Alternative Building Materials:

Testing and Modeling of the Performance of Phase-Change Materials on Thermal Comfort and Energy in Vancouver

An applied research project submitted to the British Columbia Institute of Technology in partial fulfillment for the degree of Masters of Engineering – Building Science

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Introduction to Phase Change Materials (PCMs)

- PCMs are materials that utilise the latent heat of fusion, the energy associated with a phase change
- PCMs have a high latent heat of fusion and convenient temperatures at which their phase change occurs
- PCM will store or release heat while maintaining a constant temperature, maintaining favourable heat transfer as the temperature difference is maintained
- PCMs keeps the interior cooler during the day and warmer at night, reducing the daily hot/cold fluctuations and keeping the interior temperature more stable; thus reducing the amount of peak heating or cooling required
- Temperature regulation is even more important in passive house design, where high insulation, high air tightness, and large window areas tend to cause overheating from massive solar heat gains
- PCMs simulate thermal mass much like concrete does, but are much smaller in size and lighter in weight, potentially increasing the amount of floor space and making it a viable option in lightweight design

Research Problem

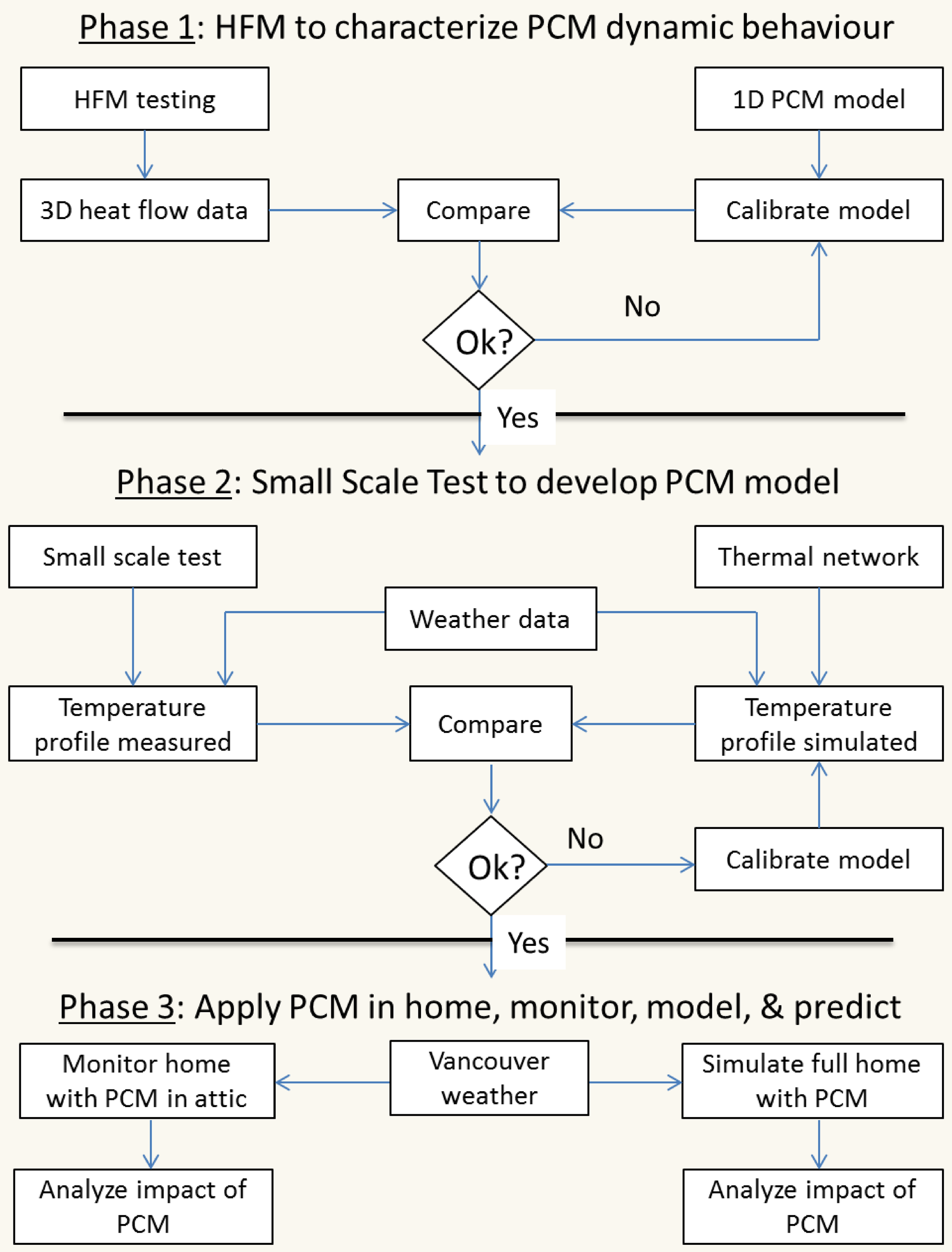
- What are the benefits, if any, in using PCMs in a Passive House located in Vancouver

