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Impact of movable external shading system on daylight availability of office building in hot and dry climate of India.

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Fig 1: Exterior and interior view of the primary case study, Safal Profitare, Ahmedabad, India.

WHICH ARE YOUR ARCHITECTURAL (R) SOLUTIONS TO THE SOCIAL, ENVIRONMENTAL AND ECONOMIC CHALLENGES OF TODAY?

Research summary

As our fast interdepended global world enters the depth of the 21st century, everyone's immediate attention is to mitigate climate change by various means. One of the proven methods to address climate mitigation is to reduce energy consumption in buildings. The war with global energy crisis is getting intense every second we breathe. Over all buildings account for approximately 40% of global energy consumption (1), most of which is used in making buildings comfortable. Heating Ventilating and Air-conditioning systems (HVAC) and electric lighting does take significan portion of total operational energy consumption. Various materials have influenced architectural aesthetics in recenttimes. Glass is one of them. Uses of glass in fenestration without any shading strategy have adversly affected energy consumption of building. In the current architectural scenario in the country it can be observed that commercial buildings are largely becoming energy intensive in nature, which means that a lot of energy is used in cooling, lighting and running the equipment In this context(2). This study focuses on shading strategy and a solution which meets current requiremeht of architectural aesthestics, possibility of scaling them up and its cost effectiveness. By adding a dynamic shaidng skin over the building's envelop static skin can lead to drastic reduction in energy loads and increasing thermal and visual comfort at the same time. Keeping materials, finishing and geometry into consideration the design possilities are immense and can indulge the deisgner in varied possibilities. Study provides insight into visual and energy performance of shading devices. The study relies on field measurements and numerical calculations to understand its effectiveness.

Keywords: Daylighting, dynamic shading device, louvers, office building, hot and dry, India,

1. Introduction

Architectural expressions over various time periords have responded to multiple factors at a given phase, be it social, economical or cultural. Newer thinking and innovation has led to a change in trends, expressions to respond towards climate being one of them. Architects have responded to it in very diverse manner over long history.

Its a know fact that building energy loads have always increased and are still on the rise at extreme levels. Heavy reliance on electric light and super efficienct electric lighting have made inroads across the globle, however importance of daylit spaces with visual connection with outside world still considered as one of the best design strategy.

A naturally well lit space with thermal comfort conditions has a big impact on personal satisfaction and productivity of occupants. In hot and dry climate, where along with extereme tempretures one has to negotiate with intense solar radiation also. To strike delicate balance between daylight and radiation is very critical. Penetration of direct radiation along with daylight will make spaces uncomfortable or will use more energy to make them comfortable. Less availability of daylight will put panelty on energy consumption for lighting. Lighting and cooling loads combined are the highest utilizer of energy which in turn leads to higher energy consumption , thus challanging the demand of energy performed buildings. Hence it is necessary to look at both dayling and cooling together as an issue of energy cunsumption.

Hence its imperative to look at strategies which can allow architects to strike balance between daylight and thermal comfort without using much of energy. For the purpose of the study authors have evaluated a shading device system commercially available in Indian marked named Verticle Rigid Louver System (VRLS) by Facade Appliccation for Conservation of Energy (FACE)

2. Research objectives

Objective of study is to understand daylight and thermal performance of external movable shading devices. Selected external movable shading devices can be adjusted depending upon occupant preference. Study also investigates daylight and thermal performance of external movable shading devices when they are placed at various positions.

Measured light data will provide us with data which helps us calculate how much light penetrates from the building skin. Measuring outdoor and indoor surface temperatures of various build in elements the study can achieve U-value and heat coefficient. The expected outcome will help us compare different shading positions of the shading device, thus based on its interpretations one can achieve results that demonstrate the best optimal opening angle for a specific time.

Exterior shading devices also help us to reduce the peak electricity demand resulting in low peak demand charges attained from utilities and reduction in mechanical equipment cost. Movable shading device helps the user to control the daylight inflow hence achieving the desired light quality for specific purposes. External shading devices can help user control the amount glare getting inside hence not interfering with the activity.

