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Research paper

A Study of Improving Thermal Environment of External Louver through Establishment of Test Bed

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Abstract

Background/Objectives: To improve a thermal load by increasing internal thermal effect of a building from direct solar radiation through an increase of glass windows.
Methods/Statistical analysis: Through the establishment of test beds of the same size, the data of temperature, humidity, solar insolation and PMV of each test bed with or without external louver are acquired to analyze thermal environmental with the simulation.
Findings: For the analysis of thermal environment, the amount of energy consumption has been analyzed through the simulation and the data of temperature, humidity, solar insolation and PMV have been acquired for the analysis. With the simulation, about 20% energy saving has been confirmed and the daily averages of temperature and humidity between 8AM to 7PM have been calculated to calculate the maximum temperature difference to be 9.4℃. The solar insolation between 9AM and 7PM was 300W/m^2 or below.
Improvements/Applications: The improvement of thermal effect with an external louver has been confirmed. It may be applied to the louver system to improve building thermal environment, awning to control direct solar radiation, blind to improve uniformity of illumination intensity toward building during daytime, external blind and ceiling louver system.

Keywords: *Direct Solar Radiation, External Louver, External Awning, Natural light, Thermal Environment, Insolation*

1. Introduction

The rate of area of glass window is increasing in recently constructed buildings as the rate of high-rise, acceleration and appearance are concerned. The increase in the rate of area of glass windows is to expect excellent performance of natural light and view. When the sunlight enters in through a glass window, both light and heat enter. If these incoming light and heat do not leave and stay inside, this phenomenon becomes a greenhouse phenomenon[1].This greenhouse phenomenon directly leads to an increase of cooling load and thus it is the most effective to block an insolation load coming in through a glass window of a building in advance. A louver is a device to intercept a direct solar radiation through a glass window of building and this louver is used as a typical solution to resolve issues of a facade made of glass materials. An external louver may block about 40~50% more summertime sunlight than an external awning. The direct solar radiation and natural light coming inside may affect cooling load significantly and depending on the measure to control the direct solar radiation, the natural light may be maximized and the cooling energy may be saved. In some countries, the application of louver with great effect in energy saving and differentiation of design to cover weaknesses of curtain wall is increasing as more skyscrapers are constructed and major European Countries like Germany are distributing more outdoor louvers being attached to an outside of a building.

For studies of external awning in Korea, there are A Study of Energy Analysis and Applicability of External Awning to Reduce Cooling Load within High-rise Multi-unit Dwelling in Korea[2], An Analysis of Reduction of Building Energy under Reflectivity and Type of Blind-type External Awning[3], A Study of Horizontal Louver-type External Awning to Reduce Lighting Load and Heating/Cooling of Office Space[4], A Comparison of Lighting Performance between General Awning and Louver-type Awning in a Lecture Room[5], A Study of Application of Stand-alone-type External Awning for Improvement of Environmental Performance of Building[6], An Experimental Study of Effect on Indoor Environmental by Application of Awning in Winter[7], A Study of Awning Planning and Glazing Material for Energy Saving in Small-scale Office Space and Building Facade[8], An Evaluation of Daylight and heat Performance for Awning Planning and Glazing Materials for an Office Building[9] and A Study of Improving Operation Precision of Sun Tracking System for Natural Lighting[10], but there is no increase in demand due to issues in endurance, lowering of aesthetic perspective and construction cost.

Therefore in this study, the effect of improving thermal environmental by an external louver is to be confirmed through the establishment of test bed to lead to distribution of the most effective external louver for reduction of cooling load that may increase greenhouse effect from the direct solar radiation coming in through a glass window of a building.

2. Materials and Methods

A lover blocks or disperses direct solar radiation coming in through a glass window to improve the uniformity of illumination and indoor thermal environment. In general, an external louver is installed outside a building and thus the structural stability is necessary against factors like wind pressure and the endurance shall also be assured through review of materials to lighten burden of its own weight. The slit material of louver used in this study is aluminum and a louver has been designed to be a module-type with an adjustable width for application into different building shapes and window sizes. A louver shall operate along with a position of the Sun and to maintain a normal line with the Sun at all-time, a louver slit shall have the maximum slope angle with a horizontal plane during sunrise and sunset and shall have the minimum slope angle with a horizontal plane at noon. A linear motor has been applied for operation of a louver and a rotational angle of louver slit has been 2° or less in control.

