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A Study on the Performance Evaluation of Moblie Light Shelf System According to the Distance between the Light Shelf and the Window

Sunhyeon Kwon

The Graduate School of Techno Design, Kookmin University, Jeongneung-dong
Seongbuk-gu, Seoul, 136-702, Korea

Heangwoo Lee

The Graduate School of Techno Design, Kookmin University, Jeongneung-dong
Seongbuk-gu, Seoul, 136-702, Korea

Yongseong Kim

The Graduate School of Techno Design, Kookmin University, Jeongneung-dong
Seongbuk-gu, Seoul, 136-702, Korea

Abstract

Nowadays, building energy management is more important than ever. Especially, lighting energy used in the building occupies 30% of the whole consumed energy. Therefore, reducing the consumption of lighting energy could bring effective energy saving. As the system configuration, the sum of distance between the window and the light shelf reflector and width of light shelf is set to be 500 mm at maximum. The horizontal width of light shelf is set between 200 mm, the angle of light shelf is set between -90 and 90, and the horizontal distance between the window and the light shelf reflector is set between 0 mm and 300 mm in consideration of sum of width of light shelf. The light shelf system suggested in this study can be used as the basic design data for various design elements in a building.

Keywords: Light-Shelf System, Separation distance, Performance Evaluation

1 Introduction

1.1 Objective of the Study

Nowadays, building energy management is more important than ever. Especially, lighting energy used in the building occupies 30% of the whole consumed energy. This amount increases continuously. [1] Therefore, a proper measure to reduce the consumption of lighting energy could bring effective energy saving. The natural lighting system is used for reducing the consumption of lighting energy, and the light shelf system among various natural lighting systems can block natural light brought into indoors, reflect natural light using the light shelf and distribute indoor illumination evenly to improve indoor environments and reduce the consumption of lighting energy. Due to its high efficiency, various experiments and studies regarding the light shelf are being carried out. However, previous studies on the light shelf system aim at simply satisfying required indoor illuminations with a form of light shelf attached to the window. The studies on the width of light shelf have been carried out, but the studies regarding the angle variation of light shelf are insufficient. Also, most light shelves are fixed-type light shelves so that occupants receive the sense of difference while using them, and simple fixed-type light shelves also have an architecture design demerit. Therefore, this study intends to suggest the movable light shelf system according to the distance between the window and the light shelf reflector as the preliminary data for applying the light shelf system to actual design, verify the possibility verify the possibility to introduce this system and its efficiency through the evaluation of energy performance.

1.1 Method and Procedure of the Study

In this study, the movable light shelf system that the width and angle of light shelf and the distance between the window and the light shelf reflector can be changed in addition to the sun's altitude and daylight illumination is suggested in order to reduce energy consumption in buildings and establish pleasant indoor lighting environments. In order to evaluate energy saving performance of suggested system, the energy performance for each season is evaluated through the full-size test-bed that could realize actual housing conditions for 24 hours a day, 365 days a year to verify the possibility to introduce this system to the residence and its efficiency.

2 Light Shelf System

A light shelf is an architectural technology that makes light to penetrate deeper into the inner space and to block the direct solar radiation that considered the major factor of heat gain inside indoor spaces [2]. The light shelf system is a natural lighting reflection system that blocks natural light flowing indoors and bringing light deep inside by reflecting light using a light shelf in order to prevent problems such as glares or severe illumination imbalance caused by external direct lights. It is a natural lighting system that equally distributes the indoor illumination to improve the quality of indoor space and save lighting energy. It is desirable to install the light shelf system at a low position for natural light flowing indoors, but generally it is installed above the eye level of a standing person in order to prevent glares and secure the prospect right of the occupants. The light shelf system is categorized into external type, internal type, and mixed type. [3]

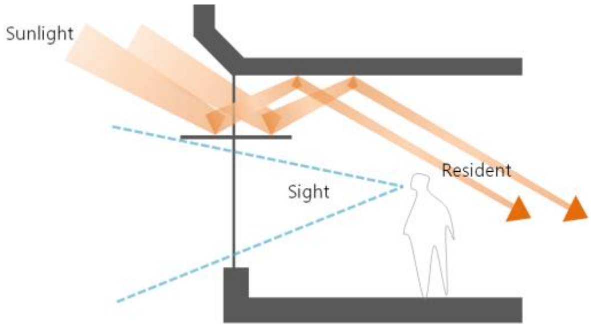

Figure 1. Principle of the Light Shelf System [3]

3 Movable Light Shelf System according to the Distance between the Light Shelf and the Window

The light shelf system according to the distance between the window and the light shelf reflector aims at optimizing natural light brought into indoors by changing the horizontal width of light shelf, distance between the window and the light shelf reflector and angle of light shelf.

