Generic Models in the Design of Solar Commercial Buildings

M. DONN[1]**, N. ISAACS**[1]
School of Architecture, Victoria University of Wellington

R. AMOR[2]
Computer Science Department, University of Auckland

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[1]School of Architecture, Victoria University of Wellington, P.O. Box 600, Wellington, N.Z.
Ph. 0-4-471 5361Fax 0-4-495 5233

[2]Computer Science Department, University of Auckland, Private Bag 92019, Auckland, N.Z.
Ph. 0-9-3737 999Fax 0-9-3737 455

SUMMARY - To promote the use of thermal simulation tools in the New Zealand environment (DOE2.1D and SUNCODE) a set of generic models were developed. These include: Standard data on building materials used in commercial buildings in New Zealand; Materials data collated into descriptions of standard buildings which are representative of commercial building `types'; Standard building model descriptions which are intended to provide an easy method for designers to start using either simulation program. As a further aid to the use of these two simulation programs standard weather files have been developed for 22 locations in New Zealand and the South Pacific. Production of these files from a base of up to 30 years' data for each location was a complex computer intensive statistical process. This process has produced not only `typical' years, but also data for hot and cold years. These are supplemented further by data for design evaluation which describes "hot and windy", "hot and calm" or "cool, calm and sunny" weeks in each location.

1.INTRODUCTION

In a world that expects its buildings to be one-off designs with increasing performance and reliability, the building design team is under great pressure to use as many of the available design analysis tools as possible. Numerous CAD systems and, in the HVAC world, simulation programs, are being marketed to meet this demand. Most design tools available today, especially thermal simulators, are derived from large research projects of the 1970's, when computer aided simulation was a popular new area of research.

Making these design tools more widely available, particularly to those with little direct expertise in the tool's application area, has led to some new problems (Hastings, 1991; Hosking et al., 1991; Levary and Lin, 1988). While it is relatively simple to encapsulate the mathematical expertise of a services engineer or architect in a program to calculate the thermal load in a room, it is far from simple to encode their expertise in application of this mathematics, both in entering the correct information into the design tool, and in interpreting the results. A naive user of a design tool requires assistance in the use of the tool, not only to interpret the results, but also to enter the initial building data accurately. It has only been in the last few years that the companies and academic institutions supporting these tools have started to look at friendly user interfaces.

In the pressured construction environment a further problem is the amount of time required to construct a description of a building for entry into a simulation program. This can take several days. When the same building is to be analysed by several different expert systems or simulators, similar base data have to be entered into each tool, entailing considerable duplication of effort, and many opportunities for error.

Updating the design or testing slight modifications requires the changes to be made in all descriptions of the building for all the design tools. Few tools are designed with a view to interfacing with other tools.

1.1Research aims:

In recent years, the Victoria University School of Architecture has undertaken a number of projects (van der Werff et al., 1990; Amor et al., 1992) which have addressed the above issues. The project discussed here had the following aims:

- ■Create a system of library files of building materials that can be incorporated easily into a building definition for input to a computer simulation.
- ■Devise a number of base building definitions, each representing a different type of building or configuration, to ease initial data input to computer simulation.
- ■Develop building descriptions which provide users of the simulation programs with a standard of performance against which to measure their own designs.
- ■Develop a system of weather data files for New Zealand, to be called upon by building simulation programs; these files should cover both extreme and typical design conditions in all the climate regions.

1.2Design Tools being studied

The design tools (CAD, simulation, modelling) used in the School of Architecture encapsulate most of the faults described in the introduction. They have very different representations of a building, model different categories of building, take a long period of time to learn, have very little internal checking of the building being modelled, etc. To give a feel for the differences in the building model used by these simulations a few of these tools are described below.

In SUNCODE (1981), a building is described in the following manner: for the outside of the building a surface is described which has windows, sidefins and overhangs in certain positions. These surfaces have a specified orientation, a fixed height and length, and may be used to orientate any number of walls, none of which have to lie in the same plane. Spaces in the building are described by a dimension, and which zones they are next to. Walls are defined as lying between two spaces, or between a space and a surface. The windows in a surface are connected to a space in the building. There is no indication of the position of the spaces relative to each other or to the positions of windows, sidefins and overhangs in a wall.