3. Methodology:

3.1 Field Study:

The study measures two major factors; Light and Solar gain, it is divided into two parts (1) Field study (2) Numerical Calculations. This paper elaborates field study, its method and results. It started with simple field measurement to understand VRLS performance.

1) Field Study: Aim of the field study is to understand daylight levels at various floor depths and at various positions of VRLS.

The research is conducted for:

1. Three directions East, South, West.
2. Indoor work environment.
3. Office buildings in Ahmedabad, India
4. Testing the efficiency of external louvers.
5. All days 7:00 AM to 7:00 PM
6. Clear sky conditions

The field study took place in the first three weeks of March 2015. The office building with movable shading devices or vertical louvers falls in hot and dry climate of Ahmedabad, India. The main building comprises of 4 separate blocks around a central courtyard. The study took place in a vacant office measuring 20x12 meters, openings in three directions except north (Fig:2). The intermediate office falls on the 2nd floor receiving light without any obstruction. The building façade is made up of aluminium framed sliding windows which is screened on the outside with vertical louvers. A 600 millimetre wide over-hang runs on each floor around the entire building. The louvers are places between the overhangs are 3meters high and 400 millimetres wide, which are made of cement bonded fibre-board panels. Aluminium is the major constituent for structural and mechanical components. 7 louvers are linked together with 20 millimetre spacing between each louver; they are hence aligned parallel to the façade. A simple pivot handle and stopper controls the movement of louvers. The louvers are operable at 5 different positions, 0, 30,45,60,90 degrees, in which 0 degree is completely closed and 90 being completely open forming a perpendicular to the glass window.

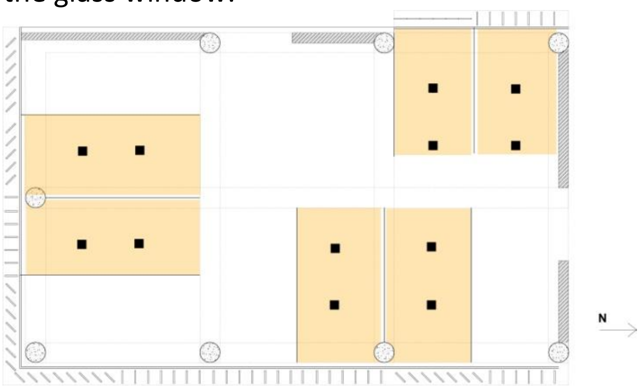

Fig 2: vacant office plan with sensor positions and louver openings.

3.1.1 Lux readings:

Maximum solar radiation inflow occurs from East, South and West directions in Ahmedabad. Two sets of readings we taken simultaneously to each other with parallel paper partitions separating the spaces. The louvers were positioned at a stationary angle over a period of 24hours and hand held hourly lux data from Testo 540 was collected from 7:00 hours to 19:00hours was recorded at working desk height of 800millimeter at a distance of 2 and 4 meters inside of the façade(Fig:2). This process was repeated for all louver positions 0,30,45,60 and 90degrees in the direction of East, South, and West. Direct and diffused light penetrates through the building façade at a certain time of day only assisted by a specific angle of louvers.

3.1.2 Surface temperature:

At the stroke of every hour when lux data was collected, surface temperature of the following positions was also recorded:

- Inside and outside of the shading device
- Inside and outside of beam and sill
- Overhang above and below
- Inside and outside of window glass and the edge of the glass
- Inside and outside of the window frame

All the surface temperatures were recorded with Fluke 561 laser temperature gun, except the window glass and its frame which was recorded with Hobo U12 loggers.

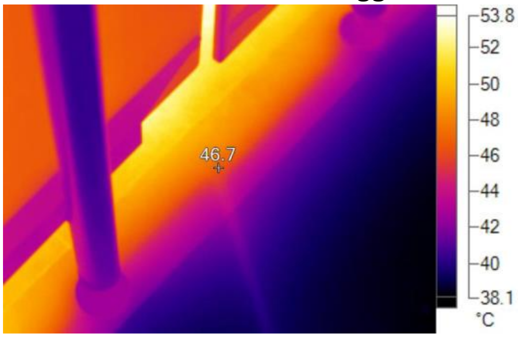

Fig 3: Thermography showing temperature variation and louvre ability to reduce solar radiation.

