Proceedings of 2nd Conference: ***People and Buildings*** held at Graduate Centre, London Metropolitan University, London, UK, 18th September 2012. Network for Comfort and Energy Use in Buildings: http://www.nceub.org.uk

Muti-purpose Atrium in Future Sustainable School Design: St Lukes C of E Primary School, an environmental study

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Abstract

Responding to future climate, UK government currently are undertaking the "BFS" programme to build up low carbon emission sustainable schools. In the study of the successful school designs, large atrium spaces have become a typical feature. This calls question: will the atriums benefit the occupants' comfort? This author attempts to demonstrate in the paper the role atrium space plays in future school design in terms of environmental comfort. Qualitative and quantitative studies are undertaken to subsequently test the daylight performance, ventilation and thermal performance in three selected classrooms and atrium space, through site monitoring, Occupants Survey, and dynamic simulation etc. As conclusion, more access to atrium space benefits the ventilation of the classrooms, while intensifying the heat loss at the same time. Hence, seeking for the balance between ventilation and thermal comfort is essential for the future atrium design.

Keywords: atrium, sustainable school design

1. Introduction

This report aims at illustrating the role atrium space plays in the future sustainable school design in terms of environmental comfort. It demonstrates how the atrium space affects the daylight, thermal performance, ventilation performance of the adjacent classrooms.

St Lukes C&E Primary School

Located in the Blakenhall district of Wolverhampton St Lukes Primary School, designed by Architype Company, constructed by Thoms Vale Construction, is the first school in UK achieved "Excellent" standard in the "BREEAM" rating. The site is located in the unban regeneration area and surrounded by communities which are in built with an existing church sits in the northern side of the entrance.

This south-eastern oriented building is a two-storey timber-frame and serves for approximate 450 students. It is divided into two parts and each part consists of one centre hub and is surrounded with classrooms. The passive design is featured in 3 points:

First, the architects constructed the school with the timber materials in order to teach the children to understand nature.

Secondly, the interior comfort is mainly controlled by the Building Management System in terms of the temperature and humidity, air flow rate, etc.

At last, the main feature for the design is to create the certain flexible educational spaces by providing the social atrium with portable partitions to replace the corridors, thus also preventing bullying occurred in narrow space.

Figure 1: The St Lukes C&E Primary School layout. Source: The Architype

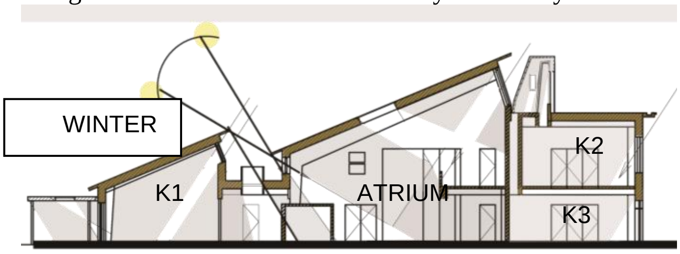

Figure 2: Day-lit for each analyses zone in summer and winter (drawn by author)

A study was undertaken in the 3 classrooms around the atrium to demonstrate how the central hub affects the surrounding classroom comfort and the research was carried out in 2 phases listed as follows (Figure 2):

1. Does the atrium space benefit the ventilation performance in the 3 classrooms or not?
2. Does the atrium space benefit the thermal performance of these classrooms or not?

2. Daylight strategy and performance prediction

	K1	Atrium	K2	K3
Average Daylight Factor	4.8%	5.2%	6.4%	5.8%
Uniformity Ratio	0.54	0.38	0.48	0.44

Table 1: average daylight factor and uniformity ratio in the analysed zones

Both K1 and atrium space has the double side light, while K2 and K3 are side-lit (Figure 2).

Table 1 shows the all the average daylight factor is around 5%, which means annually the artificial light is not needed most of the time, while the high DF value in 1ST Floor K2 shows there may be glare issue. All the uniformity ratios are controlled above 0.2, which means most of the space is not dark for the depth.

3. Ventilation strategy and performance prediction

The whole school is designed to be naturally ventilated with both manually and automated openings which are controlled by the BMS system, achieving cross ventilation, stack ventilation and single ventilation.

All the outlets and inlets has been provided variety kinds of opening ways, to satisfy the air flow rates in different weather, which can be illustrated by Fig.3. For the K1 classroom, in winter, the clerestory will open automatically in a pre-set way such as in lunch break, long time class, etc, while the low level windows and side vents will remain open for short time. However in summer, both the clerestories and the lower windows, vents can be totally opened to reach the required air flow rate. In this way, the building can be naturally ventilated and reduce energy consuming for cooling.