Objectives

- To determine the effects of using PCMs to control an interior space
- To determine if PCMs are capable of providing thermal comfort and energy savings in buildings
- To determine the feasibility of using PCMs in the Vancouver climate
- To quantify the effectiveness of PCMs for Passive House design

Vision

- Promoting sustainable design through the use of alternative materials using passive energy storage



Methodology

Divided into 3 phases

Phase 1—Material Characterization

- Heat flow meter testing to determine thermal behaviour of PCM
- Analytical model in MATLAB to predict heat flow through PCM

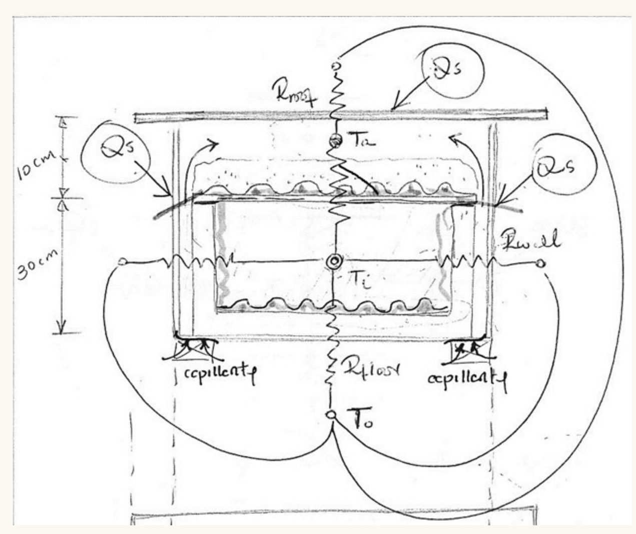
Phase 2—Small scale testing and modelling

- Two small test boxes for comparison: one with PCM, one without
- Analytical model in MATLAB to simulate performance in test boxes

