THE “WET” WINDOW

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ABSTRACT

In building construction, a concrete trombe wall can be used as a part of a cheap and eco-friendly alternative heating strategy. The benefit of a concrete trombe wall is that it can capture, store, and then re-radiate solar heat energy to mediate against diurnal temperature fluctuations. The main drawback of a concrete trombe wall (other than the square footage it requires) is that it completely blocks visible light from the interior of the structure. *This is especially unfortunate when significant portions of a building's southern exposure must be devoted to the passive strategy* – which might otherwise be incorporated into daylighting strategies.

Considering that water has about twice the thermal capacity of concrete per unit of mass, permits visible light to pass through its mass, and also considering that water has internal convection currents which redistribute internal heat more evenly than concrete, *it might be possible to create a “water window” or “wet window” which has the benefits of a simple trombe wall, but without the afore-mentioned drawbacks.*

Where a concrete trombe wall brings passive heating and daylighting strategies into *conflict* and competition for south facing square footage, a “wet window” *unites* both strategies into one. In the near future, troubling energy trends will make it increasingly important to harmonize passive energy strategies, and root out unnecessary conflicts.

1. INTRODUCTION

In this study we compare the performance of two substantially similar thermal systems – one featuring a volume of concrete and the other an equal volume of water.

System 1:
Simplified “trombe wall.” This features a thermally insulated box composed of 1” thick polystyrene rigid insulation (R5.5) containing one cubic foot of air. One face of this cube is fronted by a 1' x 1' window.
Behind this window is an air space 1.5” thick.
Behind this air space is a volume of concrete measuring 1'x 1' x 2.25”. Behind this volume of concrete is an air chamber one cubic foot in volume. (All seams and joints in the assembly are sealed with construction adhesive, in both systems.) Figure 2 illustrates the setup for system 1 and the built simplified “trombe wall” can be seen in Figure 1.

System 2:
“Wet Window.” This features a thermally insulated box containing one cubic foot of air, also made from 1” thick polystyrene rigid insulation. (R 5.5) One face of this cube is fronted by a 1' x 1' window.
Behind this window is an air space 1.5” thick.
Behind this air space is a second identical pane of glass.
Behind this pane of glass is a volume of water measuring 1' x 1' x 2.25,” which is finally followed by a third pane of glass identical to the first two.
Behind this assembly is an air chamber one cubic foot in volume. Figure 2 illustrates the setup for system 2.

Both boxes are set an equal distance and orientation from a heat source (250W heat lamp) and subjected to heating for various periods of time ranging from .5 hours to 6 hours. Data loggers record ambient air temperatures as well as temperatures inside the 1 cubic foot airspace of each system. The dual setup is illustrated in Figure 2.

Fig. 1 *The constructed simplified “trombe wall” used during testing.*

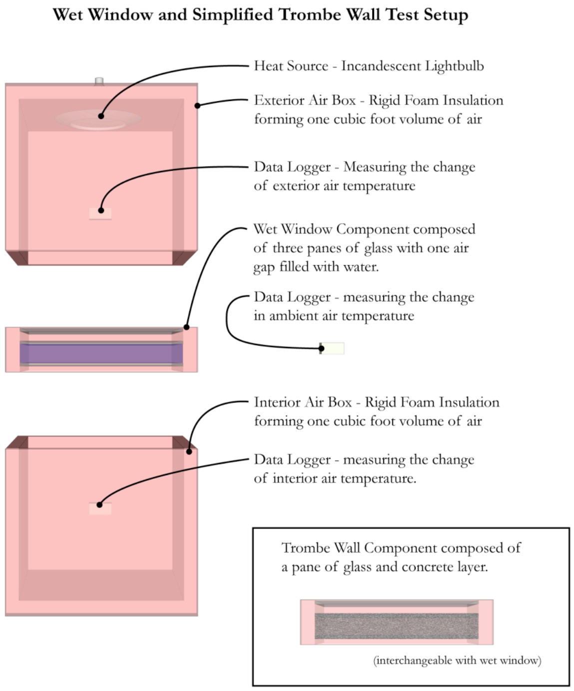

Fig. 2 *The setup for the individual experiments of the wet window and the simplified trombe wall.*