As the system configuration, the sum of distance between the window and the light shelf reflector and width of light shelf is set to be 500 mm at maximum. The horizontal width of light shelf is set between 200 mm, the angle of light shelf is set between -90 and 90, and the horizontal distance between the window and the light shelf reflector is set between 0 mm and 300 mm in consideration of sum of width of light shelf [4].

The illumination is measured with the fixed width of light shelf and different horizontal distance between the window and the light shelf reflector and angle, and then the illumination is measured again with a different width of light shelf. The process is repeated and the obtained results are compared and analyzed.

Table 1. Setting of Factors of a Light Shelf

Light Shelf Width	ⓐ	200mm
Separation Distance between Window and Light Shelf Reflector	ⓑ	0mm ~ 300mm
	ⓐ + ⓑ	500mm
Light Shelf Reflectivity	specular reflection film (reflexibility 85%)	
Meridian transit altitude	Summer Solstice	76.5°
Angle	-90° ~ 90° (10° Unit)	

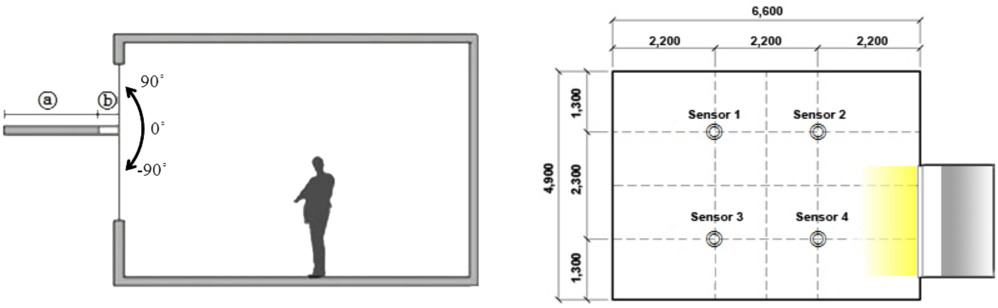

Figure 2. Configuration of Light Shelf System

4 Performance Evaluation of Light Shelf System

In order to evaluate the performance of light shelf system according to the distance between the window and the light shelf reflector, the width of light shelf and distance between the window and the light shelf reflector are set and the energy performance for each case is evaluated.

To evaluate the performance of the light shelf system according to the separation distance between window and reflector, this study conducted an energy performance evaluation on each experiment by setting up the width of the light shelf and the separation distance between window and light shelf reflector.

To verify the performance of the light shelf system according to the separation distance between window and reflector, this study established a test bed in which round-the-clock and year-round implementation is possible. The test bed included the solar altitude and external environment of four seasons (spring and fall, winter and summer) using an artificial sunray irradiation facility similar to the brightness of the actual sun. Moreover, the illumination sensor module was arranged in four sections at 2,200mm intervals, and the lighting was installed near the sensor.

Figure 3. Front View of the Test Bed

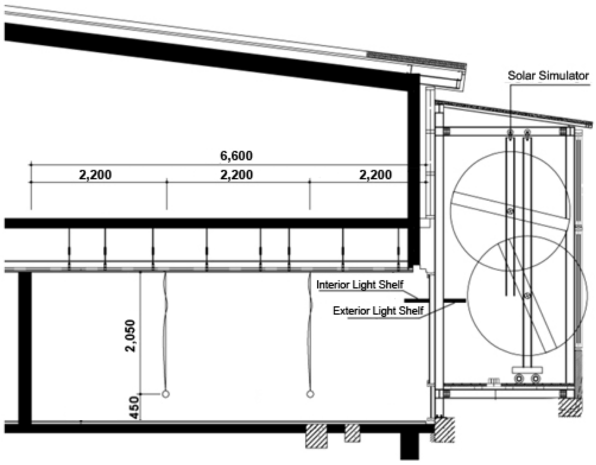

Figure 4. Cross Sectional Diagram of the Test Bed and Height of the Luminance Sensor

