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IMPACT OF ATRIUM PROPORTIONS ON THE DISTRIBUTION OF DAYLIGHT LEVEL ON THE ADJACENT SPACE IN THE SHOPPING MALL OF DHAKA CITY

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Abstract: This paper investigated the impact of well proportions (WI-Well index) on the vertical daylight factors of walls in atria under a CIE standard overcast sky. Field survey was conducted in two shopping malls- Plaza A.R. and Bashundhara City Shopping Complex (BCSC) of Dhaka city. The atriums of BCSC is very deep (WI- 3.75) and were rectangle in size whereas in Plaza A.R the shape is very close to Square (WI- 2.25). Daylight distribution curve were produced and analyzed. It is found that in BCSC the ground and first floor receive almost zero daylight. In the case of Plaza A.R. the extension of floors in atrium create obstacles in penetrating daylight in second floor, but as the first floor is raised in the atrium the first floor receives much daylight. The 3D models were then generated in the Ecotect to study the distribution of daylight in the adjacent space. These models were then exported to a physically-based backward ray tracer, Radiance Synthetic Imaging software to generate realistic lighting levels. More simulated vertical daylight factors for a very wide range of atrium proportions (Changing the WI) are given. Some guidelines for supporting design are presented.

Keywords: Atrium proportion, daylight level, Radiance simulation.

Introduction

Atrium has become a significant architectural form over the past 30 years in that it can help resolve many environmental issues. This is particularly true in deep plan commercial and office building to allow natural light to reach potentially dark core areas. Architects and engineers have often used atria as a sustainable design strategy to achieve benefits such as passive heating and cooling, ventilation and day lighting. Daylight use in an atrium is particularly beneficial as the atrium well can decrease energy consumption by reducing artificial lighting use.

Daylight performance of an atrium is complex and depend on the pre dominant sky conditions in which the building stands, the roof geometry, reflectance and fenestration system, atrium orientation and geometry, design of the atrium facades including reflectance of its walls (glazed and opaque areas) and floor surfaces and the characteristics of adjacent areas. In this study, the whole analysis will be focused on investigating the impact of atrium

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proportions (WI well index) on vertical daylight levels. Radiance a ray-tracing package, was used to present vertical daylight factors for a wide range of atrium proportions under CIE overcast sky. The analysis will help taking preliminary atrium design decisions at the very early stage of design.

Validation analysis

Radiance application and validation review

For atrium day lighting, Radiance is an indispensable tool in that it could carry out investigation more efficiently than other methods. In one paper (Calcagni and Paroncini, 2004), which investigated the main characteristics of the atrium and their influences on the daylight conditions in the adjoining space and on the atrium floor, most of the results achieved were based on the Radiance simulations. Another recent study (Samant and Yang, 2007) focused on Radiance simulation and the influence of geometry and surface reflectance distribution on daylight factors at the base of atrium. A very important study concerning Radiance validation was carried out in atrium spaces by Aizlewood et al., (1997). It has been found that in atria with a simple square plan and open roof Radiance simulations agreed well with measurements, but slightly underestimated light levels for deeper atria and high reflectance surface. Later, the results were quoted in an IEA report (Fontoynont et al., 1999), which demonstrated the validation analysis of five packages for lighting simulation. 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.

Selection of atrium

In studying BCSC, central circular atrium is not selected due to lateral lights addition with skylight. Others internal atrium are of same size but orientation are different. But for this study orientation is not considered, so randomly an atrium is taken. In Plaza A.R. the central atrium is surrounded by shops and skylight is the only source of daylight. The selection of this atrium is because of its importance in design aspect in architecture of Bangladesh and also for varying well proportions.

Methodology

In this study from Literature review the basic characteristics of day lighting in atrium space is studied. From field survey lighting level were measured with the help of light meter in two shopping mall atrium each of them having different atrium proportions. Then a physical model of the building were made with the help of ECOTECT software and render through

Radiance (ray-tracing package). Simulation of day lighting levels in different level of atrium with various atrium proportions were analyzed and compared with the field data to see the change.