To quantitatively check the difference of indoor thermal environment with and without an external louver, the test beds have been designed. The size of test beds is 20 ft high and two identical test beds with same surface, height, shape, window area and wall specifications have been formed. The test beds have faced toward south, two 5 m^2windows of 2.5m wide and 2m high at the center have been placed on each test bed and the ratio of window area to the total area of standing side has been about 62%.For the evaluation of thermal environment, the actual measurement has been used for comparison of indoor temperature and humidity and PMV analysis and the actual measurement has been performed to get insolation for the same term. As factors to be measured for thermal environment, there are insolation, PMV(Predicted Mean Vote) and physical variables like temperature, air current, humidity and average radiation temperature and there are also individual variables like amount of activity, amount of clothing, age and gender. Thermal environment has been measured from August 3, 2015 to September 3, 2015 and during this term, the acquisition of effective data for temperature and humidity has been performed for 26 days, 20 days or PMV and 6day for insolation.

A thermometer and a hygrometer have been installed 1 m vertically away from the center of test beds to measure the data every 5 min and the PMV measuring device has been installed 1 m horizontally away from a thermometer and a hygrometer and 0.8 m vertically high from the surface to acquire data every minute for 3 days alternatively between the regular building and the building with blind. A pyrheliometer has been installed 1m right from a thermometer and a hygrometer and 0.2 m away from a window to minimize any shade effect to acquire the data every minute. Figure 1 and Figure 2 display plane view and front view of the regular building test bed. Figure 3 and Figure 4 display plane view and front view of the test bed with external louver. Figure 5 and Figure 6 display planer plan and standing view for arrangement to measure thermal environment.

Figure 1: Regular Building (plane view)

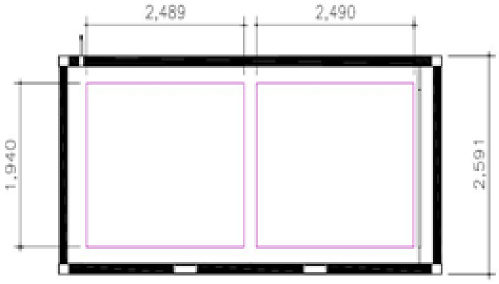

Figure 2: Regular Building (front view)

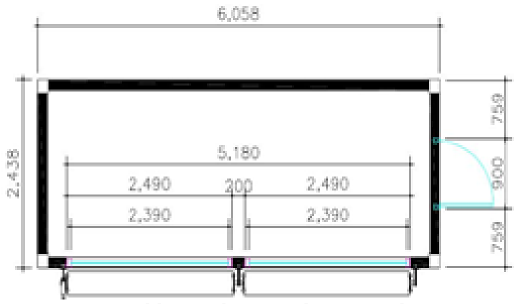

Figure 3: Building with External Louver (plane view)

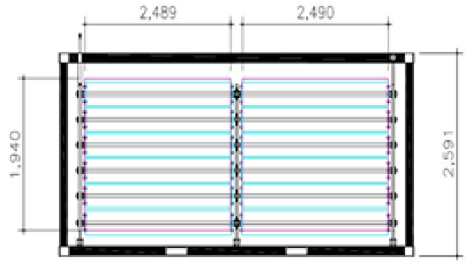

Figure 4: Building with External Louver (front view)