3.1.3 Simulation:

A second part of the study includes computer aided simulations run on Design Builder. The software helps us measures yearly heat gains and cooling loads of the entire site.

4. Results:

4.1 Lux factors:

The louvers were studied in the month of April 2015; the following figures documents the typical light conditions.

The results shown below are at a point 800 millimeters high 2 and 4meters from the window:

- The Figure6 reveals the spike in light levels in the mornings at East casting longer shadows, light mostly in the form of short shadows have moderately high lux from 11AM to 3PM in South, and a sharp increase in the West during the latter half of the day which throughout the day is consistent.
- Non obstructed morning light penetrates deep inside the space thus resulting in higher readings at 2 and 4 meters.
- During the early hours the 20mm spacing between two lovers gets in sufficient light even when the louvers are completely shut.
- The overhang cuts the high noon sun penetrating inside the building, leading to fairly consistent well lit hours throughout the day.

- Southern louvers at 60 degree opening angle falls perpendicular during 11:00 and 12:00 hours, thus having higher lux.
- Direct south west sunlight is obstructed as a building extrudes from the left edge of the west facing louver, thus leading to very few direct sunlight hours.
- A far away tall building obstructs direct light penetrating through west louver post 4:00 pm.

	Lux readings at 2meters														
	East					South					West				
time	E-0	E-30	E-45	E-60	E-90	S-0	S-30	S-45	S-60	S-90	W-0	W-30	W-45	W-60	W-90
07:00	132	583	1231	1939	2270	5	36	100	139	184	5	11	47	57	136
08:00	256	1032	2708	4475	5370	21	162	226	415	364	10	33	108	150	302
09:00	371	1145	3280	6005	8120	38	247	535	683	713	14	47	162	230	347
10:00	113	337	811	1437	1839	48	257	674	892	837	23	56	180	248	338
11:00	81	252	541	897	1172	61	250	486	1034	962	24	57	185	239	312
12:00	55	173	391	595	753	61	229	528	1058	913	26	57	224	233	295
13:00	35	140	301	450	543	64	205	450	950	898	27	77	365	375	350
14:00	31	132	252	377	454	61	184	393	887	964	57	133	564	572	584
15:00	28	99	209	320	378	55	145	317	715	813	89	248	832	869	1045
16:00	25	92	192	283	344	46	77	234	482	641	301	1138	2470	3389	5520
17:00	23	81	172	259	300	34	75	171	389	461	47	119	433	488	728
18:00	11	50	111	168	198	9	28	85	162	172	12	25	143	178	230
19:00	0	0	0	0	0	0	4	1	2	2	0	4	8	9	31

Fig 4: Lux readings at 2 meters from window, with respect to time, direction and louvre angle.

	Lux readings at 4meters														
	East					South					West				
time	E-0	E-30	E-45	E-60	E-90	S-0	S-30	S-45	S-60	S-90	W-0	W-30	W-45	W-60	W-90
07:00	101	387	930	1858	1861	1	5	30	36	44	0	4	13	18	48
08:00	154	537	1516	2723	2889	3	30	65	83	96	4	20	42	62	115
09:00	77	214	538	967	1233	8	66	149	151	191	7	23	65	98	136
10:00	50	120	273	483	645	11	79	179	188	221	11	25	63	102	132
11:00	35	91	183	308	419	14	74	166	218	258	11	24	62	88	115
12:00	25	61	126	211	266	14	84	158	242	221	10	19	60	74	91
13:00	19	48	100	164	201	15	73	129	258	213	10	25	86	104	94
14:00	17	46	93	149	184	13	66	122	205	270	15	44	143	145	159
15:00	17	42	83	135	166	11	51	118	180	217	22	80	199	245	285
16:00	17	37	73	114	144	9	25	97	148	180	35	99	277	293	510
17:00	16	32	65	101	124	7	24	63	90	155	6	20	61	72	100
18:00	6	17	39	63	73	1	6	22	46	38	1	4	21	27	36
19:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6

Fig 5: Lux readings at 4 meters from window, with respect to time, direction and louvre angle.

