# Thermal Mass Solutions

## A Net Zero Energy Strategy with Structural Implications (and Opportunities)

*By Bob Habian, AIA*

*Figure 1. Partial height thermal mass walls connected to passive ducts for night time cooling. Courtesy of Guttmann & Blaevoet Consulting Engineers.*

The Jess S. Jackson Sustainable Winery building (JSWB) project team, led by Siegel and Strain Architects, set out to design a Net Zero Energy, LEED Platinum building, at the University of California, Davis, where summer temperatures exceed one hundred degrees on a regular basis. Concrete masonry, as seen in *Figure 1*, not only saved the day, but it opened the door for IDA Structural Engineers of Oakland, CA to take a more active role in energy optimization at the earliest stages of a project.

### Energy Management is Mandatory

The production of energy is the leading contributor to carbon footprint and climate change and, in the U.S., the Building Sector consumes more energy than any other sector (*Figure 2*). In response, a number of stricter energy code requirements are being enforced across all building types. The cost of energy is rising and is a matter of growing concern for building owners. The JSWB project team set out to not only reduce their energy consumption, but together decided to reach a level of Net Zero Energy (NZE), in which the total energy consumed is offset by renewable energy production on site. The most important factor in achieving NZE is reducing the overall energy consumption to the lowest possible level.

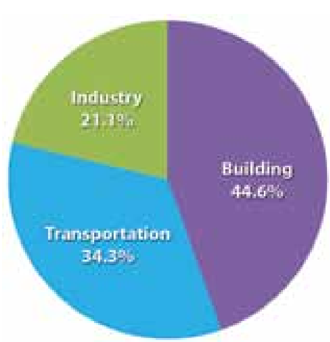


*Figure 2. U.S. energy use by sector. Data source: US Energy Information Administration (2012).*

### The Basics of Thermal Mass

The goal of every building design is to achieve internal comfort regardless of outside temperatures. In climates like Davis, California, where there are high diurnal swings from hot to cold in a 24-hour period, exposed interior thermal mass, in the form of concrete masonry, can radically decrease the overall energy consumption. As shown in *Figure 3*, interior comfort is achieved using two primary strategies, time lag and damping. Insulation by itself can only achieve time lag. Thermal mass, however, contributes to both time lag and damping. Achieving the proper balance of both is the shortest path to achieving internal comfort.

### Framed Structures Lack Sufficient Mass

The building industry in the Western U.S. has shown a long-standing preference for framed, insulated, low-mass buildings that shake and don't fall down in earthquakes. A common belief in the west is that heavy mass buildings perform poorly in seismic conditions. Most often, the building failures referenced are unreinforced or poorly constructed. In addition, the historic abundance of wood has influenced our appetite for low mass, framed solutions. As a result, we traditionally rely on a combination of insulation and air handling systems to achieve interior comfort. To that end, most project participants believe the architect and the mechanical engineer are the only ones needing to be at the table to determine an optimal comfort strategy. As conventionally framed designs move in the direction of increased interior exposed thermal mass, the structural engineer becomes a necessary participant in the discussion.

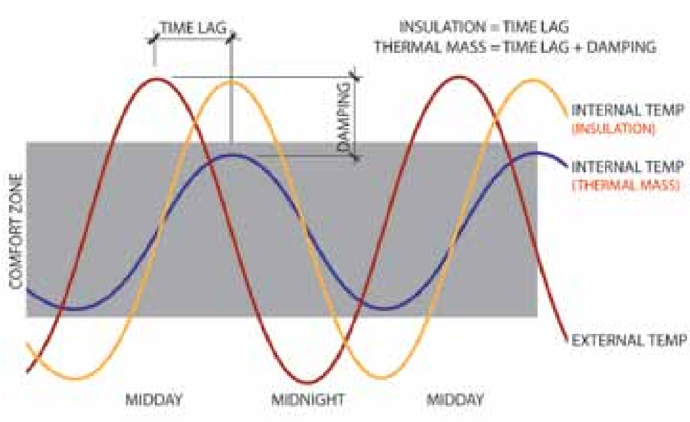


*Figure 3. Time lag and thermal damping.*

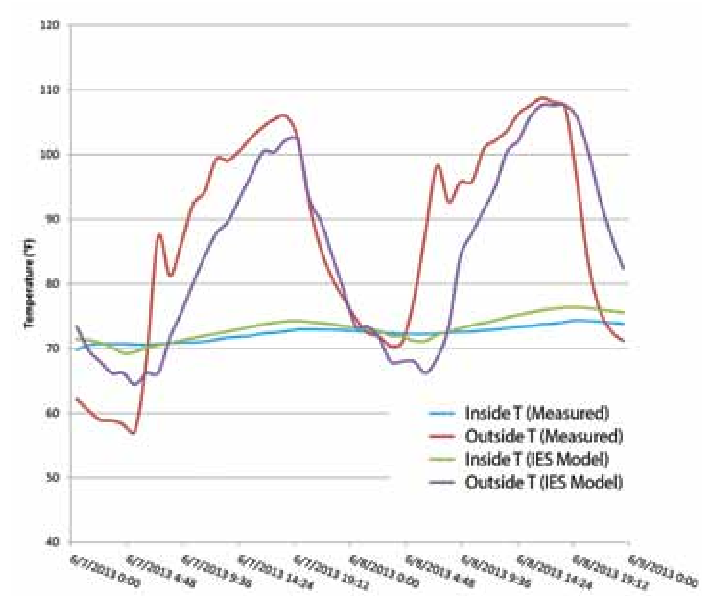


*Figure 4. JSWB – temperature comparison. Courtesy of Chien Si Harriman.*

## Finding the Right Balance of Thermal Mass and Insulation

After initially attempting to achieve NZE with a traditional metal frame building, in combination with an exterior skin of insulated metal panels, and a high degree of interior batt insulation, (R-59.6 in the walls and R-76 in the ceiling), the JSWB team determined that an insulation-only approach was simply not adequate to achieve NZE. And even though the exposed concrete slab did provide a fair amount of interior thermal mass, it did not offer quite enough to make a difference.

The mechanical engineer, Guttmann & Blaevoet, of Sacramento, California, along with their in-house thermal mass expert, engaged a strategy of trying to achieve a classic balance of time lag (due to insulation), and temperature damping (due to thermal mass). After numerous rounds of modeling, the optimal blend of exterior insulation and interior, exposed thermal mass, was achieved simply by adding a partial height, solid grouted masonry wall, that was neither load bearing nor attached to the building envelope. This wall, in combination with the exposed concrete slab, achieved enough of a mass effect to allow the team to completely eliminate any need for a traditional air-handling unit for heating and cooling. The results of the modeling are shown in *Figure 4*. With exterior summer temperatures approaching 110 degrees, the interior holds to a steady range of 70 to 73 degrees.

## So What Does NZE Mean for Structural Engineers?

OPPORTUNITY! Concrete masonry as a thermal mass component for energy optimization is a relatively misunderstood material to many mechanical engineers and architects alike. The proper integration of concrete masonry requires a careful review of the structural implications, particularly with respect to footings and connections to other structural elements in the overall project. And given the load bearing capacity and shear resistance of concrete masonry, there are many more options available today to integrate interior exposed thermal mass into the overall structural design.

On this project, the structural engineer played an important role in determining the most cost-effective placement and configuration of the concrete masonry. The mechanical engineer undertook a specific effort to determine the proper amount of surface area and volume of masonry that would have the most impact on the energy model. The structural engineer explored various configurations of the masonry and determined that a partial height wall with modest footing requirements was a more cost-effective placement than other options requiring larger footings. Additionally, it was the structural engineer that had to address how the overall system would function, the result of which was that the structural envelope would remain unattached from the concrete masonry. Together, the architect, mechanical engineer and structural engineer designed an ideal solution for reducing the overall energy requirement.

> "By adding just a small amount of concrete masonry to the interior of the building, we were able to eliminate the active mechanical heating and cooling system"
>
> *– Chien Si Harriman, Guttmann & Blaevoet*

On average, in the U.S., existing buildings account for 97% of the building stock, with only 3% being newly constructed, annually. In the western U.S., the majority of existing buildings are framed, insulated, and low mass, most of which could benefit from the addition of interior exposed thermal mass. So rather than simply competing for work on new construction, structural engineers have a tremendous opportunity to participate in the retrofit of existing buildings. And while most "energy retrofit" projects focus on high efficiency air handling systems, there is clearly a greater opportunity to reduce or even eliminate mechanical systems through the proper balance of insulation and interior exposed thermal mass.

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## And There is an Even Simpler Solution

Integral-insulated CMU, also called Hi-R H block, as manufactured under license by Basalite Concrete Products LLC, is an innovation in the masonry industry that combines the best of traditional concrete masonry with an outboard insulation and interior exposed thermal mass solution (*Figure 5*). This system, when used as a load bearing, exterior envelope solution, integrates the best elements for energy optimization in a single-wythe, solid-grouted barrier wall.

A trend toward thermal mass solutions will allow structural engineers to become early adopters of NZE strategies and to position themselves for significant project opportunities in new and retrofit construction, now and for years to come.▪

*Figure 5. Hi-R H Integral Insulation CMU. Courtesy of Concrete Products Group.*

### JSBW Project Team

**Owner:** University of California, Davis
**Structural Engineer of Record:** IDA Structural Engineers, Inc., Oakland, CA
**Builder:** Pankow Builders, Oakland, CA
**Architect:** Siegel & Strain Architects, Emeryville, CA
**MEP Engineer and Energy Modeler:** Guttmann & Blaevoet Consulting Engineers, Sacramento, CA
**Concrete Block Producer:** Basalite Concrete Products LLC, Dixon, CA

*Bob Habian, AIA, is a California licensed architect and leads Masonry Market Development for Basalite Concrete Products LLC in Dixon, California. He may be reached at **bob.habian@paccoast.com**.*