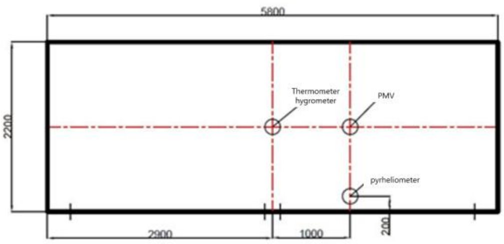

Figure 5: Planar Arrangement of Measuring Device

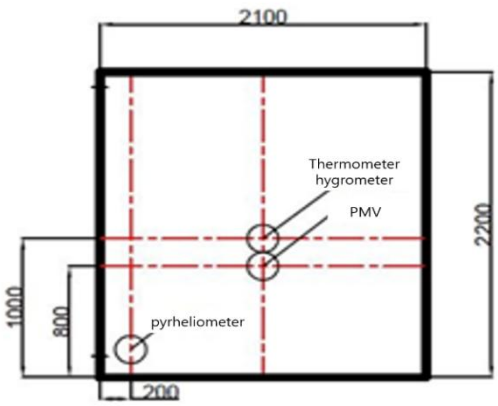

Figure 6: Standing Arrangement of Measuring Device

3. Results and Discussion

In this study, to check the improvement of thermal environment with an external louver, two test bed buildings of the same size have been designed. Figure 7 displays the actual test bed designed with the design drawings Figure 1 to Figure 4.

Figure 7: Actual Test Bed Designed

Figure 8, Figure 9 and Figure 10 show a thermometer, a hygrometer, a PMV measuring device and a pyrheliometer installed under a plane arrangement and a standing arrangement in Figure 5 and Figure 6 to measure thermal environment.

Figure 8: Installation of Thermometer and Hygrometer

Figure 9: Installation of PMV Measuring Device

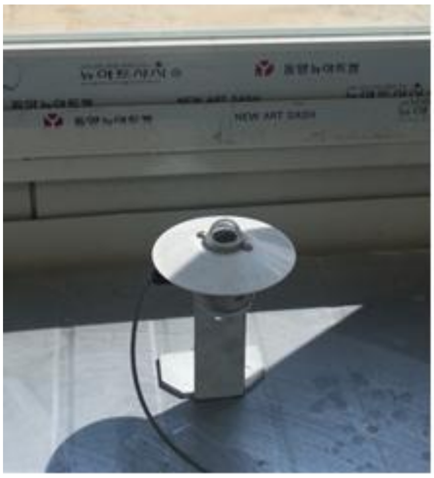

Figure 10: Installation of Pyrheliometer

To review reduction of cooling load with and without an external louver, the integrated construction simulation program by DesignBuilder Company has been used. Modeling of the test bed building for the simulation was performed by applying the dimension of actual drawings. Figure 11 displays modeling of the building for the simulation. There are two windows for the actual test beds, but for simplification of modeling, only the area of window has been applied.

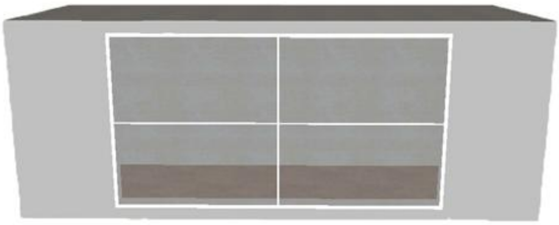

Figure 11: Building Modeling for Simulation

Table 1 is a summary of variables for the simulation of building modeling. Due to the difference between factors of actual material and factors of material in the simulation, the heat transmission coefficient of wall was applied by entering the heat transmission coefficient of actual material used after selecting the material.

Table 1: Values for Simulation of Building Modeling

Population Density	0.2	
Airtightness	0.7 ac/h	
Window Area	60%	
Wall U-Value	0.316 W/m^2	*Sandwich panel used
Blind	Outside	

Table 2 indicates the outcome of the simulation for thermal environment under the building model.

Table 2: Simulation Outcome

data	Regular Building	Building with Blind (Always on)	Building with Blind (Schedule)
June	32.6	10.3	16.9
July	50.9	28.8	33.1
August	73.1	38.6	44.4
September	57.0	18.6	34.0
Total Consumption during Cooling Time (kWh)	213.6	96.3	128.4
Saving Rate(%)		55	40

The thermal environment simulation used the region of Ulsan area in Korea province to have the weather data to be applicable for the simulation. The period to energy consumption was limited from June to September, the time when people mainly use cooling. The terms Always ON and Schedule refer to the method of applying insolation under installation of an external louver, Always ON refer to application of louver at all-time and Schedule refers to application of louver under input values of weather data. Therefore, in case of Always ON like on Table 2 above, the energy consumption of the building with blind is saved by about 55% compare to the regular building and in case of Schedule, the energy consumption of the building with blind is saved by about 40% compare to the regular building.

