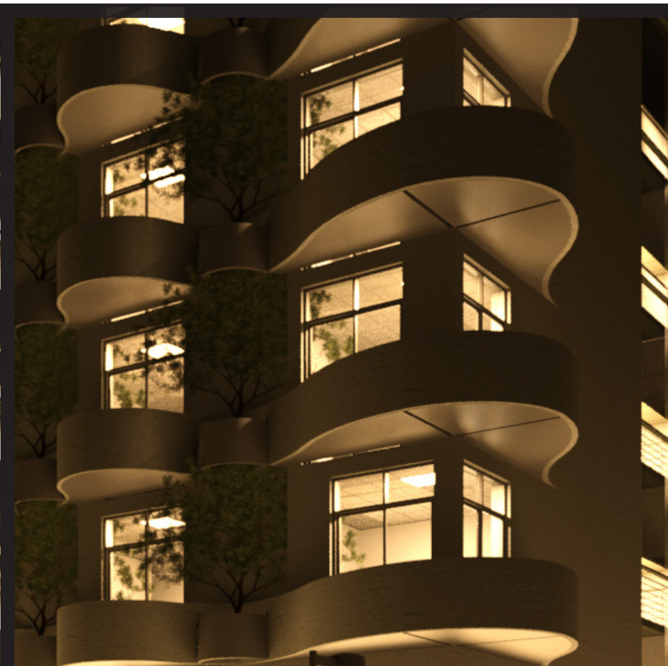
CLARKE SNELL

RESEARCH

DESIGN

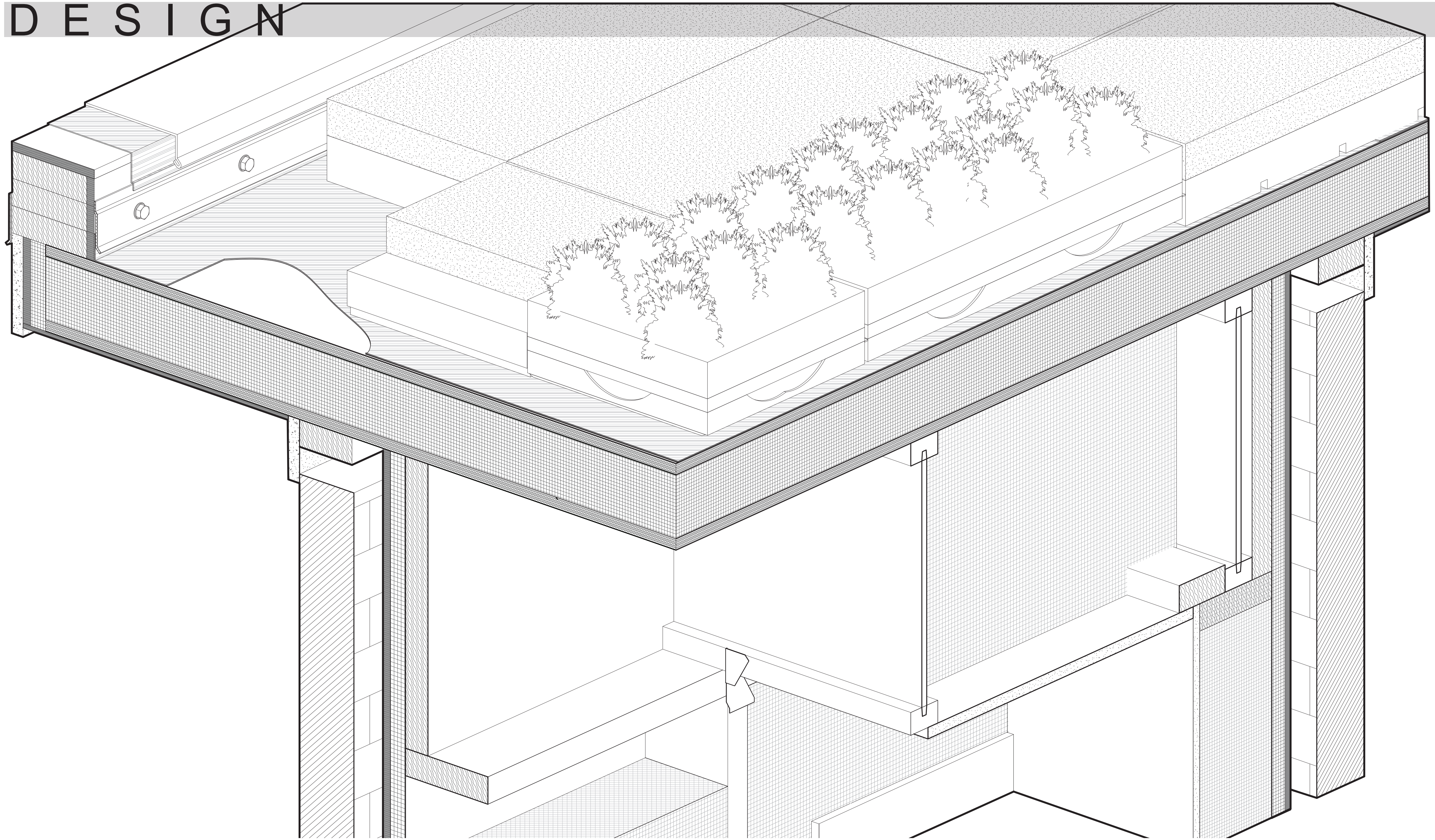


PUBLISH

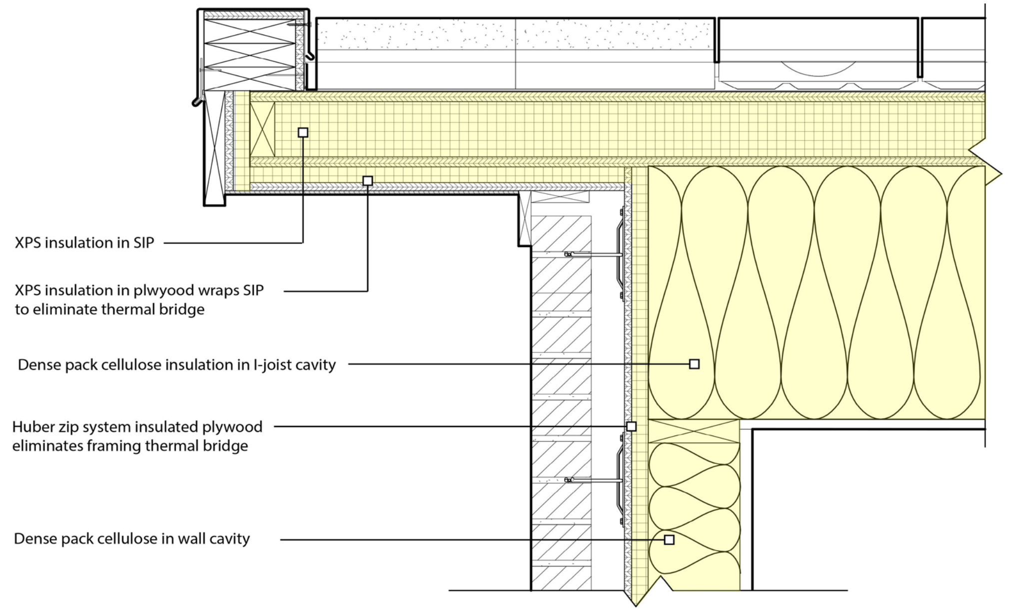
BUILD

PORTFOLIO

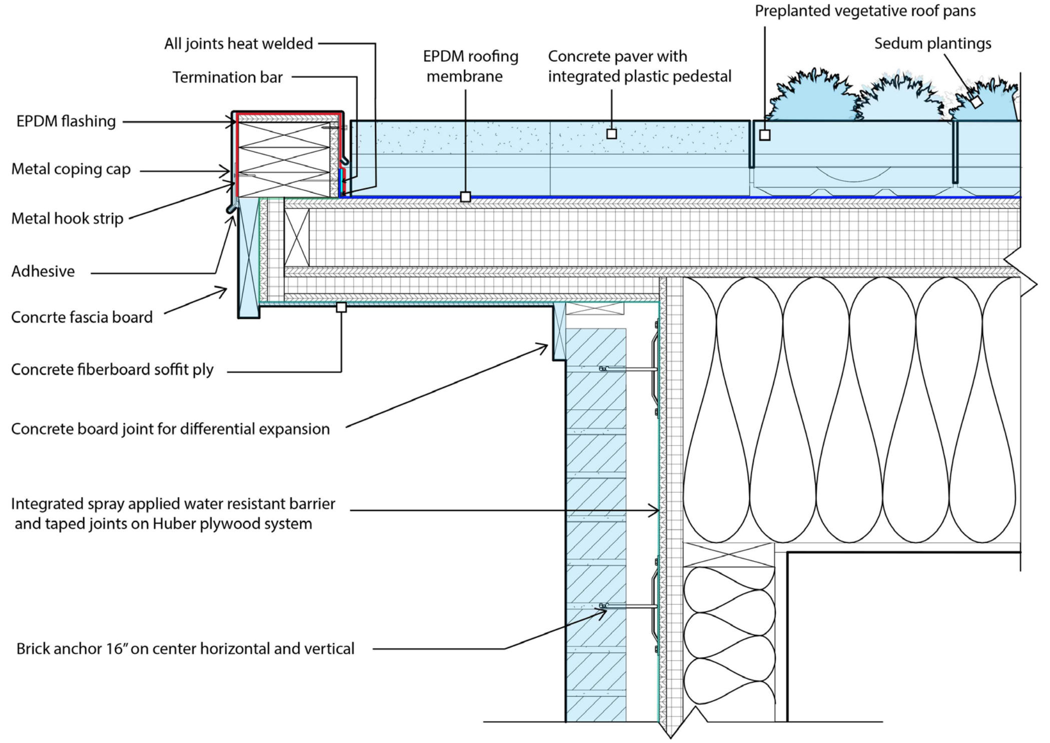
geopolymer cement concrete finish test



BIM CONSTRUCTION DETAILING.
Ongoing experimentation in drawing through modeling components first, assembling them into systems such as the model at left, and then mining documentation directly from the model such as the sections at right. This work is part of long term project to develop a library of high performanc envelope configurations that can be used in design and performance modeling taking advantage of Revit's capability to define physical characteristics of materials.

