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A Performance Evaluation of Light-Shelf According to the Reflection Rate of Finishing Material in Indoor Space

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Abstract

The question of how the energy consumption in buildings can be reduced has been a target for ongoing research, with the investigation of indoor lighting energy consumption a particularly active area. A performance evaluation of light shelf according to the reflection rate of finishing material in indoor space was thus carried out in order to reduce the energy consumption of indoor lighting, and the satisfactory depth for the standard intensity of illumination was analyzed. The evaluation was carried out in a space of 54 m², the standard living room space of an apartment house in our metropolitan area, by adjusting the reflection rate of floor, wall and ceiling. This study is a preliminary study on a performance evaluation of light shelf according to the reflection rate of finishing material in indoor space that has the aim of improving lighting performance, and the results are as follows. First, it was found that the average illumination and the uniformity ratio of illumination were improved when the reflection rate of each indoor finishing material was increased. Second, the satisfactory depth for the standard intensity of illumination at 400 lx was improved

from 2.25 m to 3.0 m on the summer solstice, and from 4.5 m to 5.75 m on winter solstice. Third, it is determined that 80% for the ceiling and 80% for the wall are appropriate when installing the fixed type light shelf on the summer solstice, and 80% for the ceiling and 60% for the wall are appropriate when installing the fixed type light shelf on winter solstice.

Keywords: Light-shelf, Material Reflectance, Performance Evaluation

1Introduction

According to an investigation conducted by the IEA (International Energy Agency) of the US in 2011, building energy consumption accounts for 38% of total energy consumption, while lighting energy consumption accounts for 22% of building energy consumption [1]. To reduce the amount of energy used, numerous and ongoing studies have been carried out on approaches to reducing the lighting energy consumption through lighting control systems and natural lighting systems; in particular, the efficiency of light shelf is recognized, and various related studies have been carried out. However, previous studies on light shelf have only focused on improving performance by adjusting variables such as height, angle and width of light shelf, and there has been no study on the finishing material used in the indoor space.Therefore, the purpose of this study is to conduct a performance evaluation of light shelf according to the reflection rate of finishing material in the indoor space, with the aim of improving the lighting performance of light shelf.

2 Standard Illuminancefor Performance Evaluation

The recommended levels of illumination for living spaces in Korea are presented in KS A 3011, and the measurement standard for illumination in domestic houses indicates the horizontal illumination on the working surface [2]. The standard reference illumination, maximum permissible illumination and minimum permissible illumination are recommended as the illumination standard according to the space. This study was carried out on 400 lx, which was the standard reference illumination for living room space.

3Setting Variables for Performance Evaluation

3.1 Setting Spatial Size and Reflectivity for Performance Evaluation

As shown in Figure 1, 6m×9m×2.5m was set as the indoor space for the performance evaluation of light shelf according to the reflection rate of each finishing material in

indoor space based on the living room space of a medium-sized apartment in Korea [3], and 40% was set as the window area ratio based on the energy saving design announced byMOLIT[4].The reflectivity of ceiling and wall were also set, based on existing studies, and the reflectivity of wall was set as 80~20% in the case the reflectivity of ceilingwas 80%. In the case of 70% and 50% of ceiling reflectivity, this study establish 70~20% of wall reflectivity, and 50~20% of wall reflectivity[5]. Floor reflectivity was controlled to be 20%, and each reflectivity was adjusted and set as 70.07%, 59.81%, 49.86%, 39.80% and 19.71%, respectively, based on reflectivity of each material provided by Radiance[6].

