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A Study on the Evaluation Performance According to the Curvature and Angle of Light Shelf

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Abstract

New recognition on resident’s pleasantness is required, as environmental problems emerge in the rapidly developing 21st century. The light environment greatly affects the visual environment pleasantness of occupants. And, most residential buildings, built recently, also use wide windows and doors a lot in terms of building’s energy use, due to much consumption of energy, arising from lighting. However, the wide windows and doors become the cause of illuminance imbalance and glare, according to the inflow of daylight, which becomes various disturbing factors such as occupant’s visual environment discomfort and work competency decline. In this context, researches on the efficient natural lighting system to make illuminance balanced and to reduce glare and energy use are conducted and linked together. From the indoor visual pleasantness enhancement and lighting energy reduction aspects, the effective natural lighting is a technique to introduce daylight into indoor maximally through design techniques or mechanical devices. Also, excessive direct light inflow should be interrupted to provide excellent natural lighting qualitatively, and the natural lighting needs to be introduced by diffusing light. Currently, research on flat florescent shelves is

the mainstream research on the light shelves, but, the flat florescent shelves cause some problems in glare. Through this research, more natural lighting can be enhanced into indoor space and a lighting energy reducing effect can be expected by inducing light deeper into spaces and generating a large area diffusion effect than flat light shelves. This research aims to verify performance and draw proper proposals by comparatively analyzing flat light shelves and curvature-applied light shelves.

Keywords: Light-Shelf, Performance evaluation, Curvature, Angle

1 Introduction

As environmental problems emerge in the rapidly changing 21st century, new recognition on resident's pleasantness is required. The light environment not only greatly affects occupant's visual environment pleasantness and work competency, but also lots of energy is consumed, due to lighting. The flat florescent shelves cause some problems in glare. Therefore, researches on enhancing the energy reduction effect and reducing glare are conducted by increasing energy reducing effect through light diffusion with application of curvature on reflective plane. Existing researches lack diversity that consider the variety and variables of light shelves, since experiments by simple curvature of light shelves were carried out.

The purpose of this research is to draw the proper illuminance of light shelves through performance evaluation by diversifying the curvature values and angles of reflective plane of light shelves.

2 Light Shelf System

2.1 Concept of Light Shelf system

The light shelf system is a natural lighting system that can simultaneously satisfy lighting energy reduction and spatial quality by balancing indoor illuminance. It is desirable to install the light shelf system on low position for the introduced natural light; however, the position at or above the standing person's eye level is general in order to prevent glare and ensure occupant's prospect right. As for the light shelf system, it is classified into external, internal and mixed light shelves. The light shelf system is to simultaneously interrupt introduced natural light to prevent extreme illuminance imbalance and glaring in the process of light introduction, due to solar direct light from outside, and let solar light come into indoor deep by reflecting light [1].

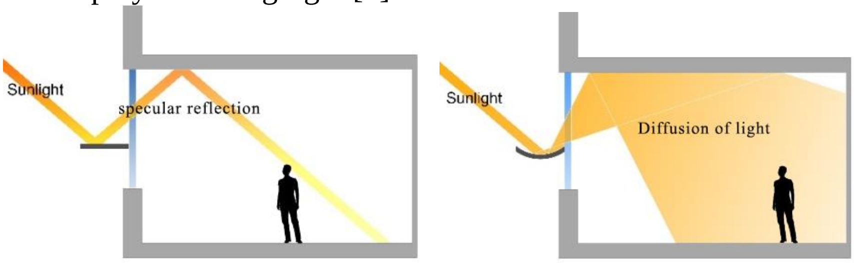

Figure 1. The principle of the shelf system of light & the principle of application light shelf system of curvature

3 Performance evaluation of the application of light shelves of curvature

3.1 Overview of test bed

This research built a test bed that can embody external light environment for 24 hours/365 days as shown in table 1. The test bed shaped sun's altitudes in the four seasons on the spring equinox, the autumn equinox, summer solstice and winter solstice, and external environment through artificial solar light irradiation equipment, of which brightness is similar to that of the actual sun[1].

