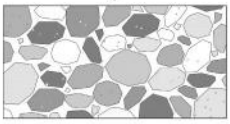
TESLA BLOCK

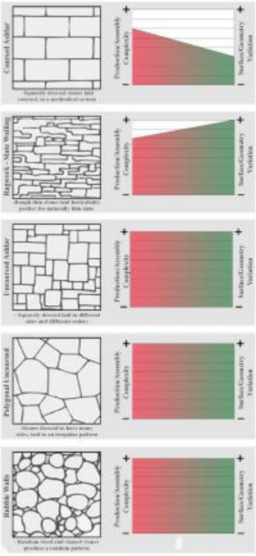
DESIGN RESEARCH OBJECTIVE

In the last 45 years the introduction of engineered reinforced masonry has resulted in structures that are stronger and more stable. Industry research has also developed a CMU block with a webbing geometry capable of reducing thermal transfer. Although these additions have improved certain aspects of performance and much advancement has taken place over this time frame, current building construction methods still rely on compressive force stacking and simple rectilinear block design which limit geometric configuration, and exterior expression for façades. Tesla Block is primarily focused on how surface geometry and articulation can be configured to offer a variety of visual aesthetics and also incorporate a performative response to the thermal environment. These aspects when combined with current CMU technologies can further refine the transfer of heat flow in the latest construction block methodologies. The research considers design aesthetic improvements to the typical brick module based off the 8x8x16 CMU. Fabrication processes for mass production is a major concern for the construction industry, and utilizing the proportions of CMU with its ease of rapid prototyping makes for easy adaptability. In designing the facade system, the project makes use of the available digital toolsets to maximize thermal performance , refine surface geometry, and offer an ideal geometry to physically fabricate and test.

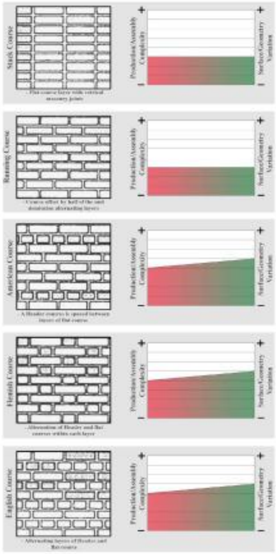
MASONRY EVOLUTION

Stone Masonry Wall

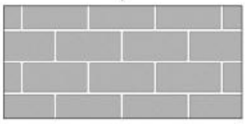


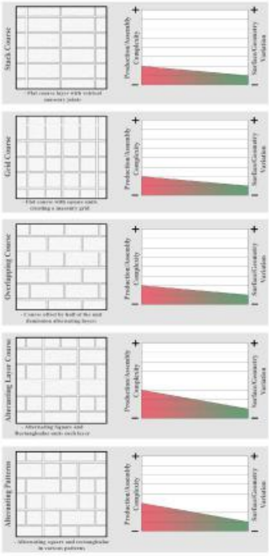


Brick Masonry Wall

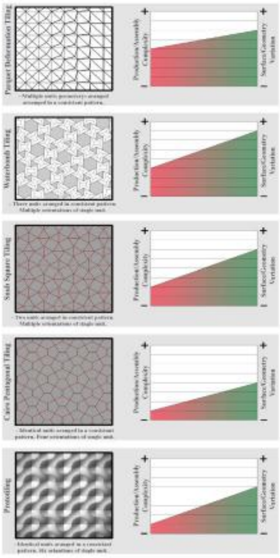


Concrete Masonry Units





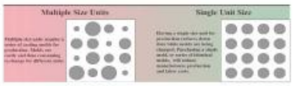
Tessellated Panel System



Production/Assembly Complexity

Increased Complexity · Decreased Complexity


Handmade · **Machine Produced**


Multiple Size Units · **Single Unit Size**

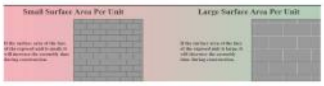

High Tolerance · **Low Tolerance**


Unique Units · **Consistant Units**

Increased Complexity · Decreased Complexity


Varying Joint Pattern · **Consistent Joint Pattern**


Solid Masonry Units · **Shell & Web Masonry Units**


Small Surface Area Per Unit · **Large Surface Area Per Unit**


Field Modifications Required · **No Field Modifications Required**

Surface/Geometry Variation

Increased Wall Customization · Decrease Wall Customization


Handmade · **Machine Produced**


Multiple Unit Geometry · **Single Unit Geometry**


Multiple Unit Sizes · **Multiple Unit Sizes**


Multiple Surface Geometry · **Single Surface Geometry**

Increased Wall Customization · Decrease Wall Customization


Varying Surface Textures · **Consistent Surface Textures**

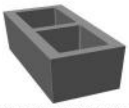

Varying Joint Patterns · **Consistent Joint Patterns**


Surface Extrusions · **Planer Surface**


Multiple Unit Orientations · **Single Unit Orientations**

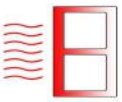
CMU BLOCK TYPES

THERMAL BRIDGING

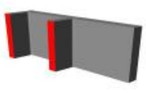


Standard Concrete Masonry Unit
Dimensions - 15 5/8" x 7 5/8" x 7 5/8"
Weight - xx

Thermal Bridging Area
~ 22 7/8 in.



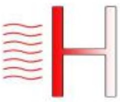
***A Block* Concrete Masonry Unit**
Dimensions - 15 5/8" x 7 5/8" x 7 5/8"
Weight - xx



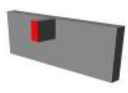
Thermal Bridging Area
~ 13 1/4 in.

***H Block* Concrete Masonry Unit**
Dimensions - 15 5/8" x 7 5/8" x 7 5/8"
Weight - xx

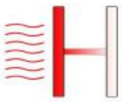
Thermal Bridging Area
~ 7 3/8 in.

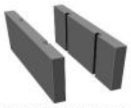


***New Castle* Concrete Masonry Unit**
Dimensions - 15 5/8" x 7 5/8" x 7 5/8"
Weight - xx



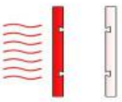
Thermal Bridging Area
~3 in.



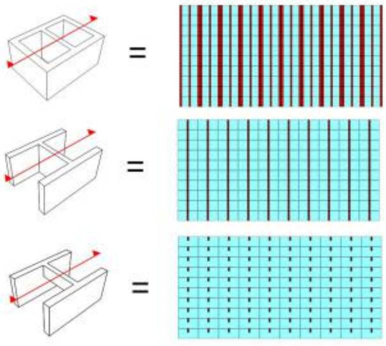


***Modified Web* Concrete Masonry Unit**
Dimensions - 15 5/8" x 7 5/8" x 7 5/8"
Weight - xx

Thermal Bridging Area
- Minimal Thermal Transfer



INTEGRA BLOCK
OLDCASTLE



Minimal thermal bridging by reducing middle web.

Insulation comparison

Block Area = 82.74 sq in
Thermal bridges = 19.86 sq in
Percentage lost 24%

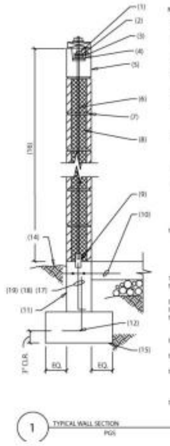
Block Area = 82.74 sq in
Thermal bridges = 6.62 sq in
Percentage lost 8.00%

Block Area = 82.74 sq in
Thermal bridges = 2.44 sq in
Percentage lost 2.90%

Advertised R-28 (proprietary)
Open Cell Foam 5.5 X 3.8 = **R-21**
Closed Cell Foam 5.5 X 6 = **R-33**
Traditional CMU R-5

