A Trombe Wall case study, by Andrew Carmichael and Ryan Dyer.

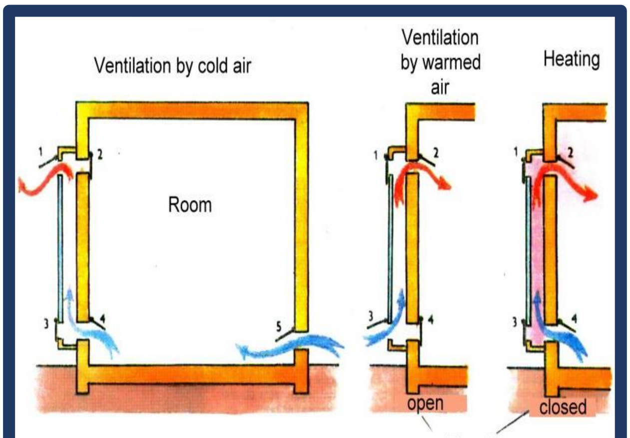

Figure 1. Visual description of the physical principles behind using a trombe wall as a natural ventilation method.

Figure 2. The Trombe wall ventilation system (left) has been modified to be used both for heating and cooling using renewable energy sources. Researched by Marwa Dabaieh from Lund University in Sweden. Tested in Saint Catherine, Egypt Photo: Insaf Ben Othm

A Trombe wall consists of a sun-facing, solid concrete or masonry wall behind a glazed space. When the sun shines, energy comes through the glass and is stored in the wall's thermal mass. When the sun sets, or is blocked, and the temperature drops the wall releases heat into the room behind. Trombe walls are commonly used to absorb heat during winter sunlight hours and slowly release that heat at night, when it is most needed.

Solar heat's higher-energy ultraviolet radiation has a short wavelength which passes through glass almost unhindered. When this radiation strikes a wall or slab, the energy is absorbed and then re-emitted in the form of longer-wavelength infrared radiation. Infrared radiation does not pass through glass as easily, so heat is trapped and builds up in the enclosed space.

A secondary benefit of this system is the ability to use it to drive a passive convection current though the room to which it is attached. As seen in Figure 1, the heated wall creates a buoyant current in the glazed space which draws cool air from the floor and heats it as it rises. This provides a second convective heating method to the main radiative one.

Interestingly, this convection current can also be used to provide ventilation and cooling if warm air is not reintroduced into the room. In this case, the current can draw in air from a cooler, shaded, side of the house.

CHAM's RhinoCFD was used to demonstrate this principle using a small scale example, where a simple room was set up with a Trombe wall on one

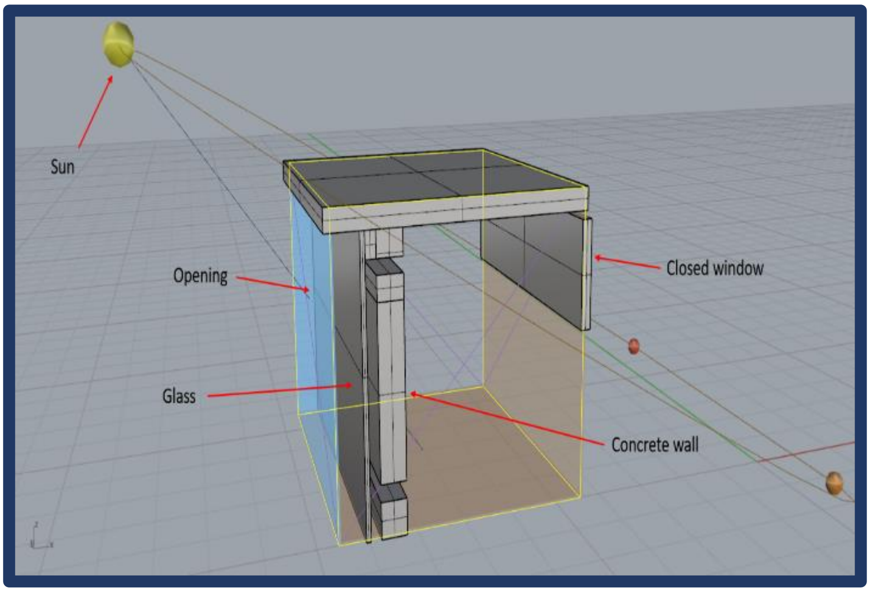

Figure 3. RhinoCFD model of the Trombe wall simulation

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face and a window opposite. The Trombe wall was designated concrete and the glass panel transparent to the incoming sun (set up with the inbuilt sun model).