The period to acquire the data of temperature and humidity is total 32 days from August 3, 2015to September 3, 2015 and the data were acquired from the regular building and the building with blind at the same time. For data analysis, the temperature and humidity data of each test bed have been compared and the temperature data and insolation have been analyzed. The data for 26 days excluding August 3, the installation data of measuring device and August 6, the day with no data due to an error have been analyzed as the effective data. The data acquired through a thermometer and a hygrometer are dry bulb temperature and relative humidity and since relative humidity changes under a temperature change the absolute humidity has been calculated through dry bulb temperature and relative humidity. Figure 12 indicates insolation time and temperature graph during the time of measuring thermal environment.

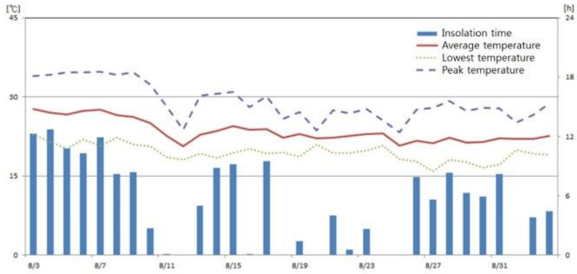

Figure 12: Insolation Time and Temperature during Measurement of Thermal Environment

The insolation time, average temperature, peak temperature and lowest temperature have been entered in to compare the data and for the standard of measuring time the Meteorological Administration Agency data have been used for the data within the data of data acquisition as the standard. The average indoor temperature from 8AM to 7PM has been 38.9℃ in the regular building and 34℃ in the building with blind, indicating that the regular building had 4.9℃ higher average indoor temperature. Moreover, the temperature difference has been on the day with relatively less insolation time and the temperature difference during acquisition has been from -4.6℃ to 9.4℃.Table 3 is a summary of temperature, absolute humidity and temperature difference between the regular building and the building with blind.

Table 3: Average Temperature and Average Absolute Humidity of Regular Building and Building with Blind

date	Regular Building		Building with Blind		Temperature Difference (K)
	Temperature (℃)	Absolute Humidity (kg/kg’)	Temperature (℃)	Absolute Humidity (kg/kg’)	
Aug. 4	44.3	0.0137	39.3	0.0137	5.0
Aug. 5	47.8	0.0131	40.6	0.0147	7.3
Aug. 6	48.1	0.0131	40.2	0.0149	7.9
Aug. 7	48.3	0.0133	40.1	0.0149	8.2
Aug. 8	43.4	0.0157	36.9	0.0162	6.5
Aug. 14	44.1	0.0136	36.7	0.0162	7.4
Aug. 15	45.6	0.0122	38.5	0.0149	7.1
Aug. 16	35.2	0.0141	31.1	0.0155	4.1
Aug. 17	40.9	0.0120	35.3	0.0146	5.6
Aug. 18	32.8	0.0128	28.5	0.0143	4.3
Aug. 19	37.3	0.0127	31.7	0.0140	5.7
Aug. 20	27.3	0.0154	25.0	0.0164	2.4
Aug. 21	34.7	0.0143	31.6	0.0172	3.2
Aug. 22	33.8	0.0132	31.4	0.0157	2.5
Aug. 23	36.7	0.0126	32.5	0.0151	4.3
Aug. 24	31.5	0.0130	28.2	0.0152	3.3
Aug. 25	23.2	0.0142	27.7	0.0168	-4.6
Aug. 26	42.5	0.0103	40.9	0.0150	1.6
Aug. 27	37.9	0.0109	31.9	0.0133	6.0
Aug. 28	44.6	0.0098	36.4	0.0133	8.2
Aug. 29	41.0	0.0098	34.2	0.0122	6.9
Aug. 30	41.0	0.0100	33.7	0.0124	7.3
Aug. 31	44.9	0.0102	35.5	0.0127	9.4
Sep. 1	31.4	0.0113	27.9	0.0127	3.5
Sep. 2	36.4	0.0119	30.8	0.0141	5.6
Sep. 3	36.5	0.0123	36.6	0.0147	-0.1
Avg.	38.9	0.0125	34.0	0.0146	

Figure 13 and Figure 14 show the graph of temperature and absolute humidity of the regular building and the building with blind, indicating the typical trend on the with high temperature and the day with low temperature. In case of the day with high temperature, the temperature at 1 PM showed at most 12.9℃ of temperature difference and in case of the day with low temperature, the maximum temperature difference was 6.2℃.

