Learning from Measurement

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Abstract

The Built Environment Research Group (BERG) at the School of Architecture and Building at Deakin University is involved in the monitoring of building energy consumption, lighting and acoustic levels, as well as material and thermal performance. Such measurements have taken place in several buildings over the last few years. This has been the result of a deliberate policy of BERG to initiate a process that completes the loop of design, prediction, monitoring, verification, teaching, then back to design again.
This paper presents a summary of some projects that have involved building monitoring. We have established a methodology for measuring buildings which will be discussed, as well as the reasoning behind our desire to monitor buildings in general. The paper will present a summary of the results of measurement acquired to date (energy consumption, schedules, operation, etc.) and the lessons that have been learned from this monitoring program.

1. BACKGROUND

The Built Environment Research Group (BERG) endeavours to research the daily performance of buildings and thereby discover those design parameters that are successful and those that are not. We strongly believe that only through rigorous long-term measurement do we actually discover how our buildings perform. Several projects are presented in this report and a brief summary of the measurements taken is provided, as well as what has been learned and what most likely remains to be researched in the future. The discoveries in these investigations are by no means the complete story of the building's performance. Such investigations lead to design improvement, enhance our intuition on building performance and lead to a better understanding of what why buildings perform as they do.

Our findings also have the advantage of providing real-world evidence for our computer simulation verification. We often use simulation packages to compute lighting levels, thermal results and energy use prior to the measurement as well as during the design and development stages of a project. Through measurement and post-occupancy evaluation we are able to reconfirm our findings. A long-term advantage of the verification process is to form a sense of trust and degree of prediction accuracy in the simulation package. Currently we generally use the software packages to provide us with 'relative' differences in performance. As we learn more about how building systems perform in the real world, we are gaining the potential to predict 'absolute' results.

2 METHODOLOGY

The following format is used to assess each building. Criteria are selected for each project where they are relevant and can be measured (see Table 1 below).

Table 1 Monitoring criteria details

Criteria	Details	Equipment used	Units
Capital cost	To be derived from builder	-	$ and $/m^2$
Building envelope	U values of surfaces	Infrared sensor, HFM	W/m^2
Window analysis	Glass temperature and heat flux	Thermocouples, HFM	degrees C and W/m^2
Predicted energy requirement	Overall energy use broken down into subsections	Energy analysis program TRNSYS	kWh / m^2 .a
Energy consumption rate for electricity usage	kWh meter pulses logged every 15 minutes with external meter for overall	Kilowatthour meter Current meters	kWh and kWh/ m^2 .a
Energy consumption rate for gas usage	Flow meter to be installed on each gas line with pulses sent back to data logger	Gas flow pulse meters	kWh and kWh/m^2 .a
Energy cost of operating heater	Tariffs are to be recorded. Costs to be calculated from energy consumptions	-	$ and $/m^2$ .a
Efficiency of appliance		Heat flux meters and weather station	Written report
Radiant panel temperature	Surface temperature of panels (ie radiant heaters)	Thermocouples	degrees C
Mean desk temperature	A mid level mean radiant temperature	Globe thermometers Hobo temp. loggers	degrees C
Noise	Measured in appropriate locations	Hand held meter	dB
Stratification	Temp sensors installed at 0.2 m, 1. 2 m, 2 m. Temperatures logged every 15 minutes	Hobo temperature loggers	Degrees C diff between floor and ceiling
Relative humidity	The relative humidity of the air is to be measured in each space.	Hobo relative humidity loggers	RH%
Pre-heat time	Time from heaters start-up to time when the desired room temperature is reached.	Data logger	Hours
Lighting system	Level of energy consumption	Ammeter, clamp type	W/m^2
Control of equipment	Details of the controls of each type of equipment are to be detailed	-	Written comments
Infiltration	Unwanted air movement	Door air blower	air changes per hour
Ventilation requirements	Outdoor exchange rate via open	B&K Innova gas analyser	air changes per hour
Occupants / absenteeism	The number of occupants are to be recorded each day. Small sample is statistically dubious	Activity sheet filled in by teachers	% of total possible for a term
Safety	Does installation comply with AS.	-	Comment yes or no
Energy source	Elec, gas, green power	-	Written report
External environmental effects of fuel selected	Greenhouse gas emissions	-	Tonnes of CO_2 using EPA figures
Indoor air quality	CO_2, dust particles and air freshness should be assessed	Yet to be determined	
Staff rating	Staff to complete response form each week. Note small sample number	Staff response form	Summary of written comments
Student rating	Students to complete response form each week. Note small sample number	Student response as for staff response	Summary of written comments
Life cycle costing	Costs to be assessed are		$ analysis over 20 years.
Buildability	Comments will be sought from builder	-	Written comments
Aesthetics	Comments will be sought from architect	-	Written comments

3 DEVELOPING A BRIEF

One of our first projects was to provide a Case Study for the IEA Task 21: Daylighting project. The Park Ridge Primary School was selected for this study as it was an example of a daylighting system for classrooms. We proceeded by developing a summary of parameters to be measured. This brief helped in determining the range of required sensors as well as the experimental layout. A lesson learned is that the brief requires careful planning and a coordination between the measurements that are desired and those that can actually be delivered.

