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# REFLECTIVE SUBFLOOR INSULATION INSTALLED TO CONTEMPORARY INDUSTRY PRACTICE

*An Empirical Validation Study*

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**Abstract.** The adoption of increased thermal performance requirements, as specified in the Australian National Construction Code, has been linked to a significant reduction in the use of timber platform flooring systems. This appears to be related to perceptions of thermal performance differences that may occur between timber platform and concrete slab-on-ground flooring systems. Industry has responded by providing a range of products that provide subfloor insulation, including batt-bulk, rigid, spray-in-place foam and reflective systems. For what appears to be a cost-of-construction reasoning, the reflective systems have gained a significant portion of the subfloor insulation market. However, industry and government have raised concern with regard to industry knowledge of and the application and installation of reflective subfloor insulation products as a component of platform floored systems. In this research, a contractor installed a reflective subfloor insulation product as per their standard practice. The insulation was not installed to the manufacturers specification. To quantify the thermal performance effect, data was collected from unoccupied unconditioned and conditioned modes of operation. For comparison purposes detailed thermal simulations were completed using the AccuRate HER software. This paper discusses the differences that were observed between the measured and simulated zone temperatures and energy data during the heated mode of operation.

**Keywords.** Reflective subfloor insulation, Empirical validation.

## 1. Introduction

The increased minimum thermal performance requirements for housing in Australia has led to a significant shift from the use of timber platform floors to concrete slab-on-ground floors (Henderson, 2005; Iskra, 2004). This general adoption appears to be caused by perceptions that any thermal mass is good, regardless of quantity or solar access, and that it is too costly or construction process too restrictive to insulate timber platform flooring systems. The manufacturing and construction industry responses to the increased insulation requirements for timber platform floors has led to a range of reconfigured and new subfloor insulation products. These have included batt (or bulk) products with varying support systems, rigid polystyrene systems (some with reflective foil) and a range of reflective foil and foil sandwich systems. Many of these products have borrowed from or redesigned internationally accepted systems to suit Australian construction practises. However, industry representative bodies and government agencies have raised concern with regard to industry knowledge of and the specific installation requirements for reflective subfloor insulation products.

Within this context, the enclosed-perimeter platform-floored test cell, at the University of Tasmania, was used as a testing and empirical validation platform to explore contemporary reflective subfloor installation practises and any thermal performance effect that may occur. The first stage of the research task was to allow a contractor to install the product as per their standard practice, with no additional input from the manufacturer or the university. The insulation installation was not completed to the manufacturers specification. To quantify the thermal performance effect of this installation method, data was collected from unoccupied unconditioned and conditioned modes of operation. After the data was collected, a site-specific climate file was developed and using the AccuRate software (V2.0.2.13 SP1), detailed thermal performance simulations were completed. Four simulation types were developed included recognition of thermal bridging and the inclusion of the timber structure as thermal mass. Finally, this paper then discusses the differences that were observed between the measured and simulated zone performance from the continuously heated mode of operation.

## 2. Test Building Configuration

The three test cells located on the Newnham campus, University of Tasmania, were purpose built for material thermal performance analysis and empirical validation research tasks for industry and government collaborators (Dewsbury, 2011; Dewsbury & Fay, 2013; Dewsbury, Fay, Nolan, & Vale, 2007; Dewsbury, Soriano, & Fay, 2011; Dewsbury, Soriano, Nolan, & Fay, 2009). The methods of construction analysis, data collection and thermal modelling follow the principles and actions of previously accepted empirical validation tasks (Bowman & Lomas, 1985; Delsante, 2005a; Guyon & Rahni, 1997; Jensen, 1991; K. Lomas, Martin, Eppel, Watson, &

Bloomfield, 1994; Rahni, Ramdani, Candau, & Guyon, 1999; P; Strachan, 2000; P. Strachan & Vandaele, 2008). The test buildings comprise an unenclosed-perimeter platform-floored, enclosed-perimeter platform-floored and a concrete slab-on-ground floored construction systems. For this task the enclosed-perimeter platform-floored building was utilised. The measurement profile within the test cell, for this task included a vertical measuring array:

1000mm below ground level temperature,

- Ground surface temperature,
- Mid-subfloor zone temperature
- Outside subfloor insulation surface temperature
- Inside subfloor insulation surface temperature
- Outside platform floor surface temperature
- Inside platform floor surface temperature
- 3 x 600mm test cell room temperature
- 3 x 1200mm test cell room temperature
- 3 x 1200mm globe temperature
- 3 x 1800mm test cell room temperature
- Inside ceiling surface temperature
- Outside ceiling surface temperature
- Outside ceiling insulation temperature
- Mid-roof space air temperature
- Inside sarking surface temperature
- Outside sarking surface temperature
- Inside sheet-metal roof surface temperature
- Outside sheet-metal roof surface temperature.

A site weather station collected data for air temperature, relative humidity, wind speed, wind direction and global solar irradiation (Delsante, 2005a; K. Lomas, Eppel, Martin, & Bloomfield, 1994). A collaborator provided equipment to collect high quality energy consumption data at 15 minute intervals. With the exception of the energy use data, all other data was collected at 10 minute intervals. All data, once cleaned, was averaged to hourly values for analysis. Other data that was collected but is not discussed in this paper includes a range of heat flow (flux) measurements, direct vertical north solar irradiation and diffuse solar irradiation and energy use from intermittent heating and cooling modes of operation. The results and analysis from this other data will be included in future publications.

## 3. Insulation Installation

The principle purpose of this research task was to ascertain the thermal performance impact of incorrectly installed reflective subfloor insulation. The research steering group consisted of representatives from the government regulators, CSIRO, energy retailers, and air-conditioner, insulation and timber product manufacturers, and UTAS building scientists. Within this group it was generally accepted, from life experience, that reflective subfloor insulation was rarely installed correctly and that this should have an impact on the thermal performance of respective new housing. Within this context the insulation manufacturing collaborators selected an insulation installer, who in there own words “had installed the product for years” to install a market leading reflective subfloor insulation product. Figure 1 illustrates the installation method, which was not to the manufacturers specification. A previous paper discussed this issue (Dewsbury, Geard, & Fay, 2013).

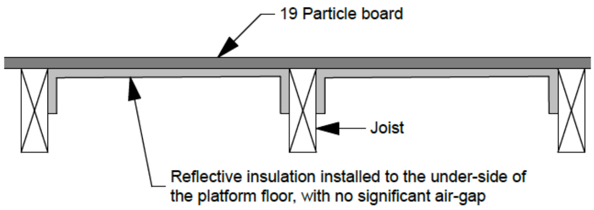


*Figure 1: Diagram of reflective subfloor insulation installation*

## 4. Detailed Building Thermal Simulation

The AccuRate house energy rating (HER) software (V2.0.2.13 SP1) was used to perform the detailed non-standard building thermal simulations. AccuRate has been developed over several decades by the Australian government and is the benchmark Australian HER software (Marker, 2005). The detailed simulations included improvements to the ‘front end’ data entry, modifications to default values within the simulation input scratch file and the use of a site and time specific climate data (Poissant & Pelland, 2008; Torcellini, Pless, Griffith, & Judkoff, 2005), as shown in Table 1. After the initial analyses were completed, government collaborators requested that a additional simulations be completed which included the thermal mass of the built structure within the floor, walls and ceiling. For ease of identification the simulation types were named no-mass and with-mass.

## 5. Results and Discussion

The thermal environment was measured at intervals of ten minutes. The data was cleaned and amalgamated into an average hourly temperature. A mix of text and graphical means of analysis were used to complete these tasks. Graphical analysis was then used to compare the average hourly temperature for each zone with the simulated hourly zone temperature. An example of the measured hourly temperature for the subfloor zone is shown in Figure 2.

