Comparative Advantages of Glazing and Shading Alternatives for Office Building in Composite Climate of India

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Abstract: *Glazing and shading should be viewed as two important facets of commercial and office building design in order to provide good visual comfort, reduce glare and solar gain. External shading devices are increasingly utilized for controlling the amount of excessive solar gain. The present work deals with the influence of solar shading devices as well as various glazing system and in combination with, on the energy demands of a typical air-conditioned office building for composite climatic conditions. The impact of glazing system properties, shading device type and their combinations are measured and analyzed. The result explores that electrochromic glazing would itself reduces as much as 91% of the solar gain. Slat tilt angle of louvre shading would emerge as a key variable to reduce solar heat gain. Some optimum slat angles for different projection louvers are additionally suggested.*

I. INTRODUCTION

Buildings consume about 30% of the total primary electricity consumption in India [1]. With the change in the climatic conditions [2], energy consumption of the buildings increases perpetually for maintaining the thermal comfort for the tenant. Excessive solar gains are resulted due to large window area corresponding to increase in cooling load. Advanced glazing and shading options plays a consequential role in procuring this thermal comfort. An external shading device reduces the cooling energy demand by cutting off the direct solar radiations falling on the glazed area. Hammad and Abu-Hijleh [3] proposed an external dynamic louver system for an office building in the UAE; energy savings for electrochromic windows with overhang for commercial buildings in the USA are analyzed [4]. According to ASHRAE [5] glazed areas completely shaded from the outside cut off 80% of solar heat gain; while total energy savings of 60% were estimated by louver shading devices on different facades of a building [6]. Around 59% savings in solar heat gain was calculated with electrochromic glazing for an office building in hot, dry climate [7] and as much as 70% of solar gain was reduced by optimized horizontal louver shading devices for Italian building [8]. Some experimental configuration of the external shading device is proposed for South Korea residential apartment [9] and 50% reduction in annual cooling energy demand for shading control with 20% roller shade transmittance is quoted [10]. Effect of glazing systems for a large office building with different orientations, control strategies was analyzed [11].

Mitigation of solar heat gain through external windows is one of the foremost requisites for maintaining the internal comfort conditions inside the building. Glazing material properties as well as local shading devices (Overhangs, Sidefins and Louvre) has the major influence on solar heat gain. Employment of external shading devices reduces the cooling energy requisite considerably, but an increment in the heating load will be observed.

The aim of this study is to provide simplified criteria for engineers and architects in order to optate the efficacious glazing systems and local shading techniques to manage the window solar gains for standalone office buildings in Indian composite climate.

II. METHODOLOGY

In the present study a single storey standalone office building having 132.6 m^2 occupied floor area and roof height 3m is considered as a base case, located at Allahabad, Uttar Pradesh, India, in composite climatic conditions. The building has partial internal partitions only, just for dissevering the chambers of the employees. The building analyzed has south–east orientation. The constructional details of the building are shown in table 1.

Table 1: Constructional details of the existing building (base case)

Envelope element	Construction details	U value ($W/m^2 K$)
External wall	1.2 cm plaster, 23 cm bricks, 1.2 cm plaster	1.684
Roof	1.2 cm plaster, 12 cm RCC (2% steel), 1.2 cm plaster	2.959
Ground floor (bottom to top layer)	10 cm sand and gravel, 10 cm cast concrete, 2 cm mortar, 2 cm marble stone	2.642

The existing building (base case) has full construction on its north and west wall without any glazing system, while south and east wall have 30% glazed area having single, 3 mm clear (U = 5.894 $W/m^2 K$) glazing system with aluminium (U = 5.881 $W/m^2 K$) as a window frame material. No external shading devices were employed with the windows for base case condition.

The building has been planned for 0.75 people/m^2 occupancy and the official working time emanates from 9 a.m. to 6 p.m. from Monday to Friday, and from 9 a.m. to 2 p.m. on Saturday. According to ASHRAE 10 l/s of the external air is required for a person working in an office [12].

Single zone, constant volume, direct expansion (DX) based AC system is utilized having a coefficient of performance 3.0 and cooling set point chosen are 26°C DBT and relative humidity 50%. Mode for air temperature distribution is assumed as 1 –mixed (air is fully mixed air and uniform inside air temperature). The metabolic factor is set at 92.5% of men [13]. The target illuminance level is taken as 500 Lux. For the lighting purpose conventional fluorescent tube lamps (FTL) of 36W are used. Load of office equipments (computers, printer fax machine) is taken as 25 W/m^2.