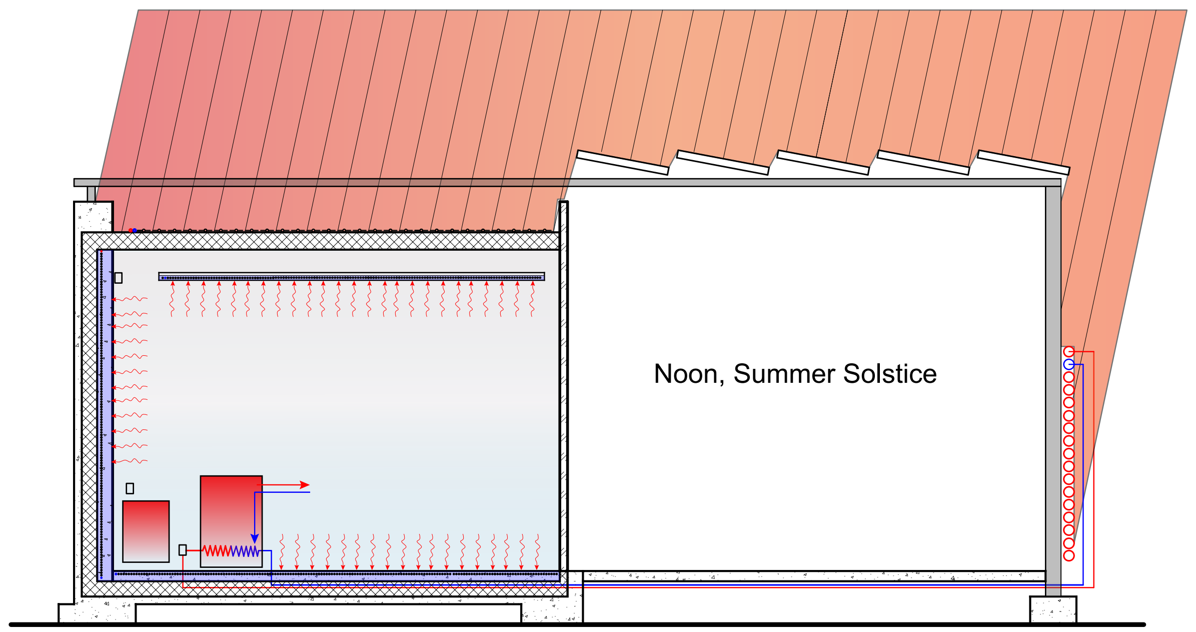


2 Horizontal Section - THERMAL
1" = 0'-6"

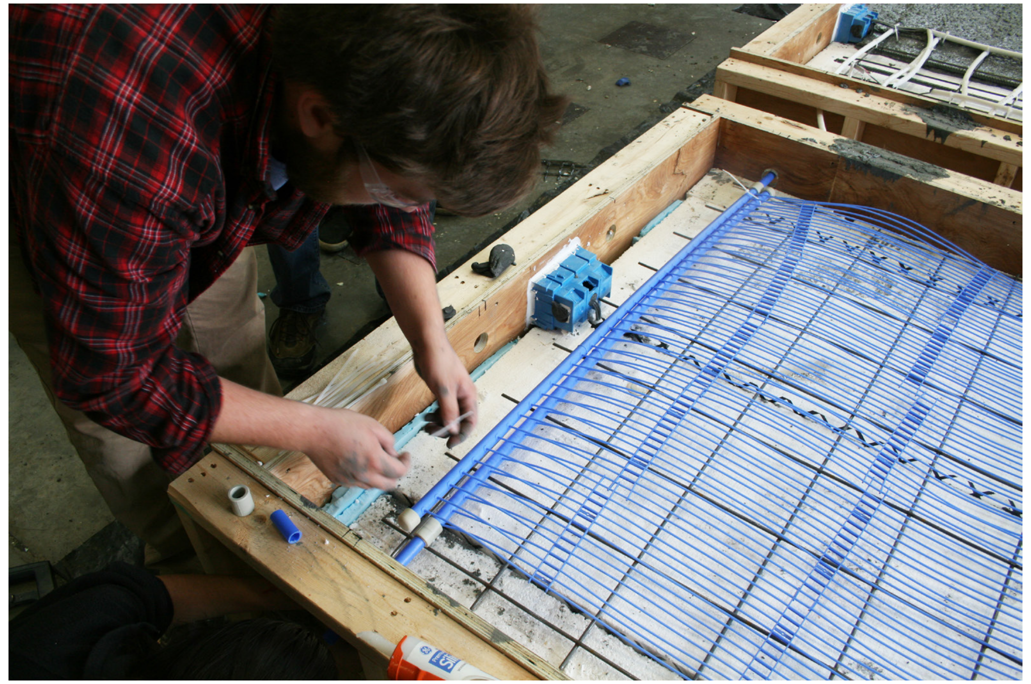


