Influence of surface parameter on adjacent space in atrium office building

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***Abstract*— The reflective characteristics of the surfaces enclosing an atrium space can significantly influence the distribution of daylight in adjacent spaces. The aim of this research was to examine the influence of atrium geometry and surface reflectance distributions on daylight level at the base of the atrium. Ecotect and Radiance programmes were used to simulate square, four-sided, saw tooth and top-lit atria under sunny and clear sky conditions. For each of the experiments the range of reflect were 0.2, 0.4 and 0.6. Models were built for atriums with a well index of 0.5, 1 and 2. Finally some conclusions for supporting daylight design in atria are presented.**

Keywords- Atrium, daylight, radiance simulation, surface reflect

I. INTRODUCTION

Today, atria are used in relatively modern buildings including office buildings, shopping malls and hotels. The atrium space has proved itself to be popular with both building designers and building users [13]. Also, using daylight as part of an integrated and controlled lighting strategy is a key component of a sustainable, environmental approach to architectural design [14]. Studies have shown that Daylight has advantages in terms of sustainability, work efficiency, energy efficiency, and human health [8, 9].

The use of daylight by an atrium is one of the best ways to enhance the energy efficiency and improve the indoor environment against external harsh conditions [3] and it can radiuses electrical energy and need to artificial lighting in adjoining spaces [7].

McHugh et al. (1998) showed that 90 percent of office workers would prefer to sit near a window and in offices with more sunlight, and that work time tends to be longer when appropriate sunlight exists.

The important parameters in the day lighting of atrium buildings are the shape of the atrium and its orientation to the sun, the transmittance of the roof, the reflectivity of the atrium surfaces and the glazed areas, which affect the daylight conditions in the adjoining space and on the atrium floor. [4]

In this project at first, an attempt was made to gain some further understanding of the problem through an experimental study of the effect of atrium roof and atrium roof obstructions upon the daylight in atrium buildings. Then compare influence of reflectance of wall in to interior amount of daylight in adjoining space.

A. *Adjoining space*

Atria provide opportunities for daylight to enter into the heart of a building and thereby potentially increase the amount of occupied space in large buildings that can be naturally tit. In addition, an atrium might provide the adjacent spaces with a link to the 'exterior terms of variations in natural light levels.

The quantity and quality of natural lighting in the spaces adjacent to an atrium are dictated by (i) the natural light within the atrium as dictated by its roof and enclosing walls; (ii) the aperture and internal reflective characteristics of the space.

The area adjacent the atrium is built as an open space 6 m wide from the atrium wall to the external wall. In the scale model the wall and floor surfaces were simulated using black colour and in the computer simulation the same reflectance values are used. The choice of a reflectance value of 0.2 for the atrium walls (completely black) is due to the need of evaluating, in the experimental analysis of the scale model under real sky conditions, only the contribution of the atrium to the global lighting conditions without any contribution of the light reflected by the atrium walls. The successive numerical simulation reproduces the same conditions explained above to obtain a comparison between experimental and numerical data and as a result a validation of the software. In a second step the effect of three different reflectance values of the atrium walls were analyzed by the computer simulation with the aim of evaluating the contribution of the walls reflected.

B. Atrium shape and geometry

The daylight performance of an atrium is strictly dependent on its geometrical aspect. According to Liu et al. [10], Baker et al. [1], Kim and Boyer [5], the shape of an atrium can be described and quantified with a geometric parameter, such as the WI which represents the relationship between the light-admitting area and the surface area of the atrium. Three basic geometric parameters such as PAR, SAR [2] and the WI, which is a combination of PAR and SAR, will be used to study the relationship of daylight distribution and geometry of atriums:

$$\text{PAR} = \frac{\text{Width}}{\text{Length}} \quad (1)$$

$$\text{SAR} = \frac{\text{Height}}{\text{Width}} \quad (2)$$

$$\text{WI} = \frac{H(W+L)}{2WL} \quad (3)$$

This parameter permits a comparison between several atrium shapes connected with a specific height of the building. In this paper ten cases are analysed using as parameter the "Well Index"; Table 1 sums up the atrium geometric characteristics in terms of Well Index, plan and section aspect ratio. The range of validity of the analyses depends on the previous ten cases with a WI included between 0.38 and 1.68.