The DOE2 (1981) data files are quite different from the SUNCODE data files, both in structure and in completeness of the building description. The association of a wall with a space and a window with a wall is made by the location data for each object. All walls described after a given space definition, up to the next space definition, are part of that space. Similarly all windows and doors described after a given wall, up to the next wall or space definition, are part of that wall. All walls are located explicitly by the X and Y co-ordinates of the lower left hand corner of the wall, and the azimuth angle of the wall. Similarly, windows are located explicitly on the wall by the X and Y offsets from the lower left hand corner of the wall.

The DXF standard (1990) is merely a system for exchange of graphic information. In order to define a wall, or a space defined by a grouping of walls, this graphic information must be structured systematically. In order to do this, it is typically necessary to overlay a structured data input system for the graphics or CAD system which creates the DXF file: a model of a building.

By contrast to the above, a recently created simulator such as the RADIANCE lighting program (Ward, 1992) describes a building in the following manner: each object in the building which might affect the light reaching or being reflected around the interior is defined using geometric coordinates and physical properties. The positions of windows, walls and even chairs and tables which may be of importance in light reflection, all are defined in one coordinate system. This geometric absolutism makes exchange of data from CAD systems to RADIANCE easier than to the above thermal simulators.

2.TYPES OF BUILDINGS/CONFIGURATIONS

The project restricted the types of buildings that it was concerned with to **Non-Residential or "Commercial" Buildings**. This work adds to the extensive work already undertaken on New Zealand low energy residential buildings (van der Werff and Donn, 1990). An inherent assumption that is also placed on the types is that they are to be "standards" against which either solar or low energy buildings are to be judged.

1 shows the wide range of possible building "types" that are relevant for non-residential buildings. This kind of list is standard in this research area. The activity and the building are often confused in the description. Thus, an "office" building is a common description both of the building itself and the activity it houses. It was determined, early in the project, that a definition of a basic building "type" must be a combination of both the building and the type of activity housed. This new building "type" description is incorporated into each basic computer model.

Table I "Building" types examined

‘Stand alone shop, eg. corner dairy.
‘Up to 5 shops in the same block, each of the corner dairy size
‘Stand alone food barn
‘Houses converted to commercial offices
‘shopping malls
‘a shop within a shopping mall/small block of shops
‘warehouses - storage
‘warehouses - art galleries, etc
‘showrooms: car, furniture
‘garage
‘underground mall
‘airport terminals
‘factories, printing plants, etc
‘2-storey office developments
‘multi-storey buildings
‘hotels
‘motels
‘restaurants
‘libraries
‘mcdonald-type takeaways - large
‘small takeaways

2.1Building Types

The following range of basic types of building was defined. Each could house a number of different occupations or activities:

1)Small shop (e.g. dairy).
2)Small shop with house attached.
3)Small shop within a row of shops.
4)Two storey office/ retail building.
5)A single floor within a multi-storey building.
6)Barn or warehouse building (e.g. supermarket)

Table II Combinations of building and occupation modelled

Occupancy Type building type:	retail	office	consulting	public
single zone bldg	y	n	y	y
multi-zone bldg	y	n	y	n
row of shops	y	n	y	n
2/3 storey bldg	y	y	y	y
multi-storey bldg	n	y	y	n
barn	y	n	n	y

2.2Occupation types

Four dominant occupational or activity classes were defined.

1)Retail
2)Office (e.g. clerical)
3)Consultancy (e.g. legal, medical)
4)Public (e.g. art gallery, museum)

Twelve different combinations of building type and occupation type were determined to be representative. The combinations that have been modelled are shown in 2.

These twelve combinations are further subdivided according to their "construction type". This was required because the varying construction types cause a significant change in the model that is used as input for each of the computer programs. In total 27 base computer models were created for each program.