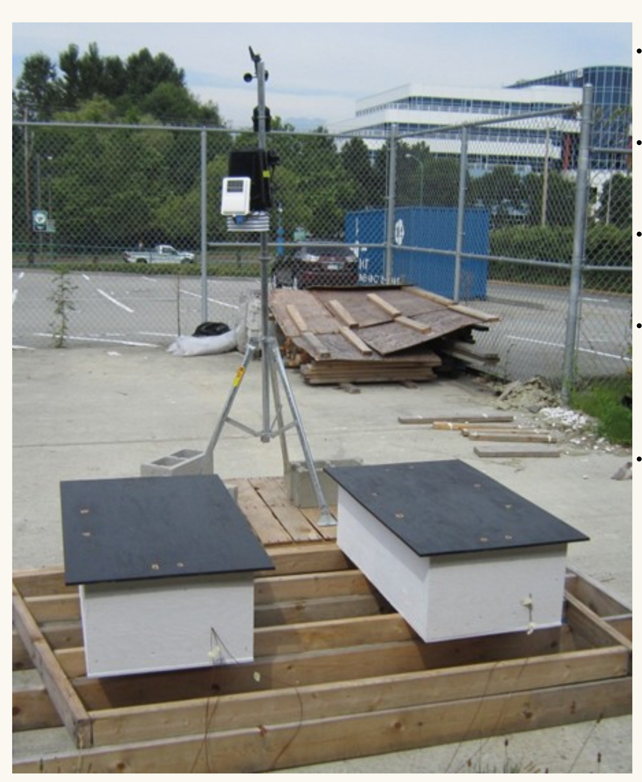
Phase 3—Home application of PCM

- PCM placed in attic of home to determine thermal comfort
- Life cycle cost analysis of PCM using EnergyPlus*

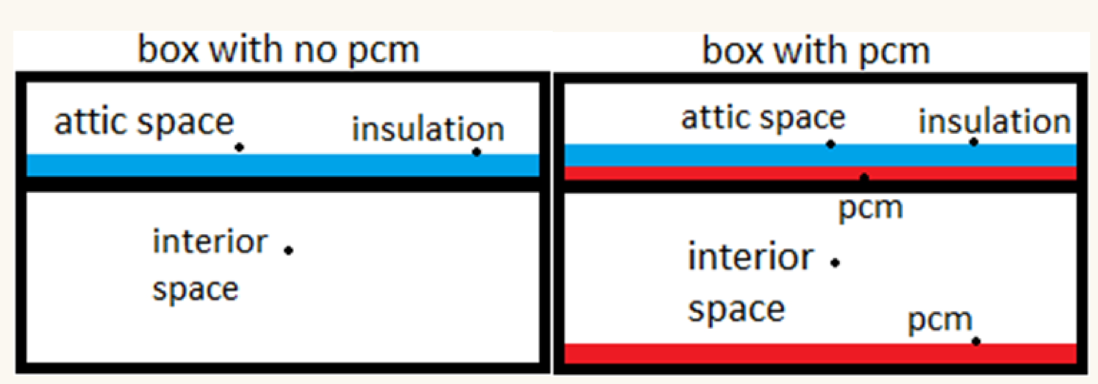
- The PCM used in this project was BioPCM, generously donated by John Lovatt of BCIT
- BioPCM was packaged in a large sheet of individual cells
- The PCM used has a phase change temperature of 23 °C or 25 °C



- Concept sketch of small scale test box for modelling
- The model used a network of nodes connected by various 1D heat transfer processes



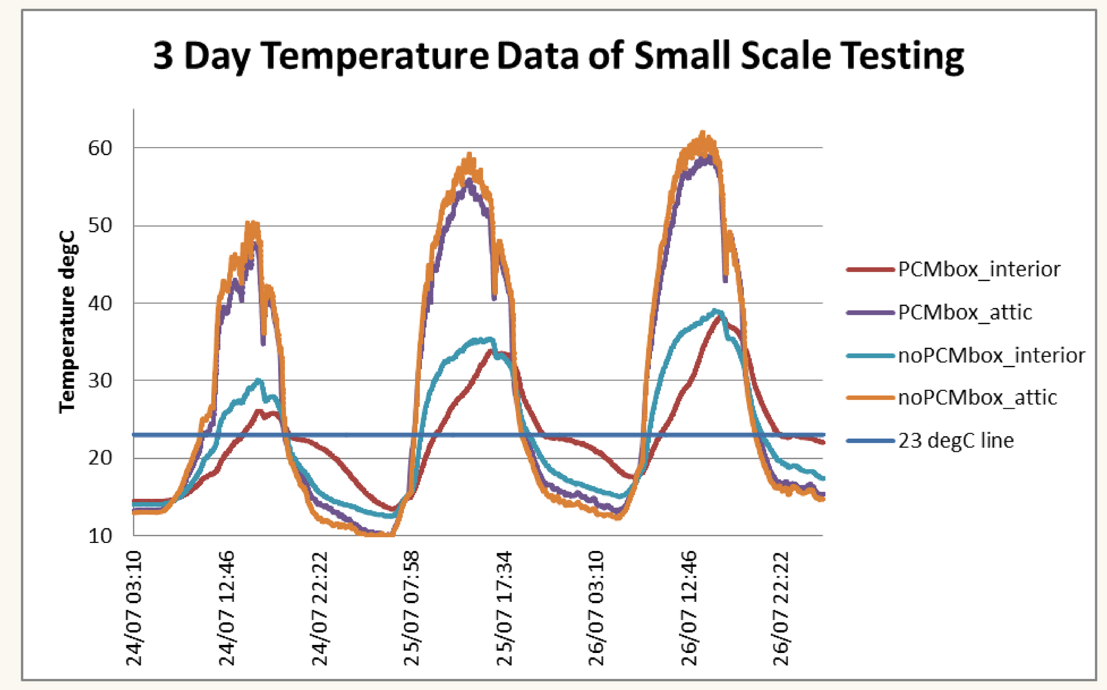
- Small scale testing set up with a weather station
- One box contains PCM and one does not
- The boxes were designed to emphasize solar heat gains
- The boxes were designed to be economical and simple to construct
- Thermocouples running into the box measure the temperature at key locations