Table 1. Setting of test-bed

Test bed Outline	
Room size, Material	4.9m(W) * 6.6m(D), 2.5m(Celling height) / Wall : reflexibility 46%,
Window size, Material	2.2m(W) * 1.8m(H) / Pair glass 12mm (3mm * 6mm * 3mm)
Direction	South
Chamber model Outline	
Chamber size	4.5m(W) * 2.7m(D) * 4.6m(H)
Artificial Sunlight	2.08(W) * 2.8m(W)

3.2 Overview of Light shelf

As demonstrated in Table 2, the width, height and curvature values of the light shelf were set at 400mm, 1,800mm and 0°, 40° and 80°, respectively, and the angles of the reflective plane were set at -10°, -5°, 0°, 5° and 10°, respectively. The reflective sheet with 85% of reflexibility was used for the surface of the reflective plane.

Table 2. Setting of Light shelf

Light shelf width	400mm	
Light shelf height	1800mm	
Light shelf Curvature	0°, 40°, 80°	
Light shelf Angle	-10°,-5°, 0°, 5°, 10°,	
Light shelf reflectivity	specular reflection film (reflexibility 85%)	
Meridian transit altitude	Summer / Fall & spring/ winter	76.5° / 53° / 29.5°
Type	External Auto type	

3.3 External Environment of Experiment

As exhibited in Table 3, basic illuminance values were shown by setting four seasonal culmination altitudes.

Table 3. External Environment of Experiment

Seasons	External illumination	Basic illumination			
		1	2	3	4
Summer	80000(lx)	188.23	272.10	166.21	787.18
Spring/Fall	60000(lx)	733.40	1057.69	687.85	2409.03
Winter	30000(lx)	934.97	910.42	1303.78	7769.79

3.4 Performance Evaluation Method and Results

The method to evaluate performance is as follows:

First, the results drawn by the performance evaluation method are demonstrated in Table 4, and the proper values of each variable were drawn, based on standard illuminance, 440lx, suggested by KS A3-11. However, proper values were drawn with variables approaching 400lx. If four sensors go beyond 400lx, the light shelf's variable approaching 400lx was regarded as the proper variable.

Second, uniformity illuminance ratios were drawn according to the curvature and angle of the light shelf, and they were reflected in performance evaluation.

The results according to the performance evaluation method are presented below:

First, the proper variables of the curvature-applied light shelf were drawn as 40° and 10° in curvature and angle on the summer solstice, and 0° and -10° in curvature and angle on the spring/autumn equinox, and 0° and -10° in curvature and angle on the winter solstice. Due to unnecessary illuminance inflow of more than 400lx by light diffusion upon application of curvature in the cases of the spring/autumn equinox and winter solstice, curvature application is not necessary; however, lighting performance improvement can be demonstrated by curvature application of the light shelf in the case of the summer solstice.

Second, as a result of drawing uniformity illuminance ratios, according to light shelf's curvature and angle, the uniformity illuminance ratios showed improvement upon application of curvature, and thus, curvature-applied light shelf is favorable to the improvement of light environment.