Table1. Well index and PAR and SAR of the analysed atria

Width×Length (m×m)	Height (m)	WI	PAR	SAR
8.5× 10	3.5	0.38	0.85	0.4
8.5× 10	7	0.8	0.85	0.8
8.5× 10	10.5	1.25	0.85	1.2
8.5× 10	14	1.68	0.85	1.6

In this study, four-sided square atrium spaces with different well heights were selected as atria. In order to create atrium spaces of different heights, a total of rectangular atrium-side modules measuring 8.5m (w) , 10m
(l), 21m (h) were constructed as shown in Figure 1. The window area was covered by a clear glass sheet to simulate the specular effect of window glass.for solid area choose 0.2, 0.4 and 0.6 reflectance. As this study focused on daylighting in the atrium space itself, all of the wall selected without window.
Tow shape roof were selected in this stady showed in figure 1.

Figure1-roof shape and model study

II. VALIDATION ANALYSIS

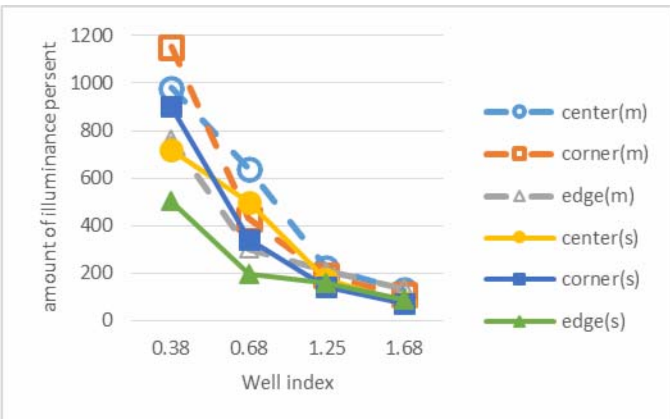
A. Radiance application and validation review

The development of RADIANCE began in 1988 by Ward at the Lawrence Berkeley National Lab. The calculation method used by Radiance is a light backward ray tracing approach in which the path of a ray reaching the eye or a measurement point is traced back to an object in the scene and then to the light source. Each ray has certain intensity or 'weight', which changes after intersecting a surface depending on the reflection. RADIANCE can be used to model lighting or daylighting in a complex space, and can also provide realistic pictures of the modelled environment which could be helpful for the evaluation of visual comfort and light quality. Sky conditions can be set as clear sky (with or without sun), CIE standard overcast or uniform sky [3].

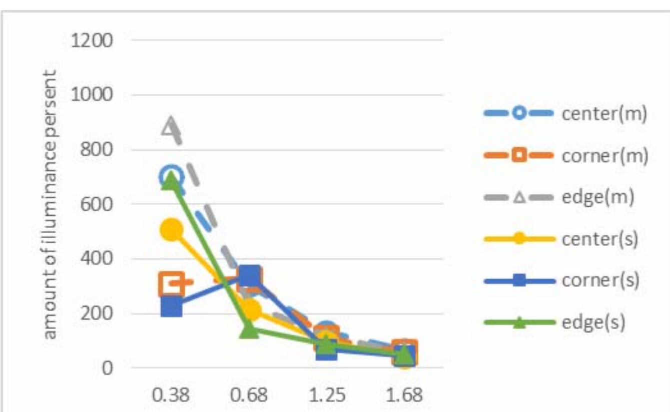
Radiance has already been validated by several studies over ten years ago [11,12,15].These investigations showed Radiance simulations could achieve a relatively high accuracy in typical daylit spaces compared with model measurements and theoretical analysis. Today it has become the most powerful package for simulating complex scenes and supplying more precise results. A recent study [6]. The discussion about Radiance applications in it showed that ambient parameters settings are quite crucial for the accuracy of simulated data; improper ambient parameters could bring big errors and convergence testing is essential for each different model.