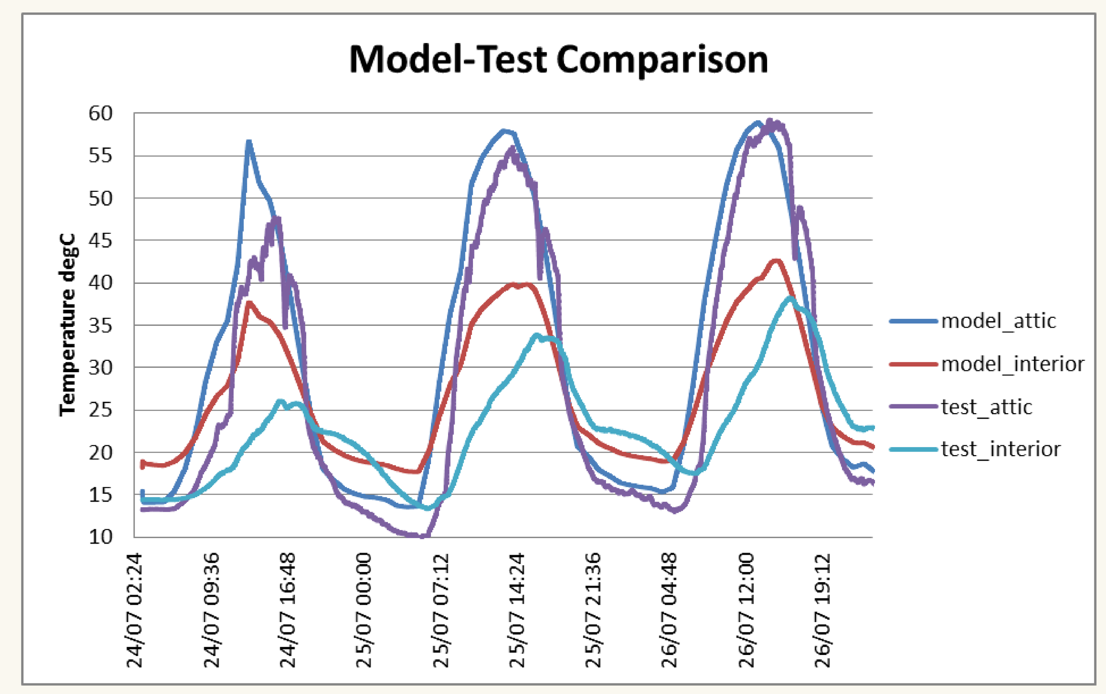
- Visual representation of the test boxes showing key elements
- The insulation in the attic space is fiberglass
- Not shown: the walls and floor of the box are insulated with XPS