Table 4. Application performance analysis result of the curvature

Times	Seasons	Light-Shelfs			Ceilling illumination				uniformity ratio
		width	cuvature	Angle	1	2	3	4	
12H~2H	Summer	400mm	0°	-10°	155.57	344.88	134.63	814.05	0.372
				-5°	188.79	415.80	160.91	936.10	0.378
				0°	212.90	473.28	182.37	1039.49	0.382
				5°	237.83	526.65	208.09	1167.89	0.389
				10°	283.56	591.22	259.15	1402.29	0.409
			40°	-10°	164.12	391.91	142.51	853.99	0.367
				-5°	196.81	464.69	171.28	993.21	0.375
				0°	222.98	504.26	198.01	1110.78	0.389
				5°	248.88	550.54	229.10	1244.03	0.403
				10°	293.30	597.94	295.65	1387.73	0.456
			80°	-10°	196.70	459.84	184.57	1029.42	0.395
				-5°	224.28	474.77	224.17	1097.35	0.444
				0°	240.97	492.31	252.43	1100.71	0.462
				5°	246.83	485.22	263.81	1099.59	**0.471**
				10°	251.46	491.57	260.23	1141.02	0.469
	Spring/ Fall	400mm	0°	-10°	681.66	1022.76	632.62	2527.57	0.520
				-5°	704.95	1061.85	653.96	2612.41	0.520
				0°	745.33	1136.72	689.64	2743.43	0.519
				5°	771.62	1167.08	713.60	2825.78	0.521
				10°	813.84	1236.96	760.02	3027.51	0.521
			40°	-10°	732.90	1104.69	682.53	2842.00	0.509
				-5°	755.23	1120.08	705.82	2907.72	0.514
				0°	791.88	1169.16	745.21	2987.16	**0.524**
				5°	800.57	1196.61	754.65	3048.72	0.520
				10°	834.68	1271.06	793.00	3243.79	0.516
			80°	-10°	740.84	1127.57	697.38	2911.46	0.509
				-5°	750.16	1130.90	705.86	2911.46	0.514
				0°	770.12	1166.66	725.79	2992.15	0.513
				5°	784.76	1202.43	741.97	3077.83	0.511
				10°	808.47	1261.50	768.96	3226.32	0.507
	Winter	400mm	0°	-10°	937.43	975.83	1183.88	7486.47	0.354
				-5°	962.86	995.73	1223.34	7604.88	0.357
				0°	990.96	1052.67	1265.42	8125.21	0.347
				5°	1005.34	1054.04	1291.83	8459.54	0.340
				10°	1010.25	990.60	1318.76	8246.17	0.343
			40°	-10°	1021.02	991.39	1412.10	7043.78	**0.379**
				-5°	1046.01	1003.61	1455.92	7189.57	0.375
				0°	1055.52	1036.31	1471.82	7814.11	0.364
				5°	1058.40	1030.99	1478.78	8164.81	0.351
				10°	1054.93	1008.93	1470.93	8063.93	0.348
			80°	-10°	973.03	948.44	1359.30	7055.40	0.367
				-5°	987.49	988.63	1374.00	7602.72	0.361
				0°	1000.32	995.92	1390.98	7958.53	0.351
				5°	1003.55	988.04	1393.41	7942.96	0.349
				10°	991.67	984.30	1362.61	7898.24	0.350

▭: Indicating illuminance introduced optimally, **bold**: maximum value of uniformity illuminance ratio

4. Conclusion

This research conducted an experiment on culmination altitudes' external illuminance values in the order of the summer solstice, spring equinox and autumn equinox and winter solstice by controlling variables at 400mm in light shelf width and from noon to 14:00 in time. The variables for curvature were set at 0°, 40° and 80°, respectively. Angles were set as the variables of -10°, -5°, 0°, 5° and 10°, respectively, in order to compare illuminance values.

The conclusion of this research is as follows:

First, the proper variables of the curvature-applied light shelf were drawn as follows: curvature and angle at 40° and 10° on the summer solstice, 0° and -10° on the spring equinox and autumn equinox and 0° and-10° on the winter solstice, respectively.

Second, as a result of drawing uniformity illuminance ratios, according to curvature and angle, the improvement of uniformity illuminance ratios was demonstrated upon curvature application, and therefore, curvature-applied light shelf is favorable to light environment improvement.

This research has significance in that lighting performance and proper proposals were drawn, according to light shelf's curvature and angle. However, this research has limitation, because the variables on the width, materials of light shelf and the indoor finish materials were controlled. The further research taking into account such a limitation needs to be conducted.

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