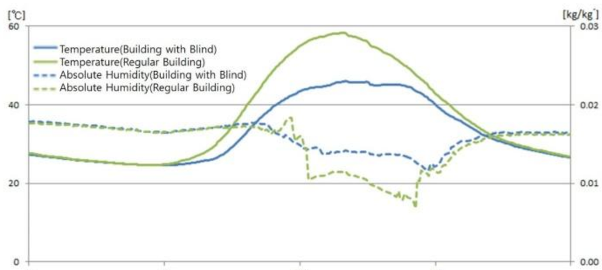

Figure 13: Temperature and Absolute Humidity on August 6

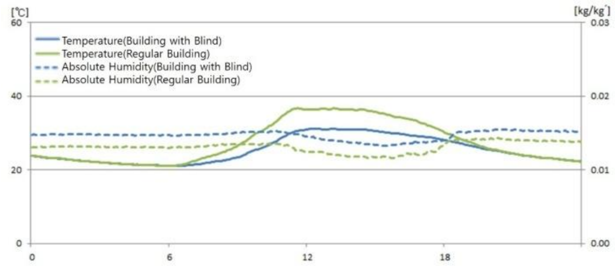

Figure 14: Temperature and Absolute Humidity on August 18

The PMV data have been acquired for 20 days from August 14, 2015 to September 3, 2015 and the data on August 17 has been excluded due to an error. The data for 10 days in 3 day term of the building with blind and the regular building have been used for the analysis. Figure 15 shows the percentile of PMV data. The percentile value shows the minimum value, medium value and maximum value along with the top 25% and the bottom 25% of the total data.

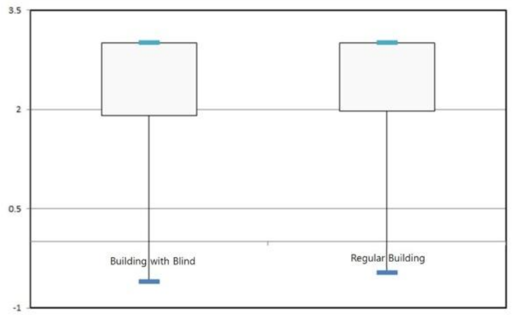

Figure 15: Percentile of PMV Date

Table 4 indicates the percentile of PMV data and Table 5 indicates the average PMV.

Table 4: Percentile of PMV Data

%	Building with Blind	Regular Building
Min	-0.61	-0.47
25%	1.91	1.97
50%	3	3
75%	3	3
Max	3	3

Table 5: Average PMV

date	Regular Building	Building with Blind
Aug. 14		2.81
Aug. 15		2.74
Aug. 16		2.66
Aug. 18	2.77	
Aug. 19	2.90	
Aug. 20	1.52	
Aug. 21		1.81
Aug. 22		2.17
Aug. 23		2.44
Aug. 24		1.69
Aug. 25	0.15	
Aug. 26	2.90	
Aug. 27	2.72	
Aug. 28	2.89	
Aug. 29		2.50
Aug. 30		2.59
Aug. 31		2.64
Sep. 1	2.43	
Sep. 2	2.85	
Sep. 3	2.79	

Figure 16 and Figure 17 indicate the PMV of the regular building and the building with blind.