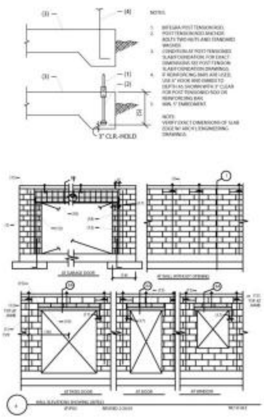
Post tensioning of CMU system

Windell Bernett Residence

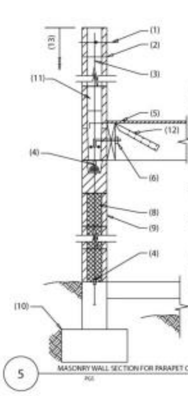


NOTES:
1. 1/2" Ø NUT - TIGHTEN PER GENERAL STRUCTURAL NOTES.
2. HARDENED WASHER ABOVE & BELOW DIRECT TENSION INDICATOR WASHER.
3. LOAD INDICATOR WASHER INSTALL WITH "BUMPS" UP.
4. 1/2" X 5" X 3" STEEL BEARING PLATE.
5. SPECIAL INTEGRA PLATE BEARING BLOCK AT RODS ONLY.
6. 7/16" Ø SMOOTH RODS W/ 1/2" ROLL THREAD ENDS DESIGNATED AS POST-TENSION ROD.
7. HORIZ. JOINT REINF. WHERE SHOWN ON WALL PLAN AS MANUFACTURED OR SUPPLIED BY SUPERLITE BLOCK.
8. HATCHED AREA INDICATES FOAM.
9. 7/16" Ø X 12" X 3" (LLV) ANCHOR BOLT (SAME MATERIAL AS TENSION ROD) COUPLER PER GSN AS MANUFACTURED OR SUPPLIED BY SUPERLITE BLOCK.
10. 2 #4 CONT. BARS W/ ANCHOR BOLT IN BETWEEN AS SHOWN FOR COMMERCIAL PROJECTS. FOR RESIDENTIAL IT IS AN ACCEPTABLE ALTERNATE TO STACK THE BARS ONE ABOVE THE OTHER.
11. CONCRETE STEM BY OTHERS.
12. DESIGN OF FOUNDATION TO STEM PER DESIGNER.
13. NOT USED.
14. FINISHED GRADE AS OCCURS.
15. VERIFY FOOTING SIZE & DEPTH W/ ARCHITECTURAL DRAWINGS.
16. VERIFY WALL HEIGHT W/ ARCHITECTURAL DRAWINGS.
17. DEVELOPMENT LENGTH PER CODE REQUIREMENTS.
18. POST-TENSION ROD ANCHOR BOLT DOES NOT NEED TO OCCUR AT THE SAME LOCATION AS THE VERTICAL STEM REINFORCING.
19. AT MASONRY STEM USE ANCHOR BOLT PER DETAIL 1A WITH MIN. 12" EMBEDMENT.

TYPICAL WALL SECTION
NO SCALE

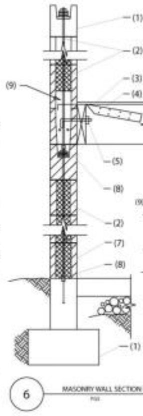


NOTES:

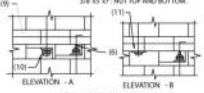


NOTES:
1. PARAPET WALL DESIGN PER CODE.
2. CONVENTIONAL MASONRY CONSTR. ABOVE BOND BEAM.
3. #4 VERTICALS TO MATCH VERTICAL WALL REINF. - THREAD ONE END TO MATCH COUPLER.
4. COUPLER FOR 7/16"ü ROD PER G.S.N.
5. ROOF SYSTEM AS OCCURS.
6. ANCHOR BOLT TO BE SET INTO 8" DEEP GROUTED BOND BEAM WITH 2 #4 CONT.
7. NOT USED.
8. CROSS HATCHED PORTIONS INDICAT FOAM.
9. THE INTEGRA WALL SYSTEM
10. FOR ADDITIONAL INFORMATION SEE DETAIL 1.
11. STIPPLED AREA INDICATES GROUT - AT VERTICAL REINF. ONLY.
12. SIMPSON PAT TYPE @ 48" O.C. PER ICBO #1211 OR EQUIVALENT.
13. VERIFY WALL HEIGHT W/ ARCH'L DRAWINGS.
14. THIS DETAIL APPLIES ONLY WHERE SPECIFICALLY CUT ON PLANS.

MASONRY WALL SECTION FOR PARAPET CONSTRUCTION
NO SCALE



NOTES:
1. FOR ADD'L INFORMATION SEE DETAIL 1.
2. CROSS HATCHED AREA INDICATES FOAM.
3. FLOOR SYSTEM AS OCCURS.
4. SIMPSON PAT TYPE @ 48" O.C. PER ICBO # 1211 OR EQUIVALENT.
5. SET ANCHOR BOLT INTO 8" DEEP GROUTED BOND BEAM W/ 2 #4 CONT.
6. COUPLER AND ANCHOR BOLT 7/16" C X 4" X 3" (LLV).
7. THE INTEGRA WALL SYSTEM
8. COUPLER FOR 7/16"ü ROD PER G.S.N.
9. STIPPLED AREA INDICATES GROUT.
10. INVERTED PLATE BEARING BLOCK WITH TYPICAL STEEL BEARING PLATE.
11. STEEL PLATE: 6" WALL 5/16"x4"x5". 8" WALL 3/8"x5"x7". NUT TOP AND BOTTOM.



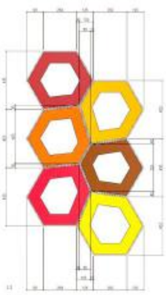
X ALTERNATE ANCHOR BOLT CONNECTION AT 2nd FLOOR WHERE POST TENSION RODS DO NOT COINCIDE

NOTE:
1. THIS ALT. DETAIL IS TO BE USED FOR CONDITIONS WHERE ROD LOCATIONS FOR 2nd FLOOR DO NOT COINCIDE WITH 1st FLOOR LOCATIONS
2. THIS DETAIL APPLIES ONLY WHERE SPECIFICALLY CUT ON PLANS.

MASONRY WALL SECTION FOR TWO STORY CONSTRUCTION
NO SCALE

SPANISH PAVILLION
FOREIGN OFFICE ARCHITECTS

Spanish Pavillion



create a fluid pattern without being repetitive. The skin of the building is formed by 6 different blocks, that rise from a hexagonal base (like most of the decorative elements in Gothic and Islamic art) and are then deformed. The blocks are assembled with steel wires, creating a colorful carpet fastened to the building from the back by means of an aluminum frame. The combination of the 6 elements creates a variegated texture of geometry and color. The six colors chosen are variations of red and yellow (the colors of the Spanish flag) that symbolize the colors of wine, blood, roses, the sun, the sand and all that is internationally associated with Spain.
The blocks are made of ceramic, a material that is very widespread on the Spanish coast of the Mediterranean and in Japan, and were produced in Spain and shipped all the way to Aichi with the specific intention of bringing some of the "land of Spain" to Japan.
Through the perforated tile wall a continuous infiltration between the inside and the outside is created, as between a cathedral and its parvis, between the east and the west.

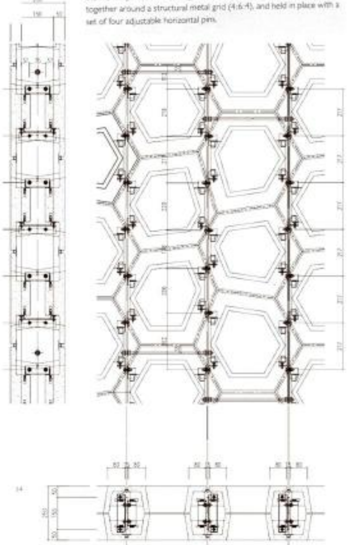
ALEJANDRO ZAERA-POLO, AZPA/FOREIGN OFFICE ARCHITECTS (FOA)
AICHI, JAPAN

This approximately 24,000 square foot pavilion was designed to represent Spain at the Aichi International Exhibition in Aichi, Japan in 2005.[1] The system developed for the façade was intended to evoke lattices identified with Spain's combination of Christian and Islamic architectures. The complexity of this Gothic and Islamic tracery was developed as a system of six different ceramic tiles based on a hexagonal pattern. The system was designed to never have to repeat. Each tile was manufactured in one of six different colors, as a solid surface or with an offset donut hole. Using only six molds the designers are capable of creating 72 different tile types (4:6:1).

The manipulated hexagonal pattern once again is used here to create a tile system, which does not have the typical grid of components and lines to pull the eye across the surface. Additionally, the manipulation of the hexagon used here helps to blur the horizontal and diagonal lines which would be created by a conventional hexagonal grid (4:6:3).

Each of the six units follows a vertical centerline, allowing only vertical variation, while maintaining a consistent maximum offset. The perimeter of each set of six hexagons "resets" back to the edges of conventional symmetrical hexagons, allowing for the tiling of different variations of the set of six. Additionally, each of the six tile types can be fired with one of six different colors of glazing. To create a third variable the tiles can be fired either as a solid exterior or as an offset donut.

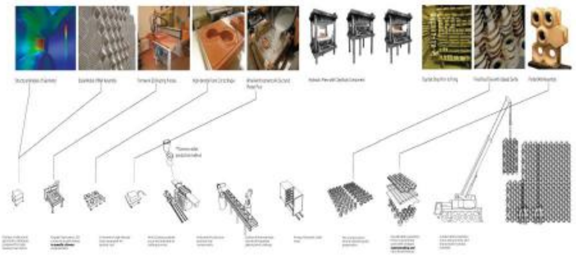
Combinations of each set of six tile shapes are patterned across the surface to allow the builder to construct the system with an idea of consistency, while still creating an intense sense of variation. The tile wall is symmetrical through its thickness, each tile is sandwiched together around a structural metal grid (4:6:4), and held in place with a set of four adjustable horizontal pins.