* The life cycle cost analysis portion was not completed due to time constraints

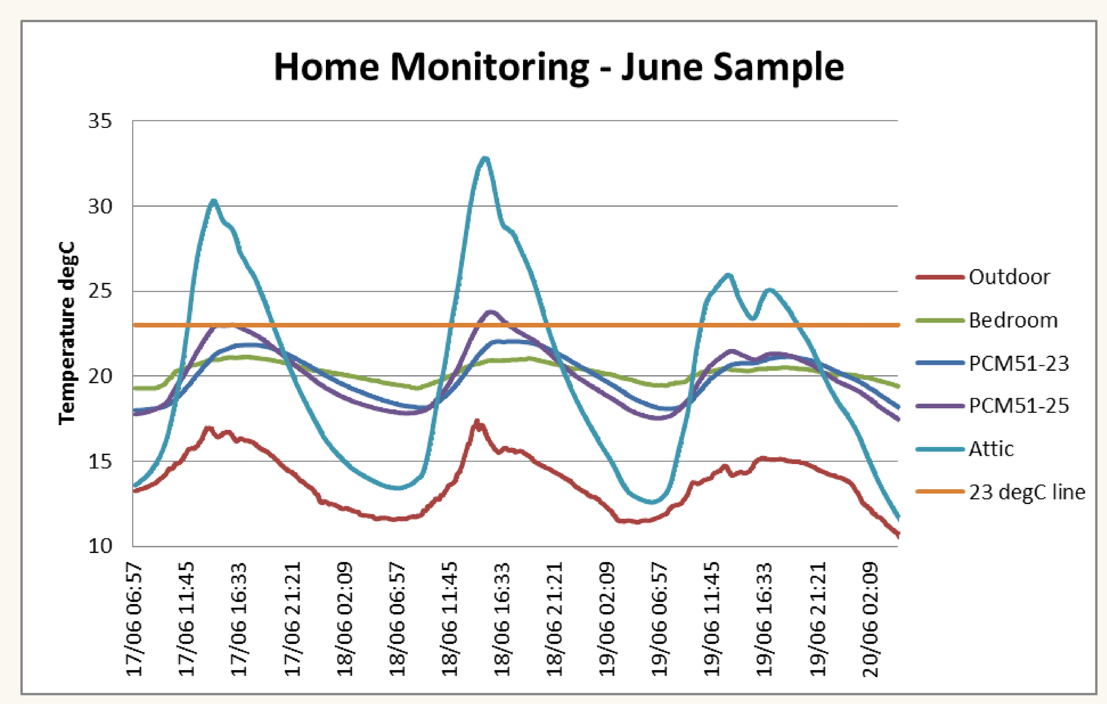
Results



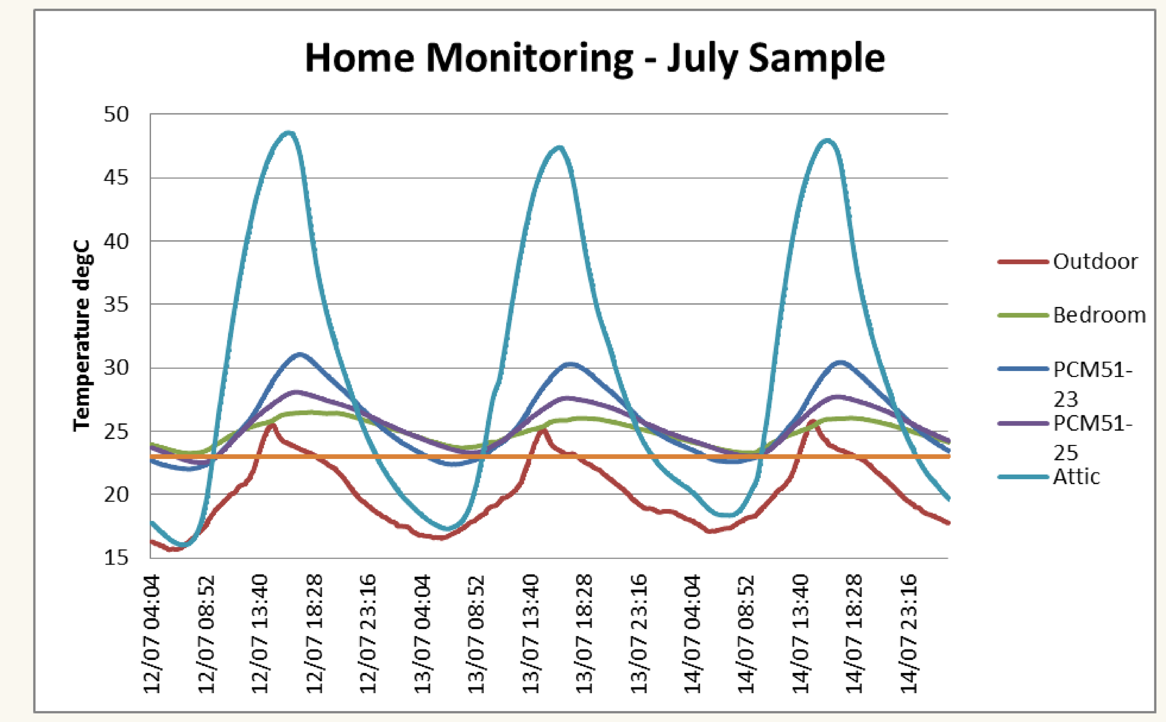
- The attic temperature of both boxes were identical due to a lack of any temperature control
- The temperature of the interior space with PCM had a lower peak temperature during the day and a higher peak temperature at night
- The temperature of the interior space with PCM lagged behind the space without PCM by about 2-3 hours
- The temperature of the interior space with PCM rose significantly during the day
- When the temperature of the interior space dropped at night and reached the phase change temperature of the PCM (23 °C) the temperature profile flattened out significantly as the PCM slowed the temperature drop
- The dip in the attic temperature was caused by localized a nearby tower structure
- The differences in peak temperature between the interior space with and without PCM decreased on hotter days



- The small scale test model was able to fairly accurately simulate the behaviour within the small scale test boxes
- The accuracy of the model improved as it progressed and continue to iterate
- The model was unable to reproduce the same amount of time lag and peak temperature reduction



- The bedroom temperature followed the trend of the PCM temperatures rather than the trend of the attic
- The bedroom temperature is maintained within a small range of 18-22 °C
- The bedroom temperature has a time lag relative to everything else
- The PCM temperature are kept below the phase change point
- The house was occupied during this time and the behaviour of the occupants are unknown
- The sudden drop in the exterior temperature is cause be shading



- The July sample was much hotter than the June sample
- The bedroom temperature is maintained between 23-26°C
- The time lag of the bedroom temperature is shorter than that in the June sample
- The PCM temperatures are kept above the phase change point

Conclusion

- The presence of the PCM keeps the interior temperature cooler during the day and warmer at night
- Given PCMs in a building, the occupants would experience improved thermal comfort as the temperature would not fluctuate as much over a 24 hour period
- Occupants that are more comfortable in a building would be less likely to rely on mechanical temperature controls, saving energy and money in heating/cooling
- The presence of the PCM evens out the temperature profile of the interior space, making it flatter and making it more consistent over a longer period of time
- By spreading out the temperature profile, even if mechanical control was required, the amount required would be less at a given time
- The PCMs reduce peak loading on mechanical systems and shift the energy costs later in the day
- The shifting of energy costs is useful in some locations where daytime energy rates are much more expensive that night time.
- The shifting of energy costs also reduces strain on power plants

Future Work

- Improving the model for the PCM and design of the small scale test boxes
- Perform a whole building energy analysis to see the effects of the PCM in a Passive House throughout the year
- Use the whole building energy analysis to perform a life cycle cost analysis

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