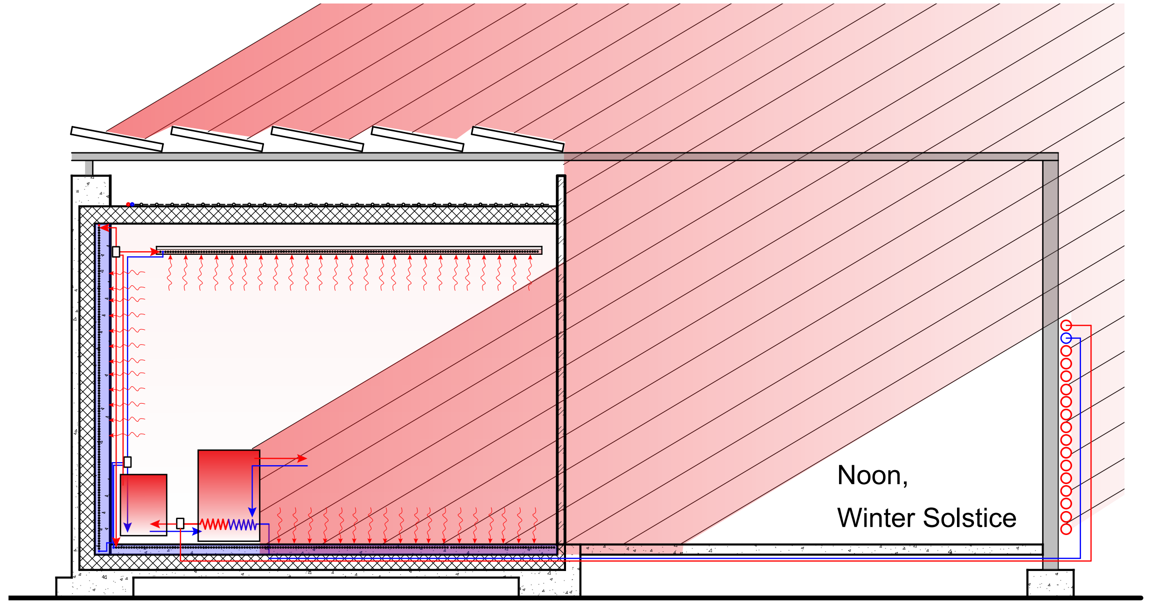
4 Horizontal Section - PRIMARY SEAL
1" = 0'-6"