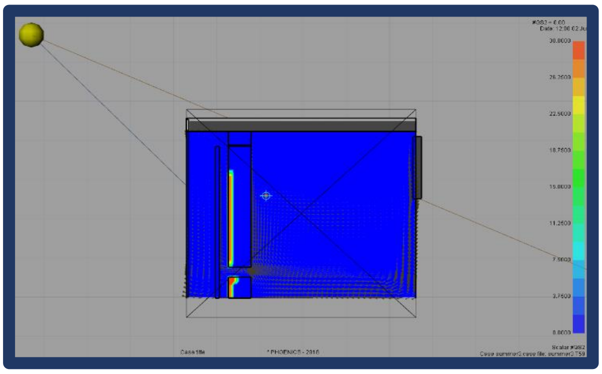

Figure 4. RhinoCFD's inbuilt solar model easily calculates and displays the areas upon which the solar radiation impinges based on the latitude and time of day that are prescribed.

The simulation was run in transient mode for 100 minutes, with a step size of 2 minutes, which was small enough to ensure convergence. Given the symmetrical nature of the geometry, the case was run in 2D, with only one cell in the Y-direction. This case ran for winter "room warming" and summer "room cooling" and its effectiveness was demonstrated.

For the winter case, the ambient temperature was set to 15 degrees at the start of the simulation, with direct solar radiation set to 800W/m^2. This flux was applied only to the areas directly illuminated by the sun; it was assumed there was no diffuse radiation present. RhinoCFD's solar model automatically calculates where this area should be, based on prescribed solar elevation and time of day. This area changes with the movement of the sun as time advances, but in this case the variation is minimal.

Simulation Setup Details

The mesh used comprises 2240 cells, with up to 5 cells in the glazed space to capture accurately the convective plume in the area. The KE-Chen turbulence model and Immersol radiation model were selected with wall emissivity set to 0.9.

In the summer case, aside from the change in geometry to allow the warm air to escape the glazed space, and the ambient temperature being set to 25C^o, all other conditions were as per the winter case.

Results

Winter Case

Looking at temperature distribution inside the room after 100 minutes, it can be seen that it increased substantially from 15C^o to about 20C^o, with a visible current through the glazed space.

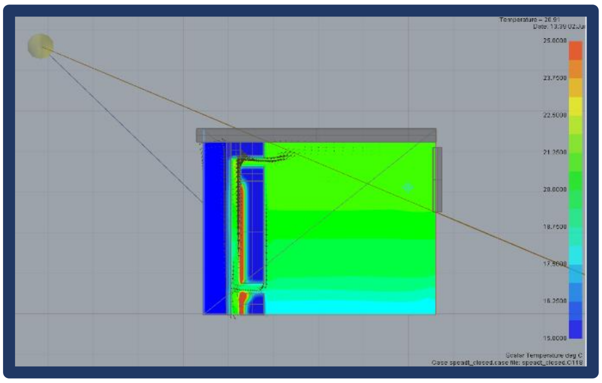

Figure 5. Temperature distribution in the room for the winter simulation after 100 minutes.

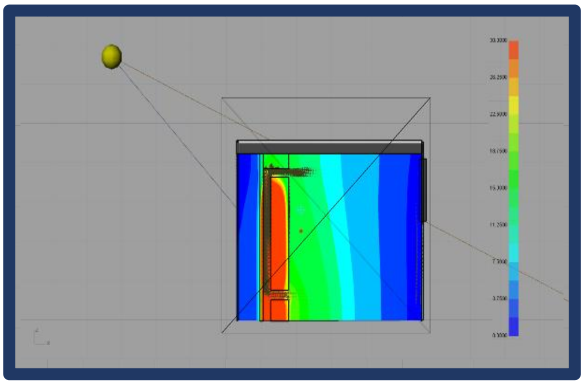

Figure 6. Radiant temperature in the room from a steady-state simulation.

Another interesting aspect is the effect of radiation in the model. A separate steady-state simulation looking at this shows how the radiative temperature calculated by the model behaves as expected: the trombe wall accumulates energy and heat is trapped by the glass façade in front of the wall. Heat is then able slowly to penetrate into the room, helping to warm it.

