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Candidate for Bachelors of Science in Architecture
Discipline Stream: Building Technology
Class of 2015
Sesen-Aten Temple

Passive Thermoregulation in Unreinforced Masonry

The Sesen-Aten Temple was inspired by Guastavino’s thin unreinforced masonry vaults, and Eladio Dieste’s doubly-curved concrete shell structures. Our design explores the ability of unreinforced masonry forms to perform passive thermoregulation in a desert climate.

Class: 4.440 Building Structural Systems I
Semester: Spring 2013
Instructor: John Ochsendorf
Collaborators: Phillip Hu
Site Location: Cairo, Egypt
Program: Spiritual Space
Materials: Structural Clay Tile, Stabilized Soil
Span: 160’; Height: 60’; Area: 20k sq. ft
Sesen-Aten Temple

We used graphics statics to determine the forces in our dome based on our loading case. We determined our loads based on the geometry of our tributary area (assuming an initial near-funicular shape).

Maximum Force in Dome: 195 kips
Design Stress: 1 ksi
Live Load: 30 psf
Total Self-Weight: 3300 k lbs

Dome Sizing - Standard Load Case

Dome Sizing - Assymetrical Load Case
Oculus Sizing

The structural masonry fins act as a solar chimney by absorbing solar radiation and heating the air around them, creating a convective updraft.

Depth-Stiffening

This flow draws air up and out of the building, flushing it constantly. Intake air passes underground to cool before it enters the building.

Solar Chimney Effect

Passive Cooling w/ Natural Convection
Coral Reefs in Silico

Corals are colonies of tiny jellyfish-like creatures that permanently anchor themselves to rock and form calcium carbonate shells. Multiple species of virtual coral are simulated here in Processing - populating a quantized ocean where they are born, anchor themselves, grow, and eventually die. Their virtual calcium carbonate skeleton is then rendered and 3D-printed, a tangible history of thousands of virtual beings struggling for self-perpetuation.

1. Polyp anchors.
2. Polyp produces CaCO₃ blocks.
3. Polyp matures and dies, leaving skeleton.
4. Erosion constantly knocks off CaCO₃ blocks, which drift.
Gwelutshena Educational Center

Off-Grid Educational Space in Soil

In this design for an educational center in rural Zimbabwe, locally sourced materials are used to address issues such as durable, termite-resistant seating and desks, daylighting, natural ventilation, and structural integrity - with special attention paid to providing adequate daylighting and thermal comfort without electricity. We used physical models and software tools to evaluate the performance of our design.

Class: 4.411 D-Lab Schools
Semester: Fall 2013
Instructors: Les Norford, John Ochsendorf
Site Location: Gwelutshena, Zimbabwe
Community Partner: ORAP (Organization of Rural Associations for Progress)
Collaborators: Adam Blakeway, Katie Gertz, Tiandra Ray
Materials: Stabilized Soil Tiles, Rammed Earth
Primary Structure: **Catenary Soil-tile Ribs**

Secondary Structure: **Soil-tile Barrel Vaults**

Interior Partitions: **Barrel Vault Bays**
Gwelutshena Educational Center

Programmatic Considerations: Flexible Spaces, Collaborative Learning / Presentation

Technical Considerations: Rainwater Runoff, Off-grid Daylighting/Thermal, Durable Seating

Conceptual Sketching

Structural Form-Finding: Hanging Paper-Clip Chain
Physical Model Analysis Tools: **Lightmeter, Windtunnel + Anemometer + Glycol Smoke**

Software tools: **DIVA, Ladybug, Phoenics**

Daylighting Testing

Ventilation Testing (Windtunnel)
Das Beam

Designing for Controlled Failure

The objective of this competition was to design a beam that would fail as close as possible to a minimum load of 100 lbs, without significant deflection at 50 lbs. We used physical failure testing to determine a failure stress for our balsa wood batch, and parametrically determined our beam profile based on the moment function for a simply-supported beam.

Class: 4.440 Building Structural Systems I
Semester: Spring 2013
Instructors: John Ochsendorf
Collaborators: Phillip Hu
Objective: Failure at 100 lbs
Materials: Balsa, Glue
Tools: Laser-cutter, Rhino
Strategy

1. Minimize the effect of glue joints and local material strength variations.
2. Minimize depth of beam to stress wood primarily axially along grain.
3. Minimize effect of construction error with "soft" pad under loading plate.

Platform to accept loading plate - 4”x4”

Depth determined parametrically based on moment function.

Depth added at ends to account for shear forces.

Support pins

Required Span: 24”
Das Beam

Beam Sizing Method:

1. Test beams of known dimensions to failure, noting maximum load capacity.
2. Determine average failure stress.
3. Determine required depth as a function of position along beam length.

Material Testing

\[
\text{Given that: } \sigma = \frac{My}{I}, \quad I = \frac{bh^3}{12}, \quad M = \frac{PL}{4}
\]

For a point load at the center of a beam of length L, width b and depth h:

\[
\sigma = \frac{3PL}{2bh^2}
\]

Where P is the weight of the load (bucket and water) on the beam.

Finding a Failure Stress

\[
\text{Given: } I = \frac{bh^3}{12}, \quad \sigma = \frac{My}{I} = \frac{bhL}{12} = \frac{6M}{bh^2}
\]

Therefore:

\[
h(x) = \sqrt{\frac{6M(x)}{b\sigma}}
\]

Determining the Moment Function
Testing to Failure - Global Torsional Buckling

Why “Das Beam” took on more load than predicted:

**Global Twisting:** Bundles were not glued together, allowing them slide past one another and allow global twisting. Some of the load was therefore carried in resistance to twisting.

**Extra Thickness:** Extra material was added at the ends not following the moment function in order to account for shear.

**Compression in Construction:** In the final glueing of the plates on the top and bottom of the beam, we slightly compressed the laminations, from somewhere around 4.5 inches to 4 inches, possibly making it slightly more dense than our test beams.

**Safety Factor:** We applied a safety factor of 8.5% in our design to ensure failure above 100 lbs.
Our design for a community library in Makuleke, South Africa includes an outdoor Maker Space pavilion. We are currently prototyping the structure at MIT using only materials and tools available in rural South Africa. We learned "stick" welding - a portable and low-cost (but technically challenging) welding technology common in developing countries.

**Portable Workshop in Steel**

- **Class**: 4.491 (Independent Study)
- **Semester**: Spring/Summer 2014
- **Advisors**: Les Norford, Chris Dewart
- **Collaborators**: Katie Gertz, Tiandra Ray
- **Materials**: Mild Steel, Dimensioned Lumber, Corrugated Galvanized Roofing Sheets
- **Tools**: MIG/SMAW Welding, Metalworking

![Community Library Plan](image)

![Maker Space](image)

![Installing Corrugated Galvanized Roofing](image)
“Stick” Welded Connection

Gusset Connection Detail