Variables of the light shelf system in the experiment were the angle of the light shelf and the meridian altitude of spring and fall, summer and winter to produce the result value. The width of the light shelf was external type 200mm based on previous studies and contents of variables related to the light shelf system, and the height was 1800mm so that it does not cause inconvenience to the visibility of people. The surface reflectance of the light shelf system used the 85% reflective sheet. The meridian altitude of summer, spring and fall, and winter was set up, and the experiment was conducted by increasing the angle change of the light shelf in 10 ˚ units from –90 ˚ to 90 ˚.

Table 2. Measurements of Illumination Sensor (Distance 0mm, Summer Solstice 80,000 Lux)

Light Shelf Angle	Sensor1	Sensor2	Sensor3	Sensor4
-90˚	40.84	650.13	161.50	2319.44
-80˚	41.23	641.29	163.07	2292.13
-70˚	33.57	625.36	132.75	2242.56
-60˚	33.57	599.68	132.75	2158.67
-50˚	28.95	580.20	114.49	2085.89
-40˚	29.60	580.63	117.07	2111.15
-30˚	34.37	608.52	135.93	2233.50
-20˚	23.13	573.58	91.49	2076.81
-10˚	30.53	613.86	120.75	2304.31
0˚	42.56	738.69	168.31	2748.10
10˚	72.03	861.34	284.87	3552.94
20˚	158.15	889.23	445.88	3794.58
30˚	165.04	755.09	655.50	3043.30
40˚	132.44	774.57	523.75	4341.48
50˚	62.25	734.72	246.19	2690.53
60˚	66.61	714.34	263.44	2632.88
70˚	46.40	697.08	183.49	2540.88
80˚	38.73	662.99	153.18	2338.65
90˚	39.13	652.36	154.74	2349.78

Table 3. Measurements of Illumination Sensor (Distance 50mm~300mm, Summer Solstice 80,000 Lux)