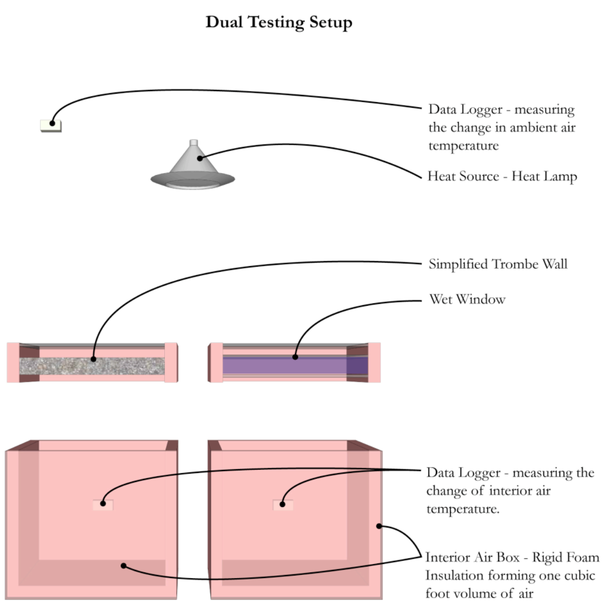

Fig. 3 *The setup for the dual testing.*

2. <u>HYPOTHESIS</u>

The system with the wet window will maintain a 1°F higher interior air temperature than the system with the simplified trombe wall.

3. <u>INDIVIDUAL TESTING METHODOLOGY</u>

TEST 1: Our first experiment was to test how well the simplified trombe wall performed in transferring and holding heat. To begin, the heating lamp was turned on for 30 minutes allowing for the exterior temperature to rise. The lamp was then turned off and the apparatus was left to sit for approximately 8 hours. The data loggers were set to record the temperature of the outside air, inside air, and ambient temperature every 2 minutes. See Fig. 4 for the graphed data.

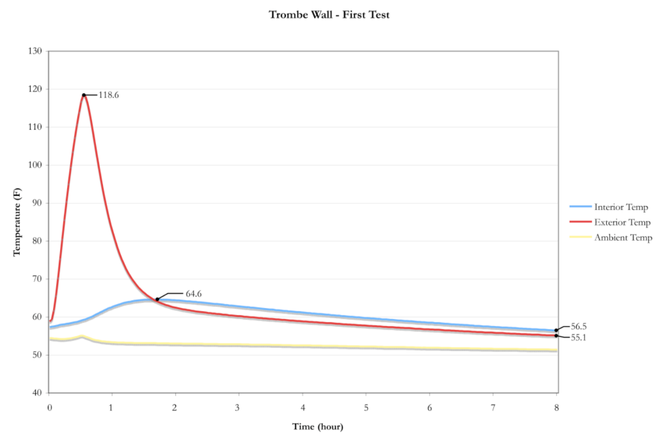

Fig. 4 *Graphed data from the first test with the simplified trombe wall.*

TEST 2: The second experiment was a repeat of the first experiment. This was done in order to establish that we are capable of replicating the experiment conditions and to get the similar results. See Fig. 5 for the graphed data.

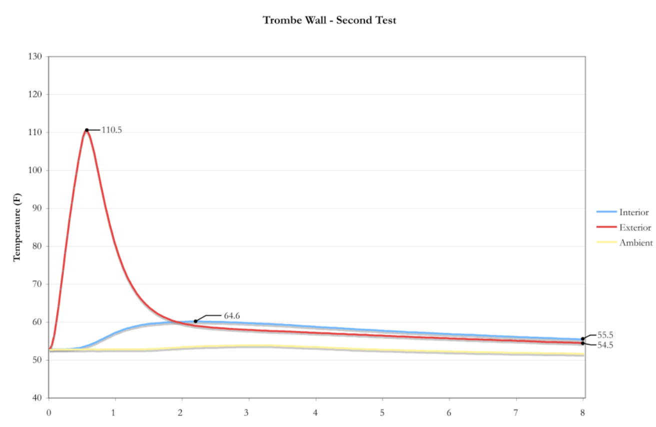

Fig. 5 *Graphed data from the second test with the simplified trombe wall.*

TEST 3: In our third experiment we tested the wet window concept. To begin we allowed the heat lamp to run the standard 30 minutes in order to heat the outside air. The lamp was then turned off, and data loggers were set to record the temperature of the outside air, inside air, and ambient temperature every 2 minutes, for a period of 8 hours. See Fig. 6 for the graphed data.

