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

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ABSTRACT: Facing the changing climate in the future, the UK government currently are undertaking the "BFS" programme to build up low carbon emission schools, aiming at achieving zero carbon by 2016. In a study of successful school design, large multipurpose spaces have been becoming a passive strategy for both environmental and communal purposes. This author attempts to demonstrate in the paper the role of Atrium in future school design with regards to the environmental contribution. St -Lukes C of E Primary school, as the first school in UK achieved 'Excellent' standard in 'BREEM' rating, is selected to investigate. Quantitative and qualitative studies, as site monitoring, occupants' survey and dynamic simulation etc, are carried out to subsequently test daylight ventilation and thermal performance in three selected classrooms and Atrium. Furthermore, in order to reduce the energy consumption, several proposals are carried out and the feasibilities are tested separately. The comparative result indicates that more access to the atrium space benefits the ventilation of the classrooms, intensifying the heat loss. Hence, controlling the size of opening area in atrium and seeking for the balance between ventilation and thermal comfort are essential in designing a sustainable school.

Keywords: atrium, sustainable primary school design, environmental comfort

INTRODUCTION

a) Background

Facing the changing climate for the future, reducing the carbon emission and providing a sustainable teaching environment are becoming emergent tasks in designing schools, for which plans are required to be set out by Government. The BFS-'Building school for the future' programme is undertaken to reduce the energy consumption by the UK government. According to the DCSF (2006), it's the responsibility for schools to cultivate students and staff by inspiring them through learning, meanwhile increasing their sense of pride by creating a comfortable study environment.

One interesting tendency in design is that more and more activities are moved out from small classrooms to the central hubs, which enhances the communication between different ages as well as reduces the bullying behaviours.

This report aims at illustrating the role atrium space plays in future sustainable school design in terms of environmental comfort. In this case, it tries to demonstrate how the atrium space affects the daylight, thermal performance, ventilation performance of the adjacent classrooms.

b) Atrium environmental Strategy Study in sustainable school design

Atrium spaces, are widely advocated to be applied in the design due to the original advantages from the natural forms.(CIBSE, 2007) It benefits the adjacent room by providing sufficient ventilation to improve the air quality and drive surplus heat. Atrium space also brings more daylight to the inner, transferring the light to the surrounding, acting as a buffer zone to prevent direct sunshine (CIBSE, 2006). It benefits the adjacent room by providing sufficient ventilation to improve the air quality and drive surplus heat. Atrium space also brings more daylight to the inner, transferring the light to the surrounding, acting as a buffer zone to prevent direct sunshine (CIBSE, 2006).

ST LUKES C&E PRIMARY SCHOOL

Located at the heart of Blakenhall Gardens regeneration area of Wolverhampton, St Lukes Primary School, designed by Architype Company, constructed by Thomas Vale Construction, is the first school in UK achieved an "Excellent" standard in the "BREEAM" rating. It is surrounded by communities with a church sitting on the northern side of the entrance. Thomas Vale Consumption (2009) pointed out that the building is considered as *'Radically reduced energy consumption and improve the internal comfort'*.

This building is two-storey timber-framed and east-west oriented with all the classrooms facing south and north. It serves for approximate 450 students (containing 30 nurseries) and divided into two parts – the western part for Senior students while eastern part for nursery and Junior. Each part is one hub centred, surrounded by classrooms.

These central atriums are designed to provide accommodation for activities containing cooking lessons, library, group study, etc (Fig.2).Thus, these spaces should be fully considered to meet the different needs.

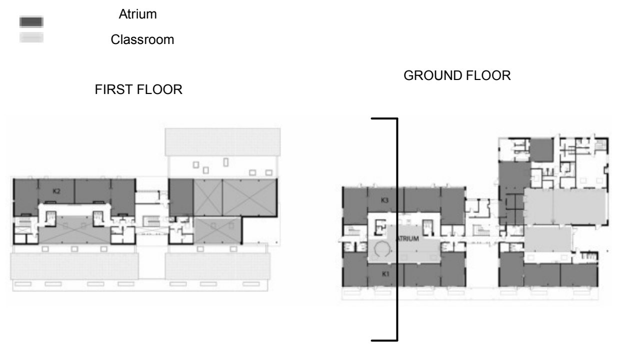

Figure 1: Plans of St-Lukes Primary School (source from Architype, redrawn by the author)

Figure 2: Atrium of St-Lukes C&E Primary School (photo source from Architype)

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

1. Does the atrium space benefit the ventilation performance in the 3 selected classrooms or not?
2. Does the atrium space benefit the thermal performance of these classrooms or not?
3. What's the main issue for the comfort of students in classrooms? Is there any solution to improve the building performance?