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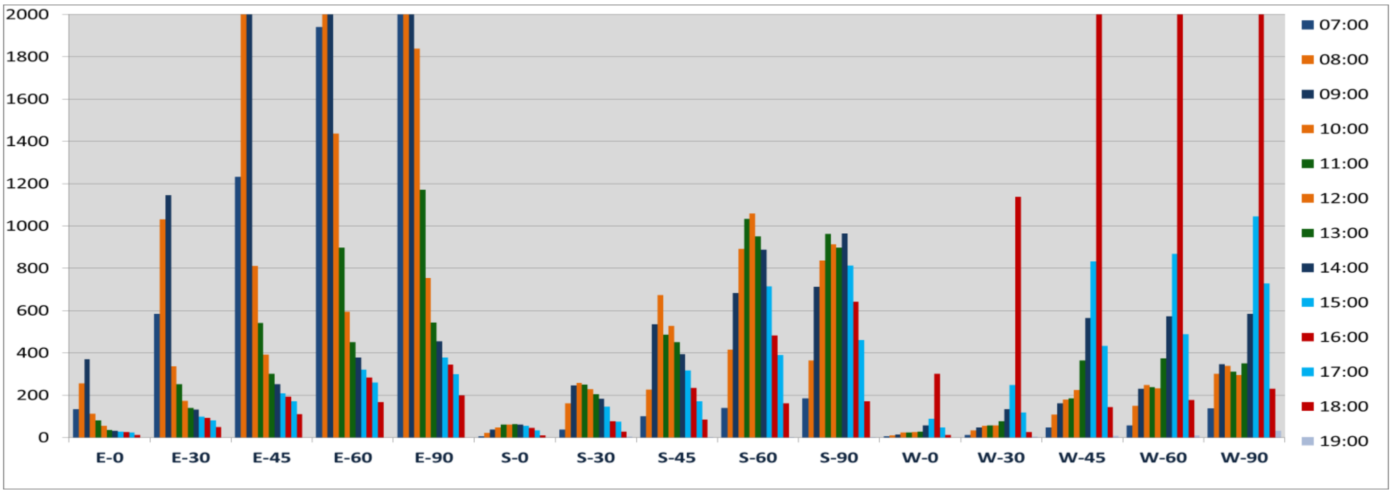

Fig 6: Lux readings at 2 meters from window, with respect to time, direction and louvre angle.

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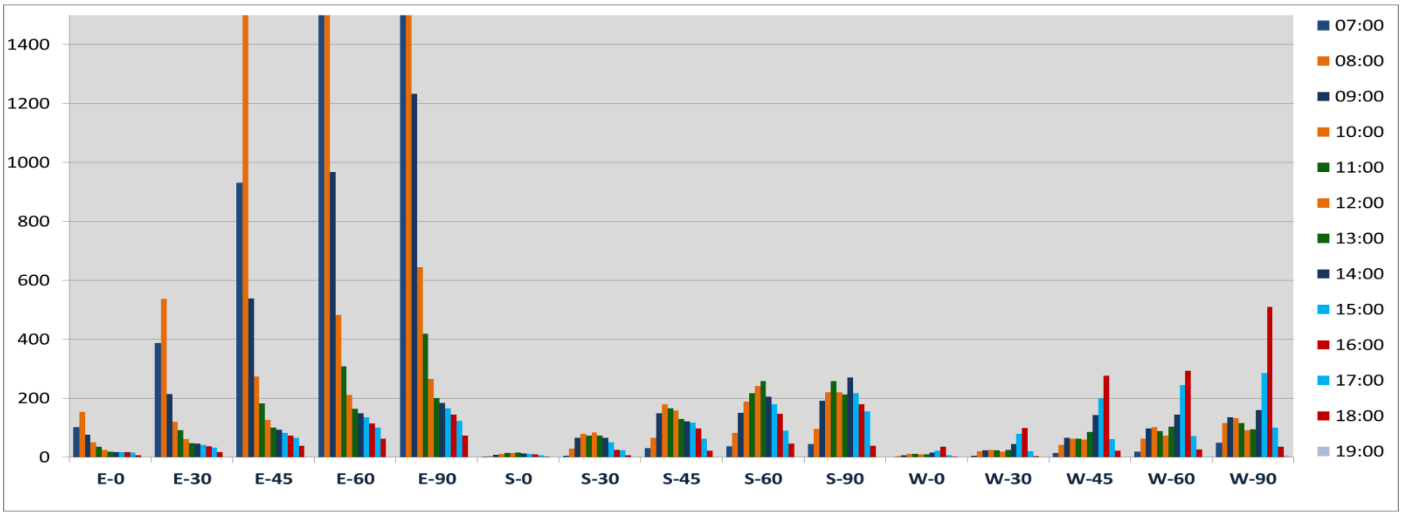