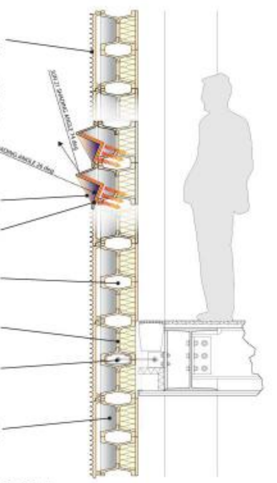
ECO-CERAMIC MASONRY SYSTEM
JASON VOLLEN

Barrel Cactus. Self-Shading and Thermoregulating Surface Articulation.

EcoCeramic was a grant funded research project that investigated composite materials in ceramic architecture. The project moves through prototyping, fabrication and assembly of the wall system. By integrating natural homologues and analogues into EcoCeramic research the designers intend to decrease the summer thermal gains, and increase the solar gains in winter months. The masonry wall demonstrated the design potential of ceramics and the effectiveness of passive design strategies. Testing is accomplished through the use of data loggers, guarded hot box and control tests for smaller experiments.



EMERGING BUILDING TECHNOLOGIES IN CERAMICS : PERFORMANCE MASONRY SYSTEM



Panel with high surface articulation tuned for self-shading

Summer sun is blocked from tile brim with **reflecting glaze**

Winter sun is absorbed by collection surface with heat absorpting glaze

Tile geometry blocks summer solar access and allows winter solar access to heat absorbing glaze

Ceramic tiles re-radiate into interior living space during winter months

Interior air cavity

Fiberglass tabs held in place by zip ties

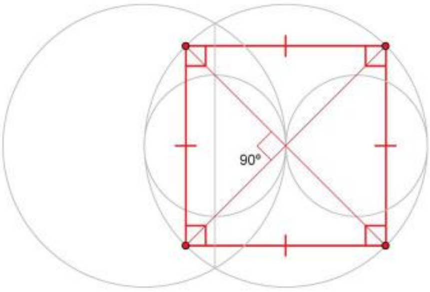
Ceramic wall system tied back to steel

Ceramic fiber glass composite structural block

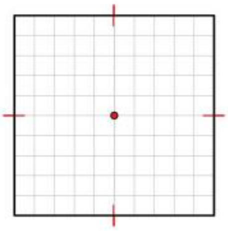
WALL SECTION DIAGRAM LOOKING WEST: 1"= 1'

SQUARE GEOMETRY

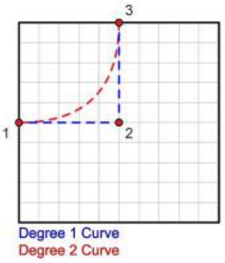
A square is a regular quadrilateral. It has four equal sides and four equal 90-degree angles, or right angles. The opposite sides are parallel, and the diagonals bisect each other at right angles.



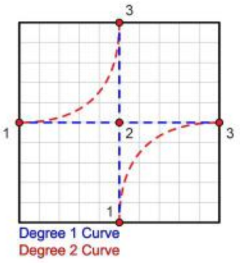
The geometry is subdivided into a 10x10 grid and a single point is positioned at its centroid.



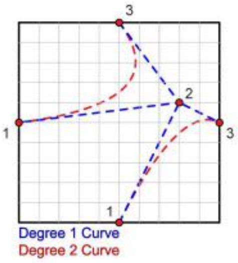
A single NURBS curve drawn along three points in order produces a curvature result that is varied depending on degree type specified.



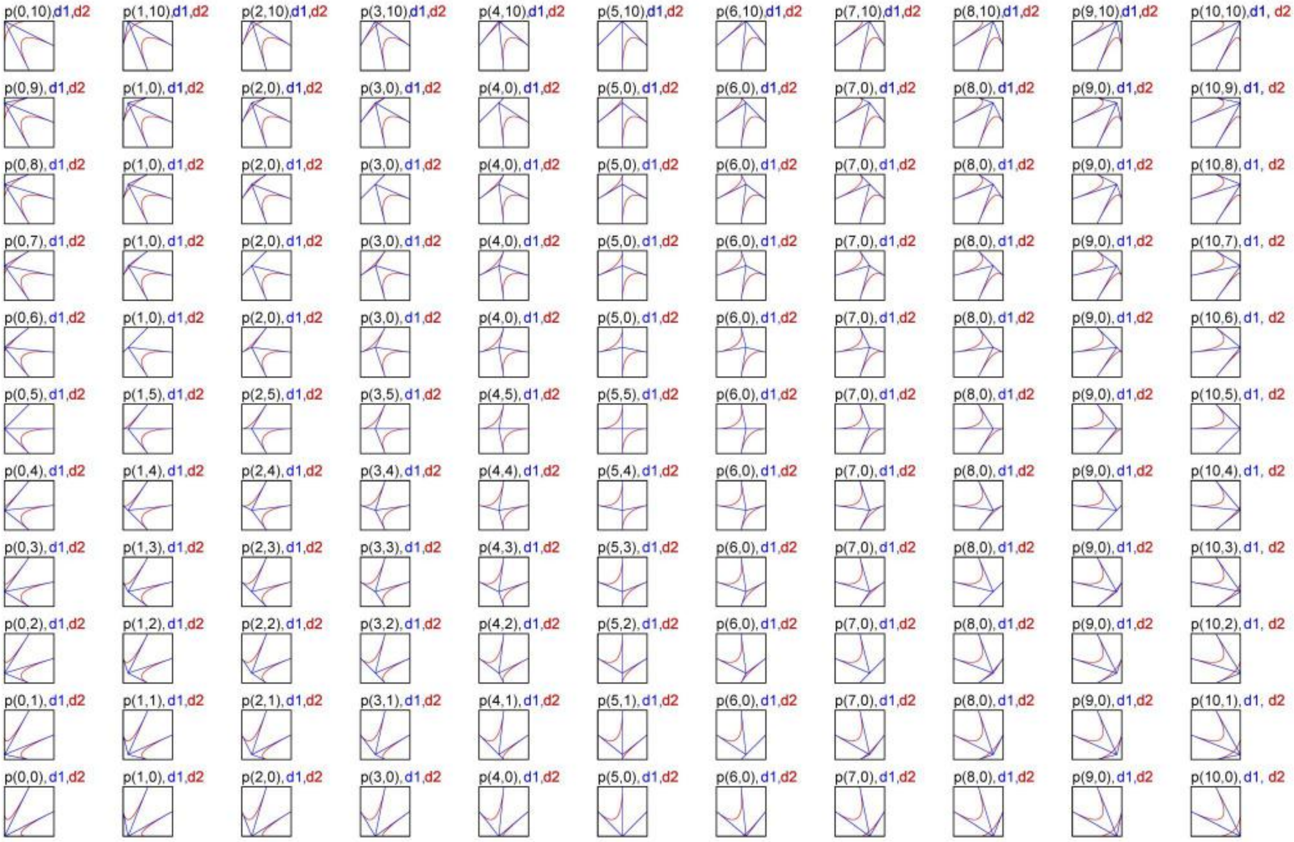
A second NURBS curve drawn from opposite sides in similar order to the same centroid produces a mirrored curve of the first.



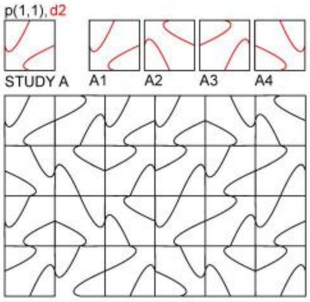
Shifting point two around the grid and keeping the start and end points of each of the two NURBS curves fixed produces a curvature variation depending on point location.