THE POST OCCUPANCY EVALUATION SURVEY

The environmental comfort of the building was qualitatively evaluated by using the occupants' surveys, through questionnaires and interviews. Since we can't get access to pupils, our respondents contains 10 stuff (20% of total), such as teachers, cleaners, officers, who have long-term stayed, qualified to be surveyed.

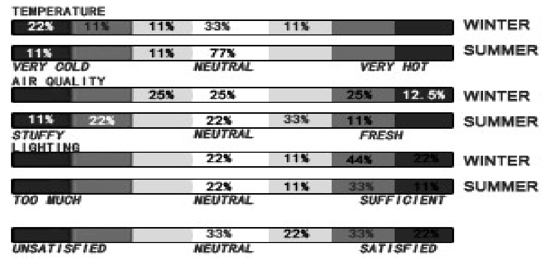

Figure 3 : Staff's POE survey results: proportion of the different satisfactory rates

From the survey resulting from the staff, overall they are satisfied with the building conditions: the lighting and noise comfort remain the levels between neutral and satisfactory, even there are slight problems of acoustic during the break time and glares occurred occasionally. However it also indicates there are some issues of cold, poor air quality observed from the appeared extreme data. That's why in the DEC report (Display Energy Certificate) of the building evaluation, there is large amount of energy consumed for heating.

THE ENVIRONMENT PERFORMANCE OF BUILDING AND ATRIUM EFFECTS

a) Lighting strategy and performance prediction

In order to create a wonderful visual comfort, the designers created various kinds of classrooms and atrium relying on natural-daylight. It can be indicated from Occupants' survey that the overall lighting condition performs well except with some glare issues occurred sometimes.

According to the Development of the Education and skills (DfEs, 2003) a school should take daylight as the main health source. From the Environmental Design Guide, 'an average daylight factor of 5% if a room is to be day lit without supplementary lighting….', also in order to control the depth of the room, "the uniformity ratio –the ratio of the daylight at the back of the room to that at the front- should reach 0.2 for good level". Furthermore, in the BREEM standards, with regards to the ratio of classrooms, 'the uniformity ratio should in the range 0.3-0.4 for side-lit rooms….'

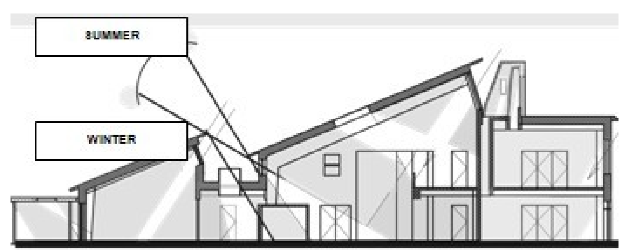

Figure 4: Section of St-Lukes C&E Primary School showing the daylight strategies (source from Architype and redrawn by the author)

	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 selected zones

Shown by Figure.4, both K1 and atrium space has the double side light, while K2 and K3 are side-lit.
Table 1 shows all the average daylight factor is around 5%, which means annually the artificial light is not needed most of the year, while the high DF value in 1st Floor-K2 shows there may be glare issues occurring. All the uniformity ratios are controlled above 0.2, which means the depth of the room is considered in design for light.

b) Ventilation strategy and performance
The natural ventilation is essential to the comfort of pupils while air-conditioning system can totally meet the needs of occupants (D.J.Clements, H.B.Awbi, 2006). The supply of the sufficient natural air flow will benefit students' performance, since it will move the polluted air out and distribute fresh air.

The whole school is designed to be relying on natural ventilation with both manually and automated openings, which are controlled by the BMS system (Building Manager System), achieving cross ventilation, stack ventilation and single ventilation. (Based on POE survey)

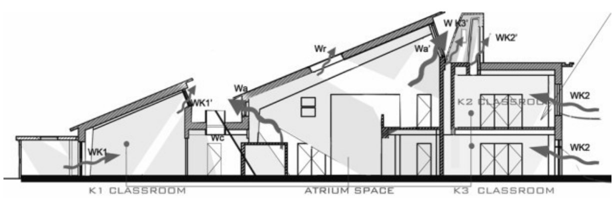

Figure 5: Section of St-Lukes C&E Primary School showing the ventilation strategies (source from Architype and redrawn by the author)