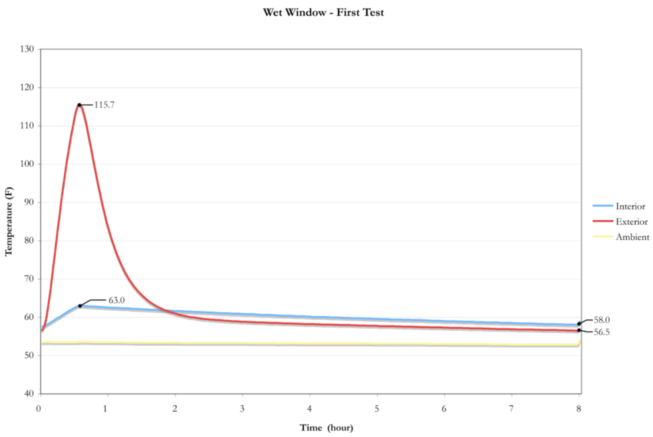

Fig. 6 *Graphed data from the first test of the wet window.*

TEST 4: The fourth experiment was a repeat of the third experiment. See Fig. 7 for the graphed data.

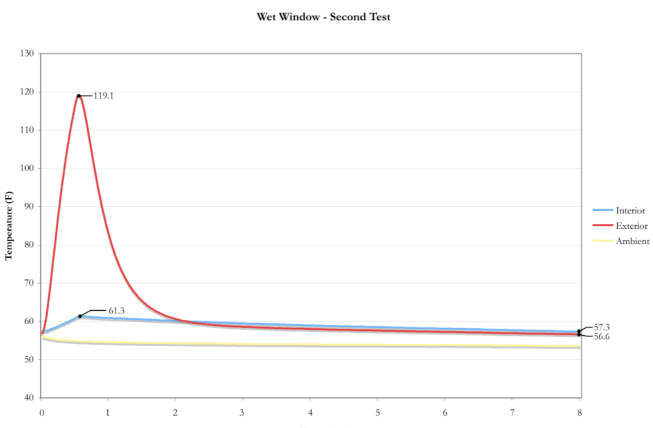

Fig. 7 *Graphed data from the second test of the wet window.*

4. <u>DUAL TESTING METHODOLGY</u>

In order to minimize the variables present in our individual testing, our second group of experiments aimed at testing the two apparatuses at the same time. For each consecutive experiment the heat lamp remained on for a longer period of time:

Dual Test 1 – Lamp on for 2 hours
Dual Test 2 – Lamp on for 3 hours
Dual Test 3 – Lamp on for 4 hours
Dual Test 4 – Lamp on for 5 hours

In each experiment, the setup was tested over an 11-hour period (which included the hours with the lamp on). The graphed results can be seen in Figures 8 – 11.