Fig 7: Lux readings at 4 meters from window, with respect to time, direction and louvre angle.

4.2 Solar Heat Gain Coefficient (SHGC):

With sunlight comes heat which in turns warms up the interior environment, resulting in higher energy consumption to control the environment. The cement fibre louvers act as a flexible screen controlling the light which reduces and increases SHGC.

Centre of glass inside surface temprature.															
TIME	EAST					West					South				
	0	30	45	60	90	0	30	45	60	90	0	30	45	60	90
07:00	27.38	26.89	27.65	26.92	27.75	27.51	30.07	30.04	28.00	29.38	28.75	29.74	27.14	26.87	28.52
08:00	28.17	30.37	31.23	33.50	33.39	27.97	29.02	31.08	28.64	31.90	31.10	29.89	27.36	27.04	29.69
09:00	30.04	32.74	33.52	38.70	38.62	28.79	31.59	32.51	31.00	33.16	30.27	30.04	28.00	27.90	30.52
10:00	31.61	33.89	34.86	39.77	40.75	30.55	33.86	34.36	33.05	33.76	30.80	30.70	28.87	28.84	31.56
11:00	32.77	34.44	35.50	37.07	37.45	32.02	35.50	35.64	34.62	34.62	31.46	31.46	29.94	29.97	32.38
12:00	33.00	34.02	35.40	36.02	35.96	32.79	36.55	36.88	37.18	35.89	32.07	32.15	30.80	30.87	33.16
13:00	32.64	33.73	35.05	34.18	35.13	33.44	36.23	36.85	37.76	37.76	33.03	33.18	31.94	32.15	33.73
14:00	32.56	34.31	35.48	34.57	35.37	34.26	36.20	36.80	37.48	38.12	36.72	38.25	37.18	37.65	38.45
15:00	32.59	34.62	35.42	34.76	35.26	34.52	36.17	37.02	37.21	38.27	36.15	36.74	35.85	38.45	39.57
16:00	32.51	34.20	35.10	34.36	35.05	34.78	35.21	36.91	35.93	37.90	36.34	36.85	36.96	43.07	46.23
17:00	32.41	34.12	34.68	34.12	34.52	34.41	34.55	36.23	35.29	37.27	36.47	36.80	33.97	34.49	44.97
18:00	32.05	33.57	33.94	33.44	33.81	33.76	34.20	35.72	34.52	36.05	33.73	33.84	32.92	32.82	35.48
19:00	31.48	32.38	32.90	32.15	32.79	33.05	33.21	33.37	33.05	33.78	32.92	32.82	32.07	31.77	34.20
20:00	30.87	31.15	31.43	30.87	31.43	32.30	32.54	32.69	32.20	33.59	32.28	32.12	31.54	31.23	32.98
21:00	30.07	30.37	30.65	30.04	30.72	31.82	32.07	32.90	31.16	32.12	31.66	31.43	30.95	30.67	32.23
22:00	29.62	29.62	30.14	29.39	30.02	31.31	31.51	32.43	30.75	31.87	31.03	30.82	30.60	30.34	31.64
23:00	29.24	29.34	29.64	29.07	29.59	30.75	31.13	32.00	30.29	31.08	30.29	30.09	30.32	30.12	31.26
00:00	28.92	28.94	29.27	28.64	29.32	30.07	30.87	31.56	30.02	30.52	29.79	29.67	30.02	29.79	30.90
01:00	28.57	28.47	28.67	28.20	28.74	29.49	30.60	31.26	30.01	30.37	29.79	29.64	29.69	29.49	30.55
02:00	28.32	28.07	28.10	27.78	28.20	29.32	30.70	30.93	29.97	30.04	29.57	29.41	29.39	29.22	30.37
03:00	28.05	28.05	27.55	27.83	27.55	29.44	30.60	30.87	29.79	29.72	29.44	29.29	28.97	28.92	30.12
04:00	27.70	28.05	27.14	27.85	27.11	29.09	30.42	30.44	29.67	29.41	29.14	28.94	28.79	28.74	29.94
05:00	27.55	28.00	26.84	27.85	26.77	28.47	30.24	30.09	29.24	29.28	28.84	28.67	28.67	28.59	29.82
06:00	27.38	27.97	26.79	27.90	26.70	28.25	29.89	29.72	28.82	28.87	28.59	28.39	28.57	28.49	29.41

