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A Study on Performance Evaluation of Punching Plate Reflecting Plate-Applied External Light Shelf According to Vent Ratio

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Abstract

Global energy consumption shows uptrend each year in the rapidly changing contemporary era. Building energy consumption accounts for 38% of total energy consumption, and lighting takes up high ratio with 22% in the building energy consumption. Lighting is actually applied to various researches and spaces. The light shelves make illuminance balanced by introducing natural light to indoor spaces. Among the light shelf types, external fluorescent light shelves are known to be more excellent in lighting performance, compared to the internal fluorescent light shelves and mixed fluorescent light shelves. However, the light shelves externally protruding by high wind pressure have difficulties in applying them to high rise buildings. This research proposes a punching plate reflecting plate-applied external fluorescent light shelf that can be designed for and applied to high rise buildings. This research verified the lighting performance of the existing light shelves and the circle-shaped punching plate reflecting plate-applied light shelves with vent Ratios of 29.55%, 32.59%, 34.27% and 40.22%, respectively, by building a test bed. According to the increase of vent Ratio, the lighting performance of the latter showed higher indoor-distributed illuminance with reduced awning area the former.

Keywords: Light-Shelf, Vent Ratio, Evaluation performance

1 Introduction

In the building energy, problems related to energy are caused, due to increase in lighting energy use amount. In regard with this, the natural lighting system using external natural light has outstanding effect. The light shelf reduces high illuminance around windows, and increases illuminance in the space apart from the windows. In this way, the light shelf distributes even illuminance, and also provides visual stability. As such, the light shelf is applied to diverse spaces through recognized lighting energy savings. The light shelf is divided into external, internal and mixed light shelves. The external fluorescent light shelf is suitable for lighting performance improvement, compared to the internal fluorescent light shelf and mixed fluorescent light shelf. In Korea, however, the ratio of six story or higher buildings accounted for 39.61% from 2008 to 2012, based on Statistics Korea's data [1]. Concerning high rise buildings, the light shelves externally protruding by high wind pressure have difficulties in applying them. This research aims to propose a punching plate reflecting plate-applied light shelf that can be designed for and applied to high rise buildings.

2 Punching plate reflector applicable light shelf

2.1 Concept of Light shelf

A light shelf reflects solar light coming into indoor spaces through windows to the indoor ceiling as a method to introduce external light, and thus, introduces natural lighting inside of indoor spaces. The light shelf offer more even distribution of light than lateral day lighting. As shown in <Figure 1>, the light shelf introduces external daylight using the materials with high reflective rate like aluminum or silver-plated metal, and evenly distributes the illuminance of indoor spaces, improves indoor spatial environment, and reduces energy used for artificial lighting. Actually, it is a natural lighting system. As mentioned above, the types of light shelves are classified into external, internal and mixed (used foexternal and internal spaces), according to installation position.

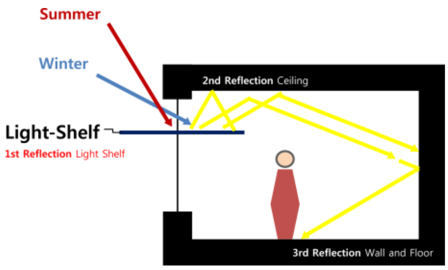


Figure 1. Concept of light shelf

2.2 Concept of punched reflector

This refers to metal plate with regular hole pattern on the thin plate. The punching plate reflecting plate with unique design factors and various patterns are widely used with different usages in various spaces. As demonstrated in <Table 2>, the processing is conducted, according to certain-sized diameter and vent Ratio. As demonstrated in <Table 1>, the punching plate reflecting plate is processed, according to client's order in various shapes such as quadrangle, long hole and clover including circle and oval shapes as shown in <Table 1>. Based on the dimensions of punching plate holes used in punching metal industry, those dimensions were used as the data to set vent Ratio of performance evaluation. This research conducts research limited to the circle shape, which is a general type of perforation.