The contributions of the external shading devices and different glazing system on the energy performance of the building will be analyzed by modelled the building using DesignBuilder [14] as shown in fig.1. DesignBuilder v 3.0.0.105 is a modular tool and has inclusive utilizer interfaces for EnergyPlus dynamic thermal simulation engine. DesignBuilder consists of hourly weather files of ISHRAE that are being used for simulation purpose.

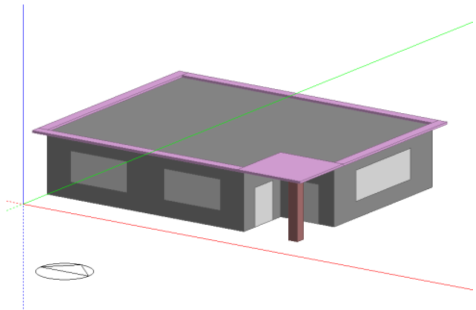

Fig. 1: Typical office building model used for simulation purpose.

The cooling and heating needs for different climates in India are listed in table 2. It is clear from the weather conditions that cooling energy need is much higher than the heating ones. Cities in composite climates required very mild heating in December – January, therefore heating load calculations are not taken in this study. And for cold climatic conditions shading devices has no designation, so it can be also ignored from this study.

Table 2: Cooling and heating requirements for different climates in India

City	Climate	Cooling Needs	Heating Needs
Allahabad	Composite	March – October (8 months)	December – January (2 months)
Jodhpur	Hot and dry	February – November (10 Months)	No heating required
Chennai	Warm and Humid	Round the year	No heating required
Bangalore	Moderate	March – July (5 Months)	No heating required
Shimla	Cold	No cooling required	October – March (6 months)

III. RESULTS

The subsisting building with single, 3 mm clear type glazing and no local (external) shading devices is considered as a base case. The annual solar gain through windows without any shading devices (base case) is emerging to be 6939 KWh. Several other options of shading devices, glazing option and their coalescences are analyzed to reduce the window solar gain. The annual cooling energy requirement for the base case in four different climatic conditions is shown in fig. 2.

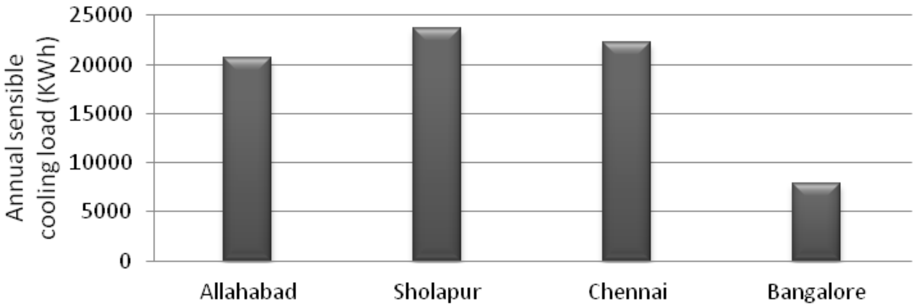

Fig. 2: Annual sensible cooling load for various climates.

Although Sholapur has required only 10 months cooling, but due to hot and dry climate it has maximum value as compared to Chennai which needs round year cooling.

Various shading devices are employed and simulated with the subsisting conditions of the building. The simulated reports are plotted in the fig. 3. Table 3 enlisted different cases of shading.

Table 3: Different shading options implemented

Cases	Shading options
Case 1	No shading (base case)
Case 2	0.5m Overhang
Case 3	1.0m Overhang
Case 4	0.5m Sidefins
Case 5	1.0m Sidefins
Case 6	0.5m Louvre with 0° slat tilt angle
Case 7	1.0m Louvre with 0° slat tilt angle
Case 8	1.5m Louvre with 0° slat tilt angle
Case 9	0.5m Overhang + 0.5m Sidefins
Case 10	1.0m Overhang + 1.0m Sidefins
Case 11	0.5m Sidefins + 0.5m Louvre with 0° slat tilt angle
Case 12	1.0m Sidefins + 1.0m Louvre with 0° slat tilt angle
Case 13	Overhang + Sidefins + Louvre with 0° slat tilt angle (all 0.5m projection)
Case 14	Overhang + Sidefins + Louvre with 0° slat tilt angle (all 1.0m projection)