Literature review

WI (well index) as a measurement tools for atrium proportions.

Jiangtao Du, Steve Sharples 2009 in their study Radiance simulations were used to analyze the impact of well geometry and surface reflectance on vertical daylight levels under a CIE standard overcast sky. Well geometry can be quantified in terms of the well index (WI), which is a function of well length, width and height.

WI=h (W+L)/ 2WL

W: atrium width

L: atrium length

h: atrium height

WI: well index

Sky conditions of Dhaka city: The climate of Dhaka is tropical and has mainly three distinct seasons – the hot dry (March- May), the hot humid (June- November) and the cool dry season (December- February) (Ahmed, 1995). In composite climates like Dhaka, where both overcast as well as clear conditions are observed during the course of each year, designers face difficulties to choose the condition, based on which they should take the design decisions. The ways and means of tackling the two conditions are quite contrasting to each other (Ahmed, 1987). Windows with fixed horizontal overhead is suitable for overcast sky condition, on the other hand vertical and movable devices are recommended for clear sky. In such cases, it is the overcast sky with steep luminance gradation towards zenith and azimuthal uniformity (CIE, 2004) that presents the more critical situation and hence, design for daylight should satisfy good lighting criteria under overcast conditions (Evans, 1987).

Brief description of the selected atrium

The size of the atriums are given in fig 1.1& fig 1.3. The atrium roofs had different type of transparency (fig1.2 and fig 1.4), floor and wall reflectance also varied so no comparison between the two shopping mall is provided. The purpose of this study is to observe difference in lighting levels due to different atrium proportions, comparison between the two proportions need further study.

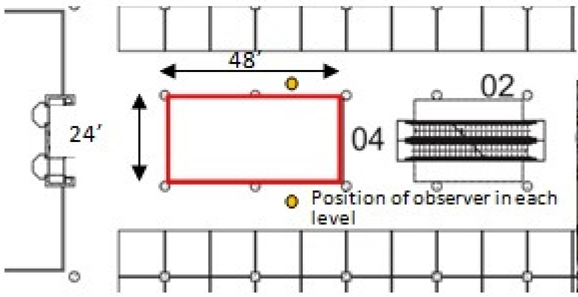
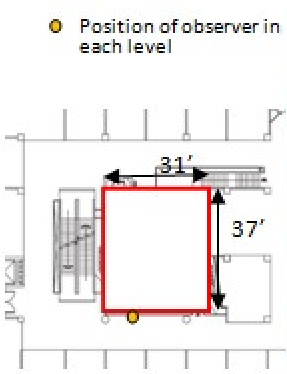


Fig1.1: plan of the atrium of BCSC **Fig1.2:** atrium roof and view of BCSC



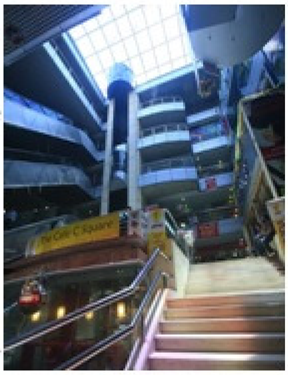
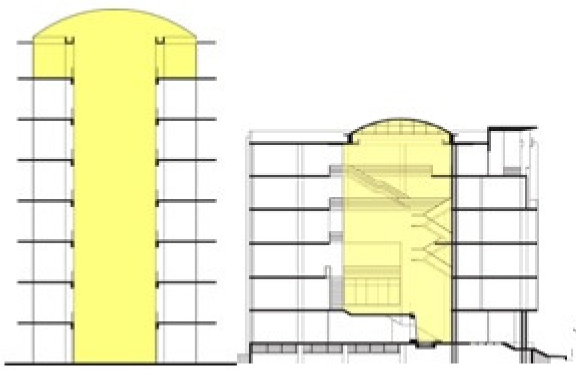


Fig1.3: plan of the atrium **Fig1.4:** view of the atrium of Plaza A.R.