Annual Hybrid Passive Radiant Heating/Cooling Cycle

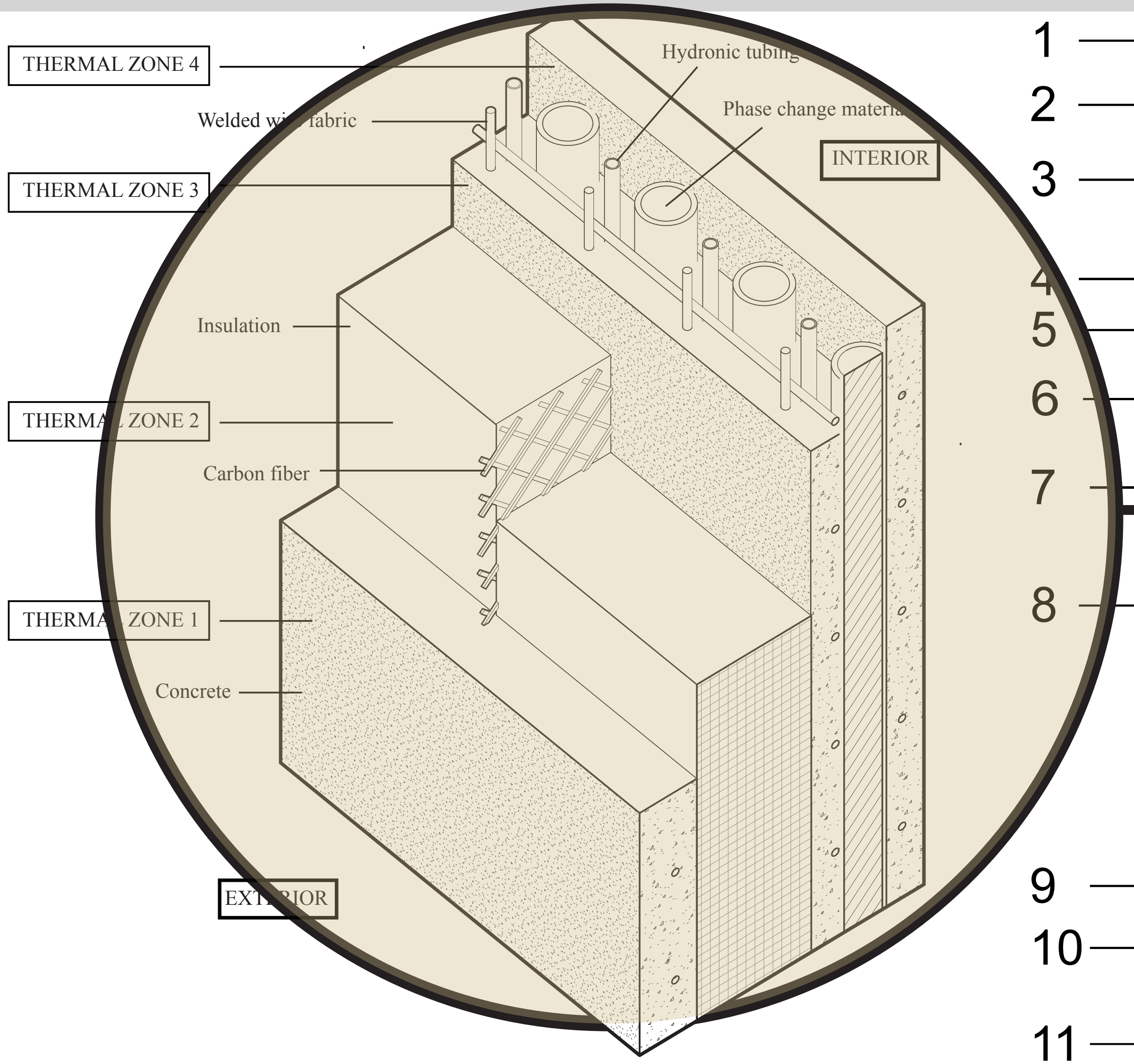


The building interior and southern exterior living space are shaded from the summer sun by the solar electric (PV) array. Thermal mass in walls, floor, and cloud takes on heat during the day, keeping interior temperature stable.