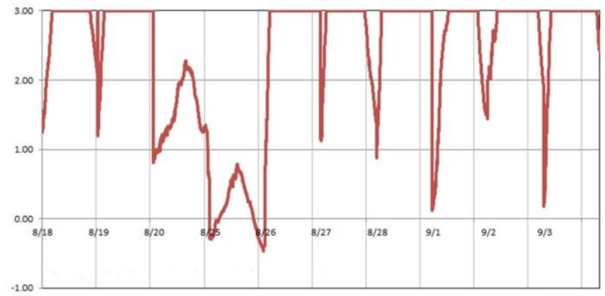

Figure 16: PMV of Regular Building

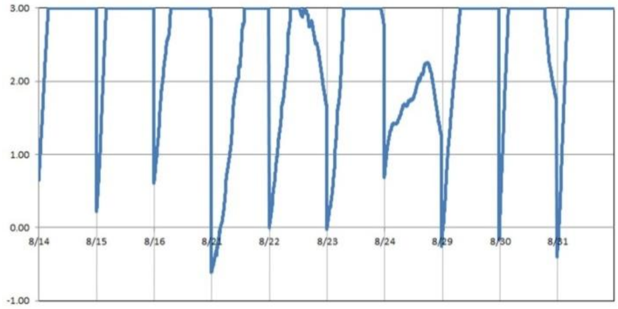

Figure 17: PMV of Building with Blind

Most PMV values are close to 3 the maximum value as the temperature is measured high at the test bed for experiment instead of actual residential space. The days with PMV not close to 3 indicate that there was no time of insolation on these days. Therefore, it has been confirmed that the PMV is affected by the time of insolation. The insolation data have been acquired for 22 days from August 13 to September 3 and the data for 16 days excluding the day of installation on August 13 and the day with errors have been taken as the effective data for analysis. Figure 18 indicates the insolation graph of the regular building and the building with blind between 8AMand 7PM.

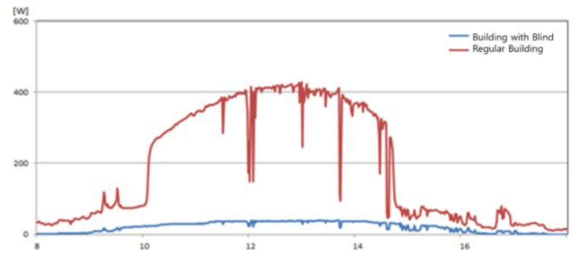

Figure 18: Insolation on August 28

The days with insolation below 100W/m^2 in the graph of regular building are cloudy days and these data are not highly reliable as the data of analysis. On the day with the daily average insolation of 100W/m^2 in the regular building the insolation difference between the building with blind and the regular building was high and the maximum difference at around 1 PM was about 390 W/m^2 as shown in figure 19.Table 6 is a summary of daily cumulative insolation of the regular building and the building with blind.

Table 6: Daily Cumulative Insolation of Each Test Bed (August, 2015)

Date	Daily Cumulative Insolation of Regular Building (kWh/m^2)	Daily Cumulative Insolation of Building with Blind (kWh/m^2)	Rate of Saving Insolation by Building with Blind(%)
15	105.7	13.3	87
16	32.9	4.9	85
17	88.7	11.8	87
18	30.9	3.4	89
19	51.6	6.9	87
20	17.3	1.2	93
21	43.1	6.9	84
22	37.4	5.6	85
23	47.7	7.1	85

24	25.8	3.3	87
25	8.2	0.5	94
26	99.7	10.5	89
27	92.3	9.3	90
28	114.5	12.5	89
29	71.3	10.2	86
30	99.2	10.9	89

4. Conclusion

In this study, the test beds have been established to check the effect of improving thermal environment of a building and the analysis of thermal environment with and with and without external louvers has been performed. The analysis of thermal environment has been performed through the simulation categorizing energy consumption, temperature, humidity, insolation and PMV. In the simulation, it has been confirmed that when it is Always ON, about 55% of energy consumption has been saved compare to a regular building and about 44% of energy consumption has been saved when it is under a schedule. The daily averages of temperature and humidity in between 8AM to 7PM of a regular building and a building with blind have been calculated and the maximum temperature difference was 9.4℃. In case of insolation, just like measurement of temperature and humidity, the insolation in between 8AM and 7PM has been measured and the cumulative insolation for the term of analysis was 0.5~12.5kWh/m^2, while the solar transmittance value was 300W/m^2 or below. Through this study, it has been confirmed that a building with blind shows improvement on thermal environment and on cooling energy saving compare to a regular building.

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