DOR: 20.1001.1.24234931.1401.9.1.10.1

Original Article | Volume 9, Issue 1, Spring & Summer, p. p. 32-35

Received: 05/24/21 | Journal of Renewable and New Energy

Accepted: 07/12/21 | jrenew.ir

Investigating the Effect of Clerestory Window Components to Improve Daylight Illuminance in Pitched Roof Buildings in Humid Climates

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Received: 24 May 2021 Accepted: 12 July 2021

Abstract

Clerestory windows are one of the best ways to increase the penetration of light in Low-rise buildings. However, in rainy climates with cloudy skies, receiving daylight will be more critical. Since the physical component of buildings in this climate varies according to the type of roof slope, the shape of the interior roof, and the plan's geometry. The fundamental question is: What physical characteristics can receive the maximum light from the Clerestory window in Pitched low-rise buildings? The research aimed to investigate the potential of Clerestory to improve daylight in a Pitched-roof. In the present study, Rhino software was used to design 3D models, and the Diva plugin in Grasshopper software was used to evaluate the “daylight factor.” Data indicate that; regardless of the geometry of the plan and form of internal reflection, the most effective component is the “roof slope ratio,” which creates the most significant change in interior lighting. Moreover, the 18-degree roof slope with a ceiling ratio (4-12) is the best efficiency, and provides 3.3% (A.DF) among the various. By considering the slope of the roof component and the shape of the interior reflector, the geometry of the square plan creates more appropriate daylight in the interior space.

Keywords: Clerestory window, Daylight, Pitched Roof, Overcast Sky

1. INTRODUCTION

The utilization of unsustainable resources has led to a health crisis, limited energy resources, and environmental pollution, which has made it necessary to pay attention to renewable energy. Since Clerestory windows are one of the most common methods for penetrating light to pitched roofs, studying their behavior in cloudy skies under different physical conditions can be helpful for designers. Therefore, by extracting the physical components of clerestory windows and testing each of them in different conditions, the optimal pattern of Clerestory in Pitched roofs will be obtained [1,2]. On the other hand, since there is a research gap in the light behavior of these openings in pitched roofs spatially in temperate and humid climates, it will be doubly important to address it and the need for extensive research in the field of daylight supply solutions in these buildings. Will be considered [3].

However, choosing the right solution to transfer daylight into the building has always been associated with many challenges, given the multiplicity of available parameters; prescribing proper opening makes it difficult. On the other hand, any solution to improve light efficiency in space must be based on the climatic parameters of the region and the physical conditions of the building and the city [4-6]. Limited studies have been performed on Clerestory windows in pitched roofs, but the role of roof angles or internal roof characteristics in daylight behavior in space has been neglected [7-10]. This study aimed to investigate the ability of these windows to improve daylight brightness and provide visual comfort in short, low-sloping buildings.

2. METHODOLOGY

2.1. Calculation conditions

Considering the problem, the evaluation of the productivity of Clerestory window in cloudy sky conditions is considered; in this regard, the evaluation of the “daylight factor” component is calculated by considering the sky without neighborhood barrier and in cloudy sky conditions. [11-14]. In the present study, Rhino software was used to design 3D models, and also “Diva” plugin was used in “Grasshopper” software to evaluate the “daylight factor” component, which uses “Radiance” and “Daysim” computing engines for calculations [15]. The model used in the tests is a building with a pitched roof, with a fixed area in three different geometries, which is associated with the ratio of the slope of the variable roof and the pattern of the false roof - internal reflector - variable. The test model was extracted in the first instance, assuming a constant area, three different geometries of square, transverse rectangle, and longitudinal rectangle . Next, three roof alternatives were modeled in concave, convex, and flat internal reflective roof form. In the next step, the common eight slope interval for all three roof alternatives will be evaluated in three different plans [16]. (Table 1)