B. Comparison of measurement and simulation

In this study, for scale atrium models with different well indext were reproduced in a ecotect and input into Radiance to calculate the amount of daylight under a suny and clear sky. There were three positions to be studied :center, corner and edge of atrium floor.



a.saw tooth roof shape



b.toplit roof shape

Figure 2: Comparison of illuminance level between measurement (m) and simulation (s):
a.saw tooth roof shape
b.toplit roof shape

Figure 2 illustrates the comparison between the measured data and the simulated data for the illuminance level along the centre of atrium. For the relative difference of illuminance level between simulation and measurement, the maximum, minimum and mean values are 16%, 0.3%, and 8% respectively. This section has demonstrated that Radiance simulation could be a reliable method to carry out calculation of the illuminance level on the atrium walls, although there are some small discrepancies.

C. Daylight analysis

Atrium roof shape and structure can have a maximum efficiency to provide inside lighting when in addition to provide required lighting quantity in internal space, can create a uniform distribution of lighting in the room and to avoid creating a daze as possible. Based on research conducted by Nabil and Mardaljevic J.to provide an assessment scale of natural lighting intensity regarding human visual needs in various activities in 2005, 300- 900 lux lighting amount was suggested as accepted lighting interval [7,1].(Table1)

Table1)Useful Daylight Illuminance (UDI) is a modification of Daylight Autonomy conceived by Mardaljevic and Nabil in 2005.

illumination ranges	Lighting condition
<100 lux	fell-short daylight
100-300 lux	Relatively inefficient lighting
300-900 lux	achieved daylight
900-2000 lux	Useful daylight
> 2000 lux	exceeded

D. Daylight in atrium floor

In this section to compare illuminance in atrium floor simulation all model in three hours (9-12 and 15) and with diferent reflectance (0.2-0.4 and 0.6) then average annual illuminance calculated. As seen in table 2-7, the greatest influence of atrium reflected change is increase the minimum illuminance level (100-300 lux). The increase reflected from 0.2 to 0.4 for top lit atrium, increase amount of illuminance in use full day light (300-2000 lux) between 1-12% and for saw tooth is 1-8%. When reflectance increase 0.4 to 0.6 for top lit roof amount of use full illuminance level 5-11% in crease and for saw tooth roof range of illuminance is between 7-11% .

Table2. comparing of amount illuminance present in saw tooth atrium with 0.2 reflectance surface

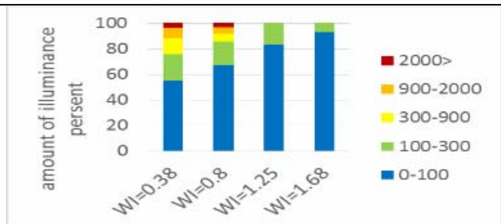
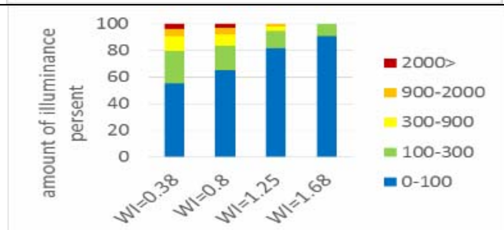
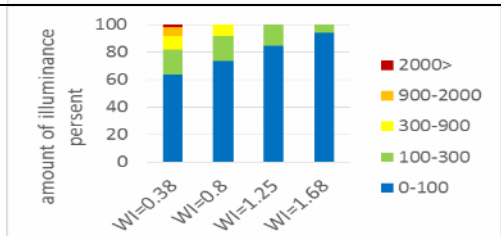
	Sawtooth roof- 0.2 reflectance
9 am	
12am	
3pm	

Table3. comparing of amount illuminance present in toplit atrium with 0.2 reflectance surface