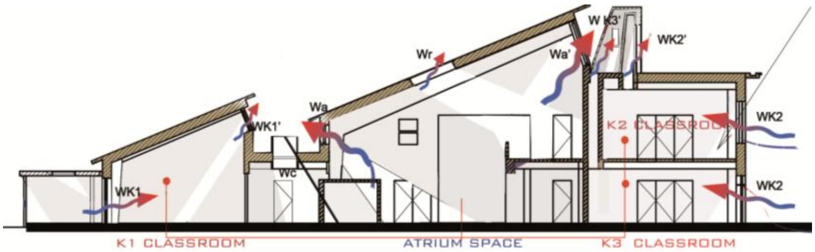

Figure 3: Natural ventilation in section- inlets and outlets (drawn by author)

4. Heating Strategy and thermal performance prediction

The whole building is mostly supplied with a woodchip biomass boiler to provide heating fuel. Aiming at reducing the energy consumption, it is designed to have large glazing area and south corridor containing the roof windows. The corridor serves as a shading device in summer to prevent overheating, while in winter it also allows sunshine coming into the classrooms due to the low solar angle, achieving more solar gain for the south façade. Furthermore the passive heating strategies are mainly based on the high insulation and air-tight of constructions. Due to the construction details, we calculated the u-value listed as follows: 0.26 W/m2.K for the concrete floor with under floor heating system, 0.145 W/m2.K for the timber roof construction, 0.18 W/m2.K for the timber constructed external walls,0.82W/2.K for the triple glazed windows.

In order to access the passive heating strategies of the buildings, TAS model is built up to do dynamic simulation. With regards to the thermal comfort benchmarks, the comfort zone temperature varies between 18-25°C for school and the summer peak temperature is 28°C, 1% of occupied time over which will be viewed as occurring overheating problems(CIBSE, 2006).The evaluation relies on the frequency of the annual temperature proportion of below, between, above the comfort zone.

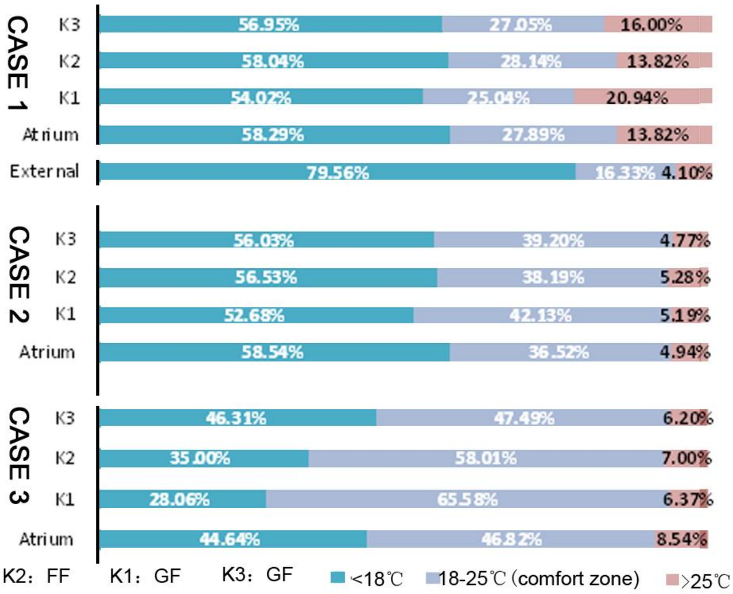

Figure 4: Annual proportion of hours for different temperature range

CASE A1: There is no ventilation and no occupants. The only heat access is the passive solar gain, to test the quality of the airtightness and insulation.

CASE A2: There is natural ventilation in the school hours but no occupants, to evaluate the ventilation cooling efficiency each room contains just 0.15 ach infiltration).