Table 1. AccuRate non-standard input modifications

| | No Mass Simulation | With Mass Simulation |
|---|---|---|
| Front-end Modifications | Modification of wall system R-Value to include thermal bridging | The use of two wall systems,<br>Wall a = insulated wall system<br>Wall b = un-insulated timber wall |
| Scratch File Modifications | Measured infiltration rates for subfloor, room and roof space zones<br>Measured internal loads for test cell room<br>Modified thermostat settings for conditioned mode of operation<br>Use of a site and time specific climate file | |
| Modification of reflective subfloor insulation | Modified from a 90mm unvented reflective insulation system to a sandwich foil system in direct contact with the platform floor. | |

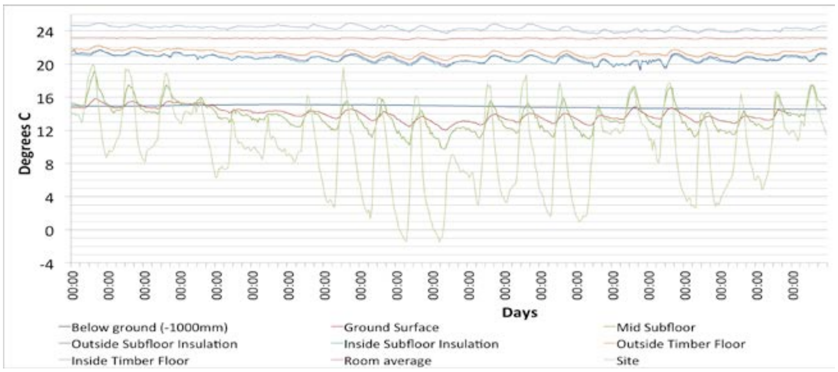


*Figure 2: Continuously heated subfloor temperatures*

## 5.1 MEASURED AND SIMULATED TEMPERATURE DATA

The measured and simulated data for each zone was then graphically and analytically analysed. The graphical comparison between the measured and no-mass and with-mass simulations for the subfloor, test cell room and roof space zones are shown in Figures 3, 4 and 5. These show the differences between the measured temperatures and the simulated with no-mass and with-mass temperatures. The data in **Error! Reference source not found.**, for the subfloor analysis, shows that the with-mass model is generally cooler than the no-mass model, and that the zone measured minimum and maximum temperatures is often centred between the corresponding values for the no-mass and with-mas simulations. The minimum, maximum and average differences between the measured and simulated zone temperatures are shown in Table 2. This table shows that the inclusion of the structural thermal mass did not provide a consistent improvement for the difference between measured and simulated data. The subfloor residual time series analysis shows a daily pattern for the greatest residual value occurring at midnight for the no-mass model and at midday for the with mass model. However, in **Error! Reference source not found.** for the roof space residual time series analysis, the no-mass graph has regular peaks at both midnight and midday, whilst the with-mass graph generally has residual value peaks at midnight. The differences between measured and simulated data are further explored in the residual time series analyses in Figures 5, 6, 8 and 9. Figure 3 and Figure 4 show the residual time series analysis for the subfloor zone. What is markedly differently between these two residual analyses is the general negative residual pattern for the no-mass model, (simulation higher than measured), versus the general positive pattern for the with-mass model, (simulation lower than measured). By contrast, the residual time series analyses for the roof space zone, as shown in Figure 5 and Figure 6, reveal a lessening of the residual value when the mass has been included in the roof space model.