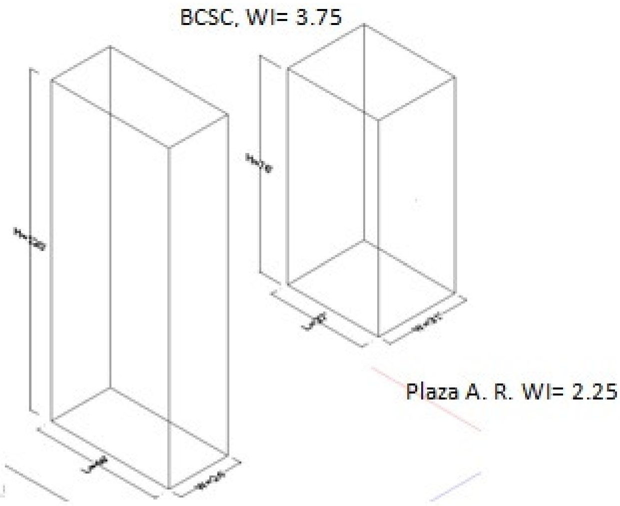


Fig1.5: section of atrium of BCSC and Plaza A.R **Fig1.6:** proportions of atrium of Plaza A.R. and BCSC

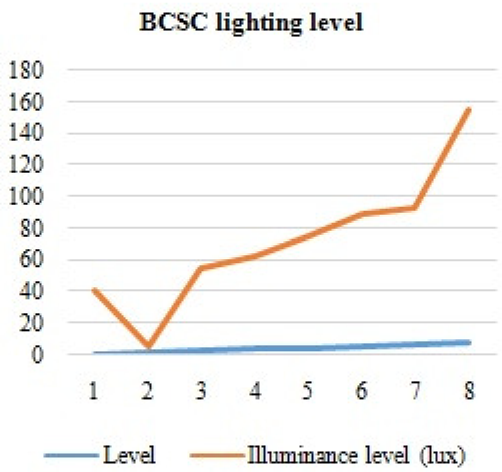
Field survey results and discussions

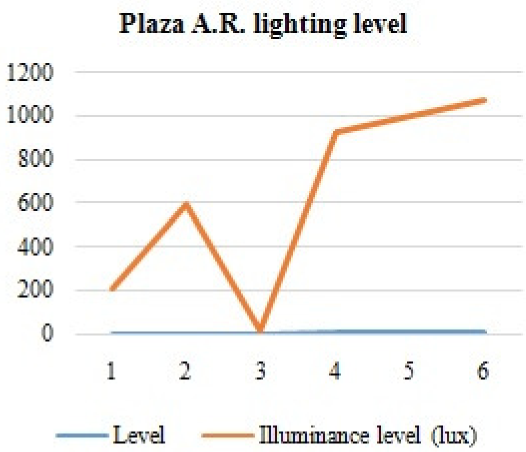
Field survey is done with the help of Digital Light Meter model no. INSTEK GLS-301. The measurements are taken at 3' level from ground along the edge of the atrium. Day time measurements were taken at 2.00 pm and night time measurements were taken at 7.30 pm. Then deducting night time light level from daytime light level to get the daylight level of the point. During the measurements it was critically observed that there was no variation in artificial lighting in both time period.