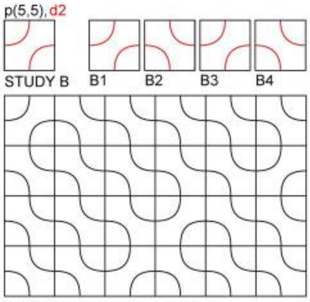
MATRIX ANALYSIS



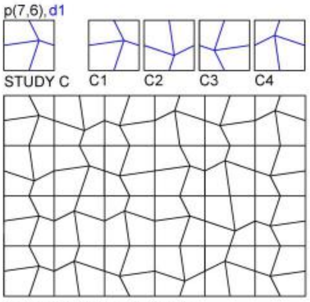
PANEL



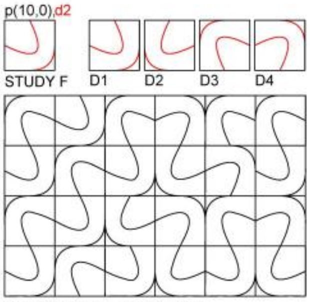
STUDY A WALL ASSEMBLY



STUDY B WALL ASSEMBLY

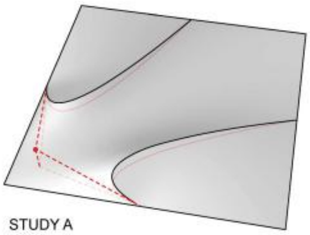


STUDY C WALL ASSEMBLY

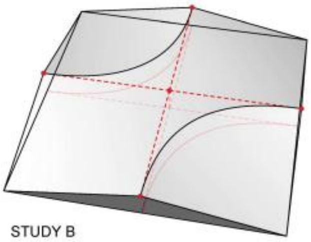


STUDY D WALL ASSEMBLY

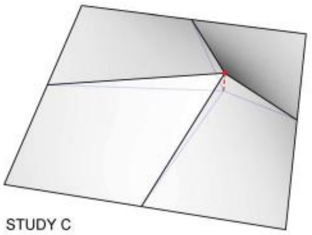
EXTRUSION AND SURFACING



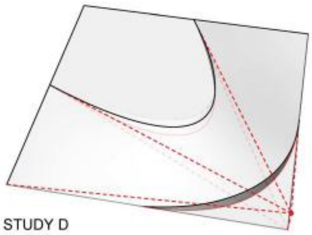
STUDY A



STUDY B



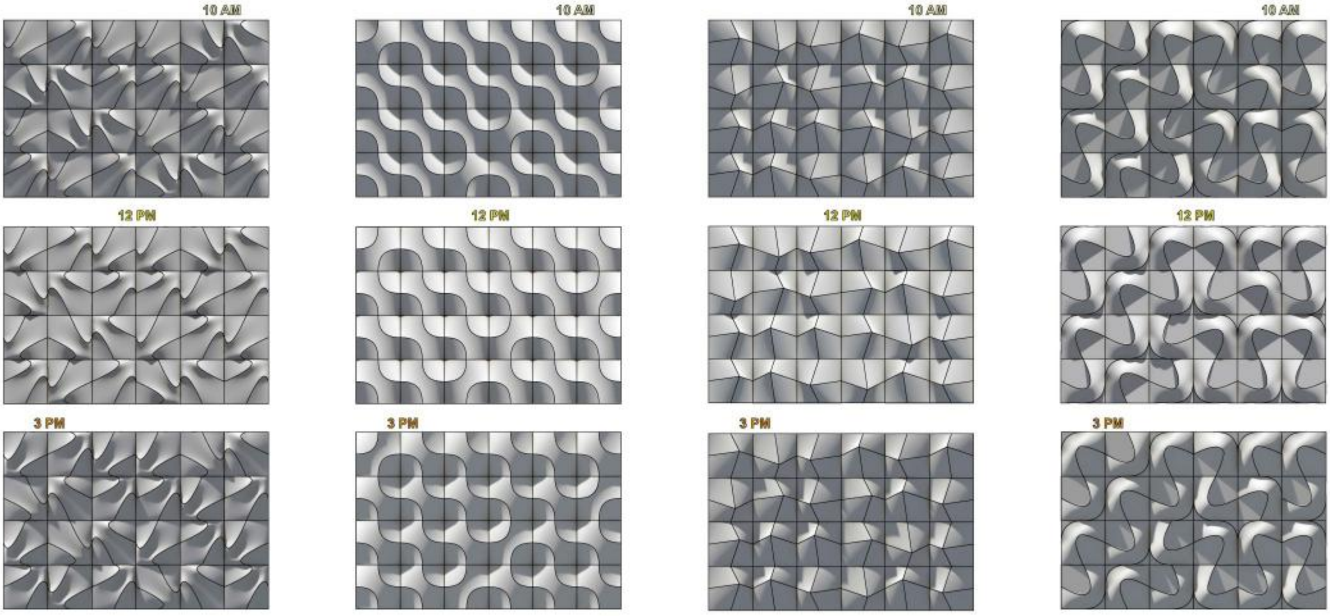
STUDY C



STUDY D

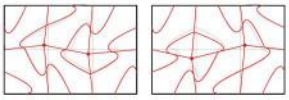
SHADOW ANALYSIS

SOUTH FACADE ORIENTATION

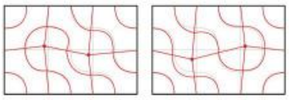


APERIODIC PANEL APPLICATION

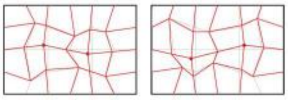
STUDY A VERTEX POINT SHIFT



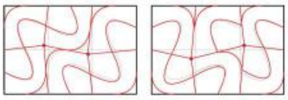
STUDY B VERTEX POINT SHIFT



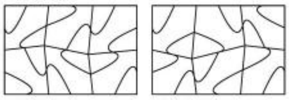
STUDY C VERTEX POINT SHIFT



STUDY D VERTEX POINT SHIFT

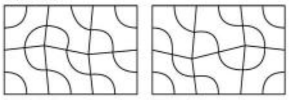


STUDY A



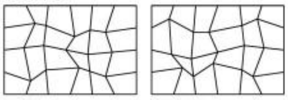
PANEL A PANEL B

STUDY B



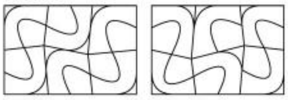
PANEL A PANEL B

STUDY C

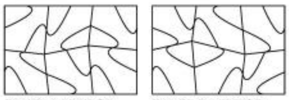


PANEL A PANEL B

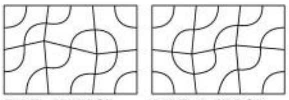
STUDY D



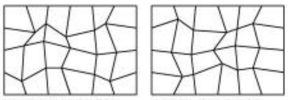
PANEL A PANEL B



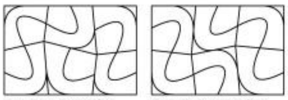
PANEL A MIRROR PANEL B MIRROR



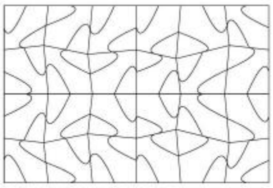
PANEL A MIRROR PANEL B MIRROR



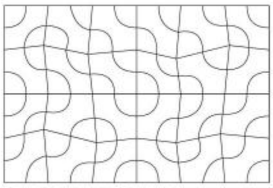
PANEL A MIRROR PANEL B MIRROR



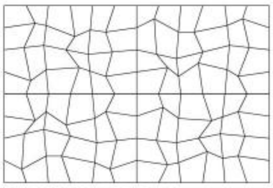
PANEL A MIRROR PANEL B MIRROR



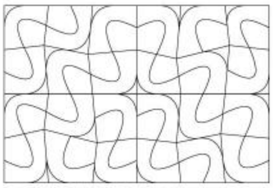
STUDY A WALL ASSEMBLED



STUDY B WALL ASSEMBLED



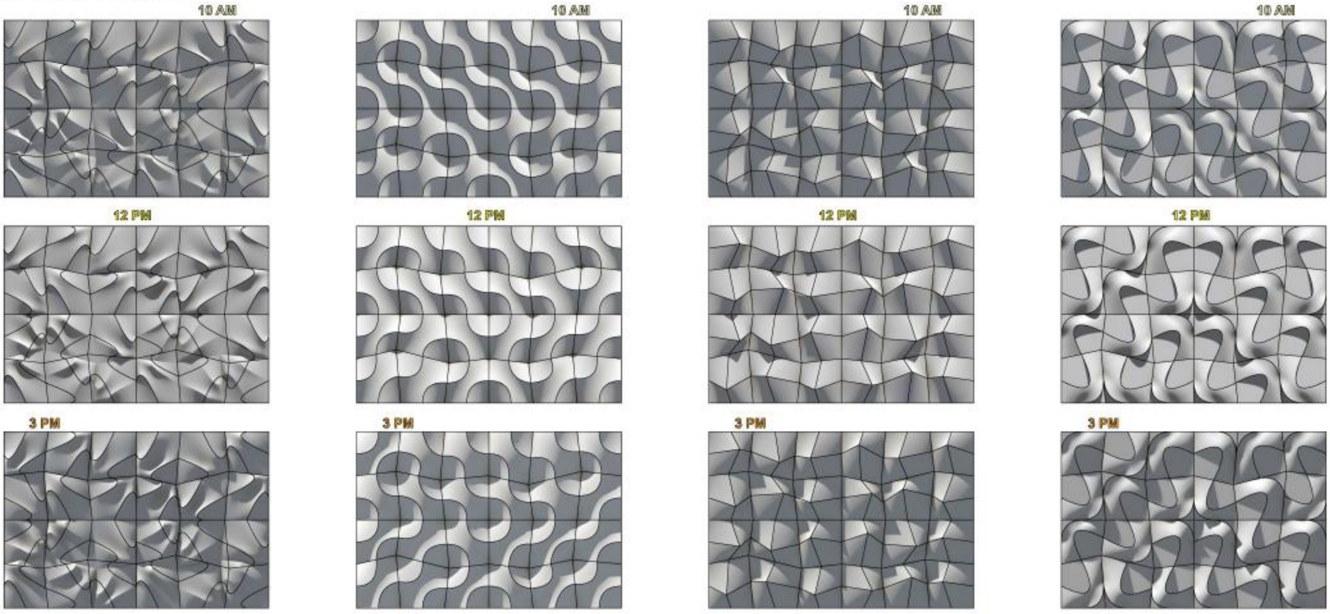
STUDY C WALL ASEMBLED



STUDY D WALL ASSEMBLED

SHADOW ANALYSIS A-PERIODIC

SOUTH FACADE ORIENTATION



INCIDENT SOLAR RADIATION

INSOLATION ANALYSIS

Solar insolation is the total amount of solar radiation energy received on a given surface area during a given time (Fig 01). The intensity of the sun varies by the clarity of the atmosphere and the angle at which the sun strikes a surface, called the "incident angle." Incident solar radiation values are given in units of energy per area (W/m2 or BTU/hr/ft2) and are usually the single most valuable metric for early design studies. *(http://www.cengage.com/resource_uploads/downloads/0495555061_137179.pdf)*

