

# A Preliminary Study on Daylighting Performance Evaluation of Light Shelf based on the Inclined Ceiling during winter solstice

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**Abstract.** Light shelf is considered a solution for the light energy issues, and thus various studies are being conducted with regard to light shelf; however, none of them consider spatial form. Therefore, this study aims to establish basic data for light shelf design by conducting a performance evaluation and producing the optimal plan for spaces with a unique form such as sloped ceiling on the winter solstice. The conclusion is as follows: 1) light shelf with a negative (-) angle on the winter solstice is inappropriate as the ceiling does not reflect the light in the inflow of natural light. 2) There are no changes in the depth that satisfies the standard intensity of illumination depending on non-installation and installation of light shelf on the winter solstice. 3) The installation of light shelf on the winter solstice has a low distribution of average illumination compared to non-installation, while the uniformity ratio of illumination is improved. 4) The optimum light shelf standard considering the uniformity ratio of illumination as well as energy saving with regard to the space of sloped ceiling on the winter solstice is the width of 300mm and the angle of 10°.

**Keywords:** Spatial, Physical Form, Light-Shelf, Performance Evaluation.

## 1 Introduction

Light shelf is considered one of the most efficient solutions for the light energy issues in buildings, and thus various studies have been conducted. However, none are based on information of the form of indoor space in which the resident is directly related, which may be a problem in Light shelf design.

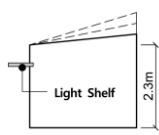
Therefore, this study aims to establish basic data for Light shelf design by analyzing Light shelf performance evaluation and producing the optimal plan for spaces with a sloped ceiling, which is a unique form of indoor space.

## 2 Set up of Performance Evaluation of Light shelf for Inclined Ceiling

### 2.1 Setup of Inclined Ceiling and Light shelf

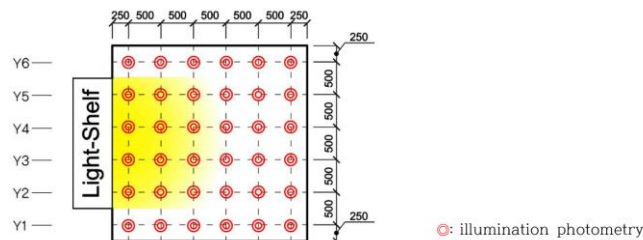
Table 1 includes contents regarding the setting of the Light shelf and sloped ceiling.

**Table 1.** Setup of Depth of Space and Light shelf

 <p>Setup of Inclined Ceiling</p>	<p>① The form of sloped ceiling reflects the lighting performance evaluation of the Light shelf by increasing the maximum ceiling height of indoor space to 2,600mm, 2,900mm and 3,200mm on the basis of the minimum ceiling height 2,300mm.</p> <p>② Positive (+) angle sloped ceiling: The height of the rear is adjusted to 2,600mm, 2,900mm and 3,200mm on the basis of the lighting surface (height: 2,300mm) on which the Light shelf is implemented.</p> <p>③ Negative (-) angle sloped ceiling: The height of the lighting surface on which the Light shelf is implemented is set up as 2,600mm, 2,900mm and 3,200mm, and the ceiling height of the rear is fixed to 2,300mm.</p>		
	Reflectivity	Ceiling:74.99%, Wall:55%, Floor:25.1%	
Window Area Ratio / Glass Material	2.0m x 1.8m / Pair-glass with 12mm thickness, penetration ratio:80.82, clear colors		
Height	1.8m	Angle	0°, 10°, 20°, 30°
Width	0.3m, 0.6m	Reflectivity	85.77%

### 2.2 Position for Measurement of Illuminance for Performance Evaluation

The location of illuminance calculation is as shown in Figure 1, and the height is set as 0.75m above the floor based on related research.



**Fig. 1.** Illumination photometry for Light shelf's performance evaluation

## 3 Performance Evaluation of Light shelf for Inclined Ceiling

Performance evaluation according to the sloped ceiling form on the winter solace as well as the Light shelf variable is as follows. First, as shown in Tables 2, the winter

solace has the same spatial depth that satisfies the standard illumination whether the Light shelf is installed or not, regardless of the ceiling height in the form of slope ceiling with the spatial depth of 3m and 6m. Moreover, in the case of sloped ceiling, increase in the ceiling height and the width of Light shelf appear as unsuitable due to the decrease in the spatial depth that satisfies the standard illumination. On the other hand, increase in the angle of the Light shelf is suitable for energy saving as the spatial depth that satisfies the standard illumination is increased. Second, when installing a Light shelf in a space with a sloped ceiling on the winter solace, the indoor average illumination appears to be low compared to when the Light shelf is not installed, which may be influenced by the awning of the Light shelf. Furthermore, increase in the angle of the Light shelf that reduces the shaded area tends to increase the indoor average illumination, while increase in the width of the Light shelf that increases the shaded area tends to reduce the indoor average illumination. Third, in the case of a sloped ceiling on the winter solace, the optimum Light shelf standards considering energy saving and uniformity ratio of illumination are the width of 300mm and the angle of 10° regardless of ceiling height.

