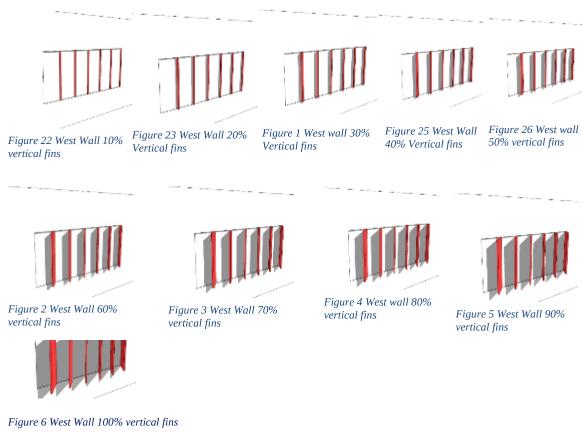

Figure 22 West Wall 10% vertical fins
Figure 23 West Wall 20% Vertical fins
Figure 1 West wall 30% Vertical fins
Figure 25 West Wall 40% Vertical fins
Figure 26 West wall 50% vertical fins
Figure 2 West Wall 60% vertical fins
Figure 3 West Wall 70% vertical fins
Figure 4 West wall 80% vertical fins
Figure 5 West Wall 90% vertical fins
Figure 6 West Wall 100% vertical fins

Figure 12 Effective SHGC for West wall

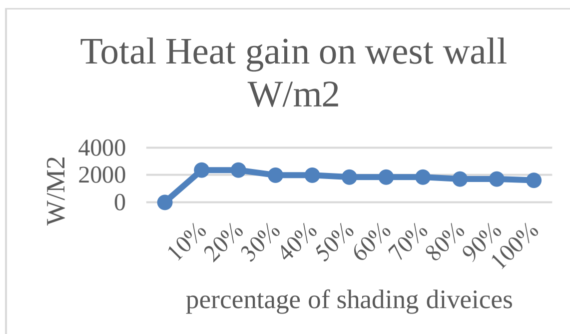

Figure 13 Heat Gain with after installing shading device on West Wall

The result from the graphs shows that if we are increasing the projection till 20% the values are similar as without any shading device, and values area start dropping from 30%.

TOTAL HEAT GAIN AFTER INSTALLING SHADING DEVICES						
f n e	STANDARD HEAT GAIN	WEST WINDOW HEAT GAIN	SOUTH WINDOW HAT GAIN	HEAT GAIN(Internal +roof+wall)	TOTAL HEAT GAIN (Glazing+roof+wall+internal)	TOTAL REDUCITIO IN HEAT GAIN
	4840.26	2354.86	2414.804	69.74	4839.404	0.856
	4840.26	2354.86	2414.804	69.74	4839.404	0.856
	4840.26	1988.86	2062.004	69.74	4120.604	719.656
	4840.26	1988.86	2062.004	69.74	4120.604	719.656
	4840.26	1842.46	2062.004	69.74	3974.204	866.056
	4840.26	1842.46	1810.004	69.74	3722.204	1118.056
	4840.26	1842.46	1810.004	69.74	3722.204	1118.056
	4840.26	1714.36	1608.004	69.74	3392.104	1448.156
	4840.26	1714.36	1608.404	69.74	3392.504	1447.756
	4840.26	1622.86	1608.404	69.74	3301.004	1539.256

Table 8 Total heat gain after installing shading device

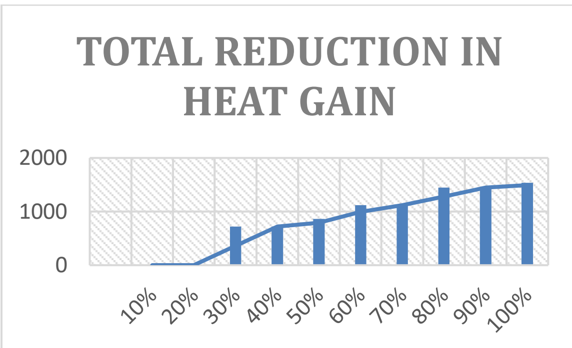

Figure 14 Total reduction in heat gain after installing shading device

As per the result above about the windows, windows perform the major role to allow heat gain. So, the study shows that to reduce cooling load shading devices are performing a very important role to reduce heat gain drastically. For this study we have used clear glass to analyse batter results we found that from

these graphs that if we increase the percentage of shading devices will get the better result of reduction in cooling load, more shading percent more reduction.

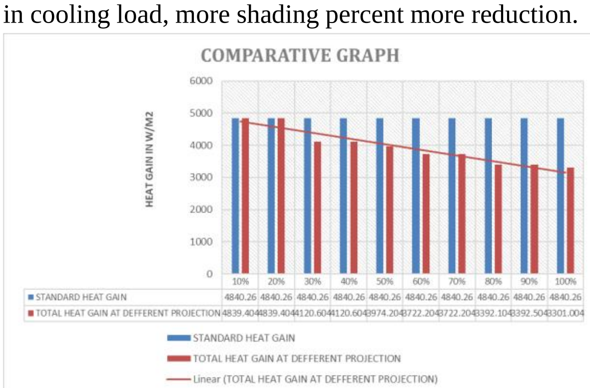

Figure 15 Comparison of south & west windows heat gain

CONCLUSION

Study shows that shading devices are useful to mitigate direct solar heat gain and reduce cooling load, by this study we come to know how much percentage of shading device can impact how much on thermal performance or cooling load.

This study shown that increasing 10% to 20% of shading device impact is similar as without shading device, actual effect of shading device or actual reduction in cooling load is from 30% projection to 100%.

Some projection impact values are being similar in this case like increasing projection from 30% to 50% its impact on cooling load is being similar and this type of similarity is producing while we increase the percentage of projection from 70% to 90% its impact on cooling load is also similar. And 100% shading device is always performing well.

FUTURE SCOPE

Future scope of this research can be help full to understand the sizing of shading device according to its impact. If we know the ECBC (Energy Conservation Building Code 2007) has state some SHGC values for particular climate and also for particular WWR.

For our condition we conduct this research in Hot & Dry climate and WWR is less than 40% so, ECBC state for this type of condition value of SHGC should be 0.25 so, with the base of this study we can get to know at what percentage of shading device we are getting 0.25 value so, we can directly decide the percentage of shading device without guessing hypothetically or without wasting extra amount in construction of shading device.

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