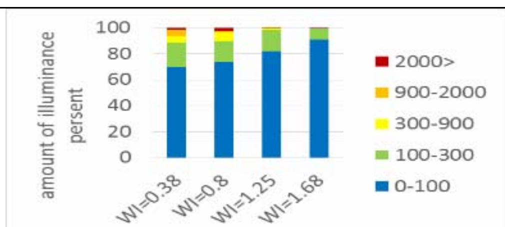
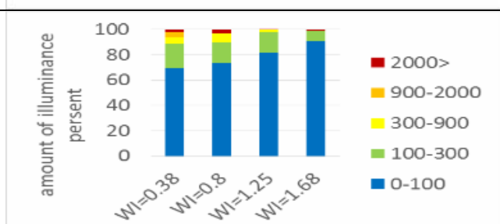
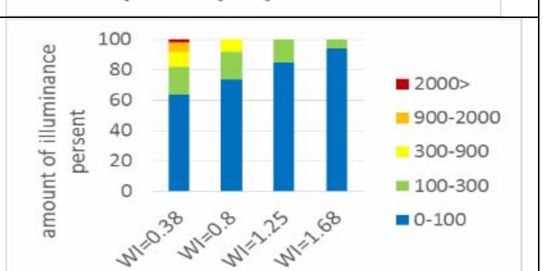
	Top lit roof – 0.2 reflectance
9 am	
12 am	
3 pm	

Table4. comparing of amount illuminance present in toplit atrium with 0.4 reflectance surface

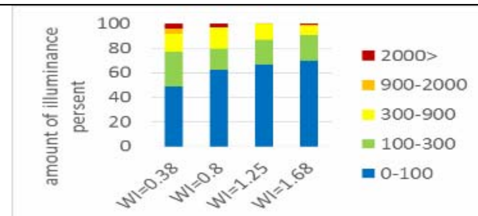
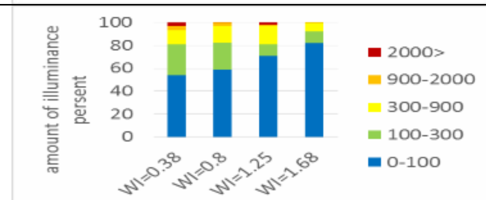
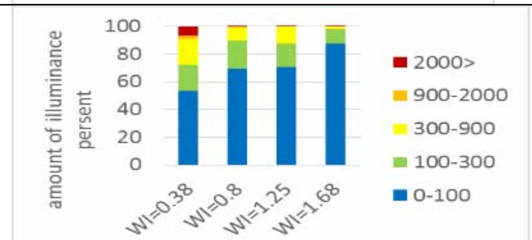
	Top lit roof- 0.4 reflectance
9 am	
12 am	
3 pm	

Table5. comparing of amount illuminance present in saw tooth atrium with 0.4 reflectance surface

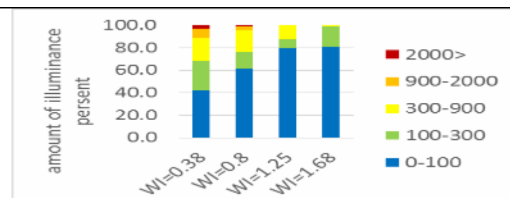
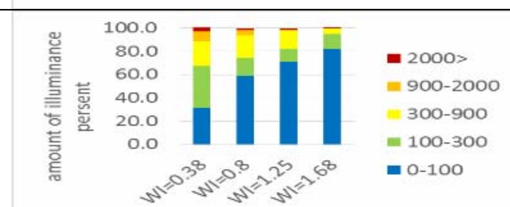
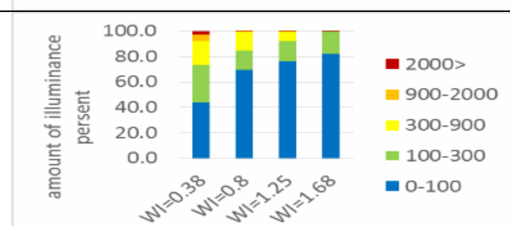
	Saw tooth roof- 0.4 reflectance
9 am	
12 am	
3 pm	