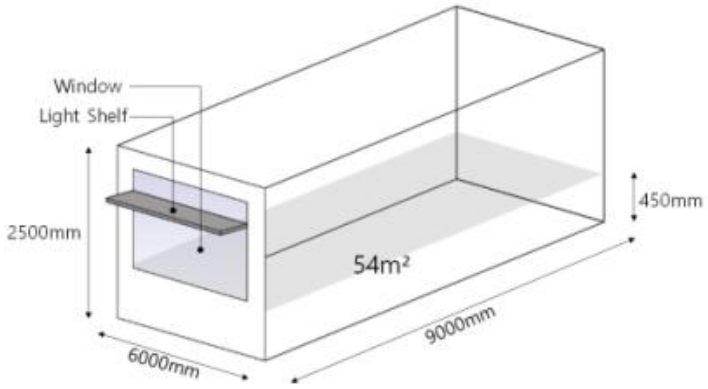


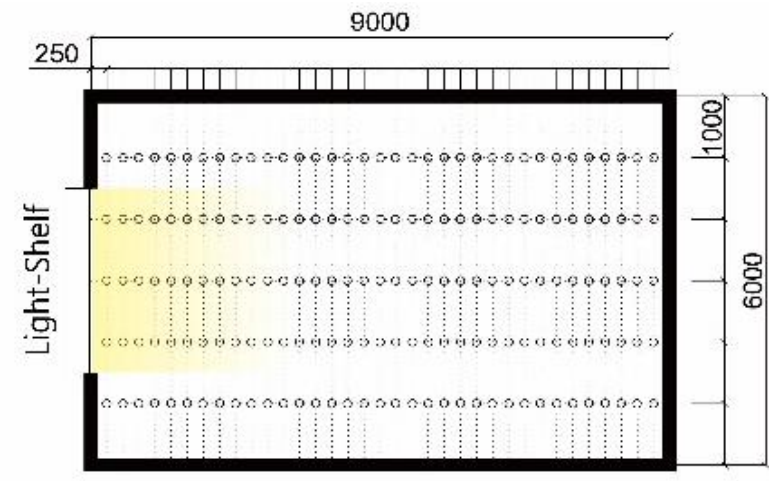
Fig 1.Setting Space for Performance Evaluation[6]

3.2 Setting Light-Shelf Variables and Location to Measure Illuminance

The variables set for the performance evaluation of light shelf are as shown in Table 2. As shown in Figure 2, the measurement positions of illumination for the performance evaluation of light shelf according to the reflection rate of finishing material in the indoor space are at intervals of 250 mm from the window, and the number of measurement positions is 175 positions in 5 rows and 35 columns. Also, the measurement height of illumination in this study was 450 mm from the surface of the floor [6].

Table1.Setting Light-Shelf Variables for Performance Evaluation

Width	Height	Reflectivity	Angle	Solar altitude at meridian passage	
300mm	1800mm	85%	0°	summer solstice: 76.5	winter solstice: 29.5



○: Location to Measure Illuminance

Fig 2.Location to Measure Illuminance[6]

4 Performance Evaluation Result of Light-Shelves

The analysis method used for the performance evaluation of light shelf according to the reflection rate of finishing material in the indoor space is as follows.1) averageilluminance according to reflectivity derived by indoor reflectivity is drawn. 2) uniformity factor is found according to indoor reflectivity. 3) spatial depth meeting 400lx, which is the standard illuminance of living room considered above, is derived. The derivation of depth meeting standard illuminance is the quantitative result of a light-shelf, and is also an important factor linked with lighting use[8].

4.1 Performance evaluation on the summer solstice

The result of theperformance evaluation of light-shelf on the summer solstice according to the reflection rate of finishing material in indoor space is as follows.: 1)averageilluminance rises when reflectivity of ceiling and wall increase during the summer solstice. Average illuminance's change scope by ceiling reflectivity increase is higher than by wall reflectivity increase, therefore, it is advantageous in satisfying indoor illuminance in the case of ceiling reflectivity increase. 2)uniformity factor tends to increase as indoor finishing material's reflectivity becomes higher, and the highest value is revealed, when reflectivity of ceiling and wall are 80%, respectively[9]. However, when ceiling reflectivity is high at 80%, uniformity factor is reduced upon the use of wall finishing material having low reflectivity, which needs to be considered in installing a light-shelf. 3) the spatial depth matching up to standard illuminance moved from 2.25m to 3.0m, according to the increase of reflectivity by each material of wall and ceiling set in this study, which is advantageous to indoor lighting energy reduction in the case of indoor reflectivity increase[6].