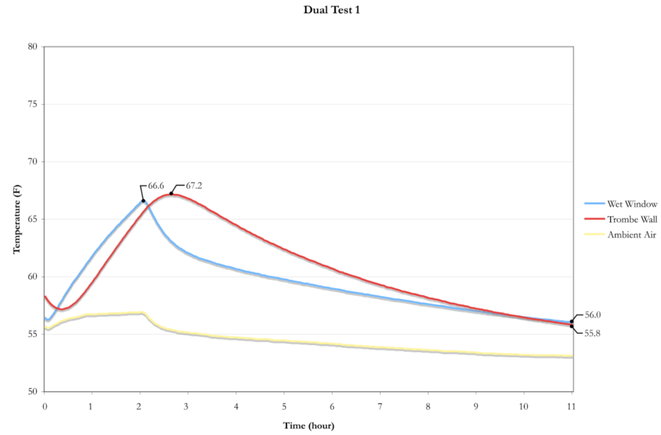

Fig. 8 *Graphed data from the first dual test.*

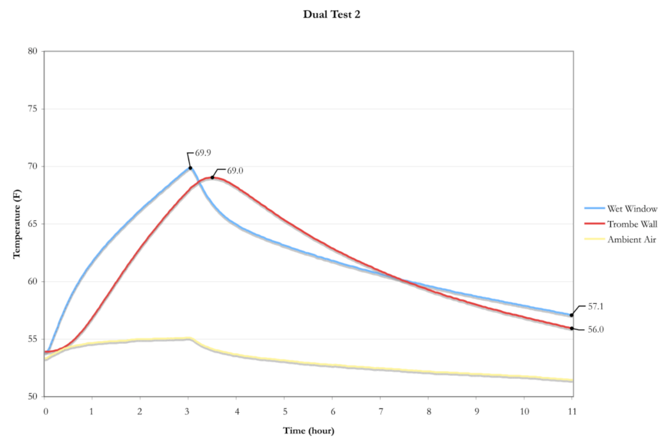

Fig. 9 *Graphed data from the second dual test.*

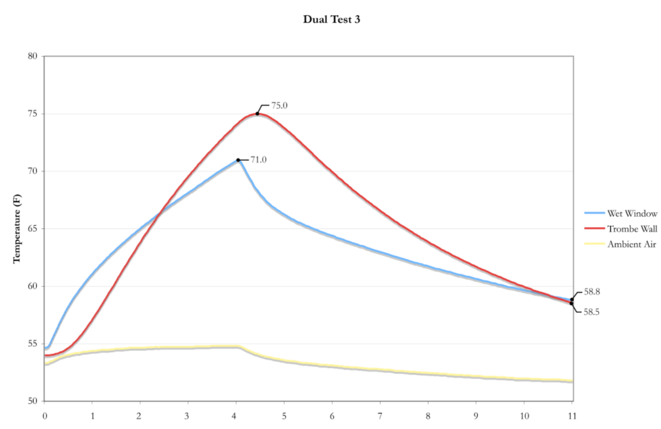

Fig. 10 *Graphed data from the third dual test.*

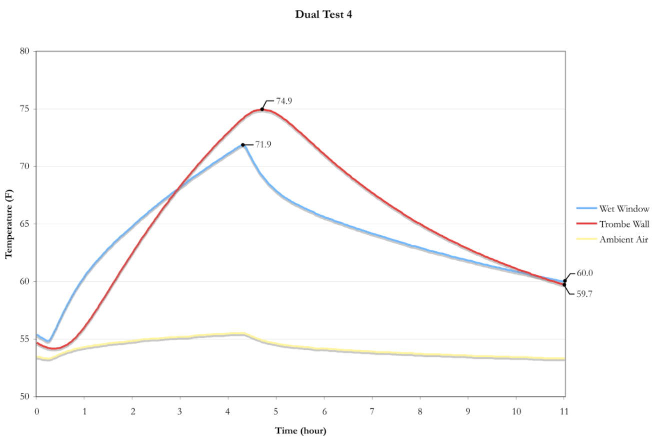

Fig. 11 *Graphed data from the fourth dual test.*

5. <u>ANALYSIS OF TESTING</u>

Upon analysis of the graphs (Figures 3 – 7), two basic differences between the two systems become clear, which relate to the point when the heat lamp is first turned on and the point at which it is turned off.

When the heat lamp is first turned on, the Wet Window system responds noticeably; interior air temperature rises almost from the moment exterior air temperature rises. The rate at which the temperature rises is initially highest in the wet window system, (Figures 8 – 11) but later the slopes of these graphs lessen as the system progresses toward equilibrium.

The simplified trombe wall system, on the other hand, lags noticeably behind – perhaps by almost a half an hour. This delayed reaction to temperature changes is a well-known characteristic of the trombe wall. The rate of temperature increase is relatively constant compared with the wet window, and, once started, seems to roughly match the slope of the graphs of the wet window system.

When the heat lamp is turned off, we see the same characteristic responses.

The wet window system again responds markedly, with a sudden change in interior air temperature, followed by a steep slope of declining temperatures, which later alter to track a gentler slope.

The "fingerprint" of this system is:
Fast initial response
Steep temperature curve
Gentler temperature curve

Whether the system is responding to the heat lamp being turned off or on, the characteristic "fingerprint" is the same.