4 PARK RIDGE PRIMARY SCHOOL, MELBOURNE

The findings from the Park Ridge study were noteworthy in reference to the differentiation of daylighting performance from various sky types over a year. It was discovered that a partially overcast day in autumn virtually matched a clear sunny day in summer with respect to interior illuminance levels (Figure 1). The results of this study proved to the researchers (and designers) that the methods of diffusing daylight in this building design were quite successful. It was also learned that the integrated artificial lighting systems control and strategy requires improvement.

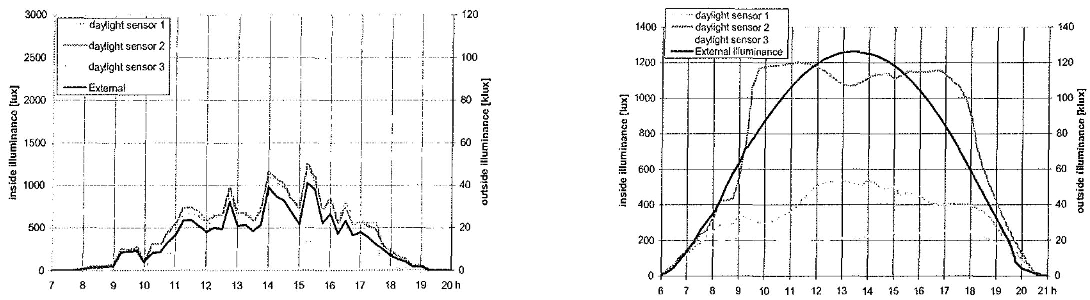

Figure 1 An Autumn Overcast and a Summer Clear Day (respectively)

5 AUBURN SOUTH PRIMARY SCHOOL, MELBOURNE

A comprehensive measurement of the environment of four classrooms was conducted over a year in the Auburn South Primary School. This project was initiated primarily to investigate the difference between radiant and convective heating in a classroom. The project provided an excellent opportunity to investigate other parameters as well. Several of these additional measurements lead to unforseen discoveries. Due to the uniform natural light on the south side of two of the classrooms, artificial lighting use was less than in the east and west facing classrooms (Figure 2). This once again demonstrates the desire for diffuse only daylight in workspaces. With respect to a comparison of heating systems, the radiant heating system consumed 60-70% less energy than the gas convective system, but in the end, the cost was the same due to the pricing structure of the utilities (Table 2). This price structures eliminate any potential savings to the customer. An additional consideration was that the CO_2 emissions per kWh of electricity are about three times that of gas.

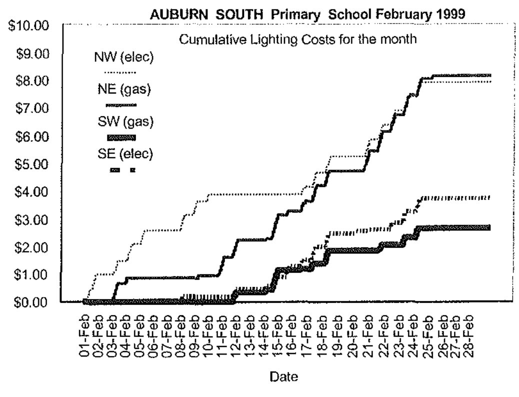

Figure 2 Artificial Light Use and Cost

Table 2 Actual Measured Energy Consumption

Classroom	June Total (kWh)
Room SW (gas)	577.93
Room NE (gas)	351.23
Room SE(electric)	186.85
Room NW (electric)	76.79

6 RELOCATABLE COOLING STUDY, MELBOURNE

A study of eight relocatable classrooms with reversed cycle systems in four Melbourne suburbs, found that the air-conditioning in each classroom consumes about as much energy as a 4 star family refrigerator. A preliminary energy consumption simulation (using TRNSYS) comes close to confirming this. In addition to these findings, it was discovered that manual control (from each user) was quite conservative and energy conscientious.