CASE A3: The building is occupied and also naturally ventilated in school hours of winter and summer to access the cooling efficiency for the internal gains, containing the occupants, lighting, equipment

CASE A4: The building is occupied, naturally ventilated and also provided with

Shown by Figure 4, concluded from Case A1 and Case A2, the temperature of most annual time is below the comfort zone and also containing the overheating issue. Then under the condition of automated openings, the natural ventilation will efficiently drive most of the redundant heat away, but the proportion of temperature blow 18 °C also slightly increased. Case A3 is the existing case, which shows the comfort proportion largely goes up with the internal gain, achieving 28%-46% of the year. According to the simulation, the active heating system is needed part of the year and also based on the DEC report (2009), the annual energy use of the building is 74KWh/M2 for heating, and 55KWh/M2 for electricity, without renewables consumed. Comparing with the typical school consumption -168KWh/M2 for heating requirement and 40KWh/M2 for electrics, this school is approximately 50% less than the normal usage in heating ,while slightly higher in electrical usage, hence it not being highly efficient in energy use-just rating 'C' level' in UK.

The comparative study was also undertaken to test whether there is solution to improve by changing the design in atrium.
Change C1: Increase the connection between the classrooms and atriums space
Change C2: Build another wall between the corridors and each classroom.
Change C3: Modify the atrium roof windows W2 to be openable, in order to evaluate the effect of more outlet of classroom
Change C4: Increase the roof windows area to be three times larger, in order to evaluate the effect of more solar gain

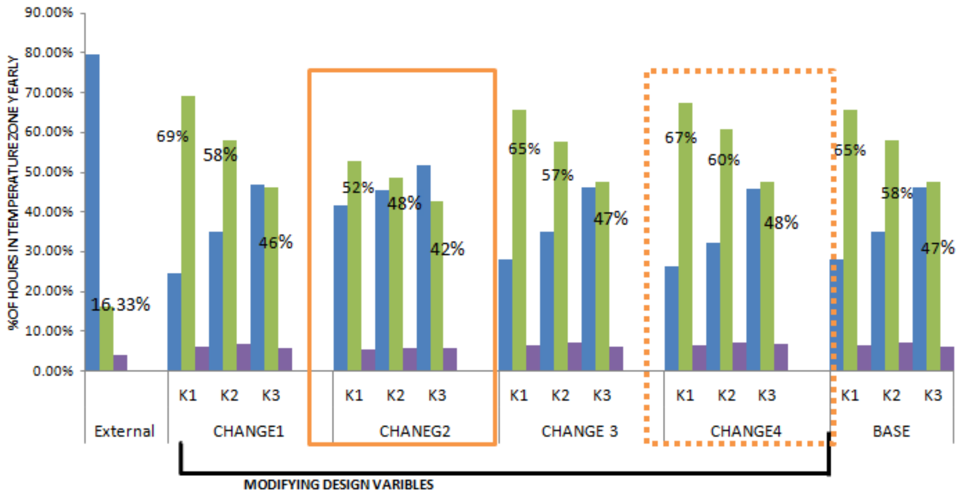

Figure 6: The different modification and the results of annual temperature zone (simulated by author, 2012)

Figure 6 shows the change 2 will reduce the thermal comfort proportion, while there is not apparently differences in other cases, except for the slightly improvement in Change 4.This means more accesses to the atrium will have negative effects and increasing the solar gain for the atrium will benefits the comfort in classrooms slightly due the large volume of the atrium space. Also with the value of solar gain going up, the overheating risk increase. Thus, in order to save the heating energy, the access area should be controlled in design, and the way to improve the environment is that: based on remaining ventilation requirement for access, isolate the classrooms from the atrium space, by such as improving the insulation quality of the walls.etc.

5. CONCLUSION

St Lukes Primary School is highly viewed by the occupants due to the well environment created for students. Most of surveyed staffs feel comfortable with the daylight and noise condition, and based on model predictions, the artificial light is not needed in the analysed area. However, they also mentioned there is a problem of cold even in summer. Thus, the building mostly relies on the heating system in winter time and the energy performance rating is just "C" level in UK. (DEC, 2009)

With regards to the ventilation, the opening systems perform well in removing the extra heat and prevent overheating. Also the social atrium space will benefit the classroom by improving the stack effect, even in sometime of summer, the required air flow rate still cannot be totally achieved.

Further accessing the thermal performance by computer modelling, more accesses to the atrium may cause more heat loss from the classrooms. What's more, increasing the area of windows in atrium to get more solar gain may benefit the thermal conditions of class, but that is not obvious because of the large hub volume.

To summarize the role of the atrium in this school design, the access between the classrooms should be critically controlled to achieve the balance between the requirement of ventilation and thermal comfort. Also, high quality of insulation should be provided to the walls between them. According to the interview with the designers, the atrium space is mainly built to support the activities of the requirement of students, hence considering the balance between environmental comfort concerns and the design purpose is significant in future school design.

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