Summer cooling load for single, 3mm clear glazing without any shading alternative is 20643.25 KWh. It is noticed that the maximum reduction in cooling load is around 2.6% for case 14. Case 8 and case 12 are proximately equivalent so selection of the shading options depends upon the aesthetic requisites. With a little compromise 1.0m Louvre with 0° slat tilt angle (case 7) will seem to be a good option with respect to the investments as well as aesthetic requisites.

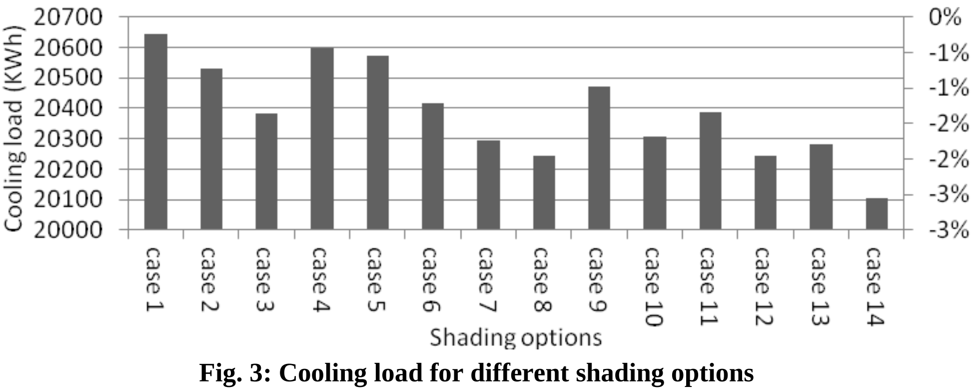

Fig. 3: Cooling load for different shading options

Solar heat gain of the cooling season are reported in the fig. 4. Case 7, 8, 12 and 14 are the most prominent of all; again case 14 has the maximum reduction of 72.8% but case 7,8 and 9 has the handsome figure range of 46.2% to 53.6%.

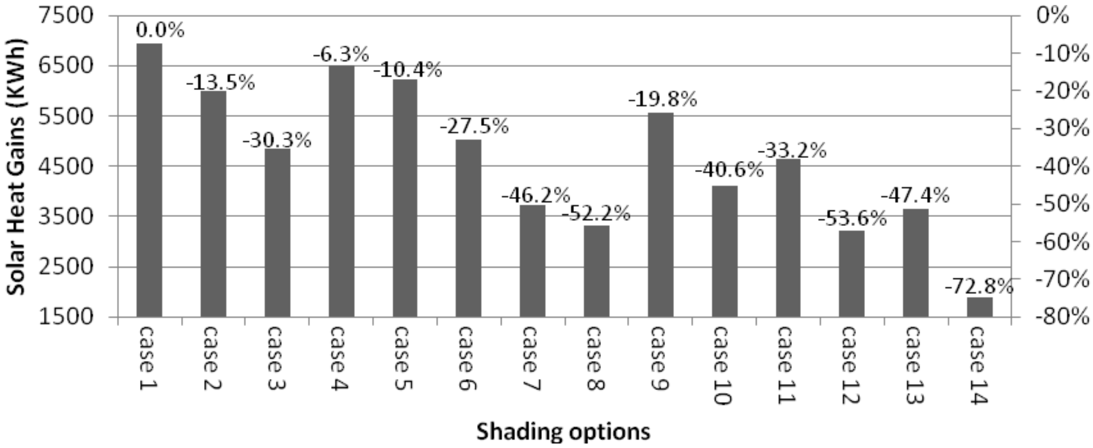

Fig. 4: Solar heat gains for different shading options

With respect to fixed shading devices (overhangs and side fins), louvre has a major advantage due to their angular mobility. Slat tilt angle of louvers will affect the solar heat gain as well as cooling load to a great extent. Also projections of the louvers have a major impact on heat gain of the building. With three louvers projections 0.5 m, 1.0 m and 1.5 m, the slat tilt angle was varied from 0° to 60°in a step of 10° increment. Fig. 5 shows the louvre terminology.