Table 3 Reversed Cycle Energy Consumption in Relocatable Classrooms

School name	Measured kWh (not full year), kWh	Factor to account for full year use	Estimated annual total kWh/ year	Estimated annual total per floor area kWh/m² .year	Estimated % of total that is cooling	Estimated annual cooling per floor area kWh/m² .year	Cooling energy kWh/m² .year
Sydenham Room 1	549 .2	1.25	686.5	11.44	39%	267.7	4.46
Sydenham Room 2	509.0	1.25	636.3	10.60	43%	273.6	4.56
Roxburgh Room 1	708.4	1.35	956.3	15.94	47%	449.5	7.49
Roxburgh Room 2	874.3	1.35	1180.3	19.67	53%	625.6	10.43
Great Ryrie Room 1	363.4	1.25	454.2	7.57	40%	181.7	3.03
Great Ryrie Room 2	661.8	1.25	827.3	13.79	45%	372.3	6.20
Hallam Room 1	498.2	1.25	622.8	10.38	16%	99.6	1.66
Hallam Room 2	507.7	1.25	634.6	10.58	43%	272.9	4.56
Averages			749.8	12.50	41%	317.9	5.30

7 CHARLES STURT UNIVERSITY (CSU), THURGOONA, NSW

At CSU there are many in-situ rammed earth buildings. Wall measurements indicate that 50% of the absorbed solar radiation is transmitted into the room. The predicted diurnal lag of 12 hours was found to be quite less (Figure 3). It is also discovered that infiltration and natural ventilation control play an important role in conditioning this type of building.

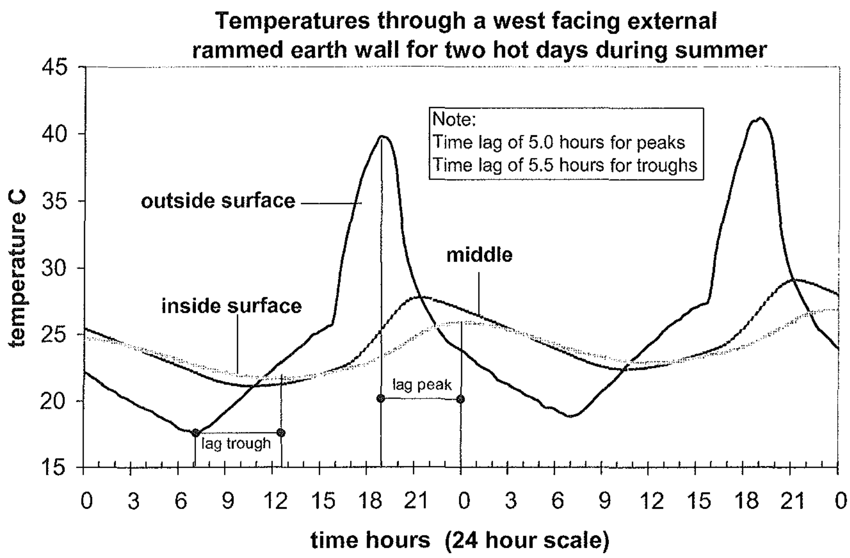

Figure 3 In-situ Time Lag Testing of a 300mm Rammed Earth Wall

8 SCOTCHMANS HILL WINERY, VICTORIA

Wall and surface temperature measurements in an above ground barrel store of a winery indicate that lightweight insulated roof temperatures reach 70C. However, the THERMOMASS (concrete insulated) walls maintain a stable uniform 20-24C temperature suggesting that similar materials as used in the walls should be applied to the roof as well.

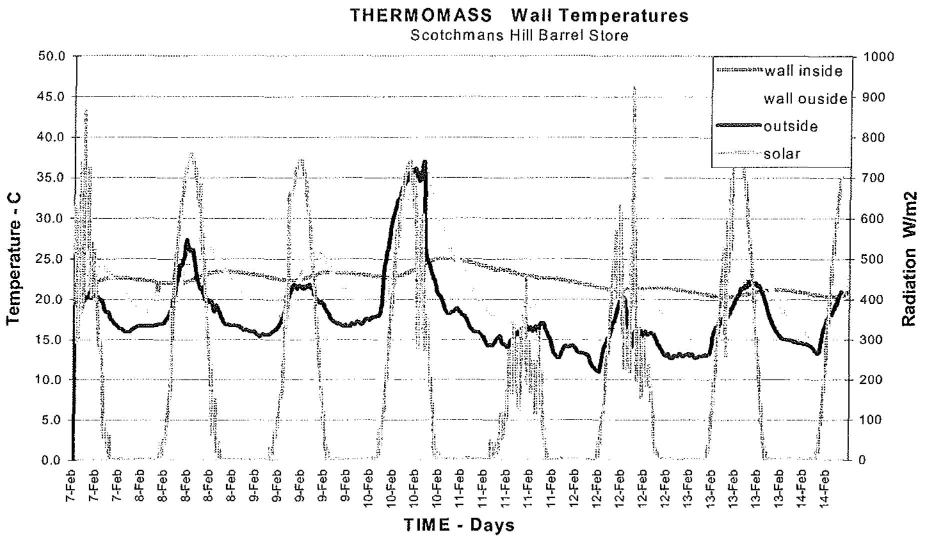

Figure 4 Charted Wall Temperatures of the THERMOMASS panel alongside external conditions

9 CONCLUSION

The above case studies indicate the importance of long term monitoring. Universities are well placed to provide this service. By using a consistent methodology, results can be compared from case study to case study if there are overlapping criteria. An additional benefit is the acquisition of hourly climatic and building performance data that can be used to verify simulation studies.

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