Fig2.1: measurements using digital light meter

Data collection from field survey

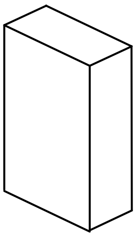
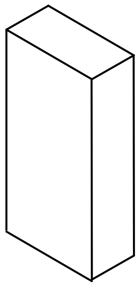
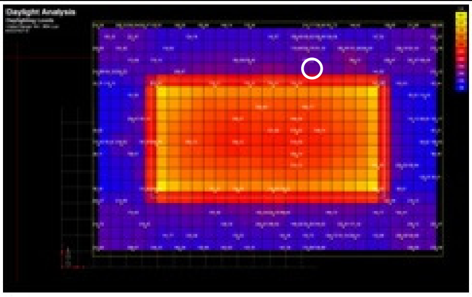
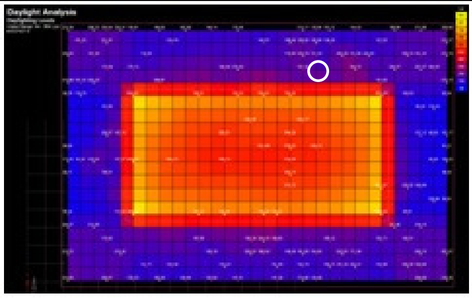
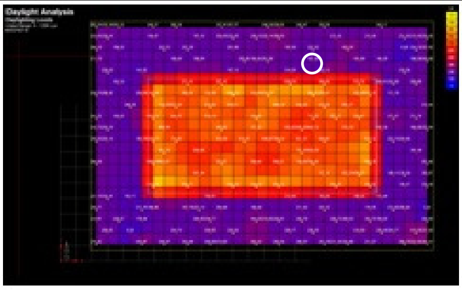
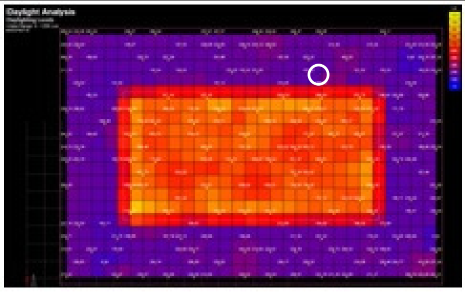
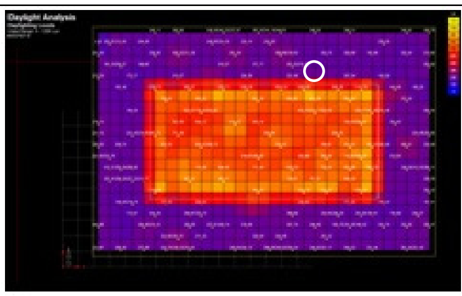
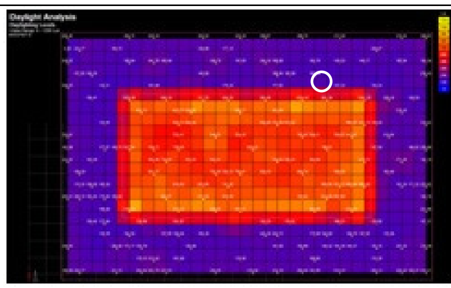
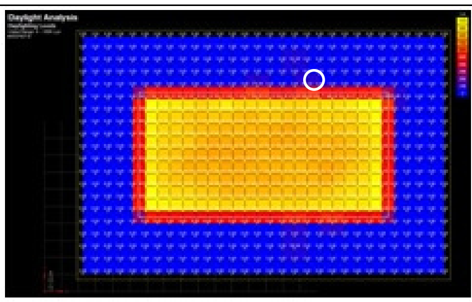
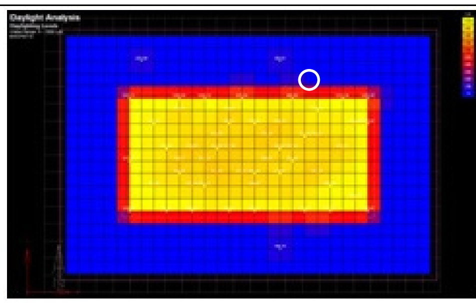
	BCSC Illuminance level (lux) WI 3.75	Plaza A.R. Illuminance level (lux) WI 2.25
Level-1	41	210
Level-2	5	594
Level-3	54	21
Level-4	62.8	923
Level-5	75	995
Level-6	89	1070
Level-7	92.7	
Level-8	155	

