A Shapely Resistance:
a study in construction for a Kindergarten
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This thesis deals with the relationship between form and strength in architecture. The proposed building is a Kindergarten which unites issues of shape, physics, and habitat. The roof is vaulted and the walls are curved for lateral resistance and in order to make folds scaled to a child. These physical moves work towards the theme of the Kindergarten: a place for the transition between home and school.
to Sarah and Grace, my tourmaline sisters
With many thanks to my parents, Milt and Louise and to all the faculty, staff and students of Virginia Tech, especially: Jim Jones, Hans Rott, Frank Weiner, Steve Thompson and the “Yellow Cube Freaks”
As Modern architects, we overcome the many forces that beset buildings - gravity, wind, ice - with the resistance of steel and concrete. The shapely resistance of the arch, the rhythm of pilasters and columns seem like complicated anachronisms against the clean and easily calculable plane. The abundance of modern construction technology leaves room for unusual shapes and conditions - the legacy of "deconstructivist" architects who have brought construction to new adaptive heights. In the wake of these moderns, there is room for the revival of the shapely resistance of new building forms and the return of the haptic properties that are highly regarded in older works of architecture.
The work of Catalan builders - such as Gaudi - and their Western descendents in tradition - Eladio Dieste and company - have highlighted the connection between form and strength in construction. My goal was to derive building shapes that draw strength from their form, rather than the props on which modern architects have come to rely. The building in the following pages is a kindergarten, one of an identical pair located on the site. It is essentially a range of vaults that span over a clerestory for ample light. The walls of the kindergarten form a wave that contributes to their lateral resistance. They are thickest in the region where they intersect the roof vaults, and they shrink to 3 inches thick at the outermost point, where they lean out and have a maximum moment.
In the space of a school, there is an opportunity to unite haptic, structural and environmental concerns. The purpose of the kindergarten is to help children make the transition between home and school. The walls house space for individual children within the body of the classroom - in addition to providing lateral resistance, the undulations house semi-private spaces scaled to the size of a child. Excluding the folds, each classroom is 735 s.f., which is ample room for the intended 15 students. The top edge of the wall is extended over the bottom; at its thinnest, the wall leans out. The walls are at once strong, voluminous, and active in the spirit of their environment.
CONCLUSION
Floor Plan

The building is based on a 3.5’ x 3.5’ module, one side of which is the height of a 5 year old child. From the innermost nodes, there are 5 x 12 squares in each classroom - from the outer nodes at the roof level, there are 9 x 12 squares. The floor of the building is made of concrete as well and is supported by a bronze latticework. The latticework travels from node to node, and it appears as faint lines on the floor.
Sections: Transverse 1 and Longitudinal 1
The sections have bilateral symmetry so I included half of each and indicated where the mirror lines are, along with the section cuts. Excluding the front elevations and the middle, the sections are typical throughout the plan. The lines on the wall represent lines left behind by formwork. The wall becomes faceted in construction, and since the top edge of the wall is longer than the bottom edge, the formwork lines must diverge.
Sections: Transverse 2 and Longitudinal 2

This drawing includes an elevation of the area between the classrooms that contain doors and the bathrooms. The end walls are mostly glass with a bronze latticework for support. In the typical section, the roof is a flat extrusion across the building. However, the roof is bowed at the end walls and over the middle of the building. The revised elevation is shown in the blue lines and in the NE elevation.
Sections: Transverse 3 and Longitudinal 3
The roof is hollow in section, but there are solid sections above the wall and at the edge and the middle of the building, which act like beams. Beneath the longitudinal sections in each drawing, there is a drawing of the plan of the wall facing the one visible in elevation. The formwork lines on the wall correspond to the facets that appear in the plan.
NE Elevation

This elevation displays a module of the trunk, head, and leg sizes of a 5 year old child. The main material is glass supported by a bronze latticework. The pieces of the module are inserted into the larger glass panels and are outlined by bronze.
Site Plan

The building site is an open, sloping plot of land in downtown Blacksburg on the edge of the Virginia Tech Campus. The site is bordered by an independent movie theater and shops on the Southeast, bars to the Northeast, and campus buildings to the North and Southwest. The kindergarten buildings are identifiable by the scalloped shadows they cast.
Model Photos
INCEPTION

Exploratory drawings, model experiments
These are the results from an experiment using clay to model a curved wall. As a modelling tool, clay is a good approximator of material in compression. A thin layer of clay can be made to stand upright without support given the proper curvature. This model is indicative of the wavelength and frequency needed to support a larger serpentine wall.
PURSUIT