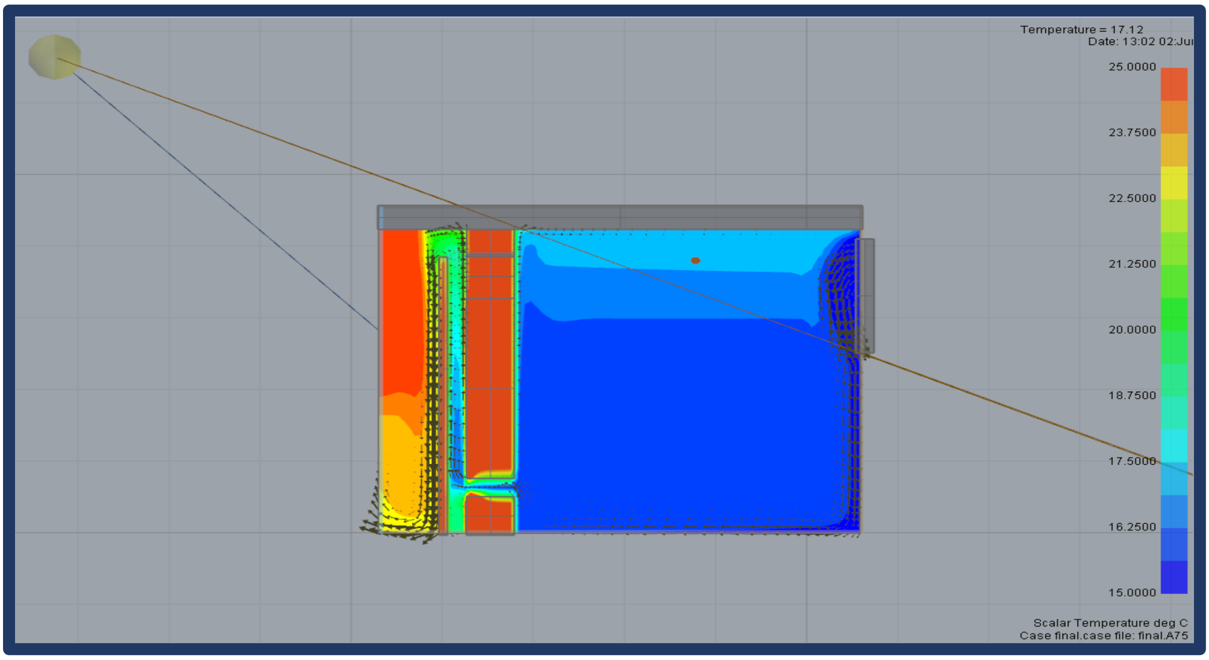

Figure 7. Temperature in the room for the summer simulation after 100 minutes

Summer Case

In the summer case, it can be seen that, despite setting the initial temperature in the room to 25C°, given a source of cool air (imagined to be from a shaded area of the house or an area with some active cooling), the Trombe wall has the effect of creating a current in the room that will help draw in cool air and displace warmer air.

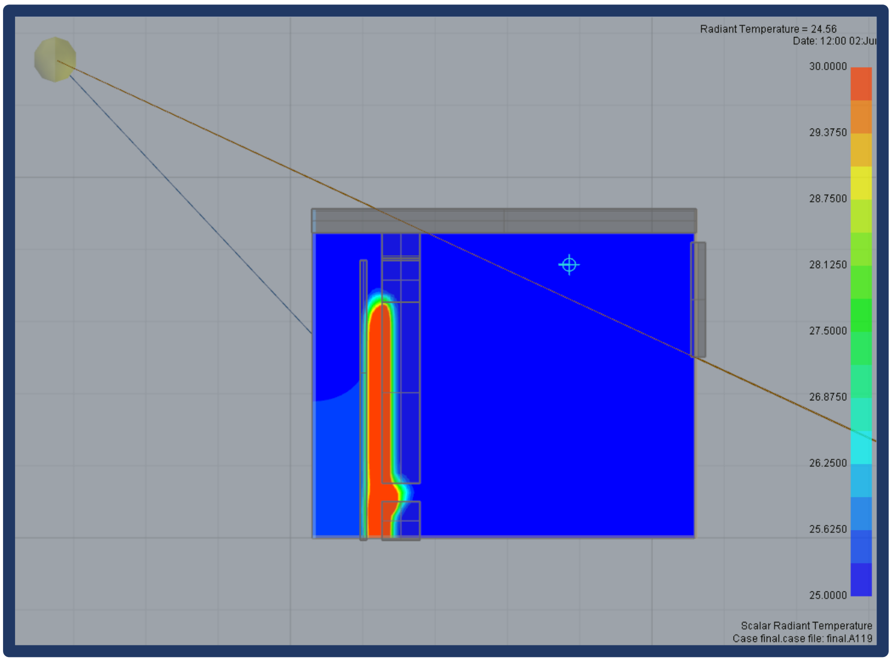

Figure 8. Radiant temperature in the room after 100 minutes in the summer simulation.

The effect of radiant temperature can be viewed, at the end of the 100 minutes run time, to ascertain its effect. Figure 8 shows that most of the radiant temperate is contained in the glazed portion of the Trombe wall and not much has penetrated the room. This corroborates the initial phase delay supposition, whereby the trombe wall does not radiate much heat during the day while it is being illuminated (due to heat still being absorbed by the wall), but instead releases it mostly at night, helping to maintain ventilation and even out temperatures in the room.