Fig 8: Centre of glass surface temperature with respect to time, direction and louver position.

The glass surface measured with Hobo sensors over a period of 24 hours clearly indicates the

Impact of direct radiation on surface temperature:

- 12degree temperature change in East window with louver opening at 60 degree in a span of 2 hours.
- Direct radiation been cut by overhangs leading to gradual rise in surface temperature in the afternoon hours in South facing windows.
- Sun light penetration into the open louvers (60, 90degree) of the West window causing the change of 7 degrees.

As shown in figure 9 and 10 one can plot how rate of heat transmission is faster while exposed to direct solar radiation vs effect of heat transfer in interior surfaces of the beam.

TIME	All louvers Inside Temp.														
	East Louveres					South Louveres					West Louveres				
	0	30	45	60	90	0	30	45	60	90	0	30	45	60	90
07:00	25.9	27.4	30.1	27.2	28	26.8	26.9	29.5	28.9	29.5	29	25.9	25.9	25.8	28.6
08:00	33.2	39.4	34.6	35.7	31	28.6	28.8	31.4	29.6	31.1	30.1	26.8	26.8	26.7	30.1
09:00	40	43.6	42	39.5	36.9	31.5	34.4	34.9	32.6	32.8	31.3	28.4	28.4	28.2	31
10:00	43.1	44.7	44	44.3	39.6	35.5	37	36.8	36.2	37	32.5	29.4	29.4	29.3	32.8
11:00	42.6	43.5	44.2	45.7	42.9	37.8	37.9	38.1	41.5	38.9	33.8	31.6	31.6	31.4	34.6
12:00	39.7	39.3	39	39	41.1	39.9	41.6	40.3	41.6	42.2	35.5	33.4	33.4	33	36.3
13:00	37.8	37.6	39	38.2	39.2	40.3	43.4	43	42.1	41	38	36.1	36.1	35.4	37.4
14:00	37.9	38.3	40.3	38.3	40.3	41	43.5	46	44.9	45.5	43.4	38.5	38.5	38.9	44
15:00	37.5	38.2	40	38	40	41.4	43.9	44.7	40.4	42.9	47.8	41.6	41.6	39.1	43.4
16:00	36.3	37.4	38.6	37.6	38.9	39.8	39.2	42.1	40.7	41.1	49	45.6	45.6	41.1	43.4
17:00	35.8	36.9	38	36.9	38	38.1	38	39.5	39.1	40.1	42.9	**35.5**	35.5	35.5	39.8
18:00	34.3	33.8	36.5	35.2	36.1	35.9	36.2	37.6	37.8	37.5	35.6	34.1	34.1	34.3	37.6
19:00	33.1	32.9	34.2	33	34.1	34.3	35.3	35.4	36.2	35.7	33.9	33.1	33.1	33.2	36.6

