A SOURCE OF ERROR IN THERMAL SIMULATION PROGRAMS

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Abstract *This short paper demonstrates the existence of an error in instantaneous heat loss calculations due to errors inherent in the input data. By implication, these errors will also be present in thermal simulation programs.*

1 Background

Interest in the ability of thermal simulation programs to describe physical reality has been synonymous with their development. Accuracy becomes increasingly important when thermal simulation is permitted as a method of verifying Building Regulation compliance such as in NZS 4243:1996.

BESTEST has demonstrated that there is variance between even the most respected simulation programs. Problems can stem from the fact the often assumptions have to be made in terms of the input data set required to run a simulation. This is necessarily true when a building design is being considered: Until the building is completed the data set is largely hypothetical.

2 Demonstration of inherent error

The problem described in this paper is the error inherent in thermal simulation programs. To demonstrate this the instantaneous heat flow through an insolated timber stud wall - which is a typical construction in New Zealand – is modelled. The construction from inside to outside is 19mm weather board on building paper on 100x50mm pine studs @ 0.65m centres, with 10mm plasterboard internal lining.

The heat loss per unit temperature difference between in and outside is given by

$$Q_{cwall} = 1/R * A * (ts - ti) \quad (1)$$

where

Q_{cwall} is the energy conducted through the wall W/m^2
R is the thermal transmittance from air to air through the wall in m^2C/W
A is the area of the wall (taken as unit measure) = 1 m^2
ts is the sol-air temperature (C), and
ti is the indoor temperature (C)

The air to air R-value of this construction is given by

$$R = 0.9.(r_{is} + r_w + r_c + r_{pl} + r_{os}) + 0.1.(r_{is} + r_w + r_s + r_{pl} + r_{os}) \quad (2)$$

where

r_{is} is the external surface resistance
r_w is the resistance of the weather boards
r_c is the cavity resistance
r_p is the plasterboard resistance
r_{os} is the external surface resistance, and
r_s is the timber stud resistance.

This expression allows for 10% of the wall construction to be studwork by area.

To evaluate this expression we are required to set values for the components of 'r'. The first problem is in establishing the external surface resistance, values of which vary between 0.03 and 0.08 m^2K/W depending upon degree of exposure. For most ordinary building materials a sheltered surface has a value of 0.08, a normally exposed surface 0.055 and severely exposed 0.03 m^2K/W. Whilst there is probably little hesitation on the part of the designer in deciding which of these three categories apply, it seems probable that there are many intermediate situations which ought to be interpolated. Values for 'normally' exposed surfaces could thus vary between 0.0425 and 0.0675.

Taking physical values obtained from the New Metric Handbook (79), the air to air R value of the wall construction cited above is found to vary between a maximum of 0.364 and minimum of 0.333 m^2K/W using the above two values, a difference of 8.5% of the larger value. If we add glass fibre insulation of R=1.8 m^2K/W the corresponding values are 1.984 and minimum of 1.953 m^2K/W, a variation of 1.5% of the larger value. The effective surface temperature (the sol-air temperature) due to the thermal effect of the incident solar radiation is given by

$$t_s = t_o + r_{is} * (G*\alpha) \qquad (3)$$

where

t_s is the sol-air temperature (°C)
t_o is the external temperature (°C)
α is the absorptance of the insolated surface (a ratio< 1), and
G is the incident solar irradiation (W/m^2)

The values for G are in the order of 10^2. The values α, the solar absorptance, range between 0.1 and 0.9. Most building materials would have a value of around 0.5 to 0.6. This range includes wood, concrete, stone etc. The value depends upon the surface colour and finish. White paint has a value of around 0.3. If we assume that the external temperature is around 22°C - not unusual for Auckland - and the α value is 0.5, and the G value is 250 W/m^2, then using the two external surface resistance values are 0.425 and 0.675, the sol-air temperatures calculated by equation (3) are 23.7 and 30.4°C respectively.

If the internal temperature is around 18°C, then the heat gain by equation (1) can provide up to four results using the sol-air temperatures based on the extreme surface resistances, and also the two R values these resistances produce. The four values of energy transfer are 25.6, 28.0, 34.2 and 37.3 W/m^2. The most extreme occurs when the two errors reinforce one another. If we dismiss this as being least likely, we are left with a variation of 6.2 W/m^2, or 18% of the larger figure.

3 Conclusion

The demonstration above used modest values. More extreme values would generate greater differences in calculated values. It can thus be seen that even modest assumptions concerning input data to thermal simulation models can lead to significant errors in output .The above calculations dealt with instantaneous heat flow through an insolated wall. Error will be much reduced in calculation for non-insolated walls, but will nevertheless be present. Results integrated over hourly iterations as performed by thermal simulation programs can be assumed to reduce the effect of this error in overall seasonal results.

It is shown that thermal simulation models of buildings are unable to model reality exactly, but are better for comparing versions of the same building. By comparing similar versions the errors are, arguably, cancelled out.

4 Reference

Tutt.P & Adler.D (1979): New Metric Handbook, Architectural Press, London (also 1997)