Table 1. Types of Punched reflector

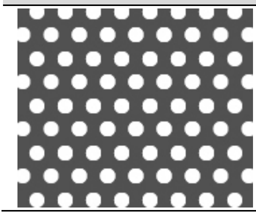
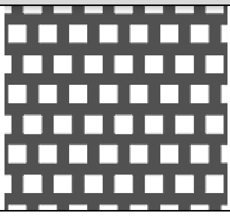
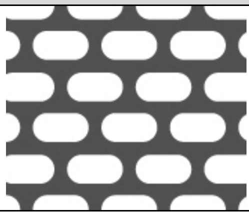
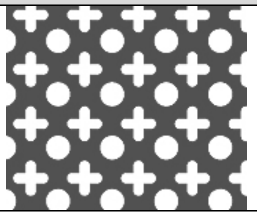
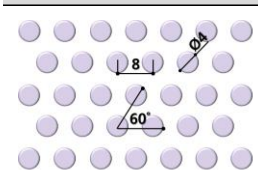
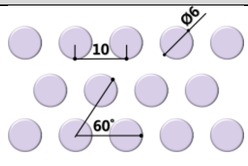
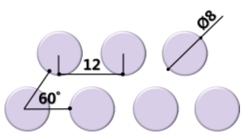
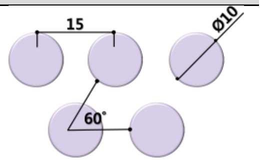
Circular type	Rectangle type	Slot hole type	Crover type
			

Table 2. Set up of vent ratio

Diameter 4 (vent rate 29.55%)	Diameter 6 (vent rate 32.58%)	Diameter 8 (vent rate 34.27 %)	Diameter 10 (vent rate 40.22 %)
			

3 Punching plate reflector applicable ore mill performance evaluation

3.1 Setting the external environments and light shelf factors for performance evaluation

As for light shelf variables set up, a test bed, where embodiment is possible for 24 hours/365 days, was built. Through artificial solar light irradiation equipment, of which brightness is similar to that of the actual sun, together with the test bed, this research shaped sun's culmination altitude and external environment. <Table 3> shows the set up of light shelf system's variables. Concerning external illuminance by time slot from 10:00 to 15:00, according to sun's culmination altitude, it was set as 30,000lx/20,000 lx for the winter solstice and 60,000lx/50,000lx for the spring equinox and autumn equinox. However, 80,000lx/70,000lx was set for the summer solstice.

Table 3. Set up of Light Shelf and meridian transit altitude

Meridian transit altitude		Winter (29.5˚)	Spring & autumn (53˚)	Summer (76.5˚)
Light shelf	width	300mm		
	height	1800mm		
	reflectance	Reflective film (Reflectivity 85%)		
	angle	Fixed-type (0°)		
	type	Punching plate reflector applicable external fluorescent shelves		

3.2 Overview of test bed for indoor environments

The test bed and the illuminance sensor position used in this research are composed as shown in Figure 3: 4.9m in width, 6.6m in depth and 2.5m in ceiling height. The dimensions of the opening part are 2.2m in width and 1.8m in height. The position of the illuminance sensor to evaluate the performance of punching plate reflecting plate-applied fixed external fluorescent light shelf is the red color-indicated part in Figure 3. To analyze the lighting performance in this research, 400lx, the standard illuminance, was set as the standard for lighting control.

Table 4. Test-bed, punched reflector applicable light shelf and Illumination analysis

Test-bed overview	punched reflector applicable light shelf	Illumination analysis
		

Regarding the sensor position to evaluate lighting performance, four sensors were deployed with 2.2m interval, respectively, based on the lighting window as shown in <Table 3> in consideration of spatial size. The illuminance sensor's height was located at 450mm from the floor, based on the working surface.