In the south GF classroom-K1, the fresh air goes through the south manual opened windows WK1 and out through the automated clerestory Wk1'controlled by switches on the wall (refer to Fig.5). In terms of K2 and K3, The air flows through the North façade windows (WK2,WK3), and move out by buoyancy from the roof vents (WK3',WK2') .The stack effect in the atrium is achieved by the roof windows and clerestories on both south and north sides. The opening percentages are changing, to satisfy the different air flow rates in varying weather. For K1 classroom, in winter, the clerestory will open automatically in a pre-set way such as lunch break period, long time class, etc, while the low level windows and side vents will remain open short time to prevent the heat system working. However in summer, both the clerestories and the lower windows, vents can be totally opened to reach the requirement of air flow rate. In this way, the building can be naturally ventilated and energy consuming for cooling is reduced.

c) The ventilation effects of Atrium on the classrooms
Comparing the different requirements for fresh air by calculatingin the Optivent Programme (invented by Prof. Brian Ford), the evaluation for the ability of stack ventilation came out relying on assessing the efficiency of achievement of air flow rate indoor. According to the CIBSE standards (2006), the minimum air flow rate should reach 0.48m3/s in the classrooms and 0.24m3/s in atrium for a primary school.

There are two situations: 1.in class, the door is closed and the air just goes out through the roof windows to outside which means there is no access between the atrium and the classrooms. 2. After class, the door is open –the air flow goes through the door to the atrium space and through the roof window and clerestories to outside.

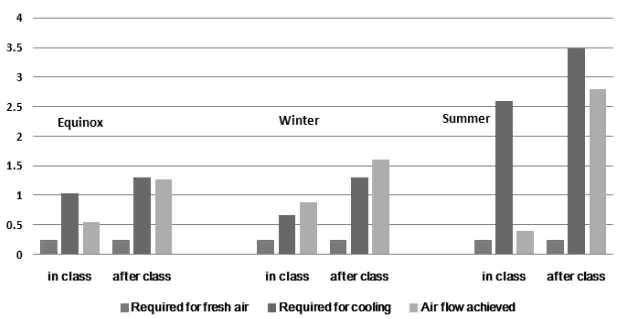

Figure 6: Air flow rate of three seasons in two conditions: after class and in class (calculated by author through Optivent)

Shown from Fig.6, when the classroom K1 is isolated with the atrium space (only the clerestories act as the outlets), it's hard to achieve the required air flow rate for the internal air quality. While with the access to the atrium with doors open, the air flow rate can be achieved even in summer time. Also by calculating the rates in comparative situations - K2 and K3 which mainly rely on the roof vents to remove the surplus heat from both solar gains and internal gains, similar results can be achieved. To conclude, the atrium space enhances the air flow in classrooms, since these areas of outlets for natural ventilation will be increased, so that the openings of the hub space will help to remove the extra heat based on the buoyancy and stack effect.

d) Heating Strategy and thermal performance prediction

The data logger measurement was taken from March 16th to April 4th, in these 3 classrooms and the centre of atrium space. To summarise the collected temperature data, the south K1 classroom has higher internal temperature than the other space, followed by the data in Atrium or north K2 classroom, because the north GF K3 classroom always has the lowest internal temperature, mainly due to the low solar gain.

In order to access the passive heating strategies of the buildings, TAS model is built up to run dynamic simulation (According to the daylight factor analysis, it is assumed that there is no artificial light in simulation, since the day light is sufficient). 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. Atrium and three Classrooms - GF K1, GF K3, FF K2, are selected to be analyzed and set the normal infiltration 0.15ach for each space.

Based on the interview, it is assumed that there are 30 students in each classroom during the occupied hours from Monday to Friday as UK typical primary school calendar. Atrium space, due to different activities undertaken in school hours, is occupied in 3 different situations-10 pupils from 9:00-11:30 for morning meetings, 30 pupils from 11:30-13:00 activities after lunch break,13:00-15:00 no occupation.

CASE 1: 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 2: There is natural ventlation in the school hours but no occupants, to evaluate the ventilation cooling efficiency. (Each room contains just 0.15 ach infiltration) CASE 3: 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.