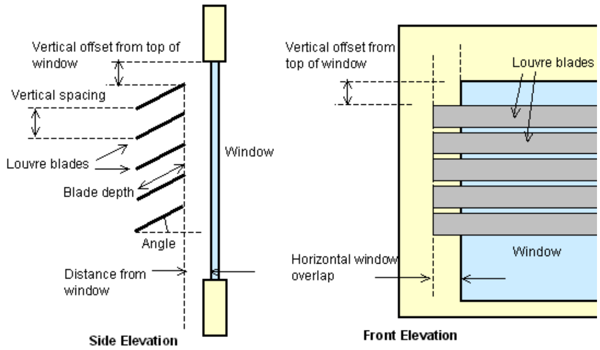

Fig.5: Louver terminology [14]

Solar heat gain through exterior windows for the cooling months is plotted in the fig 6. The analysis shows that the projected depth as well as the slat tilt angle has a considerable effect on the solar gain. Although increasing the slat tilt angle of the Louvre will result in a perpetual decrement of solar gain, but this solar gain reduces per 10° angle increment, which shows that the very large tilt angle has no significance. So there exists an optimum range for the tilt angle for which the louvre shading options are more beneficial. From the results optimum range of 0.5m and 1.0m projection louvre is 10 to 20°, while for 1.5m louvre 10° tilt angle seems to be the best one.

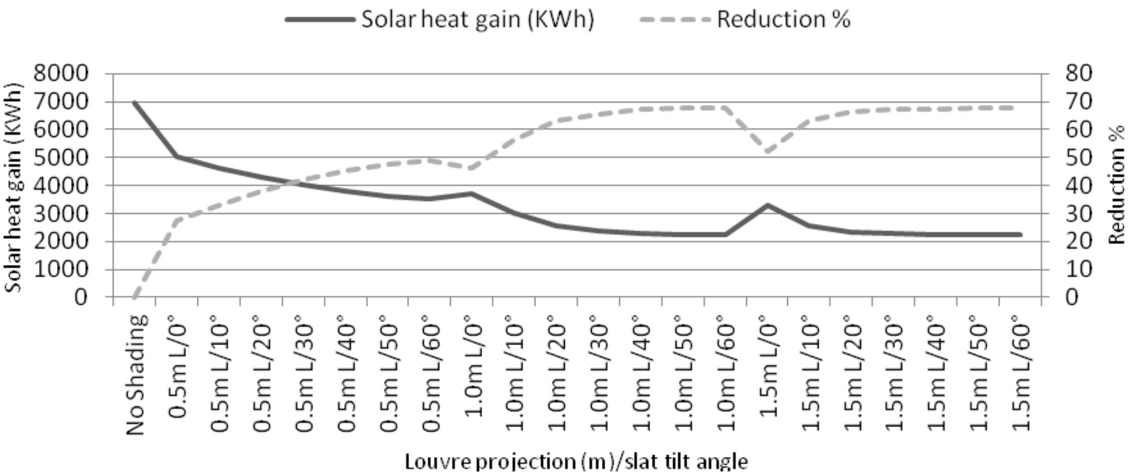

Fig.6: Solar heat gain for various projection and different slat tilt angles

Fig.7 shows the values of cooling load for the optimum angles for various projection louvre. With deference to no shading, 1.5m projection louvre with 10° slat tilt angle gives the maximum cooling load reduction. But from the economic perspective 1.0m projection louvre with 20° slat tilt angle seems to be a more preponderant option with a very little settlement.