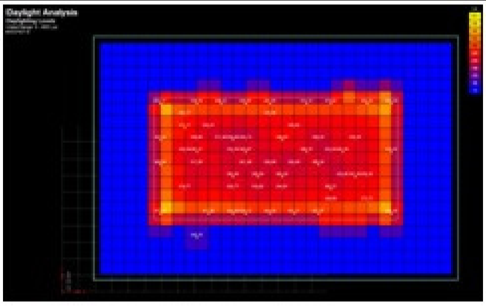
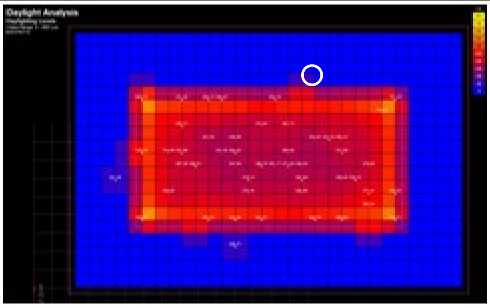
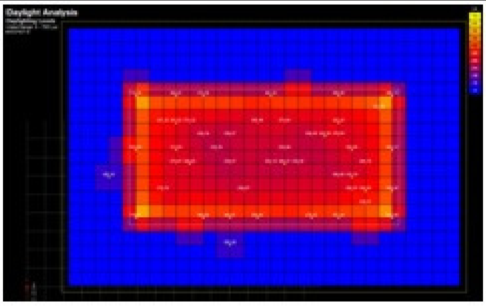
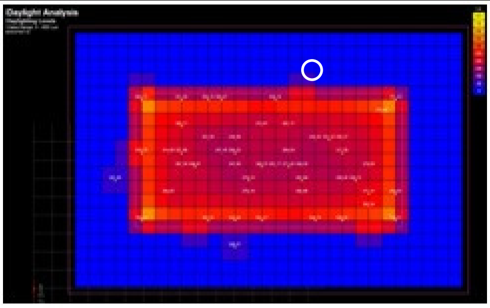
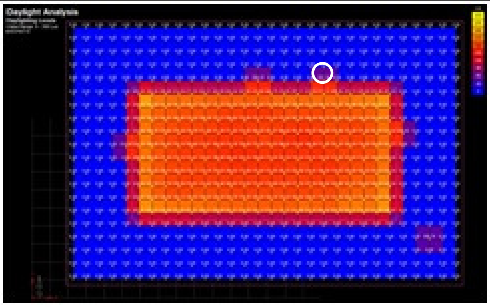
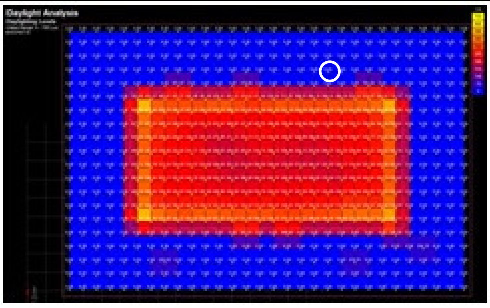