Fig9: Inside surface temp. of all louvers positions

TIME	All beams Inside Temp.														
	East beam					South beam					West beam				
	0	30	45	60	90	0	30	45	60	90	0	30	45	60	90
07:00	30.9	31.1	30.7	31.1	30.7	30.8	30.8	30.8	30.6	31.1	31.1	29.8	29.8	29.2	29.7
08:00	30.9	31.1	30.4	31.2	30.5	30.8	30.8	31.1	30.6	31.1	31.2	29.9	29.9	29.4	29.8
09:00	31	31.1	30.9	31.3	31.3	30.9	30.9	31.2	30.8	31.1	31.2	29.9	29.9	29.5	29.9
10:00	31.1	31.2	31.3	31.3	31.3	30.9	30.7	31.3	31	31.2	31.2	29.9	29.9	29.6	30
11:00	31.1	31.4	31.4	31.3	31.3	30.9	30.7	31.3	31.2	31.3	31.2	29.9	29.9	29.6	30.2
12:00	31.2	31.4	31.1	31.5	31.5	31	30.8	31.7	31.3	31.3	31.2	29.9	29.9	29.6	30.3
13:00	31.3	31.5	31	31.7	31.5	31.1	31.4	31.4	31.3	31.8	31.3	29.9	29.9	29.9	30.5
14:00	31.3	31.6	31.8	31.7	31.6	31.2	31.4	31.6	31.5	31.8	31.3	29.9	29.9	30	30.5
15:00	31.3	31.6	31.8	31.7	31.3	31.2	31.5	31.6	31.6	31.9	31.4	30.1	30.1	30.2	30.8
16:00	31.2	31.7	31.7	31.7	31.6	31.4	31.5	31.9	31.7	31.9	31.4	30.3	30.3	30.3	31.1
17:00	31.2	31.6	31.6	31.7	31.2	31.4	31.3	31.9	31.4	32	31.5	30.2	30.2	30.1	31.3
18:00	31.1	31.6	31.5	31.6	31.2	31.4	31.3	32	31.4	31.9	31.1	30.1	30.1	30	31.2
19:00	31.1	31.5	31.4	31.6	31.2	31.3	31.3	31.8	31.4	31.9	31	30.1	30.1	29.9	31.1

Fig 10: inside beam surface temperature with respect to all louver opening conditions.

A significant finding of the IMAC study is that occupants in Indian offices are more adaptive and tolerant of warmer temperatures (4)

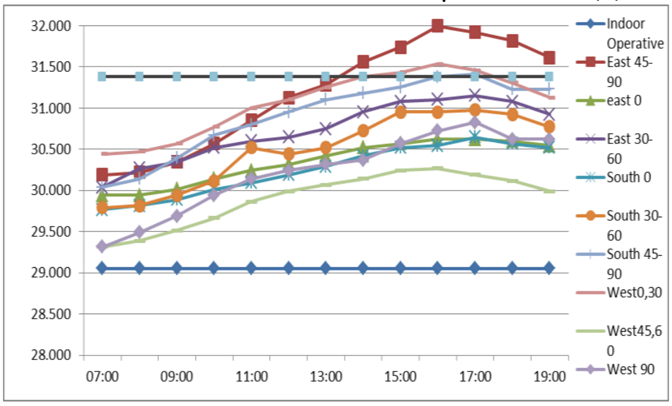

Fig 11: IMAC indoor operative temperature.

5. Future implementation

Lack of awareness and guidelines had led to minimum human interference by the occupants in operation of the movable louver. The result leads to stagnant positions of the louvers over long hours and not optimizing the louver to its maximum potential. The future implementation of the same system controlled with automation can lead to calculated and high savings in the entire building.

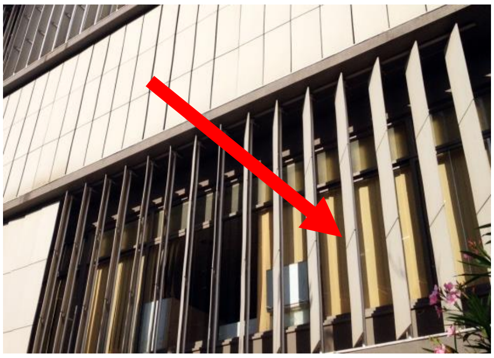

Fig 12: Use of blinds in interior face of the window

6. Conclusions

Reduction in energy consumption in built spaces has led to intensive debate and research. This study helps one understand how proper façade design and controlled strategies can help one achieve the desired visual comfort in a working environment while greatly reducing SHGC, in return reducing overall lighting consumption and HVAC loads.

7. Acknowledgments

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