Table6. comparing of amount illuminance present in saw tooth atrium with 0.6 reflectance surface

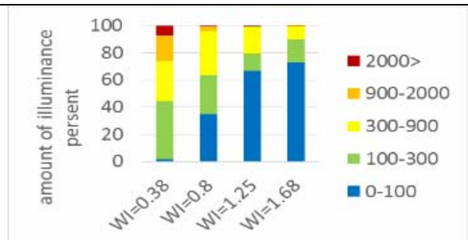
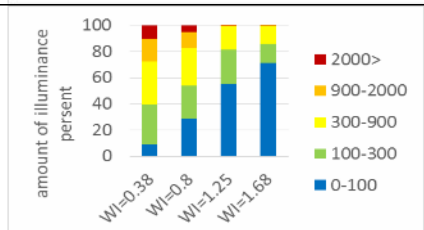
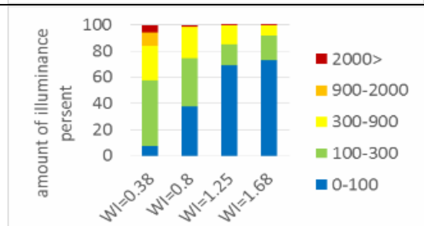
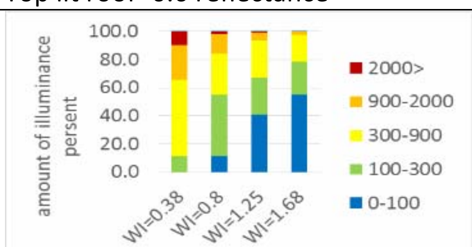
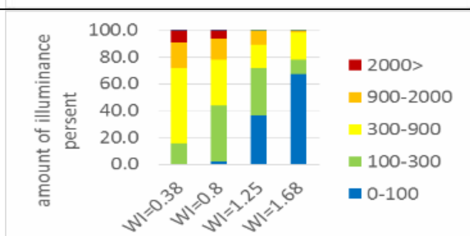
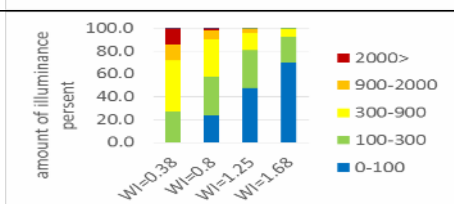
	Saw tooth roof- 0.6 reflectance
9 am	
12 am	
15pm	

Table7. comparing of amount illuminance present in toplit atrium with 0.6 reflectance surface

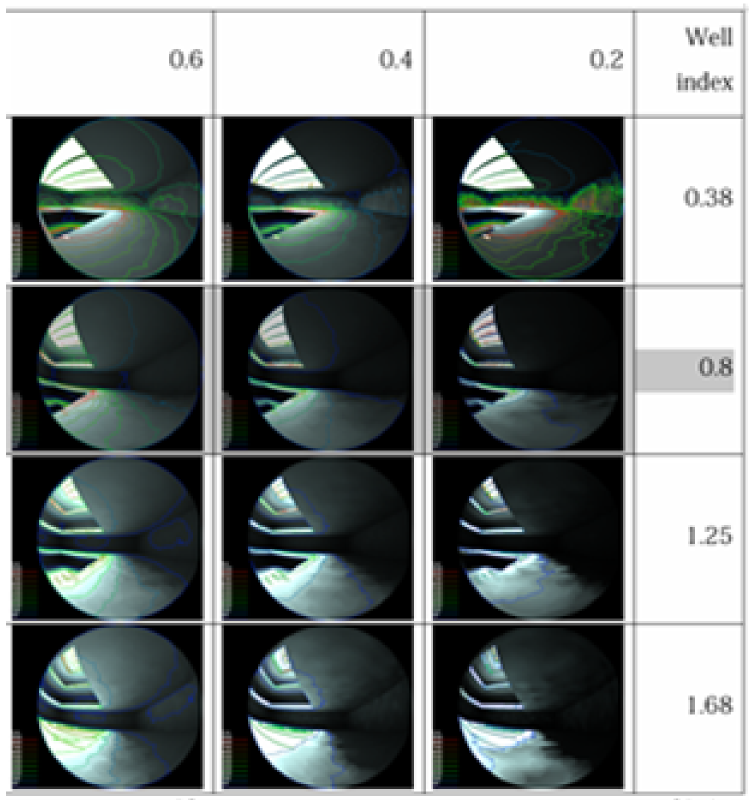
	Top lit roof- 0.6 reflectance
9am	
12 am	
3 pm	