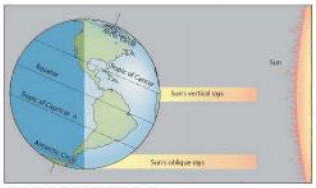


Figure 01 (courtesy of Cengage Learning)

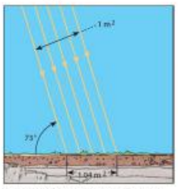


Figure 02 (courtesy of Cengage Learning)

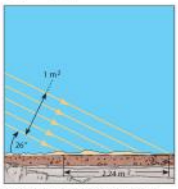
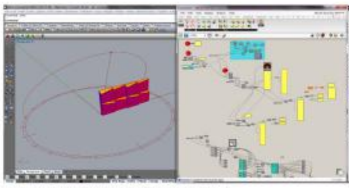


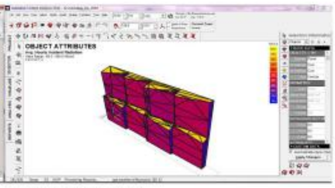
Figure 03 (courtesy of Cengage Learning)

Projection Effect: The sun's rays at a 73 degree angle in summer (Fig 02), and rays at a 26 degree angle in winter (Fig 03). The oblique sunbeam distributes its light energy over twice as much area.

Using Rhino 3D, the parametric pluggins grasshopper and Geco, and the Autodesk sustainable building design software Ecotect; solar insolation analysis were performed on the various panel geometry types, and percentages were calculated to determine which panel performed the most efficiently.



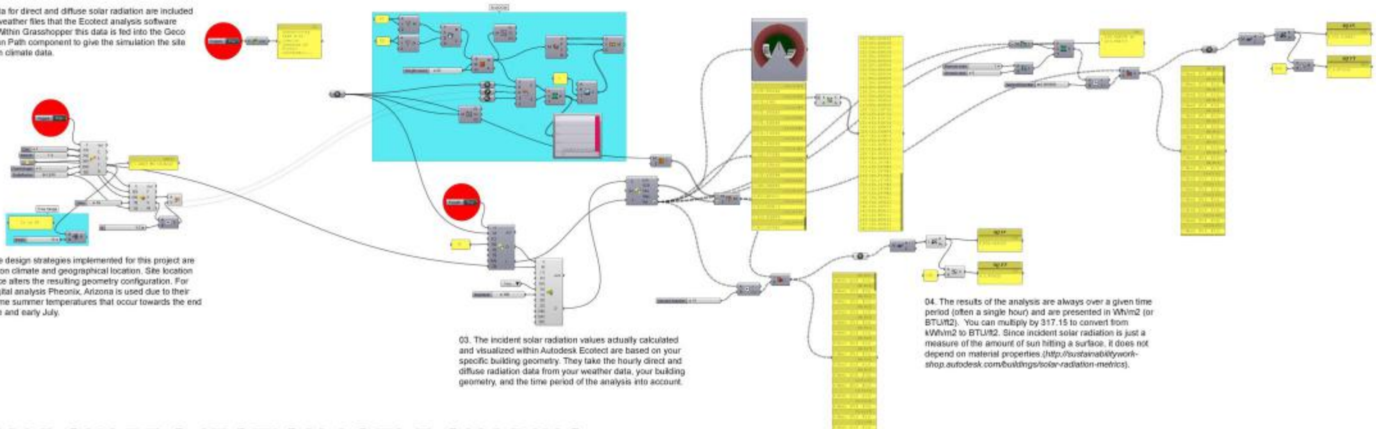
Rhino 3D and Grasshopper pluggin with Geco linking Ecotect



Autodesk Ecotect Analysis Software.

PARAMETRIC DEFINITION

GRASSHOPPER 3D / GECO



01. Data for direct and diffuse solar radiation are included in the weather files that the Ecotect analysis software uses. Within Grasshopper this data is fed into the Geco Eco Sun Path component to give the simulation the site location climate data.

02. The design strategies implemented for this project are based on climate and geographical location. Site location variance alters the resulting geometry configuration. For this digital analysis Pheonix, Arizona is used due to their extereme summer temperatures that occur towards the end of June and early July.

03. The incident solar radiation values actually calculated and visualized within Autodesk Ecotect are based on your specific building geometry. They take the hourly direct and diffuse radiation data from your weather data, your building geometry, and the time period of the analysis into account.

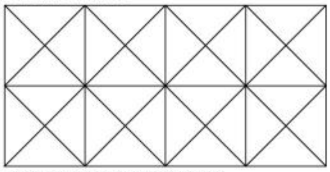
04. The results of the analysis are always over a given time period (often a single hour) and are presented in Wh/m2 (or BTU/ft2). You can multiply by 317.15 to convert from kWh/m2 to BTU/ft2. Since incident solar radiation is just a measure of the amount of sun hitting a surface, it does not depend on material properties.*(http://sustainabilityworkshop.autodesk.com/buildings/solar-radiation-metrics)*.

SHADOW PROJECTION / SELF-SHADING

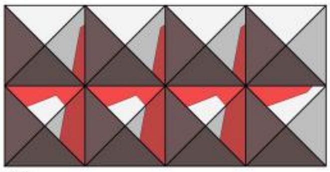
SHADOW PROJECTION / SELF-SHADING / INSOLATION

A surface exposed to radiant heating has the most impact on thermal transfer through the material. By altering the blocks geometry and creating moments of projected shadow and self-shading, several digital studies of geometry variations were conducted to determine which configurations offered the most efficient coverage of surface area based on geographic location, time of year, and time of day.

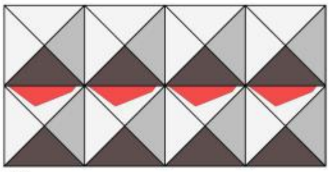
PYRAMID PANEL



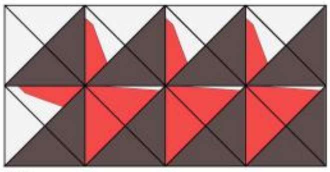
Shadow studies using Rhino 3D. South facade orientation.



10 AM



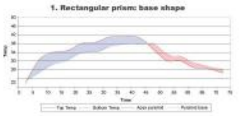
12 PM



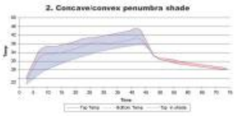
4 PM

SURFACE ARTICULATION

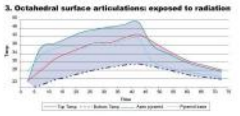
In measuring how surface orientation impacts radiant thermal gain in high performance building envelopes, the following research study was conducted with various surface types and articulations. Aluminum was used for its faster thermal transfer rate which occurs more rapidly than concrete. The aluminum was also more efficient to form precise shapes and offered a material section free of extraneous elements of any kind. It was discovered that when introducing octahedral pyramids to the exposed surface, it decreased the thermal penetration by 9°C. While maintaining the exact same net surface temperature as the base case. *J. Laver, D. Clifford & J. Vollen., "High Performance Masonry Wall Systems: Principles Derived From Natural Analogues." Design and Nature IV Comparing Design in Nature with Science and Engineering. WIT Press. pp 243 - 252, 2008.*



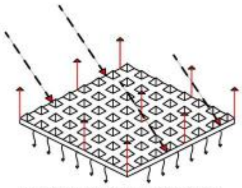
Exposed Surface: 48°C
Underside Surface: 42°C



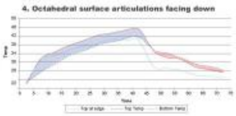
Exposed Surface: 47°C
Underside Surface: 42°C



Exposed Surface: 47°C
Underside Surface: 33°C

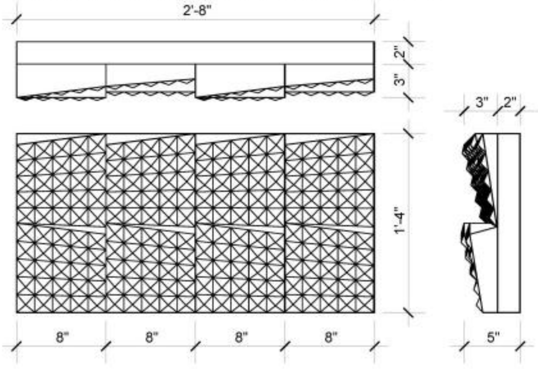


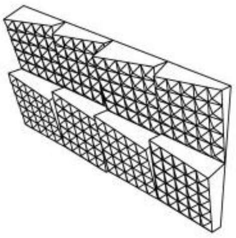
Aluminium (6061) tile with octahedral surface articulations.

