EXPLORING THE POST-FUNICULAR AT CAL POLY
The number of footings greatly affects the airiness and density of the shell.

Oculi create lighter feeling in the shell, with interesting views and solar orientation, while denser footings create protection.

Using an oculus connection to the ground to create more dynamic large and small spaces.

Loads analyzed on Karamba3D. Orange represents areas with large deformation.

Using the same shell mechanics to innovate the bench, and incorporate it into the design.
BENCH SHELTER
SLO BOTANICAL GARDEN
SPENCER BAZER
6 APRIL 2022

Work by: Spencer Bazer
Partial coverage with overhangs

Exaggerated folds

Compromise folds

Full coverage with overhangs

Folded edges

Exaggerated folds with oculus

Double roof oculus

Single rear oculus

Double rear oculus

Karamba load lines

Funicular

Work by: Kieran McCullough
Work by: Kenji Toyomitsu
SAGE GARDEN TEACHING PAVILION - SLO BOTANICAL GARDEN
REQUIREMENTS

Provide a shaded instructional pavilion with storage in the children's garden at SLOBG.

Design using the concept of funicular shell structures, and an inherited double skin shell script.

Respond to the climate and potential hazards of the site.

GOALS

Create a responsible design that reflects the principles of the botanical garden.

Generate a low-impact proposal which has minimal implications on the site.

Research and test cladding materials to address the client’s concerns with wildfire and rainwater.

Use the design as a piece of architecture which, itself, serves as a teaching device.
In the first iteration, each member of the team presented new formal funicular proposals at the instructional pavilion scale. The first ideations of a shell with three distinct spaces brought on by the ceiling heights, and one interior dividing footing continued to the next phase.
In the second iteration, or the most important step in this project, the team combined the optimistic qualities of each person’s proposals into two design options. Ideas of an enclosed cylindrical storage and one essential oculus came to the forefront. Also using analysis of the shells’ structural integrities, the team made further iterations.
In this third iteration, new techniques allowed for the team to make decisive moves with the form. Still struggling to close on one idea, the team picked the best ideas of the two, truly melting the ideas together. A drop down oculus and a half enclosed footing to divide the space lent well to the team’s design goals.
Solar Studies

With dense tree coverage surrounding the Sage Garden, the pavilion is designed to shade the summer sun that threatens to disrupt outdoor learning. Lower sun angles that avoid the surrounding foliage are able to penetrate deep into the learning area, to warm students on a colder day, because of the high, arching openings. The oculus provides an interesting focal point of natural light in the learning pavilion, but also brings light to feed the garden below, and also becoming a teaching moment dealing with solar properties.
Rain Garden
Lips on shell edges create the channeling of water to the footings.

French drains located at cusp footings funnel storm water from surface level.

Underground piping located at footings moves storm water to storage.

Rain garden catchment is sent to storage through piping.

Storage used to water the botanical gardens.

Rain Garden
The water catchment is completely exposed to offer a teaching window into water management, proper drought habits, and the importance of the botanical garden.

Resource links:
https://www.thisoldhouse.com/gardening/21016538/how-to-build-a-rain-garden-to-filter-run-off
https://www.pacifichorticulture.org/articles/designing-new-normal/
https://www.portland.gov/bes/stormwater/managing-rain-your-property/rain-gardens
Learning, Teaching, and Playing
Ramps create accessibility to the raised decking for all.
Pile Detail
N.T.S.

Tension cable to anchor connection

1/4" = 1'-0"

Structural Plan

Sizing the anchor
Larger storage space for large objects such as ladders, painting easels, and furniture.

Decking boards aligned vertically at slight angles will allow for curved surfaces on the storage container and the garden bench.

Because lumber is less than 6’ from the ground and has poor ventilation, pressure treated floor joists can be used as decking support. Pressure treated lumber naturally resists termites, rot, and fungal decay with its high chemical retention.
Small storage drawers fit under seating areas for backpacks, school supplies, and other small objects.

For a permanent structure, establish level ground by removing at least 8" of dirt, placing a growth membrane, and cover with gravel to maintain a weed resistant/breathable and level platform for deck.
The wood finishes add a vernacular touch to the pavilion located in the trees of the botanical garden. The contrast of decking and plywood distinguishes the structure from the utility in a minimal way.

Cali Bamboo decking is made with 100% recycled content, and provides great weather resistance with wood texture finish. 

Material can be painted to match the garden’s playful aesthetic.

South Elevation

The series of openings grows smaller as the designation of space changes. Large openings encourage entry and observation, while smaller openings give a glimpse of play and intrigue.

East Elevation

1/4" = 1'-0"
Static Performance

The shell performs well under self weight, with the roof adjacent the oculus being the largest source of deflection. Buckling becomes a concern at higher loads where the non-funicular free edges approach the footings. The interior shell column produces the most thrust of all the footings.

Buckling Implications

Axial Tension Force in Cables
Seismic Performance

The shell experiences small deflections under seismic loading. The longer non-funicular free edges deflect the most. Lateral loads do not introduce any deflection or buckling concerns around the oculi.
Through testing previous iterations of the double skin funicular technique, the class discovered that the plywood is capable of carrying many times the shell's own weight. The true complication through testing this system is the footing connection to nullify the shell's thrust.

With the tension cable system proposed, the second test was intended to investigate the strength of the plywood with a point load. The plywood panels appeared to be sufficient with the point load, but the wood coupling did fail in shear at a load exceeding that which the tension cables would induce.
Epoxy is an agent that gives the plywood UV protection, water protection, and still provides a laminated wood aesthetic. In combination with tape at the seams, this material study creates a membrane while continuing to show the structural design of the shell.
Using cedar wood shingles is a modular approach to cladding the shell, which creates a water barrier in combination with roof underlay. The cedar itself is rot and insect resistant, common obstacles in the garden. Combined with a coating of polyurethane, this cladding is a strong elemental membrane that interpolates the organic funicular shell.
Besides strength, the double skin shell’s largest benefit is the ease of construction. With this friction fit system, the shell is quickly constructed with minimal tools, and has endless cladding possibility.
GOING FORWARD

Moving forward from here, the largest challenge will be to develop a cladding system that prevents water damage of the plywood, and acts as a fire retardant in case of emergency. Waterproofing the connection to the ground will also be pivotal in order to convey the shell’s light touch on the ground.