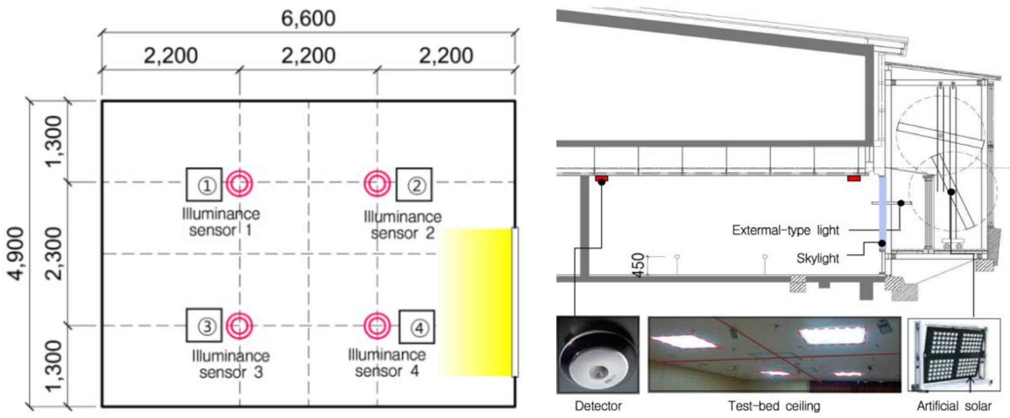


Figure 3. Plane of Test-bed, Location of illuminance sensor and Section of Test-bed

3.3 The existing light shelf and punching plate reflector applicable light performance compared to mine, analyze results of shelves

Concerning the lighting performance method, indoor illuminance distribution was drawn by perforation-non-applied light shelf and perforation-applied light shelf. Based on the drawn illuminance, performance evaluation was carried out by drawing uniformity illumination ratio. The results are presented below:

1) Table 3 conveys light shelf performance evaluation based on the light shelf without vent. In the case of the summer solstice, 400lx or less was shown.

Table 3. Light shelf performance evaluation based on the light shelf without vent

Seasons	External illumination(lx)	Illumination of Sensor (lx)				Average Illumination	Uniformity Illumination
		1	2	3	4		
winter	30,000	1266.69	1594.26	1864.10	13772.42	4624.37	0.27
	20,000	824.46	1042.84	1222.73	9161.61	3062.91	0.27
Spring & autumn	60,000	848.62	1487.70	711.53	3649.98	1674.45	0.51
	50,000	697.18	1229.75	582.94	3031.65	1385.38	0.50
Summer Solstice	80,000	299.90	856.58	103.27	1949.16	802.23	0.37
	70,000	254.92	742.01	82.86	1698.02	694.45	0.37

: This indicates higher score than 400 lx

2) Table 4 conveys the Light shelf performance evaluation based on the light shelf with vent(vent ratio:29.55%).

Table 4. Light shelf performance evaluation based on the light shelf with vent(vent ratio:29.55%)

Seasons	External illumination(lx)	Illumination of Sensor (lx)				Average Illumination	Uniformity Illumination
		1	2	3	4		
winter	30,000	1242.64	1584.06	1819.66	14048.98	4673.83	0.27
	20,000	808.43	1036.04	1193.11	9345.99	3095.89	0.26
Spring and autumn	60,000	795.81	1028.41	665.66	3449.16	1484.76	0.54
	50,000	653.18	847.01	544.72	2864.30	1227.30	0.53
Summer Solstice	80,000	261.85	908.49	67.45	2039.61	819.35	0.32
	70,000	221.62	787.43	51.52	1777.16	709.43	0.31

: This indicates higher score than 400 lx

3) Table 5 conveys the Light shelf performance evaluation based on the light shelf with vent(vent ratio:32.58%)

Table 5. Light shelf performance evaluation based on the light shelf with vent(vent ratio:32.58%)

Seasons	External illumination(lx)	Illumination of Sensor (lx)				Average Illumination	Uniformity Illumination
		1	2	3	4		
winter	30,000	1231.64	1571.18	1786.34	14193.70	18782.86	0.07
	20,000	801.10	1027.45	1170.89	9442.46	12441.91	0.06
Spring & autumn	60,000	722.29	1563.66	664.64	3818.65	6769.25	0.11
	50,000	591.91	1293.05	543.87	3172.21	5601.04	0.11
Summer Solstice	80,000	272.69	796.42	150.63	1842.98	3062.72	0.09
	70,000	231.11	689.37	124.30	1605.11	2649.88	0.09

: This indicates higher score than 400 lx

4) Table 6 conveys the Light shelf performance evaluation based on the light shelf with vent(vent ratio:34.27 %)

Table 6. Light shelf performance evaluation based on the light shelf with vent(vent ratio:34.27 %)