Table2.Illuminance Value, according to Reflectivity on the v and Depth Meeting Standard Illuminance on the summer solstice[6]

R (%)		M.I	X.I	A.I	U.F	D(m)	R (%)		M.I	X.I	A.I	U.F	D(m)
F	W						F	W					
50	20	20	14027	429	0.048	2.25	70	70	32	14231	488	0.067	2.75
	30	21	13989	431	0.048	2.25	80	20	16	14276	490	0.033	3.00
	40	26	14107	431	0.061	2.25		30	22	14307	493	0.045	3.00
	50	26	14018	437	0.060	2.25		40	28	14322	493	0.058	3.00
70	20	24	14198	469	0.052	2.75		50	30	14437	496	0.060	3.00
	30	25	14220	475	0.053	2.75		60	36	14308	500	0.073	3.00
	40	30	14303	475	0.064	2.75		70	39	14271	505	0.078	3.00
	50	26	14169	477	0.055	2.75		80	40	14339	514	0.078	3.00
	60	28	14212	484	0.059	2.75							

(R: Reflectivity, F: Ceiling, W: Wall, M.I: Minimum illuminance, X.I: Maximum illuminance, A.I: Average illuminance, U.F: Uniformity factor, D: Depth meeting standard illuminance)

4.2 Performance evaluation on the winter solstice

The result of the performance evaluation of light shelf on the winter solstice according to the reflection rate of finishing material in indoor space is as follows. First, when the reflection rate of ceiling and wall increases on the winter solstice, the average illumination tends to increase, and the average illumination increases more according to the reflection rate of the ceiling than the reflection rate of the wall, so the reflection rate of the ceiling is more advantageous for improving the light environments. Second, the uniformity ratio of illumination tends to increase when the reflection rate of indoor finishing material increases, and the uniformity ratio of illumination was highest when the reflection rate of the ceiling was 80% and the reflection rate of the wall was 60%. During the summer solstice, light is brought in deep into the indoor space due to the low solar altitude. Third, the spatial depth, which satisfied the standard intensity of illumination according to the increase in the reflection rate of each finishing material for wall and ceiling set in this study, was changed from 4.5 m to 5.75 m. This is more advantageous for improving the light environments than the summer solstice. Based on the result above, it is determined that it is appropriate to use finishing material with a reflection rate of 80% for the ceiling and finishing material with a reflection rate of 60% for the wall when installing the fixed-type light shelf[10].

Table3.Illuminance Value, according to Reflectivity on the v and Depth Meeting Standard Illuminance on the winter solstice

R (%)		M.I	X.I	A.I	U.F	D(m)	R (%)		M.I	X.I	A.I	U.F	D(m)
F	W						F	W					
50	20	42.7	23267.8	3160.3	0.013	4.50	70	70	89.8	23301.6	3297.95	0.027	5.25
	30	54.5	23032.4	3174.0	0.017	4.50	80	20	63.2	23341.4	3280.10	0.019	5.50
	40	60.1	23028.9	3185.1	0.018	4.50		30	68.9	23257.7	3295.66	0.020	5.50
	50	65.1	23060.1	3188.9	0.020	4.50		40	80.0	23312.2	3305.30	0.024	5.50
70	20	62.7	23378.8	3240.20	0.019	5.25		50	87.3	23283.4	3304.59	0.026	5.50
	30	62.0	23332.1	3255.32	0.019	5.25		60	115.9	23265.7	3327.88	0.034	5.75
	40	72.2	23270.6	3259.30	0.022	5.25		70	109.3	23283.4	3338.45	0.033	5.75
	50	72.8	23305.1	3266.43	0.022	5.25		80	111.2	23336.8	3352.72	0.033	5.75
	60	93.1	23367.3	3286.38	0.028	5.25							

(R: Reflectivity, F: Ceiling, W: Wall, M.I: Minimum illuminance, X.I: Maximum illuminance, A.I: Average illuminance,U.F: Uniformity factor, D: Depth meeting standard illuminance)

5. Conclusion

This study is a preliminary study on performance evaluation of light shelf according to the reflection rate of finishing material in indoor space for improving lighting performance, and the findings are as follows. 1) The average illumination and the uniformity ratio of illumination were improved when the reflection rate of each indoor finishing material was increased. 2) The satisfactory depth for the standard intensity of illumination at 400 lx was improved from 2.25 m to 3.0 m on the summer solstice and from 4.5 m to 5.75 m on the winter solstice. 3) It is determined that 80% for the ceiling and 80% for the wall are appropriate when installing the fixed type light shelf on the summer solstice, and 80% for the ceiling and 60% for the wall are appropriate when installing the fixed type light shelf on the winter solstice.This study was carried out based on changes in the reflection rate of indoor finishing material, but in the future the scope of research should be expanded through a comparison of light shelf systems that apply user recognition technology and dimming control systems.

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