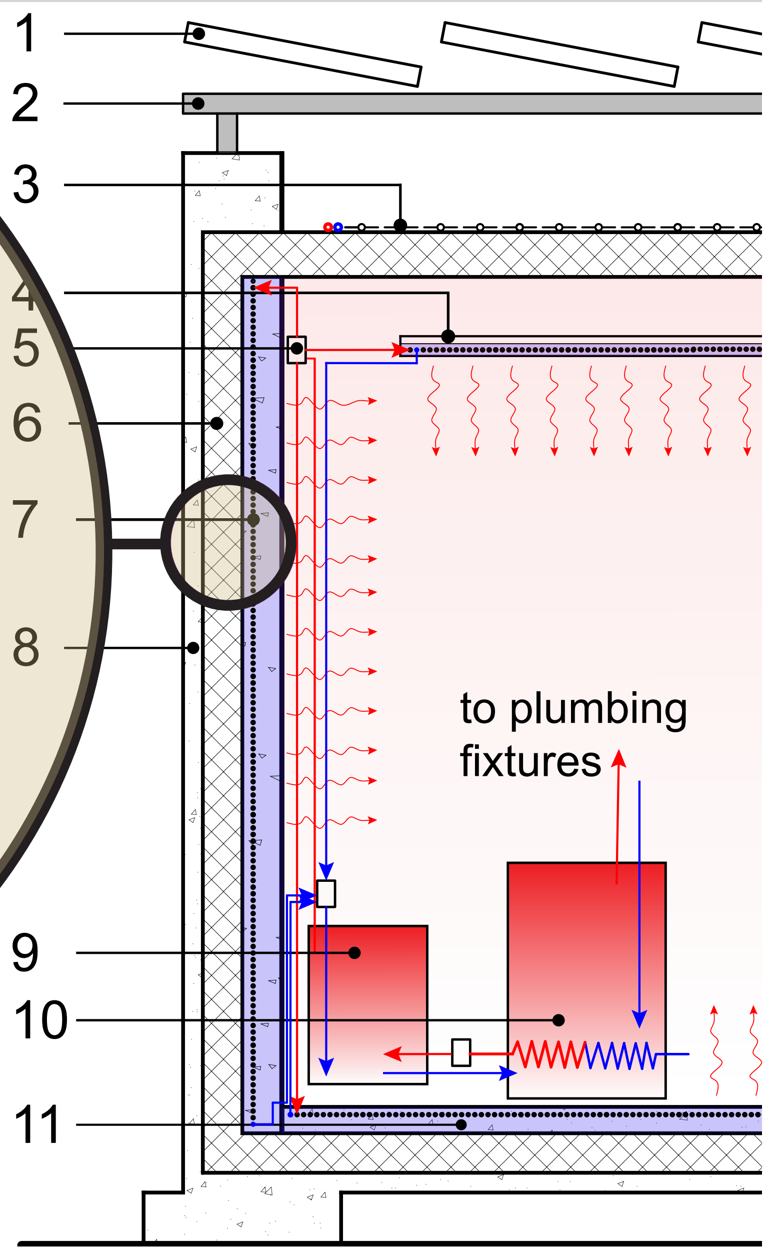




In the winter, the PV array is moved over the main roof allowing the low southern sun to reach deep inside the house where the geopolymer concrete floor, walls, and cloud store the heat. The solar thermal collectors heat water for domestic use and additional solar energy from the collectors is transfered to the concrete through the capillary tubes. Any excess heat is stored in the capillary tank.

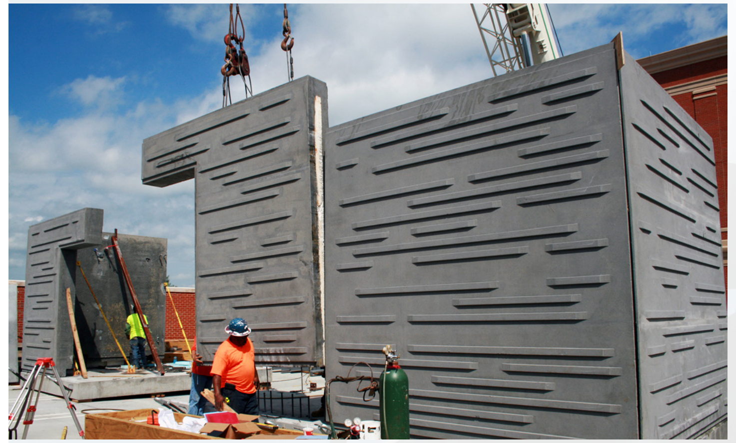


"PASSICHANICAL WALL SYSTEM". Mass-based wall system currently being tested. Hydronics embedded in interior concrete wythe are plumbed to heat exchangers that act as collectors or rejectors of energy depending on the season. A series of test panels were built and tested using geopolymer cement concrete and the full system was prototyped for the UrbanEden project (see below).



1. PV
2. Steel rack
3. Heat exchangers
4. Cloud: low mass = fast response
5. Manifold
6. Air-tight/Super-insulation
7. Wall: high mass = thermal lag
8. Exterior concrete
9. Hydronics tank
10. Solar thermal/ heat pump
11. Floor: direct gain passive solar
12 and 13: Triple pane glazing and solar thermal collectors (not shown)

GCC precast wall panels were poured at a local plant showing that this technology is feasible now.