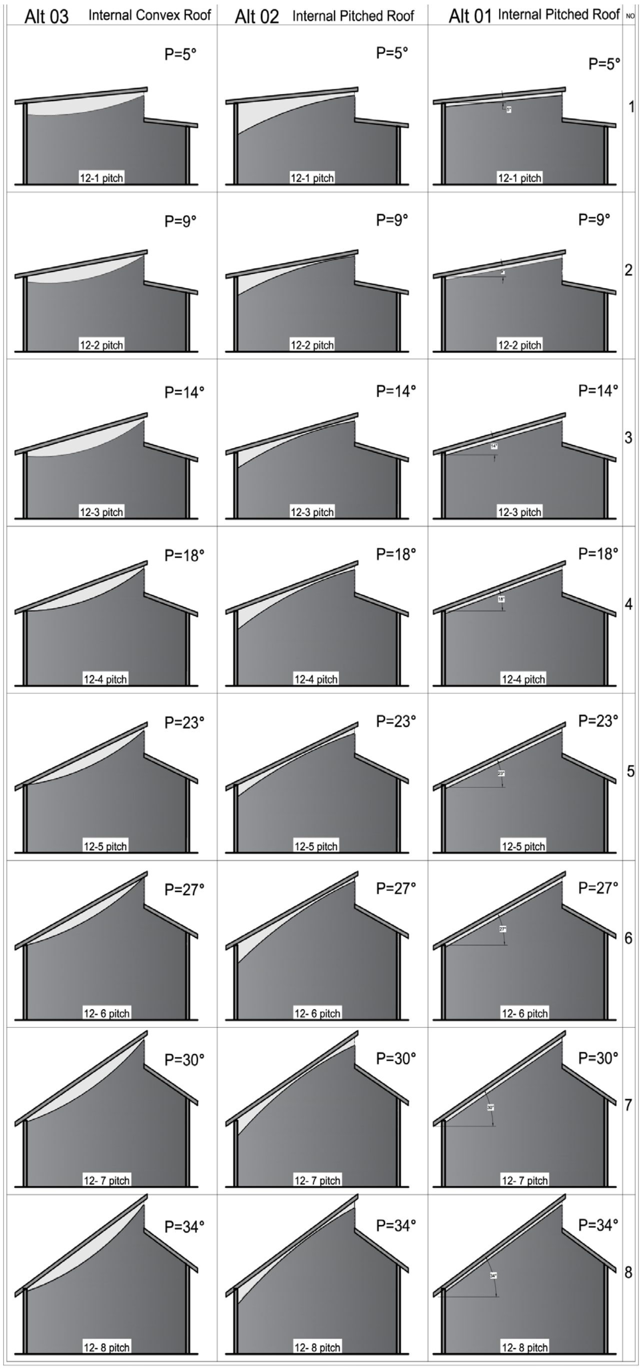

Table 1 Cross-section of test models in octagonal slope ratio

3. Data collection and analysis

3.1. Investigation of roof opening efficiency in a square plan

In the initial part of the analysis, the geometry of the square plan was evaluated in three alternatives of the interior roof pattern, and the daylight factor was measured in three intervals of minimum, average and maximum. Eight ceiling slope variables were applied for each alternative, and daylight factor was measured on the work surface. The results of the above test are listed in Table 2. The data show that regardless of the form of internal reflection, the highest light output is obtained. Therefore, in the square plan of the slope range (4-12), regardless of the reflective form, they played the most critical role in increasing daylight reception in Clerestory windows.

Table 2, Evaluation of daylight factor of the three alternatives in the square plan

(Daylight factor) %									Roof Angle	Roof Type
ALT 03			ALT 02			ALT 01				
Min	Ave	Max	Min	Ave	Max	Min	Ave	Max		
0.17	0.715	1.26	0.52	1.59	2.66	0.3	1.095	1.89	5°	12-1 Roof
0.65	1.305	1.96	0.95	1.98	3.01	0.75	1.705	2.66	9°	12-2 Roof
0.82	1.74	2.66	1.45	2.615	3.78	0.9	2.13	3.36	14°	12-3 Roof
1.9	2.9975	4.095	**2.19**	**3.335**	**4.48**	**1.3**	**2.4525**	**3.605**	18°	12-4 Roof
1.98	**3.1075**	**4.235**	0.87	1.87	2.87	1	2.2675	3.535	23°	12-5 Roof
0.97	1.9725	2.975	0.73	1.555	2.38	0.87	2.01	3.15	27°	12-6 Roof
0.53	1.399	2.268	0.43	1.23	2.03	0.68	1.53	2.38	30°	12-7 Roof
0.29	1.02	1.75	0.25	0.888	1.526	0.3	1.13	1.96	34°	12-8 Roof