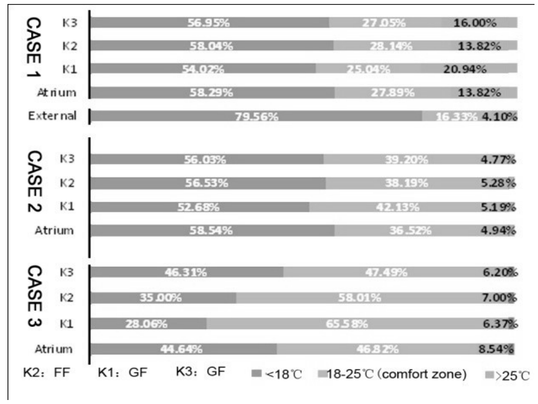

Figure 7: Annual proportion of hours for different temperature range: below, between, over comfort zone in three selected classrooms in three cases (simulated by TAS)

Concluded from Case 1 and Case 2, the temperature of most year 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 3 is the existing base, 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 and also based on the DEC report (2009) (the Display Energy Certificate which shows the energy cost to operate the building), the annual energy use of the building is 74KWh/M2 for heating, and 55KWh/M2 for electricity, without renewable 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 from ‘A’ to G’ in UK.

e) The thermal effects of Atrium on the classrooms

The comparative study was also undertaken to test whether the atrium space benefits the thermal comfort of classrooms. Hence, a Case B is carried out by reducing the opening hours of the doors, which means reducing the time of the access between the atrium and class.

Case B: Change the aperture type of the doors between the atrium and 3 classrooms to be function (only keep long-time open when the internal temperature exceeds 25° C).

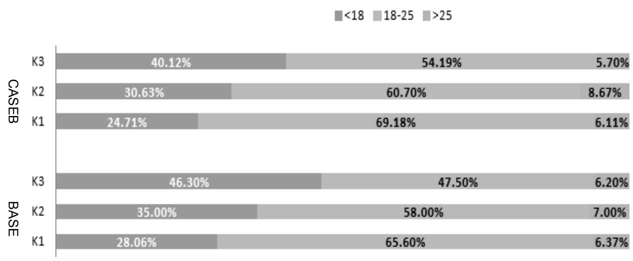

Figure 8: Annual proportion of hours for different temperature range: below, between, over comfort zone in three selected classrooms in case B and current base (simulated by TAS)

As shown in Fig.8, the overall annual thermal performance is improved since the proportion of the comfort zone increased, while the proportion of other ranges fell down. This means controlling the opening will contribute to the thermal comfort in classrooms. However, it can also be noticed that the cold issues may get worse with this change. To cut high energy costs in heating and solve the problem of cold, modifications of Change B1-B4 were taken to test whether there is solution by changing the elements of atrium.

Change B1: Build another wall between the corridors and each classroom.
Change B2: Increase the connection between the classrooms and atriums space
Change B3: Modify the atrium roof windows W2 to be openable, in order to evaluate the effect of more outlets of classroom
Change B4: Increase the roof windows area to be three times larger, in order to evaluate the effect of more solar gain (refer to Fig.9)

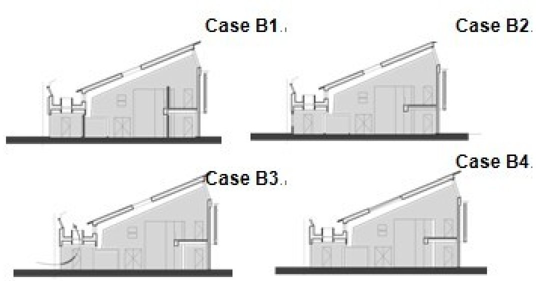

Figure 9: Section of Atrium of the corridors in four cases of change (drawn by author)

	Atrium	K1	K2	K3
>=25	9.46%	6.37%	6.37%	6.87%
>=28	2.60%	2.26%	3.60%	2.09%

Table 2: overheating assessment in the selected zones in the case of change B2 (simulated by TAS)

It can be viewed from Table 2 that Change B2 will reduce the thermal comfort proportion. This means more access to the atrium will have negative effects. The result of Change B4 indicates that more solar gain for the atrium increase the thermal comfort slightly. However, with the value of solar gain going up, the overheating risk increased at the same time (refer to Table 2). The classrooms should also be isolated from the atrium space to cut heat loss.

CONCLUSION

St Lukes Primary School is highly viewed by the occupants due to the well environment created for students. Most of surveyed staff feel comfortable with the daylight and noise condition, and based on model predictions, the artificial light is not needed in the analyzed area. However, it is 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.

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 modeling, more accesses to the atrium may cause more heat loss from the classrooms. What's more, increasing the area of roof windows in atrium to get more solar gain may benefit the thermal conditions of class, but the result is not such obvious.

To summarize the role of atrium plays in pupils comfort, 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. 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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