Plan experiments, Thesis Stance, Roof Experiments, Wall Finishes, Studies of a form-maker; Hands
Floor Plan Study # 1
This floor plan emerged from the clay studies. It was evident from the experiment that the wall needed less curvature on the top than on the bottom to keep it stable. The moment force is greater at the base of the wall. The black line represents the curvature of the bottom of the wall, and the yellow line represents the curvature at the top.
Over the course of the thesis year, professors referred to a thesis as a stance in the realm of architecture. This particular iteration seemed to have a literal balletic posture. The very thin walls turn inward for tensile support in the same way a person can turn their toes outward and feel the tension in their legs, making themselves thinner and taller. There is tremendous energy in that pose.
The plans tended towards a symmetrical arrangement, with an unchanging, repeated curve whose construction would save labor. At this point in the project, a brick wall with a uniform thickness was still intended.
Roof Study # 1
Concrete is the main material in the kindergarten because of its flexibility shape-wise, but this choice complicated the question of finish. The walls have a greater area longer at the top than at the bottom edge, so if tile were to be used as a finishing material each row would have a different number of tiles, and some of the rows would diverge at the top. In the final design, an uncovered formwork expresses the geometry of the walls.
Form Studies

The shape of a human hand became a formal grounding for the building. It appeared to be the best expression of the desired shape and function for the roof. The following studies are after the hand and the building in terms of form.
Form Studies

The study of intertwined hands was especially important because it points to joint conditions between the roof and the wall and the question of how these two separate entities will meet.
ARRIVAL

Kindergarten Form, Elevations, Studies of Window-walls, The Arc of the Roof, Plan, Section
NE Elevation
SW Elevation
SW Facade Studies
Roof Study # 2 with Floor Plan

Between each node of a curved roof there are an infinite number of distinct sections. In this drawing, six sections describe the sweep of the roof in section. Flattening it made some of the internal calculations simpler while preserving the effect of light in the space.
Study Model
In this plan, reinforced concrete is the main material of the curving walls, while the secondary walls are glass with a bronze latticework. Using concrete allowed me to vary the thickness of the walls to correspond with moment forces and the weight of the roof. The roof hits at the thickest portion of the wall. The thinner portions are free of the roof load, but they lean outwards and have a greater moment than a perfectly vertical wall.
The mechanical nature of the walls and roof became particularly evident in this section. The connection between the roof and the walls would have to be mechanical in order to achieve an organic whole. The following formwork studies pursue this type of connection.
Interior Perspective Study
CONSTRUCTIONS

Roof-Wall Intersection studies, Formwork studies
These studies are after a mechanical connection between the roof and wall, and also the consequences for the formwork on the final shape of the wall. These studies highlighted the necessity of moving from a smooth to a faceted wall and roof.
The building itself is non-orthogonal, but most material for formwork comes in straight components. The faceted surface of the building emerged from using straight boards to form the curves of the walls and the roof.
How to attach formwork to curving wall?

Does the slight duct in the wall fix the formwork solve the problem?

Plan of wall + formwork

U-shaped ribs, "Hull"

Wall in elevation
PLYWOOD V-CHAPES, MUST ATTACH TO FORMWORK
PANELS FOR ROOF CRESTS

PLUMBING SEAMS - BETTER STAGGER?

IN SECTION:

→ TO FLOOR, BASKET CONSTRUCTION

CONCRETE WALL

PLUMBING ATTACHMENT TO CONCRETE

CAST ATTACHMENT HARDWARE? CAST IN WOOD OR METAL STRIP?
For example, the metal can attach to extended metal pipe that holds the roof in place.

- The ribs for the trough of the roof will have to be joined to the ribs of the crest of the roof framework.
- Concrete will be poured directly onto the metal along with the wooden planking.
- Thermal spaces in roof, maybe styrofoam
- Framework for lower part of roof: 1st pour thin layer, fill trough, then place styrofoam, pour over top.
FOR A WORK FOR WALL:

Top curve of wall is longer than bottom curve, so more planks are needed to cover it. But they will have to be cut diagonally to fit.
Formwork Pocket will have to diverge... it will diverge under the lip of the crest.

* Trough of Roof
Front elevation

Convergent beam

Crest
Rise
Sudden beams

Side View
AFTERWORD

Ultimately, these studies show the possibilities for a marriage of form and strength in architecture. The undulating walls create volume with the quality of an embrace - a good thing in a space for small children - while adding to the lateral resistance of the wall. The vaults of the roof press against each other for added support while spanning over the space of the school, allowing for a free and open plan. Thus, the shapely resistance of form takes place in the kindergarten.
BIBLIOGRAPHY