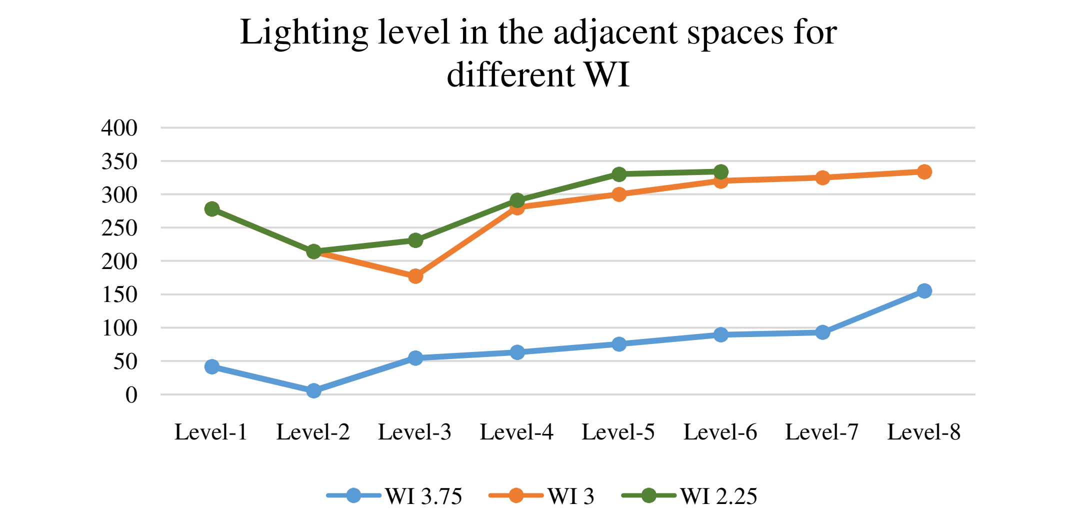


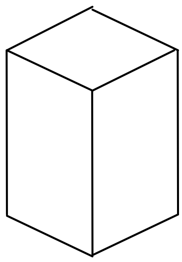
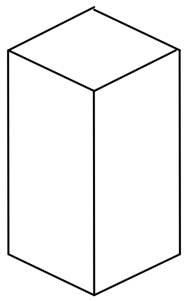
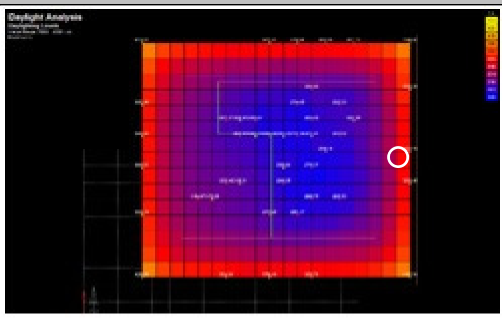
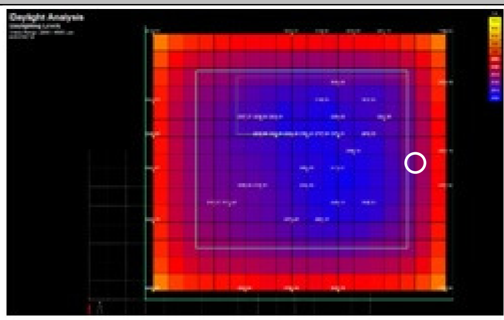
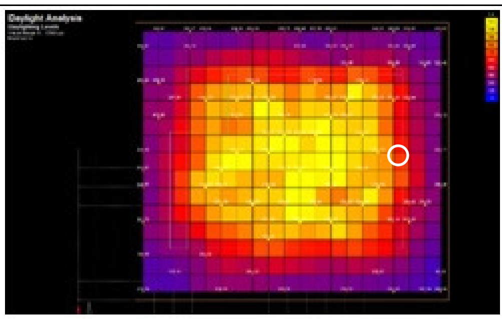
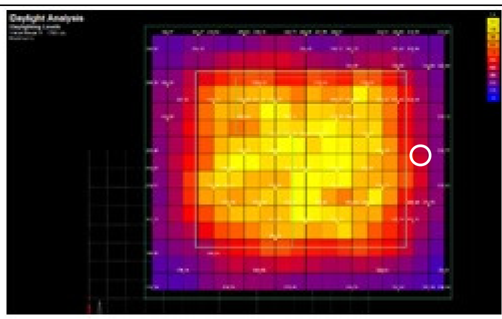
In BCSC, gradual fall in illuminance level is observed. In level 2 the daylight has nothing to contribute, where as in ground floor due to surface reflectance the level increases. In Plaza A. R. Level -2 extends in the atrium which increases light level in level-2, but extension of floor in level-4 decreases lighting level in level-3. Gradual fall in lighting level is common.