**Table 2.** Light shelf performance evaluation based on the inclined ceiling during winter solstice(Depth : 3m /6m)

Depth : 3m										
L. S.		Ceiling height 2450mm			Ceiling height 2600mm			Ceiling height 2750mm		
W	A	S.I. (m)	A.I. (lx)	U.F.	S.I. (m)	A.I. (lux)	⊕	S.I. (m)	A.I. (lx)	U.F.
N		3.00	18394	0.054	3.00	18336	0.053	3.00	18277	0.050
0.3	0	3.00	15619	0.067	3.00	15556	0.063	3.00	15517	0.063
	10	3.00	15639	0.065	3.00	15565	0.063	3.00	15517	0.061
	20	3.00	18375	0.056	3.00	17892	0.049	3.00	18268	0.051
	30	3.00	18352	0.053	3.00	18289	0.052	3.00	18241	0.049
0.6	0	3.00	15553	0.069	3.00	15491	0.067	3.00	15432	0.063
	10	3.00	15604	0.067	3.00	15525	0.063	3.00	15467	0.062
	20	3.00	15596	0.064	3.00	15541	0.062	3.00	15489	0.060
	30	3.00	18310	0.053	3.00	18268	0.050	3.00	18213	0.049
Depth : 6m										
W	A	Ceiling height 2450mm			Ceiling height 2600mm			Ceiling height 2750mm		
N		5.75	9488	0.040	5.75	9450	0.039	5.75	9412	0.039
0.3	0	5.75	8061	0.043	5.25	8021	0.043	5.25	7997	0.043
	10	5.75	8081	0.045	5.75	8048	0.044	5.25	8012	0.044
	20	5.75	9472	0.039	5.75	9427	0.036	5.75	9387	0.035
	30	5.75	9451	0.039	5.75	9414	0.038	5.75	9376	0.037
0.6	0	5.25	8006	0.040	4.75	7965	0.039	4.75	7942	0.039
	10	5.75	8048	0.044	5.75	8009	0.042	5.25	7971	0.042
	20	5.75	8071	0.042	5.25	8029	0.044	5.25	8001	0.041
	30	5.75	9426	0.038	5.25	9393	0.036	5.25	9345	0.035

W: Width of Light shelf, A: Angle of Light shelf, N: Light shelf not installed,  
 S.I.: Standard illuminance satisfaction degree(m), A.I.: Average illuminance, U.F.: Uniformity factor,  
 : This indicates lower score than the value estimated with no Light shelf installed, Bold: Ceiling value of uniformity factor

**Table 3.** Shaded and Reflection area based on the Width and Angle of Light shelf during

Light shelf		Shaded area(m <sup>2</sup> )	Reflection area(m <sup>2</sup> )	Light shelf		
Width(m)	Angle			Angle	Shaded area(m <sup>2</sup> )	Reflection area(m <sup>2</sup> )
0.3 / 0.6	0°	0.600 / 1.200	0.600 / 1.200	20°	0.201 / 0.402	0.600 / 1.200
	10°	0.406 / 0.813	0.600 / 1.200	30°	0.011 / 0.021	0.000 / 0.000

summer solstice

## 4 Conclusion

This study conducted a performance evaluation and produced the optimal plan according to the variables of sloped ceiling and Light shelf, which has significance as the basic data for Light shelf design in the future. The conclusion is as follows. First, inflow of light by the negative (-) angle Light shelf on the winter solace is unsuitable for improving lighting performance as there is no reflection on the ceiling. Second, the winter solace has the same spatial depth that satisfies the standard illumination whether the Light shelf is installed or not, regardless of the ceiling height in the form of slope ceiling with the spatial depth of 3m and 6m. Third, when installing a Light shelf on a sloped ceiling on the winter solace, the indoor average illumination appears to be low compared to when the Light shelf is not installed. Moreover, increase in the Light shelf angle that reduces the shaded area tends to increase the indoor average illumination. Fourth, in the case of a sloped ceiling on the winter solace, the optimum Light shelf standards considering energy saving and uniformity ratio of illumination are the width of 300mm and the angle of 10° regardless of ceiling height. This study is significant in establishing the basic data for Light shelf design on spaces with the unique form of a sloped ceiling while also having limitations. Thus it is necessary to continue evaluating the performance of spaces in various forms.

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