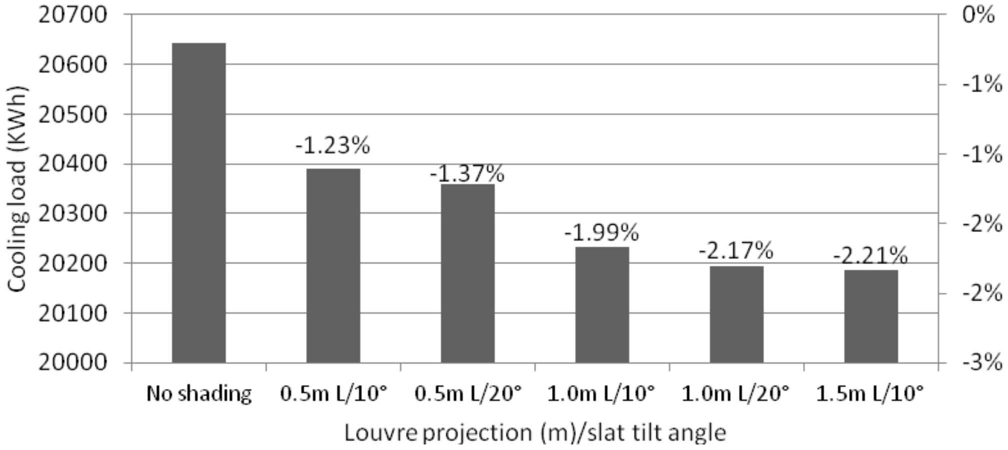

Fig7: Cooling load for some optimum louvre shadings

The optical properties and thermal characteristics of a glazing material have a foremost influence on the solar heat gain through it. Higher the solar heat gain coefficient of the glazing, higher will be solar ray's penetration through it. Five variants of glazing systems (other than base case) are selected and analyzed with different shading options.

Various glazing systems as shown in table 4 are put into service to estimate their effect on annual cooling load and solar heat gain profiles fig. 8, 9. In general, alternative 6 shows superior results than exterior shading devices as most of incident solar radiation is precluded and subsequently the cooling energy demand of the building is reduced, but it is relatively expensive option. It is clear from the data analysis that double, 6mm, low-e-coated, 13mm, air clear glazing is comparable to 0.5m projection louvre with 20° slat tilt angle in terms of cooling load requirement. And single, 3 mm clear glazing with 0.5m projection louvre with 0° slat tilt angle can be superseded by double, 6mm 13mm air clear glazing systems.

Double, 6mm, electro chromic reflective coloured, 13mm air, clear scored a maximum of 91% reduction in solar heat gain with corresponding savings of 3.8% in the cooling load. Alternative 5, 4, and 3 holds a value of 86%, 41% and 34% solar gain decrement as well as cooling load reduction of 3%, 1.5% and 1% respectively.

Table 4: Thermal properties of glazing systems

	Glazing systems	U(W/m^{2}K)	SHGC
Alternative 1	Single, 3 mm clear	5.894	.861
Alternative 2	Single, 6 mm clear	5.778	.819
Alternative 3	Double, 6mm 13mm air clear	2.708	0.697
Alternative 4	Double, 6mm, low-e-coated, 13mm, air clear	1.949	0.629
Alternative 5	Double, 6mm, reflective A–H coated, 13mm air clear	2.449	0.216
Alternative 6	Double, 6mm, electro chromic reflective coloured, 13mm air, clear	1.772	0.142

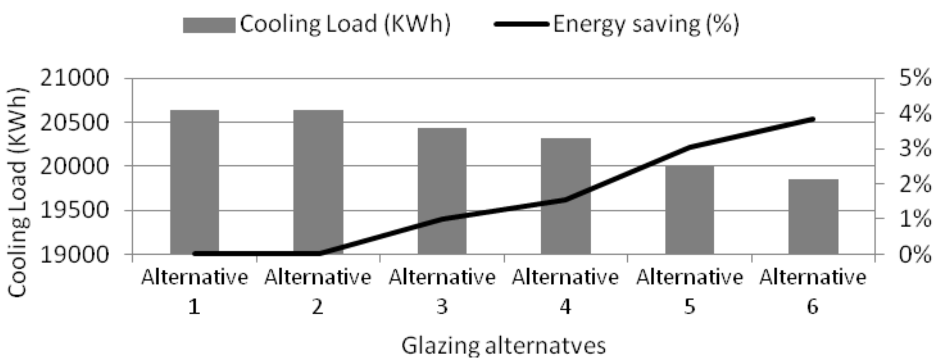

Fig.8: Cooling load profiles for various glazing systems.