The simplified trombe wall system displays its own fingerprint. Its interior air temperature continues to rise for a period of approximately half an hour, before gently cresting and slowly descending along a relatively steady slope of heat loss.

The "fingerprint" of this system is:
Slow initial response
Relatively constant temperature curve

Again, this characteristic is the same whether the system responds to the lamp being turned on or off.

The Highs and the Lows:
It should be noted that even though the simplified trombe wall interior air temperatures usually *peaked* higher than the wet window interior air temperatures, they never *ended* higher. The wet window interior air temperatures were always slightly higher by the end of the eleven-hour testing cycle.

Thermal and Visual qualities tied together:
It may safely be argued that the characteristic differences between these two systems' *thermal* performance are directly related to their decidedly different *visual* performance. The wet window allows visible light to penetrate into its interior air volume, and the simplified trombe wall does not. The data loggers prove that the wet window quickly permits not only light of the *visible* spectrum to penetrate its mass, but also *infrared radiation* – which is heat. In fact, although liquid water is a good absorber of visible light, it is an even more efficient absorber of infrared light (Fig. 12).

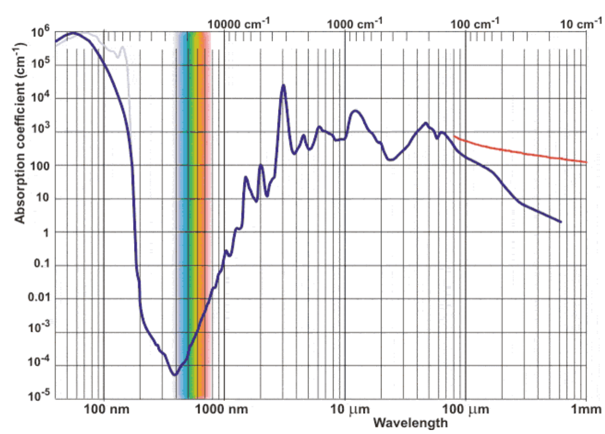

Fig. 12 *Water is a good transmitter of visible light - but it is an even better transmitter of infrared light (heat). This is the key to understanding the unique characteristics of the wet window. (London South Bank University: http://www.lsbu.ac.uk/water/vibrat.html).*

This property of water explains the wet window system's ability to move heat energy so quickly from the outside to its interior air volume.

In contrast, the simplified trombe wall acts as a *switch* to visible light energy – and initially it *appears* to act as a switch to infrared energy as well. Over a period of time, concrete reveals that it is actually a conductor of heat energy, and it is this time lag that makes it valuable in mitigating diurnal temperature fluctuations.

6. CONCLUSIONS

The simplified trombe wall provides the most even release of heat from the interior air space over the eleven-hour testing period.

It also displays the critical “lag” in conducting heat energy, which makes it so useful in climates with large diurnal temperature changes.

The wet window's ability to instantly transmit heat energy into its interior air volume is a concern, especially in climates where one wishes to delay the transmission of daytime heat until the cooler night time hours. Further tests should be performed to determine if this could be mitigated by increasing the thickness of the wet window water volume, or by doping the water with soluble mass that conducts visible light but scatters infrared light.

Although the wet window lacks the thermal lag of concrete, volume for volume, it is superior in its ability to store heat energy, this is why the wet window maintained a higher ending temperature than the simplified trombe wall. These results suggest that it would be highly worthwhile to scale the prototype from an experimental 1' x 1' unit to a full size unit to determine what effect the larger mass would have on the general shape of the interior air volume temperature curve.

7. DESIGN LESSONS

Regardless of whether or not the wet window is able to perfectly match the performance of a trombe wall, these tests show that even in this early prototypical phase, it is already able to re-radiate a considerable amount of heat energy over an extended period of time, and to maintain a higher ending temperature than the simplified trombe wall. This in and of itself is significant – especially given the fact that the wet window allows the designer to harmonize both passive daylighting and passive heating in one system, whereas the trombe wall forces these two passive strategies to compete for the same limited resource. Where trombe walls have to be used, it may be that the insertion of a wet window into a trombe wall could provide light and views to the adjoining space without significantly impacting the overall thermal performance of the system.