Table 2. Variation between measured and simulated temperatures

| | No-mass simulation | | | | With mass simulation | | |
|---|---|---|---|---|---|---|---|
| | Subfloor | Room | Roof space | | Subfloor | Room | Roof space |
| Minimum | - 2.3 | - 0.1 | - 0.4 | | - 0.6 | - 0.1 | - 1.7 |
| Maximum | + 0.3 | + 0.2 | + 5.2 | | + 2.5 | + 0.2 | + 4.5 |
| Median | - 1.0 | + 0.1 | + 2.2 | | + 0.9 | + 0.1 | + 1.9 |

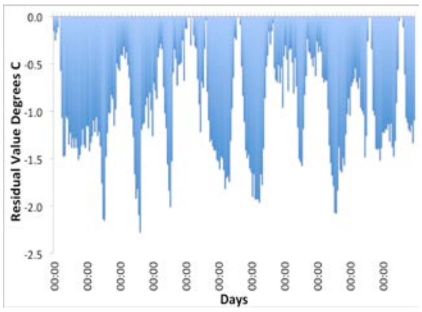


*Figure 3: Subfloor no-mass residual time series analysis: days 11-21*

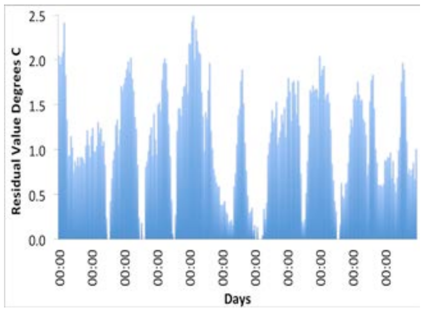


*Figure 4: Subfloor with-mas residual time series analysis: days 11-21*

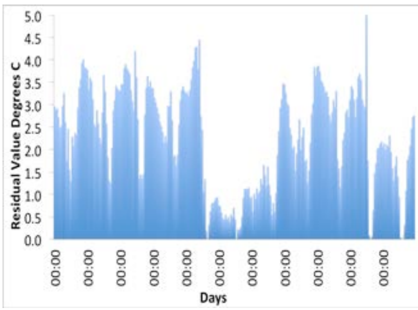


*Figure 5: Roof space no-mass residual time series analysis: days 11-21*

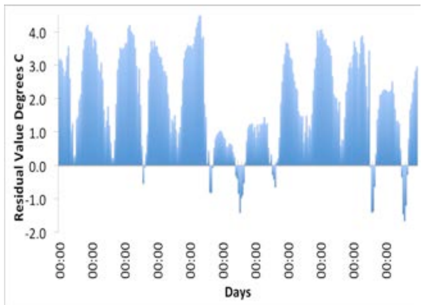


*Figure 6: Roof space with-mass residual time series analysis: days 11-21*

## 5.2 MEASURED AND SIMULATED ENERGY DATA

The final component to be compared was the measured and simulated values for energy. During the continuously heated task, the temperature within the test cell room was maintained as close as possible to 23.0 degrees Celsius, as shown in

Figure 7. The data logging equipment controlled this, with an in-line relay connected to the power supply of the reverse-cycle air-conditioner. What is noticeable in this graph is that the inside ceiling and inside timber floor temperatures were often warmer than the 600mm, 1200mm, 1200mm Globe and 1800mm air temperatures. This could be expected for the inside ceiling surface temperature but was unexpected for the inside flooring surface temperature and will be investigated further. It must be noted here that past statements have been made by the developers of the CHENATH and AccuRate tools that the software completes an energy calculation but does not predict energy use (Delsante, 2005b).

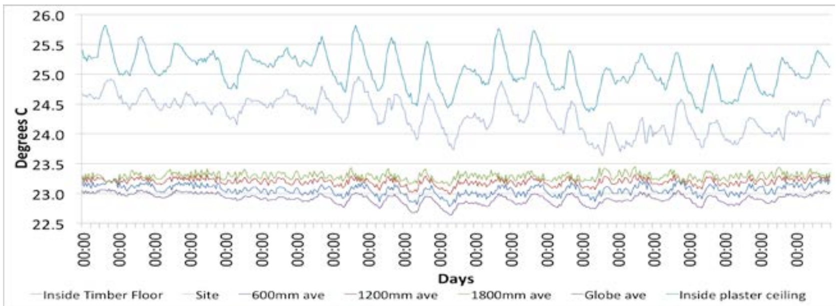


*Figure 7: Test cell room measured temperatures*

Figure 8 shows the measured and the no-mass and with-mass simulated energy use. As the air-conditioner has a better efficiency than a simple radiant or convective heater, its co-efficient of performance (COP) was required. The advertised COP of the installed reverse-cycle air-conditioner during heating operation is approximately 4.86. To appropriately reflect the appliance energy efficiency the graphs show raw measured, raw simulated and COP applied simulated data (sim data/4.86).