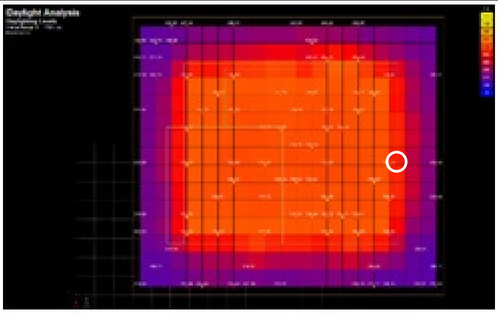
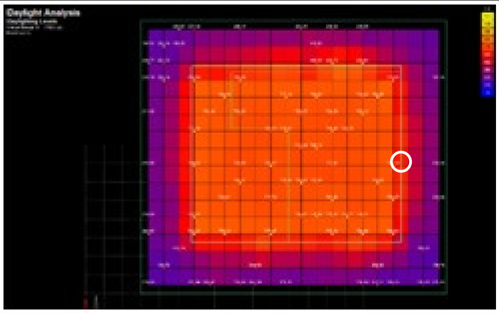
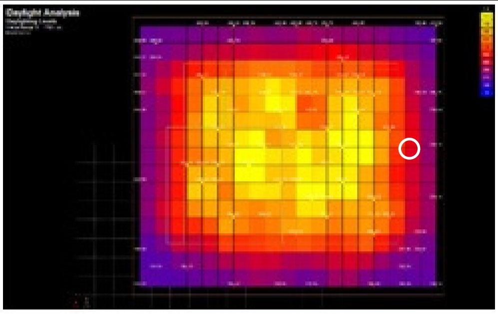
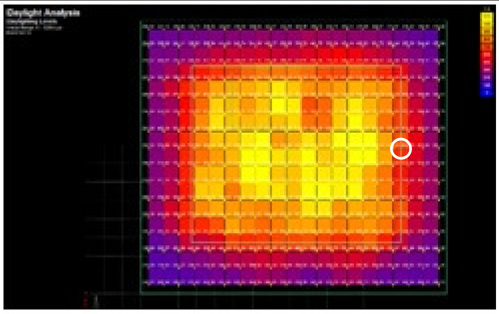
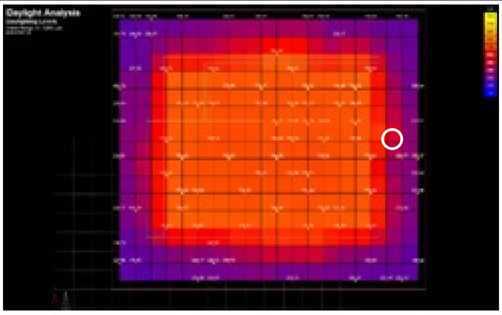
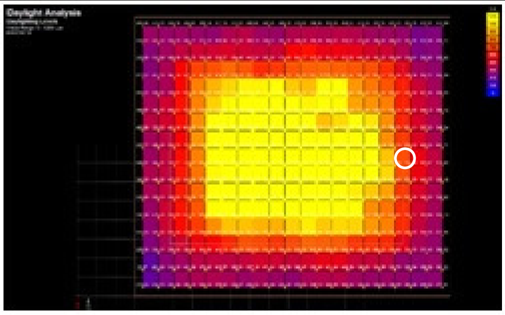
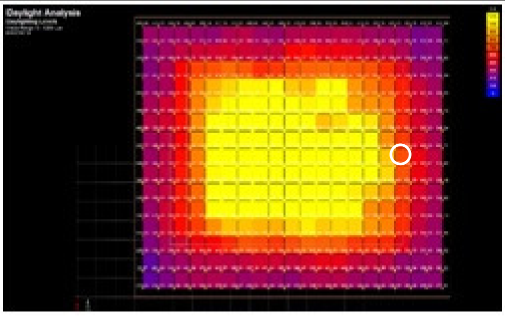
Simulation study