E. *Day light in adjoined space*

In this section, the effect of light reflecting surfaces on the adjacent space is analysis. Referring to the previous paragraph the ten atrium model were simulated also using three different reflectance values of the atrium walls to show the contribution of the light reflected by the atrium surfaces. The final aim of the simulations is to obtain a correlation between the Well Index and the Daylight level for three different reflectance values. Figures 3 give the immediate reading of the curve of equal illuminance level. For top lit with increase reflect from 0.2 to 0.4 perimeters zone in adjoin space average increase up to 1 m while when surface reflectance increase to 0.6 the premieres zone increase up to 1.5-2 meters.

For saw tooth roof the distribution interior day light slightly different. when increase reflect from 0.2 to 0.4 perimeters zone in adjoin space average increase up to 0.5 -1 m while when surface reflectance increase to 0.6 the premieres zone increase up to 1-2 meters.

A: Saw tooth roof



B: Top lit roof

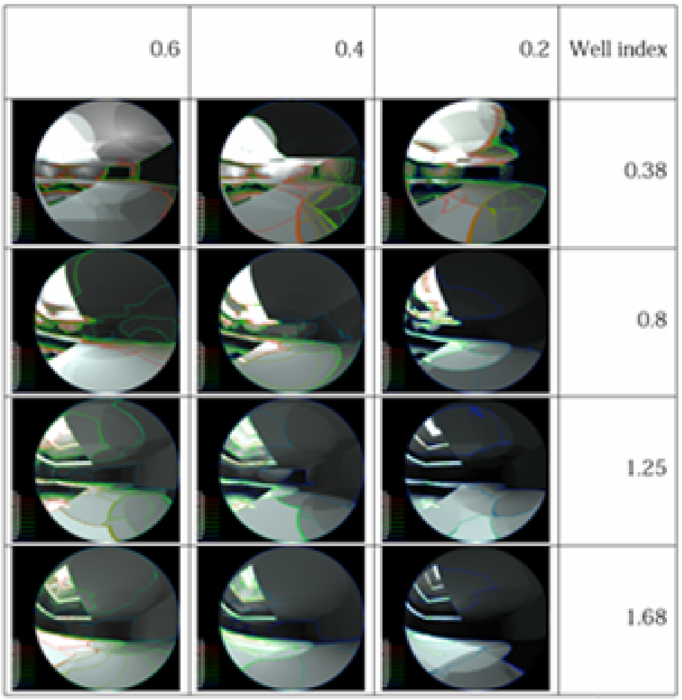


Figure 3. Amount of illuminance in adjoinspace with diferent roof shape atrium (a: saw tooth roof, b: top lit roof

III. CONCLUSION

In this study the impact of well geometry and surface reflectance on daylight level in square atria under with different atrium roof shape in a sunny and clear sky has been investigated. By reviewing some previous applications and comparing the outputs from scale model measurements, the predicted daylight levels from Radiance simulations were shown to be accurate. More simulations to determine daylight levels for a much wider geometric and reflectance range of atrium models were then performed. In terms of the reflectance of atrium surface and the horizontal distribution of daylight level on atrium floor and adjoin space have been analyzed. According this study the effects of increasing the floor reflectivity, although limited to the ground floor of atria, are significant in raising the daylight levels in adjacent spaces at that level. In general increase of 0.4 reflects has a greater impact on the interior lighting and its distribution in the adjacent space.

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