3.2. Investigation of roof opening efficiency in Rectangle plan Rec 01

The data show that at the slope of the ceiling (4-12), the most light is received regardless of the form of internal reflection. On the other hand, in Alternative 2, the slope (4-12) has the highest reception, which means that in the geometry of a rectangular plan, the concave internal reflector has a better performance than the other two options, and as the slope of the roof increases, this pattern's superiority is reduced, and it is placed in the lowest rank in higher slopes.

3.3. Investigation of roof opening efficiency in Rectangle plan Rec 02

Examination of the data shows that the maximum average receipt in this plan geometry is also related to the slope of the roof (4-12). On the other hand, in Alternative 2, the slope (4-12) has the highest reception, which means that in the geometry of a rectangular plan, the concave internal reflector has a better performance than the other two options, and as the slope of the roof increases. The superiority of this pattern is reduced, and it is placed in the lowest rank in higher slopes.

4. Conclusions

Data indicate that in celestial skylights; regardless of the geometry of the room plan and also the internal reflective form of the roof, the most effective component in the performance of skylights is the slope ratio of the roof, which creates the most significant change in indoor lighting (4-12). Slope ratio in all tests has gained the ability to provide 3.35% DF and has been achieved only in Alt 1 and in the two geometries of the rectangular plan in the range of 1.7 to 2.41 % DF. This is while the slope ratios (5-12) and (3-12) in different tests have experienced the ability to obtain daylight factor above 1.5%.

Considering the cloudy sky conditions and daylight lighting standards, the illumination range provided in the above three slope ratios is very significant. Examination of the results shows that the slope ratio (8-12) in any plan geometry condition and any internal reflective form; has the lowest efficiency of receiving daylight in all cloudy sky conditions. On the other hand, studies show that by constantly considering the component of the roof slope and the form of internal reflection, the geometry of the square plan, among the three geometries of the research plan, creates a more appropriate light behavior in the interior. In the second stage, the geometry of the rectangular plan (Rec01) has better conditions than the third geometry (Figure 1).

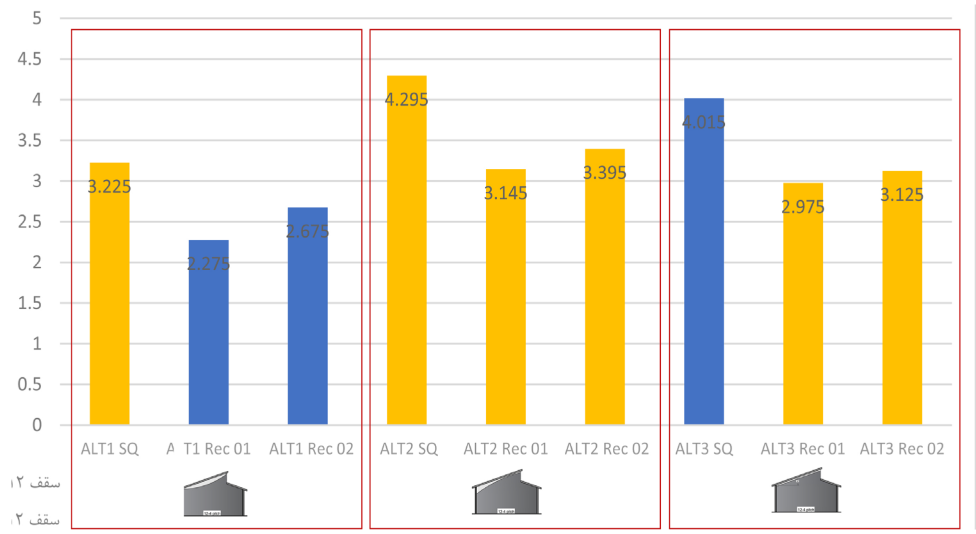

Figure 1. Comparison of all alternatives in terms of DF reception levels

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