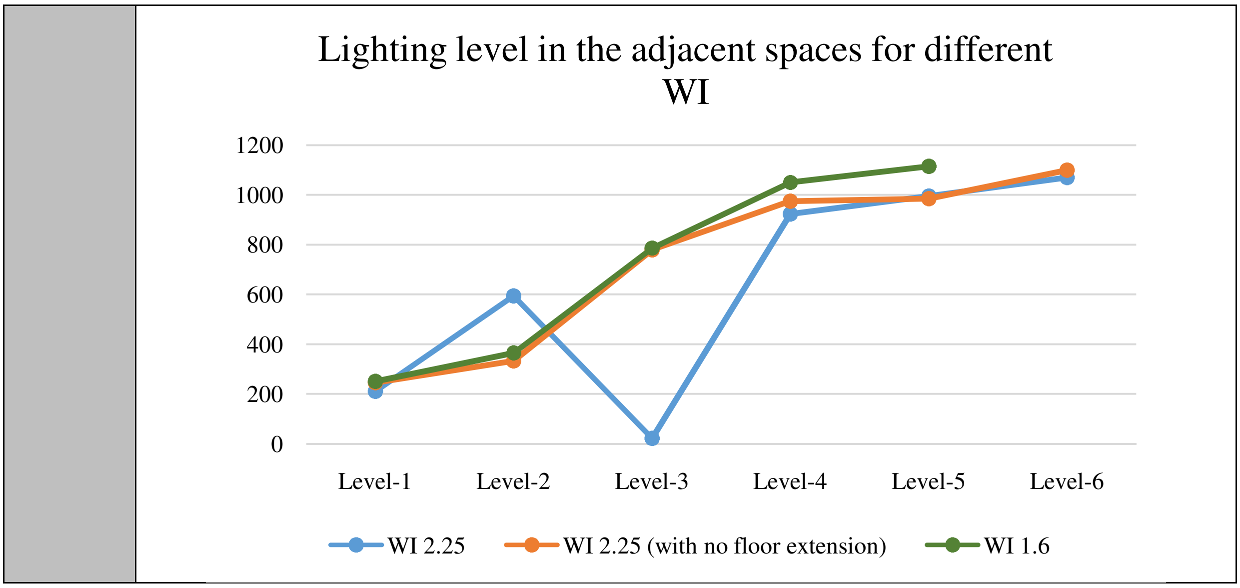
	Study on BCSC	
	WI=2.25	**WI=3**
		
	L=48’ W=24’ H=72’	L=48’ W=24’ H=96’
Level-1	 **278 lux**	 **278 lux**
Level-2	 **214 lux**	 **214 lux**
Level-3	 **231 lux**	 **177 lux**
Level-4	 **291 lux**	 **280 lux**

Level-5	 **330 lux**	 **300 lux**
Level-6	 **334 lux**	 **320 lux**
Level-7		 **325 lux**
Level-8		 **334 lux**



	Study on Plaza A.R.	
	WI=1.6	**WI=2.25 (floor extension removed)**
		
	L=37' W=31' H=60'	L=37' W=31' H=76'
Level-1	 **245 lux**	 **250 lux**
Level-2	 **332 lux**	 **365 lux**

Level-3	 **779 lux**	 **786 lux**
Level-4	 **975 lux**	 **1050 lux**
Level-5	 **985 lux**	 **1115 lux**
Level-6	 **1100 lux**	



Discussion and design guideline

From discussions above, some guidelines for supporting day lighting design in atria are following:

(1) Atrium proportions WI should not be greater than 2 in case of rectangular atrium. It is already found in study that the good result can be achieved by WI=1.5 to 2. This study also support that. (Jiangtao Du, Steve Sharples 2009)

(2) In present condition the lower two floor of atrium in BCSC are not getting any benefit from daylight. Reducing two floor add twice daylight level as shown in Radiance.

(3) In different levels of atrium, the daylight level varies in terms of an exponential form from top to bottom.

(4) From field survey and simulation result it is seen that reflectance values of floor has great impact on daylight level rise.

(5) Extrusion in atrium should be carefully designed, otherwise sudden decrease in daylight level occurs.

(6) Ground floor elevation contribute daylight level rise in upper floor due to floor reflectance.

(7) In shape the performance of almost square atrium (Plaza A. R.) shows better performance than rectangular atrium. Research on square atrium should be connected with this study.

Conclusion

In this study the impact of atrium proportions on daylight level in rectangular atria under a CIE standard overcast sky has been investigated. From the outputs of field survey the situation is analyzed. More simulations to determine daylight levels for a much wider geometric proportions were then performed. By analyzing the results some guidelines have been presented.

These conclusions are obviously limited to the specific geometries (e.g. rectangular plan). The atria with pure square and circular, triangular will be studied in the next stage. Furthermore, from the relationship between atrium proportion and the daylight level, the horizontal daylight level on the working plane inside adjacent rooms will be another topic to be investigated.

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