3.CONSTRUCTION TYPES:

The construction types describe the likely combinations of materials used in making the floor, wall, glazing and the roof of each building. The following sections outline the materials and construction methods used to "make" these 27 base computer models:

3.1Floors

- The larger the building, the more likely it is that it will also have extensive concrete foundations (and also that it will have a basement, hence concrete retaining walls, and a large air mass below ground). Buildings that have basements may well have `double' concrete walls - one being site concrete, the other structural concrete. Every base building type models an un-insulated concrete slab on ground.The exception is the multi-storey building which does not model a ground floor at all.
- Some smaller commercial buildings (those approaching the domestic scale) well have suspended timber floors. The single and multi-zone building types model a suspended timber floor insulated with aluminium foil.

3.2Walls

- Perhaps the most common wall-type in commercial construction is glass. However, glass requires a supporting system (wood or aluminium), and is rarely the only external wall type for the building. The glazed curtain wall is modelled within the two storey building. It consists of aluminium framed glazing outside the structure. This is modelled as a window, not a wall.
- Precast concrete panels are also a popular type of wall. This type is modelled as an option by the multi-storey building type.
- A completely lightweight building, i.e. walls and roof. Every building type models this type of wall. It is the only wall modelled in the single and multi-zone building types.
- A structurally heavyweight building (concrete/steel columns/floors/roof) with lightweight timber walls between the structural members. The lightweight timber construction definition in combination with the suspended 200mm concrete floor slab definition is used to model this.

3.3Roofs

- The main type of roof used in construction is lightweight and sloping (either timber or steel framed) with a lightweight cladding (say corrugated steel or tile). All roofs are of this type. The single and multi-zone and two storey building types all have a ceiling and trapped air layer. The row of shops and barn do not.

3.4Insulation

Only the single zone and multi-zone buildings are insulated. These are the domestic scale buildings. All the larger buildings (and the row of shops) have no insulation at all. The two domestic scale buildings have 100mm fibreglass insulation in both the walls and the roof.

3.5Infiltration

The infiltration rates were initially calculated using the graphical ALF method (van der Werff & Bassett, 1991). All calculations assumed that the building was in a high wind zone and in a medium sheltered area. This method works as a guide to the likely order of magnitude of infiltration in single and multi-zoned buildings. As expected for the larger buildings, the calculated infiltration rate was not realistic. In these instances, an infiltration rate of 0.1 air changes an hour was assumed.

3.6Internal Gains

Buildings are generally heated by three different sources: the sun; heating appliances or systems; and internal gains from people and equipment within the building.

All buildings were modelled as receiving heat from internal gains, scheduled in terms of operating hours, number of people working, number and size of lighting and types of equipment commonly to be expected associated with the activity housed by the building.

It is in this section that the assumptions about the activity and construction combinations are most obvious.

4.WEATHER DATA

The 22 raw weather files held by the School of Architecture contain unprocessed weather information from NZ Meteorological Service offices, with hourly values collected for 21 facets of the weather at the site. Most of these weather files contain data for a period of 26 years, see 3. None of the weather data files contain solar radiation data as very little was available outside the main centres until recently. The cost of obtaining up-to-date solar data precluded obtaining readings to supplement the files.

To make the mass of information stored in these weather files useful for simulation requires the selection of a portion of data (usually a year) formatted in a manner suitable for a simulation tool. With a resource of weather data files available, the user then has the ability to simulate their building under actual New Zealand conditions for a series of locations. The user can also easily test the building in several locations to determine its performance, even for Pacific islands.