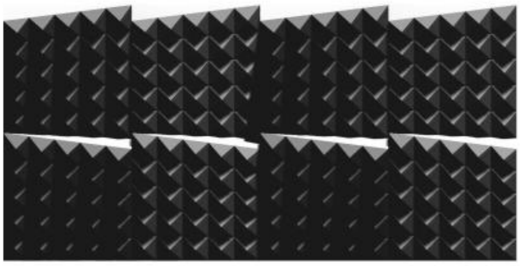


Exposed Surface: 49°C
Underside Surface: 42°C

MODIFIED EXTRUSION PANEL 03 / SURFACE ARTICULATION





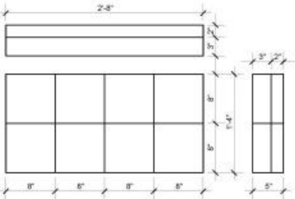


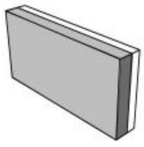
12 PM ARTICULATED SHADOW STUDY

GEOMETRIC ANALYSIS MATRIX

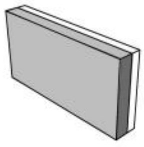
SHADOW PROJECTION / SELF-SHADING / INSOLATION

FLAT PANEL

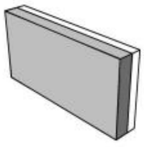




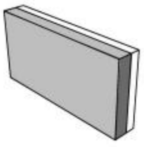
Surface Area = 4.9 ft²



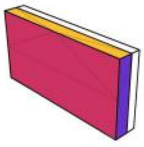
JULY 01 @ 10 AM
PROJECTED SHADOW
0.0 ft²
SELF SHADED
0.0 ft²
SHADOW / SHADE
SURFACE AREA
0.0 ft² = 0%



JULY 01 @ 12 PM
PROJECTED SHADOW
0.0 ft²
SELF SHADED
0.0 ft²
SHADOW / SHADE
SURFACE AREA
0.0 ft² = 0%

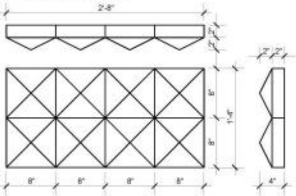


JULY 01 @ 4 PM
PROJECTED SHADOW
0.0 ft²
SELF SHADED
0.0 ft²
SHADOW / SHADE
SURFACE AREA
0.0 ft² = 0%

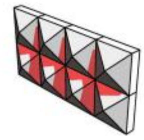


JULY 01
AVG. HOURLY INCIDENT
RADIATION > 250 Wh/m2
4.2 ft² = 86%

PYRAMID PANEL

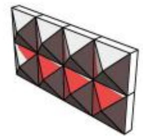


Surface Area = 3.97 ft²

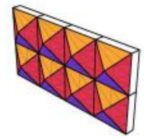


JULY 01 @ 10 AM
PROJECTED SHADOW
0.71 ft²
SELF SHADED
1.99 ft²
SHADOW / SHADE
SURFACE AREA
2.70 ft² = 68%

JULY 01 @ 12 PM
PROJECTED SHADOW
0.24 ft²
SELF SHADED
0.99 ft²
SHADOW / SHADE
SURFACE AREA
1.23 ft² = 31%

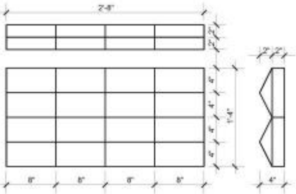


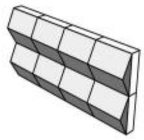
JULY 01 @ 4 PM
PROJECTED SHADOW
0.97 ft²
SELF SHADED
1.99 ft²
SHADOW / SHADE
SURFACE AREA
2.96 ft² = 75%



JULY 01
AVG. HOURLY INCIDENT
RADIATION > 250 Wh/m2
2.98 ft² = 75%

TRIANGULAR PANEL



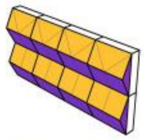


Surface Area = 4.19 ft²

JULY 01 @ 10 AM
PROJECTED SHADOW
0.67 ft²
SELF SHADED
2.10 ft²
SHADOW / SHADE
SURFACE AREA
2.77 ft² = 66%

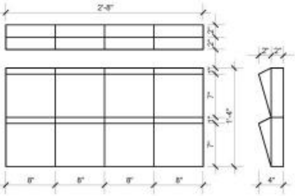
JULY 01 @ 12 PM
PROJECTED SHADOW
0.58 ft²
SELF SHADED
2.20 ft²
SHADOW / SHADE
SURFACE AREA
2.77 ft² = 66%

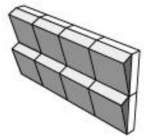
JULY 01 @ 4 PM
PROJECTED SHADOW
0.88 ft²
SELF SHADED
2.10 ft²
SHADOW / SHADE
SURFACE AREA
2.98 ft² = 71%



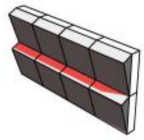
JULY 01
AVG. HOURLY INCIDENT
RADIATION > 250 Wh/m2
1.98 ft² = 47%

MODIFIED EXTRUSION PANEL 01

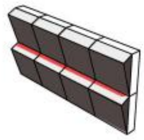




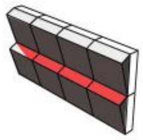
Surface Area = 4.45 ft²



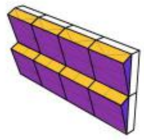
JULY 01 @ 10 AM
PROJECTED SHADOW
0.33 ft²
SELF SHADED
3.35 ft²
SHADOW / SHADE
SURFACE AREA
3.68 ft² = 83%



JULY 01 @ 12 PM
PROJECTED SHADOW
0.18 ft²
SELF SHADED
3.46 ft²
SHADOW / SHADE
SURFACE AREA
3.64 ft² = 82%

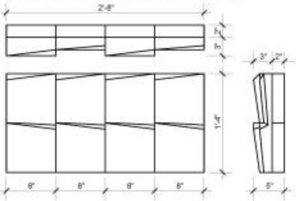


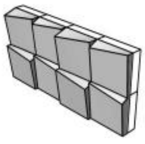
JULY 01 @ 4 PM
PROJECTED SHADOW
0.44 ft²
SELF SHADED
3.35 ft²
SHADOW / SHADE
SURFACE AREA
3.79 ft² = 85%



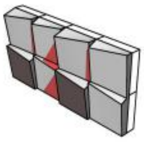
JULY 01
AVG. HOURLY INCIDENT
RADIATION > 250 Wh/m2
0.99 ft² = 22%

MODIFIED EXTRUSION PANEL 02

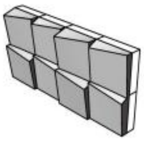




Surface Area = 4.85 ft²

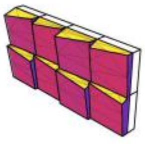


JULY 01 @ 10 AM
PROJECTED SHADOW
0.46 ft²
SELF SHADED
1.27 ft²
SHADOW / SHADE
SURFACE AREA
1.73 ft² = 36%



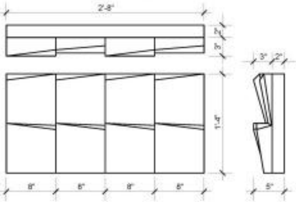
JULY 01 @ 12 PM
PROJECTED SHADOW
0.09 ft²
SELF SHADED
0.67 ft²
SHADOW / SHADE
SURFACE AREA
0.76 ft² = 16%

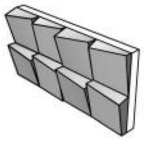
JULY 01 @ 4 PM
PROJECTED SHADOW
1.01 ft²
SELF SHADED
2.81 ft²
SHADOW / SHADE
SURFACE AREA
3.82 ft² = 79%



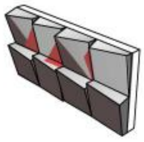
JULY 01 @ 4 pm
AVG. HOURLY INCIDENT
RADIATION > 250 Wh/m2
4.17 ft² = 86%