	Light Shelf Angle	Sensor1	Sensor2	Sensor3	Sensor4		Sensor1	Sensor2	Sensor3	Sensor4
	-90˚	41.27	656.32	162.40	2330.90		39.65	706.57	160.26	2315.59
	-80˚	41.67	647.39	163.97	2303.46		40.03	713.46	161.82	2288.33
	-70˚	33.92	631.31	133.49	2253.65		32.59	580.81	131.73	2238.84
	-60˚	33.92	605.39	133.49	2169.34		32.59	580.81	131.73	2155.09
	-50˚	29.26	585.73	115.13	2096.20		28.11	500.90	113.61	2082.43
	-40˚	29.91	586.16	117.72	2121.58		28.74	512.17	116.17	2107.65
	-30˚	34.73	614.32	136.68	2244.53		33.37	594.69	134.88	2229.79
	-20˚	23.38	579.03	92.00	2087.07		22.46	400.29	90.79	2073.37
	-10˚	30.85	619.70	121.41	2315.70		29.64	528.28	119.82	2300.49
Separation Distance 50mm	0˚	43.01	745.72	169.24	2761.68	Separation Distance 100mm	41.32	736.39	167.02	2743.54
	10˚	72.79	869.53	286.45	3570.49		69.93	1246.34	282.68	3547.04
	20˚	159.82	897.70	448.34	3813.33		153.54	2736.39	620.64	3788.29
	30˚	166.79	762.28	659.12	3058.34		160.24	2855.66	647.69	3038.25
	40˚	133.84	781.95	526.64	4362.93		128.58	2291.46	519.72	4334.28
	50˚	62.91	741.71	247.55	2703.83		60.44	1077.10	244.30	2686.07
	60˚	67.32	721.14	264.90	2645.89		64.67	1152.56	261.41	2628.51
	70˚	46.89	703.71	184.51	2553.44		45.05	802.80	182.08	2536.67
	80˚	39.14	669.30	154.03	2350.21		37.60	670.15	152.00	2334.77
	90˚	39.54	658.57	155.60	2361.40		37.99	677.03	153.56	2345.88
	-90˚	39.96	648.49	160.25	2312.98		38.64	644.14	159.90	2304.73
	-80˚	40.35	639.67	161.80	2285.75		39.02	635.37	161.45	2277.59
	-70˚	32.85	623.77	131.72	2236.32		31.76	619.59	131.44	2228.34
	-60˚	32.85	598.16	131.72	2152.66		31.76	594.15	131.44	2144.98
	-50˚	28.33	578.74	113.60	2080.09		27.39	574.85	113.36	2072.66
	-40˚	28.97	579.16	116.16	2105.28		28.01	575.28	115.91	2097.76
	-30˚	33.64	606.98	134.87	2227.28		32.52	602.91	134.58	2219.33
	-20˚	22.64	572.12	90.78	2071.03		21.89	568.28	90.58	2063.64
	-10˚	29.88	612.31	119.81	2297.90		28.89	608.20	119.55	2289.70
Separation Distance 150mm	0˚	41.65	736.82	167.00	2740.45	Separation Distance 200mm	40.27	731.87	166.64	2730.67
	10˚	70.49	859.16	282.66	3543.05		68.16	853.39	282.05	3530.40
	20˚	154.77	886.98	442.41	3784.02		149.66	881.03	441.45	3770.52
	30˚	161.52	753.18	650.40	3034.83		156.18	748.13	648.99	3024.00
	40˚	129.60	772.61	519.67	4329.39		125.32	767.43	518.55	4313.95
	50˚	60.92	732.86	244.27	2683.04		58.91	727.94	243.74	2673.47
	60˚	65.19	712.53	261.39	2625.55		63.03	707.75	260.83	2616.18
	70˚	45.41	695.32	182.07	2533.81		43.91	690.65	181.67	2524.77
	80˚	37.90	661.31	151.99	2332.14		36.65	656.87	151.66	2323.82
	90˚	38.29	650.71	153.54	2343.24		37.03	646.34	153.21	2334.88
	-90˚	39.39	656.21	715.44	629.29		39.84	36.54	39.84	35.04
	-80˚	39.77	647.28	722.37	621.88		40.23	36.05	40.23	34.63
	-70˚	32.38	631.20	588.08	608.43		32.75	35.15	32.75	33.88
	-60˚	32.38	605.28	588.08	585.67		32.75	33.71	32.75	32.61
	-50˚	27.92	585.62	507.19	565.93		28.24	32.61	28.24	31.51
	-40˚	28.55	586.06	518.61	572.78		28.88	32.64	28.88	31.90
	-30˚	33.15	614.21	602.15	605.97		33.53	34.20	33.53	33.75
	-20˚	22.31	578.93	405.29	563.46		22.57	32.24	22.57	31.38
	-10˚	29.45	619.59	534.89	625.19		29.79	34.50	29.79	34.81
Separation Distance 250mm	0˚	41.05	745.59	745.59	745.59	Separation Distance 300mm	41.52	41.52	41.52	41.52
	10˚	69.48	869.38	1261.95	963.95		70.27	48.41	70.27	53.68
	20˚	152.54	897.54	1975.18	1029.51		154.29	49.98	109.99	57.33
	30˚	159.19	762.15	2903.77	825.68		161.01	42.44	161.70	45.98
	40˚	127.74	781.81	2320.14	1177.89		129.20	43.54	129.20	65.59
	50˚	60.04	741.58	1090.58	729.97		60.73	41.30	60.73	40.65
	60˚	64.25	721.01	1167.02	714.33		64.98	40.15	64.99	39.78
	70˚	44.75	703.59	812.85	689.37		45.26	39.18	45.27	38.39
	80˚	37.36	669.18	678.56	634.50		37.79	37.27	37.79	35.33
	90˚	37.74	658.45	685.49	637.52		38.17	36.67	38.17	35.50

5 Conclusion

The light shelf system can directly respond to the world's energy issue, and as one of natural lighting systems for reducing the consumption of lighting energy used in buildings, this system has low installation expense and excellent performance. In case of movable light shelf system according to the distance between the window and the light shelf reflector suggested in this study, it is possible to find an appropriate width and angle of light shelf and an appropriate distance between the window and light shelf reflector so that the indoor daylight distribution can be confirmed and the consumption of lighting energy used in indoors can be reduced. The light shelf system suggested in this study can be used as the basic design data for various design elements in a building.

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