Melbourne City Council

Air Conditioning Sizing Methodology

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Melbourne City Council

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design advice

passive systems

design analysis

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EXECUTIVE SUMMARY

This report has been prepared by Advanced Environmental Concepts as part of the design process for the new Melbourne City Council (MCC) offices which recognises the increasing concern for the environment through adopting Ecologically Sustainable Development (ESD) practices.

A green building is a sustainable and healthy building for its occupants and the environment. An important aspect in the design of green buildings is to have a practical approach.

Practical design is the priority of this report. It focuses on the sizing of the air conditioning system for the new Melbourne City Council offices, as part of the design process. Undersizing the system would leave occupants too hot or too cold, breaching accepted comfort levels. Overdesigning the system would be highly uneconomical and disadvantageous to space usage in the building, decreasing Net Lettable Area opportunities, and increase energy consumption.

The air conditioning system in the MCC building will use chilled ceiling panels and beams for cooling, and convective fins for heating. A constant source of non-re-circulated fresh air is provided by vents in the floor via a displacement ventilation system.

Traditional sizing methodology is based on a series of parameter based calculations which best match the building fabric and its location.

The methodology adopted to size the air conditioning system is based on peak cooling loads and will be explained in detail in this report. Three dimensional thermal computer modelling is used as a tool for sizing, along with researched weather conditions to produce results which uniquely represent a particular building's heating or cooling requirements.

The South Perimeter on level 5 of the new Melbourne City Council House will be used as a basis for analysis.

The findings of the analysis carried out for level 5's South perimeter reduced peak cooling load sizes by 42%. Analysis has shown that the numerous benefits far outweigh the finding that air temperatures may rise 0.5°C as a result, which presents a strong case for adopting this sizing design methodology.

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Date	7 July 2003	
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1 INTRODUCTION

This reports the methodology which Advanced Environmental Concepts has adopted for Melbourne City Council's air conditioning system.

The Approach section explains how the methodology is based on actual building loads from a year's worth of simulations, not design calculations. This leads into the Methodology section which explains peak cooling load analysis and the importance of Test Reference Year weather files.

Any advantages and disadvantages will be summarised in the Conclusions and Recommendations section.

The South Perimeter on level 5 of the proposed Melbourne City Council House will be used as a basis for analysis. For the purposes of this report, cooling loads will refer to the cooling requirements of a building.

2 THE APPROACH

Traditionally, design parameters such as those for building fabric construction, maximum dry and wet bulb temperatures, etc are used to predict cooling load requirements.

The methodology used in sizing the air conditioning system for MCC is based on building simulation results. Using a three dimensional model of building design current 14 August 2003, dynamic building simulations and calculations are performed to produce results from which an accurate analysis can be undertaken.

These results give us hourly data for peak cooling/heating loads which we use to size the air conditioning system. These loads maintain thermal comfort within the building and offset the effects of the internal and external building environment.

The methodology can be summarised as being based on the adoption of:

- Three dimensional computer thermal modelling
- ACADS BSG/CSIRO, Melbourne nominated TRY (Test Reference Year) recorded weather data
- Sizing based on the frequency of 95% peak loads

3 METHODOLOGY

3.1 Internal and External Conditions

Internal or indoor conditions such as occupants, equipment and lighting cause heat gain into the space. Internal conditions for offices are predictable and constant, especially when there is a design occupancy of 1 person per 15m², like in the new Melbourne City Council offices.

External or outdoor conditions, on the other hand, are erratic as they depend on weather conditions, and include conditions such as solar radiation, diffuse radiation from cloud cover, and wind effects.

Because sizing is based on building simulations, the type of weather data used to provide external conditions is crucial.

3.2 Weather Data

In producing results such as the frequency of cooling loads, the type of weather data used to predict building behaviour is of crucial importance.

Test Reference Year (TRY) weather data for Melbourne city, was used for modelling the MCC building. A Test Reference Year is a weather file nominated by ASHRAE (American Society of Heating Refrigeration and Air Conditioning) representing most typical weather conditions using years of collected weather data.

Using TRY weather data in for the MCC project is beneficial because:

- it incorporates thermal mass effects
- it allows us to account for diffuse solar radiation effects from cloud cover

3.2.1 Thermal mass effects

The new Melbourne City Council building relies heavily on the thermal mass effects of its concrete ceilings to cool the building via a night purge ventilation system. This system reduces cooling loads by around 14% on a typical summer's day.

It is therefore fundamental that we account for this reduction in load caused by thermal mass effects during the air conditioning design sizing process.

3.2.2 Diffuse solar radiation from cloud cover

Traditionally, load sizing is based upon AIRAH procedures which assume that solar intensities or effects occur under clear cloudless skies.