MODIFIED EXTRUSION PANEL 03

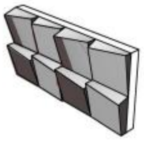




Surface Area = 4.97 ft²

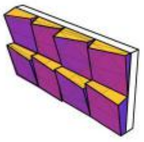


JULY 01 @ 10 AM
PROJECTED SHADOW
0.73 ft²
SELF SHADED
2.05 ft²
SHADOW / SHADE
SURFACE AREA
2.78 ft² = 56%



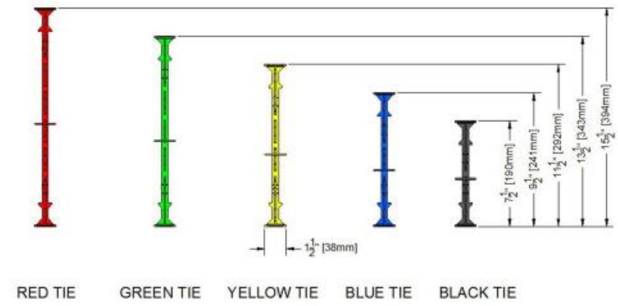
JULY 01 @ 12 PM
PROJECTED SHADOW
0.08 ft²
SELF SHADED
1.60 ft²
SHADOW / SHADE
SURFACE AREA
1.68 ft² = 34%

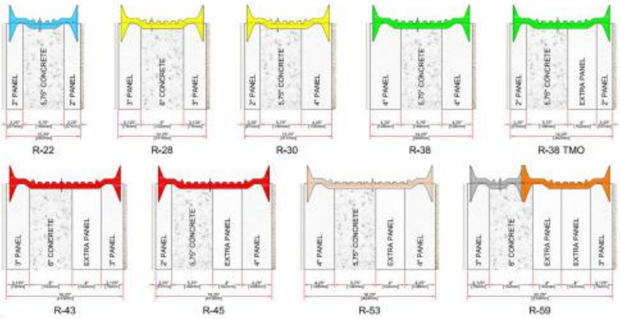
JULY 01 @ 4 PM
PROJECTED SHADOW
0.10 ft²
SELF SHADED
3.55 ft²
SHADOW / SHADE
SURFACE AREA
3.65 ft² = 73%



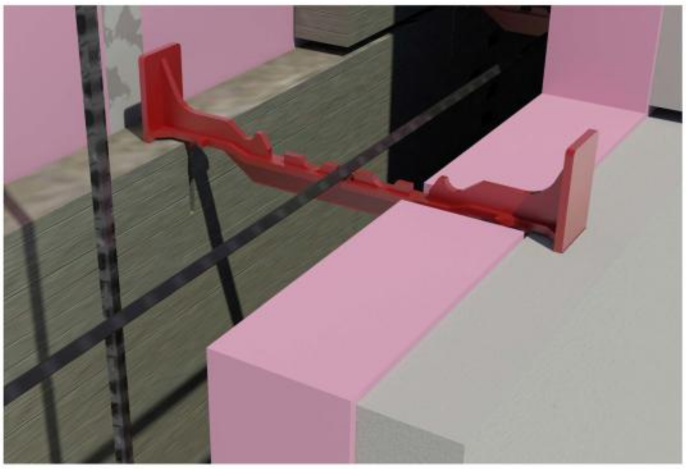
JULY 01 @ 4 pm
AVG. HOURLY INCIDENT
RADIATION > 250 Wh/m2
0.99 ft² = 19.8%