It is immediately obvious that there are similarities and differences between the data sets. The measured energy use is significantly less than the simulated energy use but the patterns of the data are similar even though the magnitudes are different. The COP applied simulated data shows a lower energy use than the measured energy use. The differences could result from the thermal properties of the test cell room or a subtle difference between the listed and actual COP of the heat pump. This is further illustrated by the residual time series analysis shown in Figure 9 (raw data) and Figure 10 (COP applied). These differences between measured and actual energy use are significant and require further investigation.

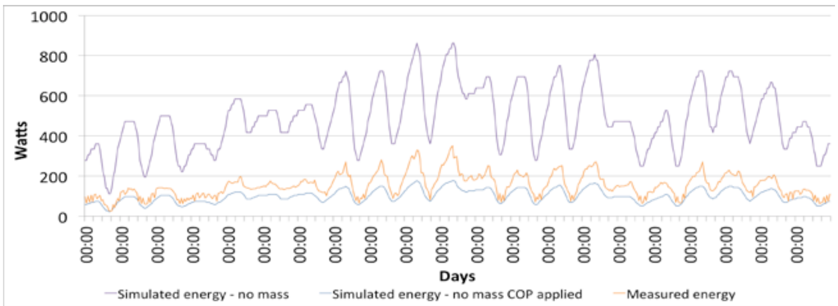


*Figure 8: No-mass measured and simulated energy use*

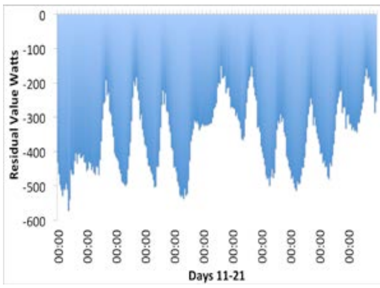


*Figure 9: Residual time series analysis - measured – no-mass simulated energy days 11- 21*

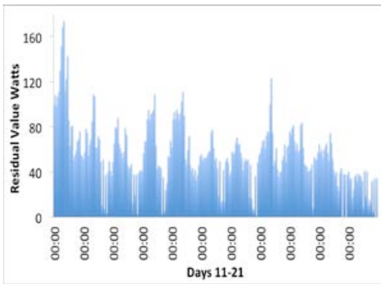


*Figure 10: Residual time series analysis - measured – no-mass COP applied simulated energy days 11- 21*