This type of approach is not appropriate when sizing air conditioning cooling for facades which are not exposed to direct solar radiation. These façades such as those which exist on the South are most likely to experience peak summer conditions during cloudy hot days, not clear cloudless hot days.

A good example of this occurs in the new Melbourne City Council building. The peak summer conditions in both the North and East façades occur when it is hot (32.7°C) and the sky is clear. The following graph will show solar radiation on this day.

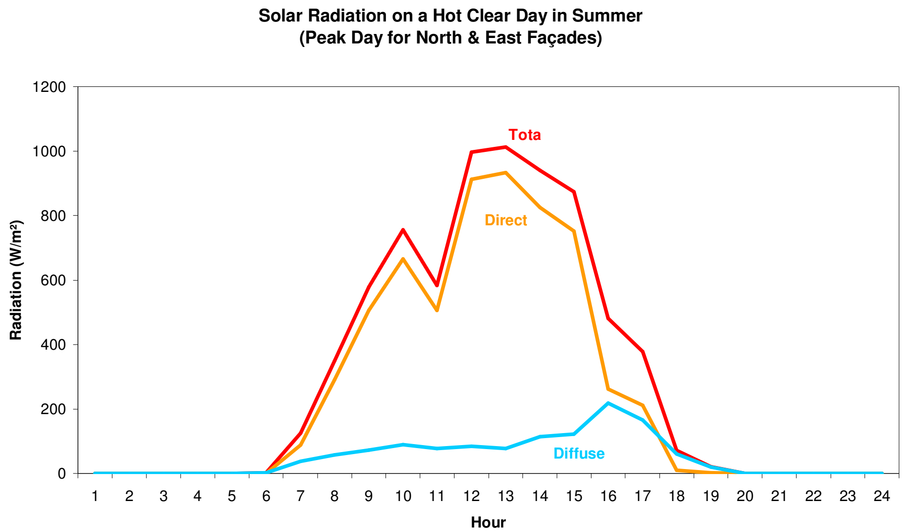

Figure 1. Solar Radiation on a Hot Clear Summer's Day

It is clear that on this hot clear summer's day that the total solar radiation is mainly influenced by direct solar radiation. And because it is a clear day, direct solar radiation is high.

However, the peak South facade loads on the MCC building occur on a completely different day which is not only hot (38.1°C) but cloudy as well. The following graph will show the effects that diffuse radiation has on total solar radiation on this day.

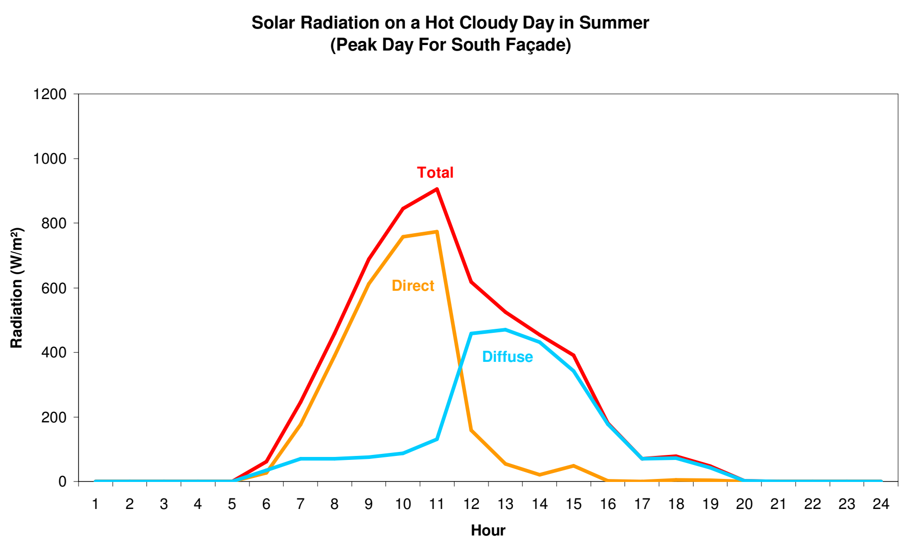

Figure 2. Solar Radiation on a Hot Cloudy Summer's Day

We can see that from 11 o'clock onwards, it is the effect of diffuse radiation which mainly influence the level of total solar radiation. Even though the temperature is higher, cloud cover reduces the effects of direct solar radiation.

Therefore, in areas subject to hot summer conditions, the effect of diffuse radiation must be taken into account as it will affect the sizing of loads for façades not directly exposed to the sun.

3.3 Zones

Air conditioning design is based on zones because different zones have different cooling requirements depending on their location.

For the purposes of this report heating and cooling requirements will be referred to as heating and cooling loads.

The following diagram shows the zone layout in the new Melbourne City Council building.