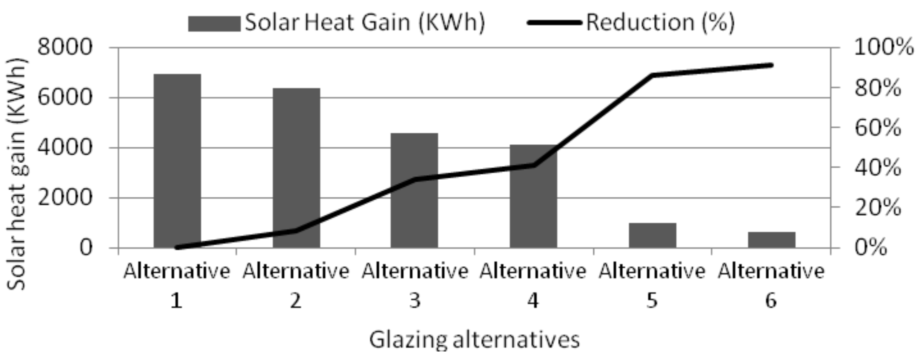

Fig.9: Solar heat gain profiles for various glazing systems.

Four different glazing systems are simulated in addition to single, 3mm clear with various shading options as shown in fig. 10. Some fascinating parities emerging are double, 6mm, low-e-coated, 13mm, air clear with 1.0m louvre with 0° slat tilt angle has the same consequence as double, 6mm, reflective A–H coated, 13mm air clear without any shading. And single, 6mm clear with overhang + side fins + louvre with 0° slat tilt angle (all 1.0m projection) is superseded with double, 6mm 13mm air clear with 1.0m overhang etc. So, one can adopt the best amalgamation accordingly.

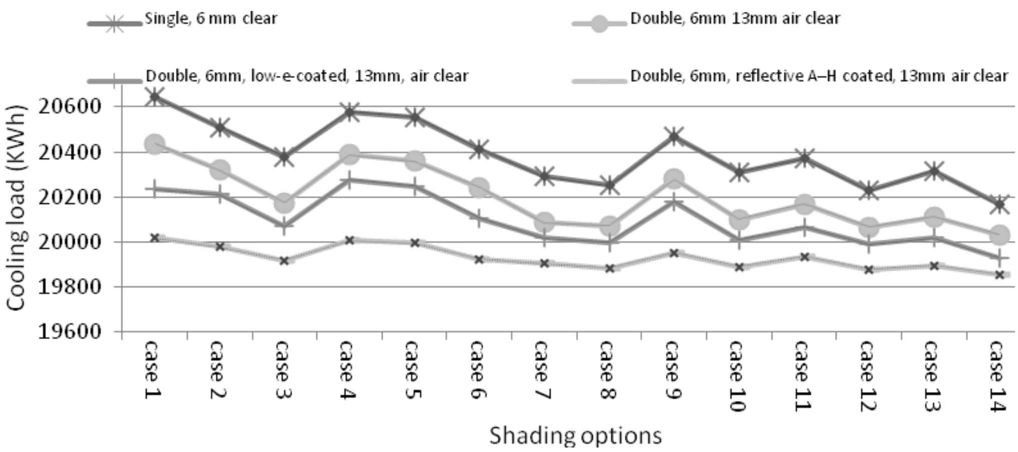

Fig.10: Cooling load variations for different shading options

Profiles for the fluctuation of solar heat gain of various glazing systems with different projected louvres having multiple slat angles are covered in fig. 11. It should be established that almost all glazing systems experienced a reduction of 27% to 58%. Louvre with 10° slat tilt angle of 0.5m, 1m and 1.5m projection emerges with a 33%, 56% and 63% reduction respectively. And for 20° slat angles the value comes out as 38%, 63% and 66%. So recurrence of the same optimum slat angles as for single, 3mm clear.

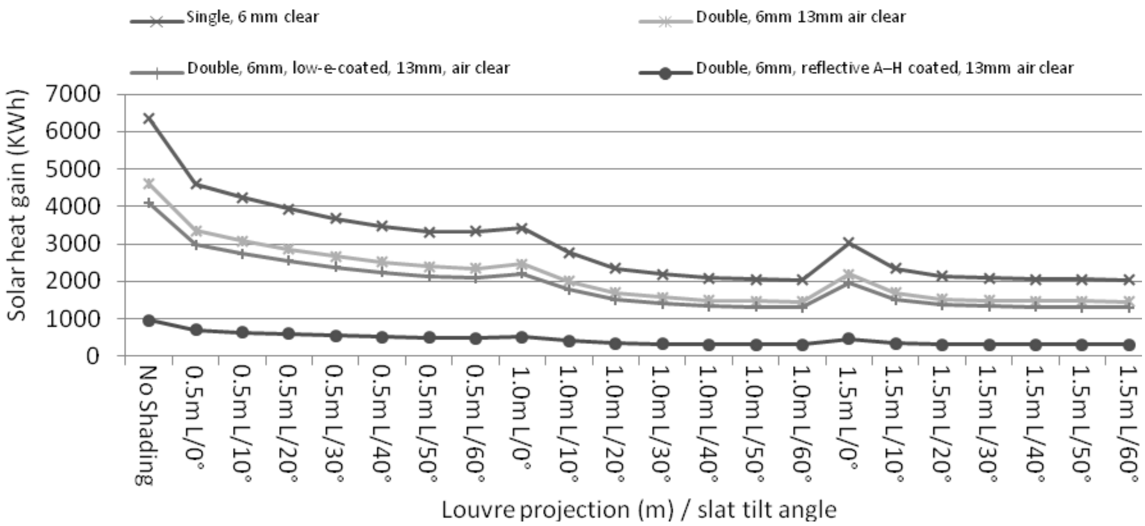

Fig.11: Solar heat gain of various glazing systems with different projected louvres and slat angles

A comparison between base case condition and various projection louvers for their optimized slat tilt angles fig. 12. The cooling load reduction will lie down in a range of 1.3% to 3.7%, for different combinations of glazing systems and louvers for various projection and slat angles.

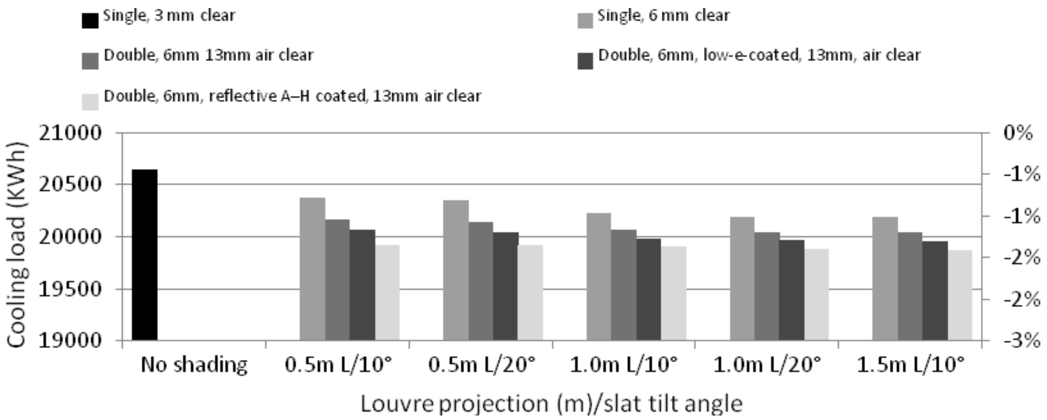

Fig.12: Cooling load comparison for different shading options for optimized slat tilt angles

IV. CONCLUSIONS

This research analyzes the influence of solar shading devices as well as various glazing system and in combination with, on the energy demands of a typical air conditioned office building for composite climatic conditions. The principal conclusions originated from the current study.

Sidefins and louvre seem to be a superior combination in comparison to the sidefins and overhang, which is very frequent in Indian buildings. Approximately 13% more reduction is possible for cases 11, 12 instead of cases 7, 8.

Overhangs and side fins are not capable to shade exterior windows entirely; therefore does not completely limit sun penetration into building. Louvre shading are seems to be more prominent fig.4. Louvre shading devices are more effective for low(<= 20°) slat tilt angles for any projected length fig. 6.

Predicated on the reduction of the amount of solar heat gain that is admitted into a building, Alternative 6 has the major impact among tested glazing alternatives (see Fig. 8). The overall solar heat gains of Alternative 6 is reduced in cooling months (March - October) by approximately 91%, compared to the overall solar heat gains of Alternative 1. The simulated result also confirms that electrochromic glazing offers high potential for noteworthy reduction in annual peak cooling load from controlling solar heat gains in composite climates.

Determinately it should be hoped that the study provides a simplified criteria for engineers and architects in order to pick out the efficacious glazing systems and local shading techniques to manage the window solar gains for similar climatic conditions.

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