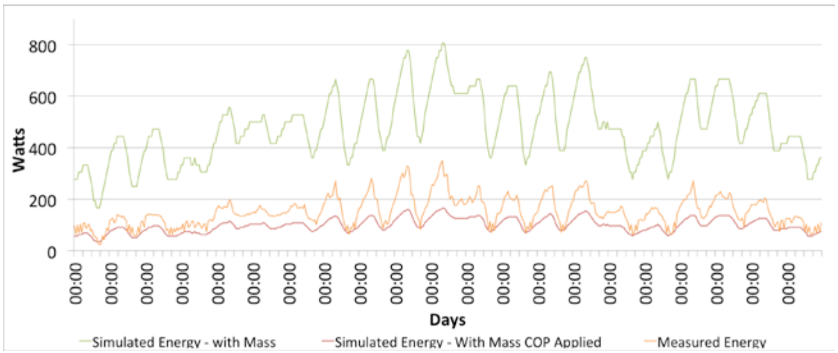


Figure 11 shows the measured and the no-mass and with-mass simulated energy use. As seen in the no-mass analysis above, it is immediately obvious that there are similarities and differences between the data sets. The measured energy use is significantly less than the simulated energy use but the patterns of the data are similar even though the magnitudes are different. The COP applied simulated data shows a lower energy use than the measured energy use. The differences are further illustrated in the residual time series analysis shown in Figure 12 (raw data) and Figure 13 (COP applied). However, the difference between measured and actual energy use is significant. The sum of the measured heating energy use was 76,672 Watts, whilst the no-mass simulation sum was 245,833 Watts and the with-mass simulation sum was 242,000 Watts. Through division a multiple difference of 3.21 for the no-mass simulation method and 3.16 for the with-mass simulation method is obtained.

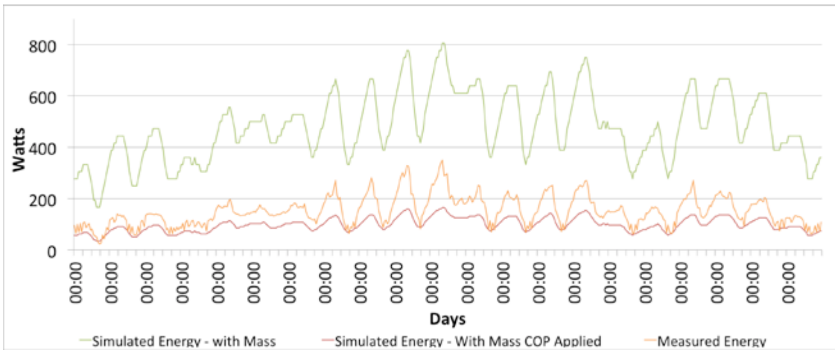


*Figure 11: With-mass measured and simulated energy use*

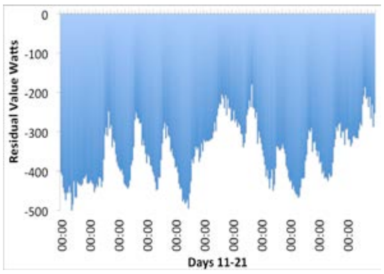


*Figure 12: Residual time series analysis - measured – with-mass simulated energy days 11- 21*

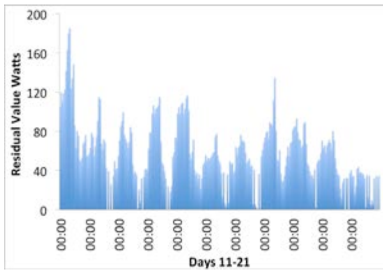


*Figure 13: Residual time series analysis - measured – with-mass COP applied simulated energy days 11- 21*

## 6. Conclusion

This research task has compared the measured thermal performance of the enclosed-perimeter platform-floored test cell with incorrectly installed reflective subfloor insulation and the corresponding detailed simulation that was completed using the AccuRate HER software. This analysis has focussed on the unoccupied and continuously heated mode of operation. At the request of research collaborators two forms of simulation were completed, namely; no-mass, and with-mass.

The graphical analysis showed that the simulated and measured temperatures followed similar patterns but there were obvious differences in the minimum and maximum temperatures. The general similarity between the as-built measured and simulated data sets indicates that a de-rating for incorrectly installed reflective subfloor insulation should be applied. The residual time series analysis illustrated the daily cycles of low and high residual values for the roof space and subfloor zones in both the no-mass and with-mass models. This could be resulting from intra-zone or inter-zone energy flows and requires further investigation and analysis. This would include previously tested statistical methods of analysis. The differences between the measured and calculated energy were significant and this would have an impact on the use of simulation data for equipment sizing and relative star ratings of houses. This research has shown that both the no-mass and with-mass models have merit but further research and analysis is required.

Further analysis and investigation is required as the differences between simulated and measured data could be caused by energy calculation algorithms in the software, a greater flow of energy through the built fabric or the reverse-cycle air-conditioner as-installed co-efficient of performance.

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