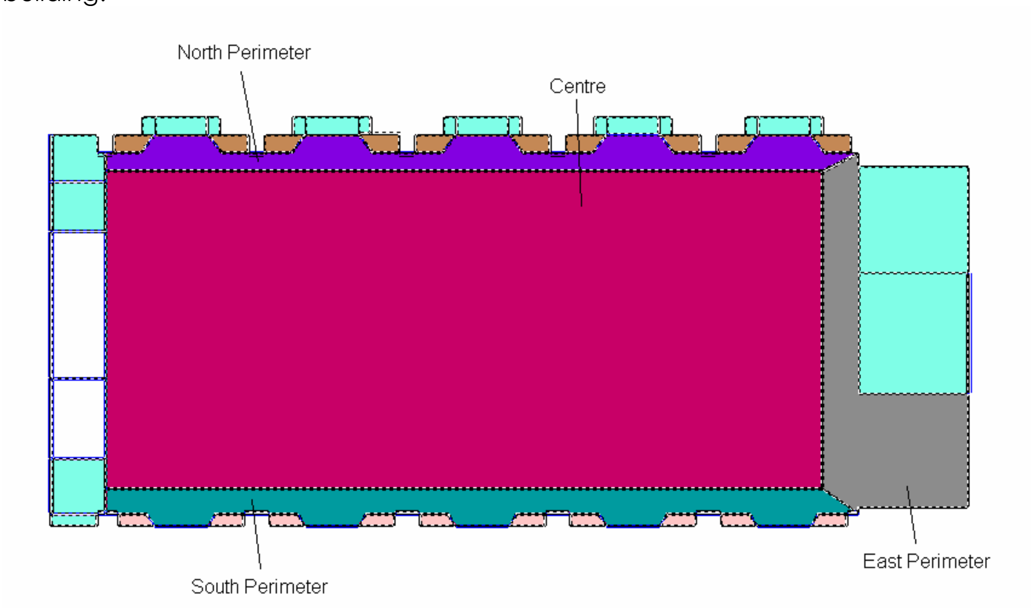

Figure 3. MCC Zone Layout

The perimeter zones protect the centre zone from the external environment. Notice that there is no West Perimeter because on the West, a zone consisting of lifts, stairs and balconies isolate the centre from the external environment.

The relationship between zones and conditions can be summarised as follows:

- Centre zones – subject only to internal conditions
- Perimeter zones - subject to both internal and external conditions

3.3.1 Centre zones

The centre zones can fixed because of their constant internal conditions but they must be sized to meet these conditions.

For the MCC building, the chilled ceiling panels are sized and fixed at 17.8 W/m².

3.3.2 Perimeter zones

The perimeter zones cannot be fixed because the air conditioning must respond to the unpredictable external environment. The system must be sized to peak load capacities instead.

The MCC building uses chilled beams in the perimeter zones which must be sized at a peak load capacity.

3.4 Sizing to 95% Peak Load Frequencies

Sizing to 95% peak load frequencies refers to sizing based on the frequency of hourly peak loads which occur for 95% of the year.

Traditionally, sizing is based on a zone's highest peak load. However, the highest peak load may not occur very often so it helps to view peak load frequencies for a better overall perspective. This can be seen in the following graph which shows the frequency of hourly peak cooling loads throughout the year.