Seasons	External illumination(lx)	Illumination of Sensor (lx)				Average Illumination	Uniformity Illumination
		1	2	3	4		
winter	30,000	1210.77	1557.88	1747.74	14077.55	4648.48	0.26
	20,000	787.18	1018.58	1145.16	9365.03	3078.99	0.26
Spring & autumn	60,000	758.62	1398.00	655.05	3401.00	1553.17	0.49
	50,000	622.18	1155.00	535.87	2824.17	1284.31	0.48
Summer Solstice	80,000	269.05	815.24	91.31	2619.87	948.87	0.28
	70,000	227.92	705.84	72.39	2284.88	822.76	0.28

: This indicates higher score than 400 lx

5) Table 7 conveys the Light shelf performance evaluation based on the light shelf with vent(Vent ratio:40.22 %)

Table 7. Light shelf performance evaluation based on the light shelf with vent(Vent ratio:40.22 %)

Seasons	External illumination(lx)	Illumination of Sensor (lx)				Average Illumination	Uniformity Illumination
		1	2	3	4		
winter	30,000	1184.51	1656.43	1685.73	13860.13	4596.70	0.26
	20,000	769.68	1084.29	1103.82	9220.08	3044.47	0.25
Spring & autumn	60,000	825.40	1385.04	681.58	3503.04	1598.77	0.52
	50,000	677.84	1144.20	557.98	2909.20	1322.31	0.51
Summer Solstice	80,000	277.31	802.02	92.36	1951.33	780.75	0.36
	70,000	235.15	694.27	73.31	1699.92	675.66	0.35

: This indicates higher score than 400 lx

The lighting performance of light shelf with the punched reflector was evaluated for different diameters of hole (Vent ratio) including 29.55%, 32.58%, 34.27% and 40.22%. The result shows that the larger the diameter of hole is, the better the lighting performance of fixed external-type light shelf is. The result of Sensor 3 which is affected by a large amount of light in front of the artificial sunlight device in the test bed is presented in a graph. The perforation-applied light shelf has smaller light amount introduced by light's reflection, compared to the perforation-non-applied light shelf. However, lighting performance decline is not demonstrated, due to reduction of awning area.

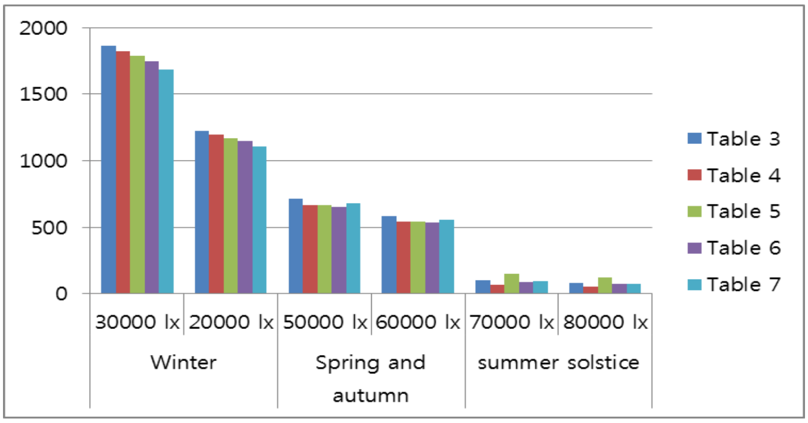


Figure 4. Illuminance3 sensor the light performance

4. Conclusion

Various studies for reducing the energy consumption in buildings are being carried out. In this study on the light shelf which is the lighting system using natural light, the performance evaluation of fixed light shelf with the punched reflector according to the diameter of hole (opening ratio is suggested for supplementing the design limitations due to wind pressure, the result is obtained as follows.

1) The fixed light shelf with the punched reflector was suggested through the review of the concept of light shelf and the literature regarding the punched reflector. 2) The lighting performance of light shelf with the punched reflector was evaluated for different diameters of hole(vent ratio) including 4mm(29.55%), 6mm(32.58%), 8mm(34.27 %) and 10mm(40.22 %). 3) In the perforation-applied light shelf, lighting performance decline does not occur by reduction of awning area, despite light shelf reflective area decrease.

It will be necessary to carry out the performance evaluation of previous light shelf and light shelf with the punched reflector in consideration of various widths and angles in future studies.

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