4.1Weather File Conversion

To get useable weather information from the raw data files required considerable analytical effort. The following significant steps were undertaken for the conversion to simulation weather data:

■remove "spikes" (spurious, random errors);
■check for missing data values, and put in estimated weather data at these points. Initial attempts at calculating values for missing data in the weather files, through the generation of sinusoidal patterns that followed the daily variations in temperature, led us to seek a better method of calculating values for missing data. After consultation with the New Zealand Meteorological Service (Reid 1990), we developed an algorithm that calculated missing data in the following fashion. For each month of every year we created a temperature profile for that month which consisted of the hourly average temperatures for that month. This profile was scaled to the first valid value before the missing data and an offset applied to each successive hour so the profile would match the first valid data after the stretch of missing data. This technique produced very realistic weather curves for periods with missing data.
■pick "good" years. Where a particular year fitted all the TRY selection criteria yet had a large number of missing values, the next closest fit was found;
■calculate monthly averages, highs and lows for each year;
■calculate monthly heating and cooling degree days for each year to compare years;
■determine long-term mean temperature, wind speed and cloud cover;
■calculate normalised temperature, wind speed and cloud cover to help in selection of particular "design weeks". It was decided that with the amount of data available for analysis it would be useful to develop weather data that would help designers test their buildings under `hot' or `cold' conditions;
■create a Test Reference Year (TRY) format data-set for entry to the DOE2.1D weather processor for generation of synthetic solar data from available cloud data.
■In some cases, required ground temperatures were not recorded for sites for which we had hourly data. Where this occurred the closest location that recorded ground temperatures was used. For some sites, ground temperatures were only collected at 0.3 metres depth, and not the 1 metre sought, and the 0.3 metre values were used. For some sites, records of ground temperatures started at a later date than some of the

Table III Weather sites

Site	Start	End
Alexandra	1978	1985
Auckland, City	1961	1985
Auckland, Whenuapai	1960	1979
Campbell Island	1970	1979
Chatham Island	1970	1985
Christchurch	1960	1985
Dunedin	1962	1985
Hamilton	1978	1985
Hokitika	1961	1985
Invercargill	1960	1985
Kaikoura	1964	1985
Kaitaia	1962	1985
Nadi, Fiji	1960	1979
Nasouri, Fiji	1973	1979
Nelson	1961	1985
New Plymouth	1961	1985
Ohakea	1960	1985
Paraparaumu	1961	1985
Raoul Island	1970	1979
Rarotonga	1970	1979
Wellington, Airport	1960	1985
Wellington, Kelburn	1961	1985

selected years' data. Where this occurred the later years' ground temperature data was used for the earlier years' data.

4.2Weather file analysis

Using the processed weather files, analyses were done to find years of weather data which are: average; hot; cold. The data was also analysed to find single weeks of weather data that met certain specific criteria:

- hot and windy;
- hot and calm;
- cool and windy;
- cool, calm and sunny;
- cool, calm and overcast.

The one percentile week of each type was selected and a year of weather data extracted around each of these weeks. This produced a suite of weather data files for each location which allow a designer to test a building for periods of extreme as well as for average weather.

With the required years of weather data identified, the next step was to extract the data from the weather files and format it in a manner acceptable to the simulation programs. At this point radiation data was required for SUNCODE and none came with the raw weather data. To overcome this problem radiation data computed by the weather calculation program of DOE2.1D was used. This calculated radiation data was extracted from the DOE weather files and incorporated into the data files used for the SUNCODE simulation program. The major caveat that must be placed on radiation data generated in this manner is that it relies on correlations between long-term average data and has thus not been `verified' for hour by hour data (IEA 1992).

This process produced 8 selected years of weather data for each site for each programme, with database files of corrected data should further work be required. A total of 8 megabytes of data for each site is now archived.

5.RESULTS

The project has shown the feasibility of the library approach to the use of thermal simulation programs. However, it has only addressed one of the problems identified in the first part of this paper. The user manuals and programs are still not "friendly". A user friendly version of the simulation program is required to enable the designer to get their "feet wet", to gain confidence in use of the program.

The level of use of the construction material libraries and of building `type' libraries in School of Architecture classes in Energy and Buildings has demonstrated their utility. An interesting by-product has been that they help the first-time user to devise their own input files to these tools by providing a ready-reference for the types and values of material properties that these simulation programs require.

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