Queensland University of Technology

Faculty of Built Environment and Engineering

Perth [redacted] Distribution Centre

A. Introduction

1. The proposed [redacted] Distribution Centre at Perth has one building with 36,000 m^2 floor area maintained as free running. It has a length of 200 m and a width of 180 m. The height to the eaves is 9.0 m. The roof slope is 3 degrees to the horizontal. This gives a height of 13.7 m to the ridge, which is in the east west direction and has a length of 200m.
2. The exterior walls are fitted with Colorbond sheets. For the dispatch bays located on the northern and eastern walls, precast panels have been used up to a height of 4.0m from the ground level.
3. It is preferred to maintain the building at a maximum indoor temperature at about 27^{o}C. Therefore, the possible use of the special coating, SkyCool, for the roof of the distribution centre is investigated.
4. The Faculty of Built Environment and Engineering of Queensland University of Technology was requested to carryout detailed computer simulation studies to investigate the thermal performance of this free running building.

B. Computer simulations

1. In order to determine the thermal performance of the distribution centre with Colorbond and SkyCool, computer simulations were carried out using climatic data for a one year period. The climatic data for 1987 was used for these since it would allow the extreme conditions that would occur over a year to be taken into account. This could be considered as a better representative sample than the climatic data averaged for many years. This is because, for a given day, the average data for many years could hide the peak values that occurred only during few years.
2. For the computer simulations, a sophisticated simulation software, DEROB – LTH was used. DEROB-LTH was originally developed at the Numerical Simulation Laboratory of the School of Architecture, University of Texas. Later, it was further enhanced and validated at the Department of Building Science, Lund Institute of Technology (LTH), Sweden.
3. DEROB, which is an acronym for Dynamic Energy Response of Buildings, is a dynamic simulation program which utilizes generalized algorithms to simulate hourly energy performance of building structures of many generic types inclusive of passive solar buildings. The input data is of two general types, namely the building description data and environmental data. The first type includes the geometry of the space defining thermally active building elements such as walls,

roof, floor and openings like doors and windows. In addition, the program can handle thermally inactive exterior shading screens which can be used to model the effect of eaves at the roof level and shading devices used over the openings. The material composition of the thermally active building elements is managed by using opaque and transparent material libraries. The effects of surface texture and colours were handled by using absorptance and emittance values of the outer surfaces. Additional input data of the first type are the orientation of the building, site, and period of simulation and schedules for forced ventilation, infiltration, heating and cooling.

4. The second type of data includes the weather data of hourly values for ambient air temperature, direct solar insolation on horizontal surface, diffuse solar insolation on horizontal surface and the sky temperature. The main climatic data were obtained from the Australian Climatic Data Bank prepared by CSIRO and Australian Bureau of Meteorology. The appropriate values of sky temperatures were determined using a front end program provided with DEROB-LTH.
5. DEROB-LTH can produce detailed output such as indoor and operative temperatures on an hourly basis, the surface temperatures of a given volume and the predictive mean vote (PPM) to indicate the thermal comfort. It can also calculate the air-conditioning and heating loads and also predict the possible indoor temperatures when the plant capacities and the operational schedules are known.

C. The simulation details

1. The simulations were carried out using a 3D model. The model has the dimensions of 200 m x 180 m. The height to the eaves is 9.0 m and the roof slope is 3°. For the roof, two different cases were considered as given in Table 1. For the insulation, 75mm thicknesses was considered. The insulation material was mineral wool and the material properties are given in Table 2.

Case	Description
Case 1	Roof with insulation, Colorbond walls & Zincalume roof
Case 3	Roof without insulation, Colorbond walls & Zincalume roof
Case 4	Roof without insulation, Colorbond walls and with SkyCool on roof exterior.

Table 1: The different cases considered for the simulations

Material type	Conductivity (W/mK)	Specific heat (Wh/kgK)	Density (kg/m^3)
GI sheets	50	0.13	7800
Mineral wool	0.04	0.24	50

Table 2: Properties of the materials used in the simulations

2. The external and internal colours of Colorbond were considered as of 50% absorptance. The floor was of slightly darker colour with 60% absorptance. The emittance of wall was considered as 85%.
3. When Zincalume was used for the roof, the absorptance was 50%. The emittance was 40%.
4. The SkyCool surface was of 15% absorptance and 94% emittance.
5. The internal loads consisted of the lighting and other electrical appliance load (10W/m2) and that due to people (150 W/m2). This gave an internal load of 360,000 W from midnight to 8.00 hours. It went up to 378,000 W from 8.00 hours to 16.00 hours and from 16.00 hours, it was 373,000 W representing 120 and 85 people working indoors with the shifts starting from 8.00 hours and 16.00 hours, respectively.

   The load due to electricity also may have the potential for further reductions with energy efficient compact fluorescent lamps (CFL). For example, a CFL of 15 W can give a lighting level on par with a 100 W incandescent lamp. If you allow another 5 W for any other losses, then, 20 W could give a lot of light. If you go for two CFLs in every 10 sq m, the electricity usage will be 40 W in total or 4W per sq m. If you use half the lights during the daytime, it would be quite easy to create a very good passive building.

   If adopted, this will save about 1250 MW hours of electricity over one year. At the rate of $ 0.15 per kW hour, this can save about $190,000 per year. This will allow recovering the extra capital cost of CFLs within the first year of operation. A CFL can last about 2-3 years or more. It is possible to do detail calculations for these on the basis of life cycle costs to obtain the exact cost benefits of alternative solutions –not included in this modelling series. This will help to get the maximum benefit of SkyCool.

6. For the simulations, the skylights were ignored since the main aim was to isolate the net effect of SkyCool. However, the same results could be obtained providing the translucent materials with a reflective foil coating that will reflect about 90% of the heat.
7. The building had no windows except the doors at the dispatch bays. The doors are considered as roller shutters.
8. The number of air changes was 0.083 ach throughout the day. This would be due to the doors being kept open. However, 0.083 air changes per hour means moving

about 33,000 cubic metres per hour during the night when the building is closed. It may be useful to consider a much lower value such as 0.02 ach (8000 cubic metres per hour) for a further refinement of the model if required.

9. The building was modelled as free running.

The results of the model is summarised below: