The Best Laid Plans...

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A design-build studio that focused on building a residence with scoria and documenting the performance of its thermal mass wall assemblies concluded with an unintentional contribution to the municipal code regarding building air tightness. The research question was dramatically altered by unforeseen building performance results.

A SCORIA HOUSE

Folding alternative materials studies into the pedagogy for design-build studios deepens the students' knowledge of material properties and underscores the value of applied research to critical practice. However, taking on the risk of building with alternative materials demands an agility in research methods that can mitigate setbacks and reframe failures.

An architectural design-build program at The University of Arizona employs the design and construction of affordable housing as a vehicle for understanding the full range of architectural practice. This particular studio examined indigenous earthen building methods as potential wall materials with the understanding that the use of locally sourced materials reduces initial construction costs and vernacular building traditions are often rooted in efforts to control indoor comfort without expensive mechanical systems. Historical[1] and contemporary[2] precedents of building with available materials in the region included the use of pumice stone – in its raw form as stackable masonry or as an aggregate in concrete products[3] . The students became enthusiastic about the thermal and aesthetic properties of "scoria", (a mixture of ground pumice stone, cement, and water) as a candidate for the perimeter walls of their project because it could simultaneously address the issues of affordability, availability[4] , and thermal performance[5] .

SEARCHING FOR MATERIALS AND METHODS

Several local mines excavate and crush larger pumice stones for use in landscaping or as aggregate for masonry units. Large amounts of "fines", small particles that are byproducts of the crushing process, are leftover and considered debris by the mining businesses. Because the known precedents neither prescribed a "recipe" for scoria mixtures nor articulated any performance criteria, a semester of research determined how scoria might be classified in the local code amendments and identified performance metrics[6]. Students prepared cylinders of varying mixtures for compression tests to establish a reliable blend for fieldwork and built full-scale mockups of the construction conditions. While these investigations progressed, students designed a dwelling with long scoria walls facing east and west. The hypothesis was: those exposures receive direct sun for only a few hours daily, thus allowing the 18" thick walls to serve as thermal flywheels, cycling heat back outside as the exterior temperatures cooled off at night.

THE ECSTACY AND AGONY OF CONSTRUCTION

With construction documents complete and building permits in hand, the studio commenced construction of the dwelling. Thermal sensors were placed throughout the scoria walls as they were built to measure thermal transfer through the material, and the data was collected for a full year after completion. During construction, students found the surface qualities of the scoria walls were satisfying and the test cylinders collected by code officials surpassed the required compressive strength thresholds. All required building inspections were approved until the final inspection for the mechanical system. The requirement for a blower door test had been recently adopted by the municipal building code and was required to be performed at completion. The house failed the first blower door test, and the studio worked to mitigate air infiltration[7] . The code requirement for a blower door test is predicated on the assumption that airtight construction is necessary for proper functioning of the HVAC system and maintenance of thermal comfort conditions within the residence. In spite of sealing all apertures and materials junctions, the test was repeated and failed again – three more times. The scoria walls themselves were filled with tiny air pockets and were just porous enough to exceed the code requirements for air exchanges. This conundrum was frustrating for the studio, but also had financial and scheduling implications.

PUNTING

Various solutions for excessive air infiltration were examined for feasibility[8] ; all would add significantly to the time and cost of

Figure 1. Students constructing scoria walls. Photo by author.

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Figure 2. Pumice stone used in Casa Caldera by DUST Architects. Photo @ Jeff Goldberg/Esto .

Figure 3. Cylinder tests and wall mockups. Photos by author..

construction. Meanwhile, as the house sat completed but unoccupied, thermal data was collected and analyzed. Preliminary data supported the thermal hypothesis of mass walls creating a stable interior temperature[9]. Based on this observation, an appointment was held with the city's head building official to review the data and request a waiver of the blower door test. The official agreed that the dwelling was apparently performing well enough to control interior thermal comfort, and cautiously required submission of one month of additional thermal data as evidence of continuing performance in order to grant a certificate of occupancy for the house.

Thirty days of sensor readings validated performance and the house was approved for occupancy. Eleven subsequent months of data substantiated that the "breathing" dwelling was indeed functioning within the human comfort zone. All project data was entered by the building official into the public record of the municipal Development Services permitted project data base, ensuring its availability as precedent for future plan reviews and code inspection decisions regarding air infiltration through earthen walls and waivers of blower door tests. In this way, the materials research gained greater significance than the achievement of a single project; it paved the way for future experimentation with thermal mass wall materials. This precedent is important for a region that has a long history of building with earthen wall materials without added layers of insulation; it is acknowledgement that airtight construction is not the only way to achieve indoor climate control.

IN RETROSPECT

In this case, the ability to use the planned thermal data documentation to address an unforeseen code dilemma was fortunate; expensive and time-consuming solutions to the problem were averted and aesthetic qualities of the project were preserved. However, lessons for this instructor include broadening the scope of the research to anticipate other environmental performance criteria, allowing more time to study material properties, and building extra contingencies into the project budgets. While difficult to accomplish within the parameters for design-build studios, these strategies would improve the pedagogy for investigations with alternative materials.

Figure 4. Street facade. Photo by Velen Chan..

Figure 5. View of kitchen and living area. Photo by Velen Chan.

Figure 6. Students construct scoria walls. Photo by Queston Kwolek.

Figure 7. Formwork for window box. Photo by Queston Kwolek.

Figure 8. Completed window insert. Photo by Velen Chan..

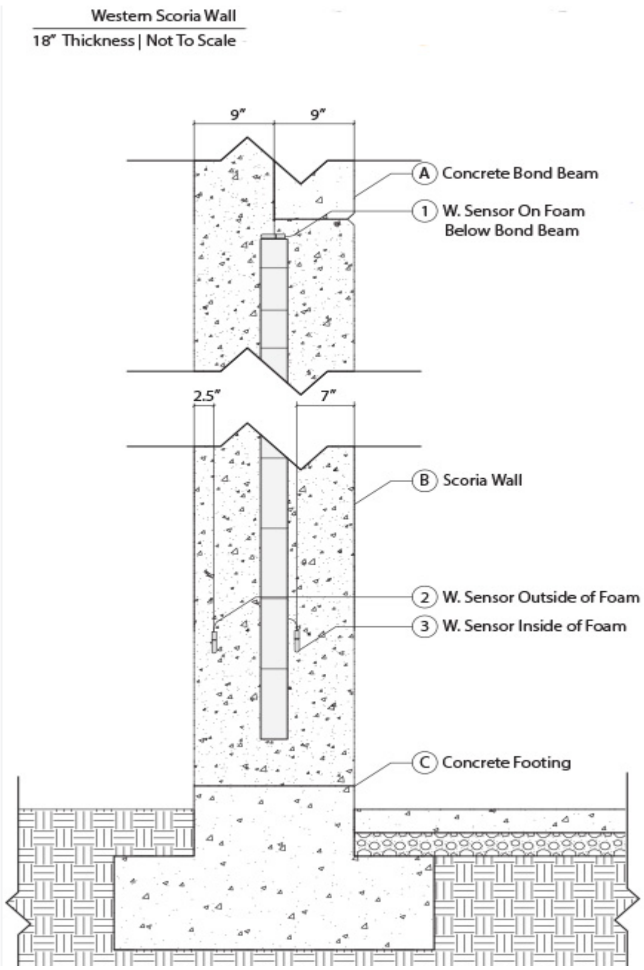

Figure 9. Wall section with sensor locations. Drawing by Chris Tansey.

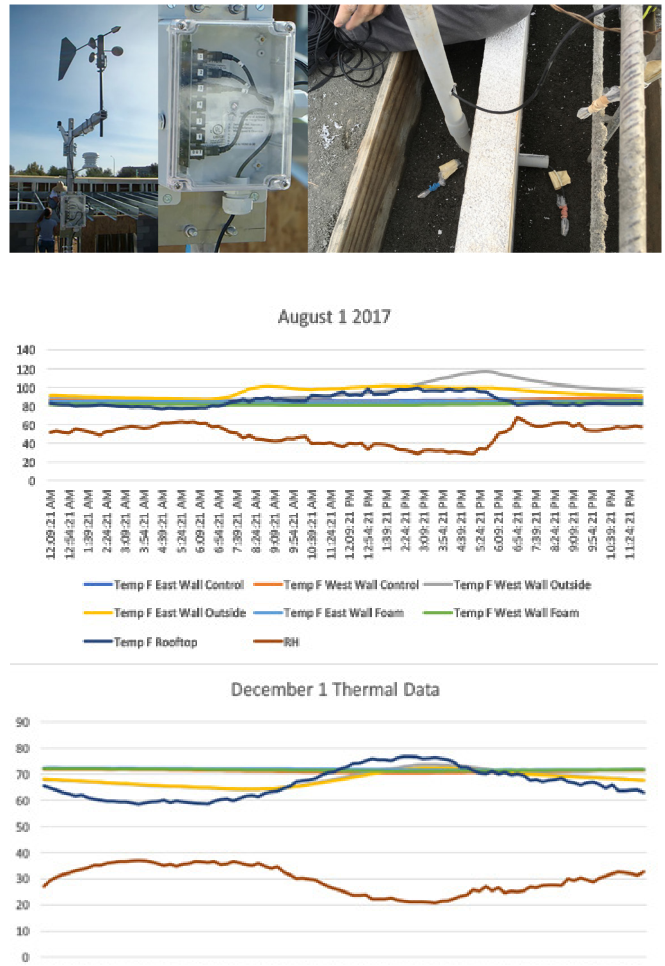

Figure 10. Thermal sensors and data. Images by author..

ENDNOTES

1. Hayes, Cade and Jesús Robles, Casa Caldera, DUST, Arizona, 2016.
2. Weiner, Paul. Tucson Lava House, DesignBuild Collaborative, Arizona, 2014.
3. McHardy, Scott. Pumice-Crete Building Systems of NM, http://www.pumicecrete.com/index.html.
4. Several regional mines excavate and crush larger pumice stones for use in landscaping (as ground cover) or as aggregate for lightweight concrete and masonry units. Large amounts of "fines", small particles that are byproducts of the crushing process, are leftover and considered debris by the mining businesses.
5. Soils science research shows that the addition of scoria stone to concrete mixes results in lighter weight with beneficial thermal and acoustic properties. The presence of air in scoria decreases the volumetric proportion of the solid materials conducting heat (compared to standard concrete) and absorbs more sound. Raiaonarison, Eddie Franck, et. Al., Effect of Scoria on Various Specific Aspects of Lightweight Concrete, International Journal of Concrete Structures and Materials 11, September 18, 2017.
6. The IRC (International Residential Code) defines the compressive strength requirement for Low-Strength Concrete as 1000 psf, while the local amendment for Earthen Materials requires only 300 psf. However, the Earthen Materials code requires the construction of a concrete bond beam to tie walls together at the roofline, whereas the code for Low-Strength Concrete has no such requirement. Low-Strength Concrete walls have vertical reinforcement requirements similar to masonry construction, but earthen walls do not because their required thickness makes them less vulnerable to lateral forces. Both types of construction require test cylinders of the wall material to be collected on site and tested for compressive strength in a certified soils laboratory.
7. Students resealed all caulked joints and weather stripping. The exterior scoria walls were also sprayed with two coatings of a clear, penetrating masonry sealant, but this was a water repellant, not an air barrier.
8. Mitigation possibilities included: continuous exterior or interior stucco, continuous exterior or interior insulation with cladding such as fiber cement panels or drywall.
9. During the desert summer with no air conditioning or ventilation, exterior surface temperatures ranged between 88° F and 130° F, but the interior scoria wall temperatures stayed stable at about 90° F.