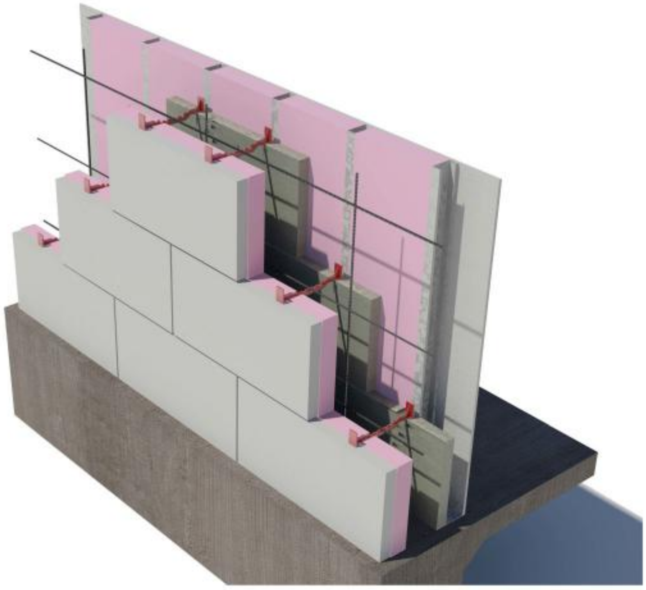
TIE PROPERTIES



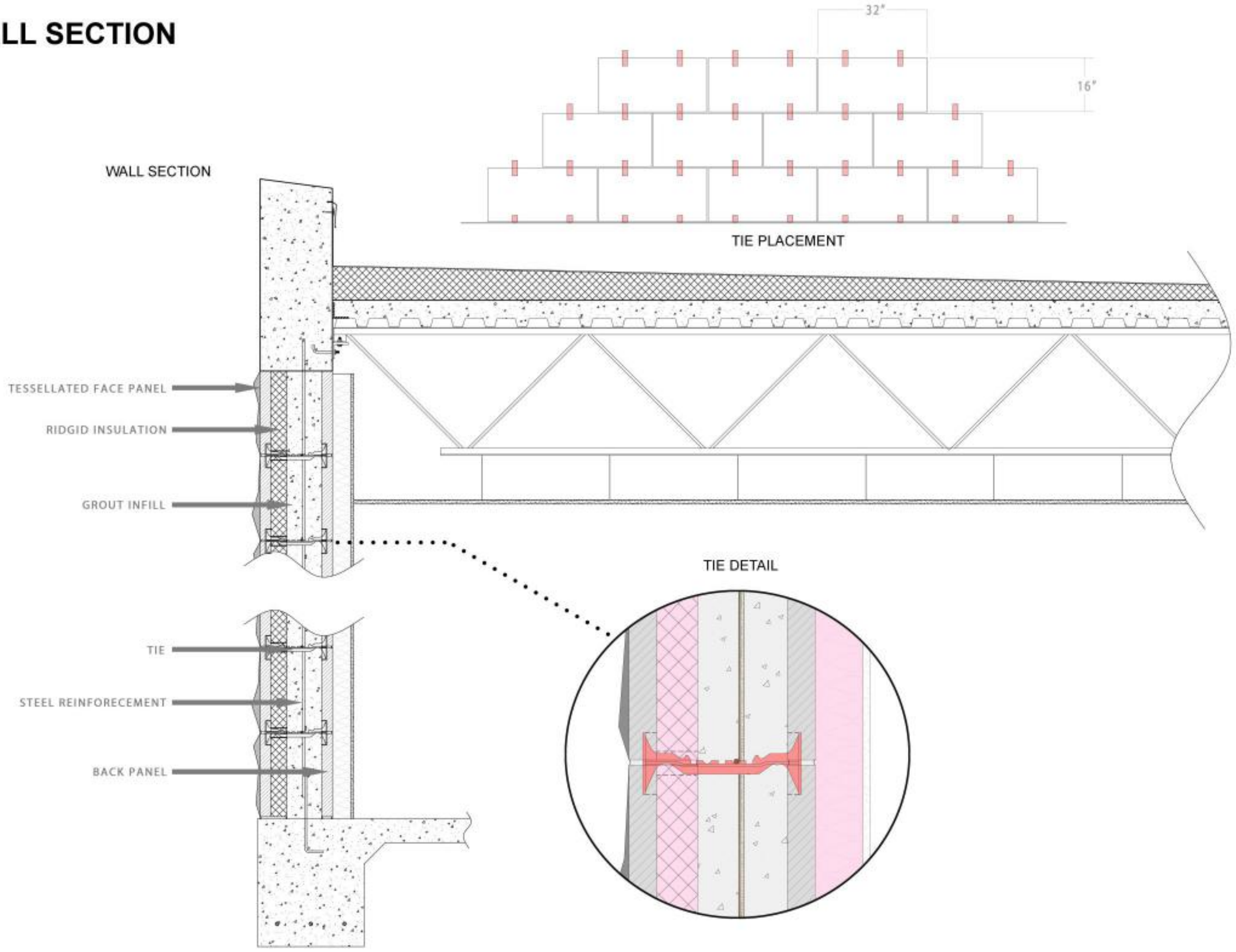


TIE DETAIL / BLOCK CONFIGURATION



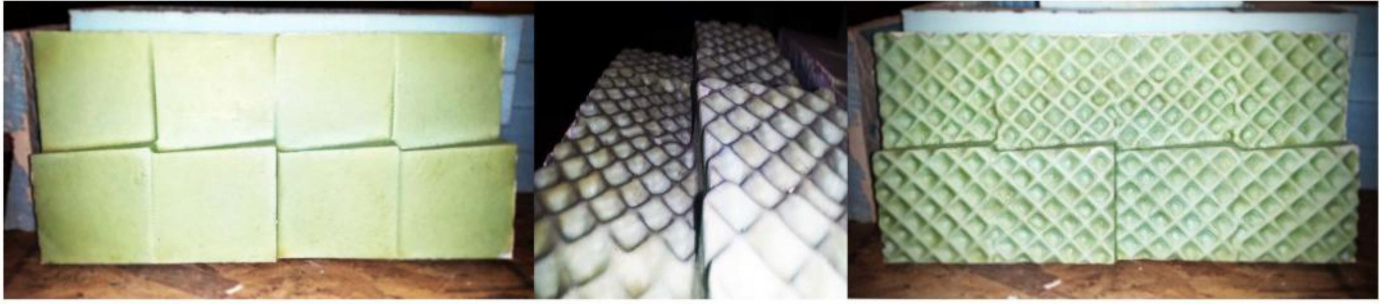


WALL SECTION

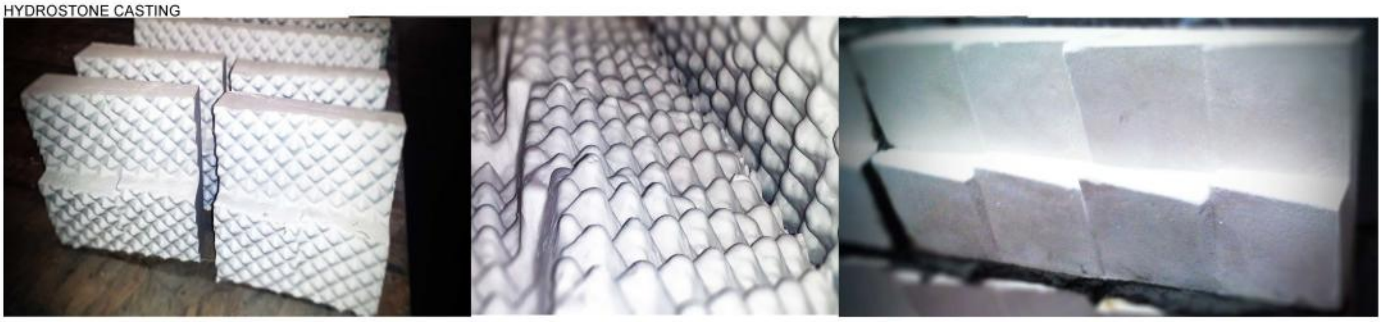


COMPUTER NUMERICALLY CONTROLLED MILLING

EPSILON EPS FOAM COATING APPLICATION



HYDROSTONE CASTING



WALL CONSTRUCTION

WALL CONSTRUCTION

WALL PROTOTYPES

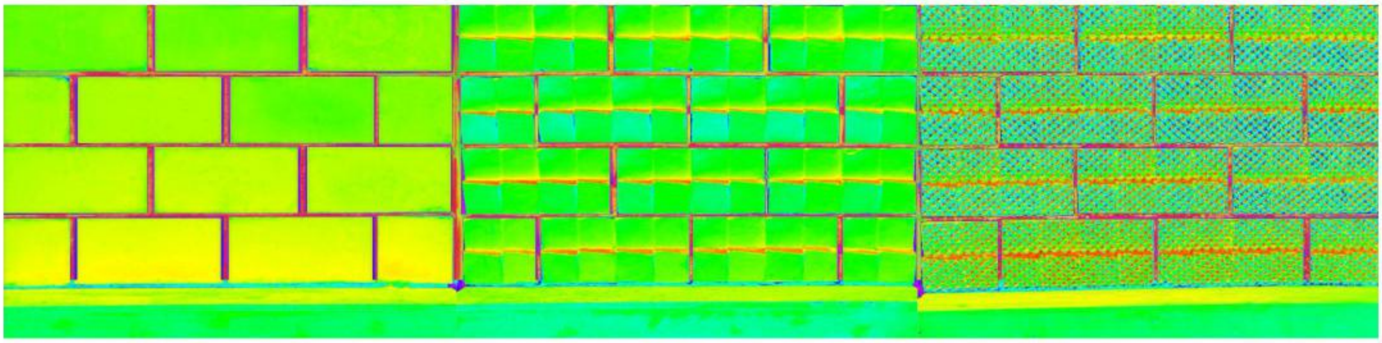
INFRARED THERMAL CAMERA

IR FLIR i7

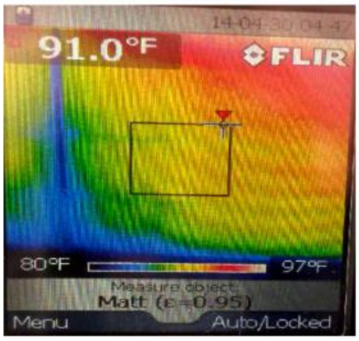
Using the FLIR i7 infrared thermal camera, a series of tests were conducted to examine thermal heat transfer through the the following fabricated wall type configurations. Modified extrusion 03 which Ecotect determined was the most effective at reducing solar insolation absorbtion, was tested against the typical flat panel configuration. A third type that included the articulated surface was also tested againt the group.

FLAT PANEL · MODIFIED EXTRUSION PANEL 03 · MODIFIED EXTRUSION PANEL 03 ARTICULATED SURFACE

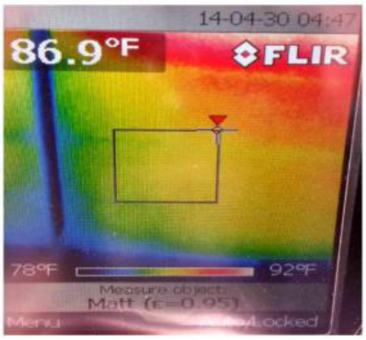
EXTERIOR SURFACE SOUTHWEST ORIENTATION



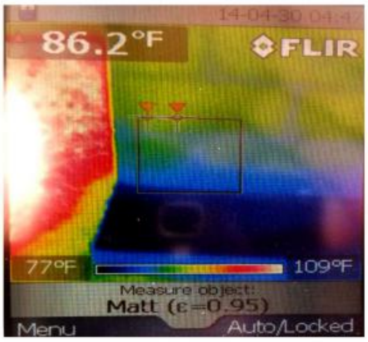
INTERIOR SURFACE SOUTHWEST ORIENTATION



Surface Temperature = 91.0 Degrees F
04-29-14 @ 04:47 PM



Surface Temperature = 86.9 Degrees F
04-29-14 @ 04:47 PM



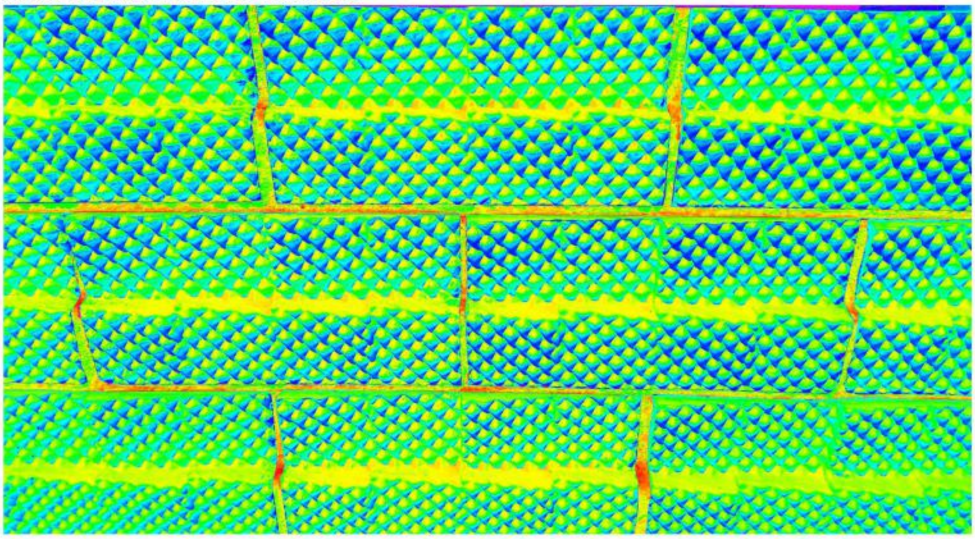
Surface Temperature = 86.2 Degrees F
04-29-14 @ 04:47 PM

ARTICULATED SURFACE

IR FLIR-17

Using the FLIR i7 infrared thermal camera, a difference can be seen in the visual thermal temperature read out of the articulated surface.

EXTERIOR SURFACE SOUTHWEST ORIENTATION



INFRARED CAMERA