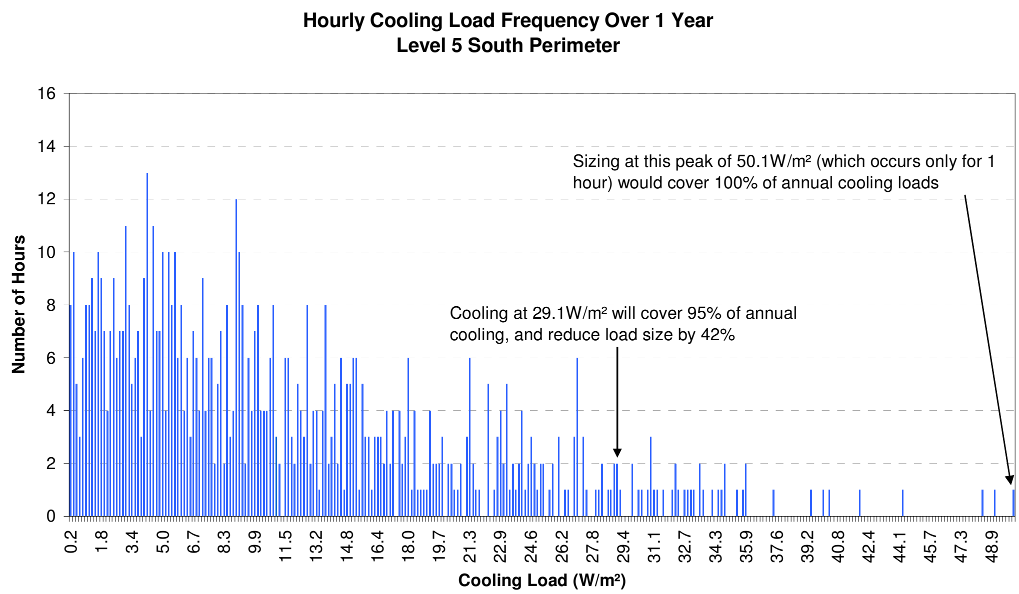

Figure 4. Cooling Load Frequency, MCC Level 5 South Perimeter

The graph shows that if the cooling load is sized at the highest peak of 50.1W/m², the system would be designed to cater for a peak which occurs for only 1 hour during the year. Notice that cooling loads past 35.9W/m² become sparse, and that these cooling loads only have a maximum demand of 1 hour during the year.

Designing to 95% of peak load frequencies is a more sensible approach to load sizing because it caters for loads that will occur for the most part of the year, not infrequent higher loads which only occur for 1 hour.

In the new MCC building, sizing for 95% of peak frequencies on level 5's South perimeter reduces the peak load size by 42%. This means that the beams are smaller, take up less space, contribute to reducing energy consumption, and cost less.

3.5 Consequences of sizing to a 95% design year

A test was carried out to see what would happen to office zone air temperatures on Levels 1 (lowest) Level 5 and Level 9 (highest) when sizing is based on 95% peak load frequencies during peak load (hottest) conditions. The results are as follows:

Zone	**Peak Air Temperatures During Peak Conditions in °C Cooling Loads Sized to a 95% Design Year**		
	Level 1	Level 5	Level 9
North Perimeter	25.5	25.5	25.1
East Perimeter	25.5	25.1	25.1
Centre Zone	25.4	25.4	25.1
South Perimeter	25	25	25

Figure 5. Air temperature results using sizing based 95% peak loads.

Note that design temperature upper limit is 25°C.

It can be seen that sizing loads to the 95% design year increases air temperatures by a maximum of 0.5°C and will make no significant effects in comfort levels during peak weather conditions.

3.6 Design Basis for Future

A key feature of the design for the CH_2 air conditioning system is that it has been designed to suit actual occupant and equipment loads. Such a design approach ensures that all elements of the system are optimised in terms of economics, space and energy efficiency. However, a consequence of such a design approach is that there is limited capacity in the system for future changes in equipment and occupant loads.

To ensure that the system does provide flexibility for future load increases, however, the following aspects have been included in the system design:

1. All chilled water risers and pipework are to be sized with sufficient capacity for future load increases to ensure that additional chilled ceiling panels can be plugged in at a later date
2. The centre zone chilled ceiling panels have been sized to allow for clusters of equipment and people within the zone rather than a fully distributed load

The above measures ensure that future flexibility is fully considered in the design without a significant impact to cost, space, and energy efficiency.

4 CONCLUSIONS AND RECOMMENDATIONS

Using results from analysis, the following is a summary of advantages and disadvantages to the sizing methodology which was adopted by Advanced Environmental Concepts for the MCC building.

Advantages:

- Using computer modelling reflects actual building behaviour
- Test Reference Year weather gives annual hourly data to reflect external conditions
- Peak loads are the results of simulations, not parameter based calculations
- Thermal mass effects are accounted for
- Diffuse radiation from cloud cover is accounted for
- Sizing is based on peak load frequencies, not highest peak loads
- Peak load sizes are significantly reduced
- Peak load size reduction produces large economic benefits
- Peak load size reduction produces large space saving benefits
- Peak load size reduction contributes to energy consumption reduction
- Comfort levels are not affected

Disadvantages:

- Air temperatures could increase by a maximum 0.5°C in the office spaces

Analysis has shown that the peak load size for level 5's South perimeter in the MCC building have decreased by 42%, without any comfort.

Based on these outstanding findings, it is recommended that this methodology be adopted by Melbourne City Council for the sizing of the air conditioning system. The methodology promotes a more sensible approach to system sizing whilst still meeting the needs of the building and its occupants now and in the future.

APPENDIX A – 95% COOLING LOADS

ZONE	Zone Spacecooling Load Analysis in W/m²								
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9
North Perim	32.4	31.6	30.3	29.5	29.1	28	27.8	26.5	36.9
East Perim	17.5	20.8	20.8	20.5	21.0	20.9	21.5	22.2	27.3
Centre	All centre zones are fixed at a spacecool load 17.8 W/m²								
South Perim	32.9	32.2	31.3	30.1	29.1	28	26.7	26.1	35