The house coming together at UNCC and as constructed on site for the competiion in California.

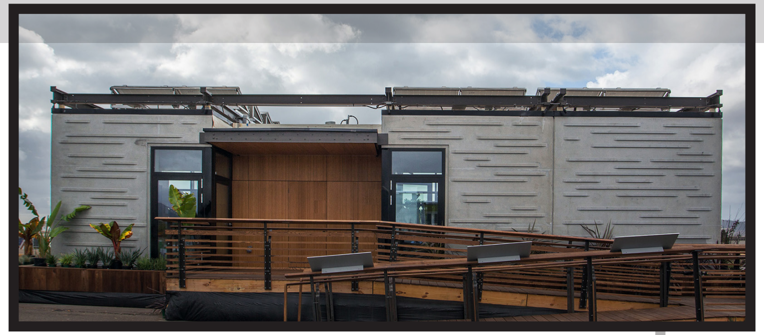
URBANEDEN.

Project designed, built, and operated for the US DOE Solar Decathlon 2013. First application of the “passichanical wall system” described above. A geopolymer cement concrete (GCC) mix was developed specifically for this project and prototyped. GCC’s have similar physical characteristics to portland cement concretes with only 25% of the carbon footprint. Since concrete represents about 7% of our collective carbon footprint, this technology could be world changing. UrbanEden was the first building in the world to utilize GCC’s as part of an insulated building envelope.

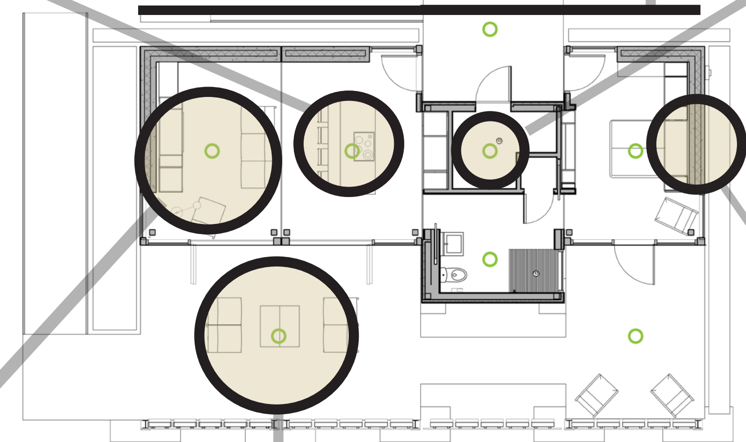
Architecurally the project concept was to create a a better urban living context through crafting a space that blurs the line between inside and out. A series of connected indoor and outdoor rooms combine into a single healthy environment: the interior completely adaptable to maximize comfort year round and seamlessly connected to a private plant-filled exterior living space, sunny in winter and shady in summer. This outdoors is distinguished from the “great outdoors” in that it is contained within a spatial definition that allows for contemporary life to continue outside, either physically or, if the weather doesn’t permit, then visually.
UrbanEden consists of four indoor modules, each with an outdoor component. Thick insulated concrete walls on the east, west, and north façade facing the street cradle the interior living space, creating a visual and aural separation from the urban context. On the building’s south side is the exterior living space, enclosed by a lush vertical garden that creates a private connection to a hybrid urban/natural environment.

Transition between these interior and exterior living spaces is provided by a high performance floor to ceiling glass wall that allows for exacting interior environmental control while maintaining a constant and seamless connection to the outside. Public and private spaces are defined formally as essentially tectonic assemblies of concrete, glass, and steel, providing an openness that feels expansive in a small square footage. These spaces are separated by a service module, a stereotomic volume of wood from which the bath and mechanical room are carved.

Small flexible interior space (kitchen counter transforms into table to seat eight) made large through connection to outdoors.



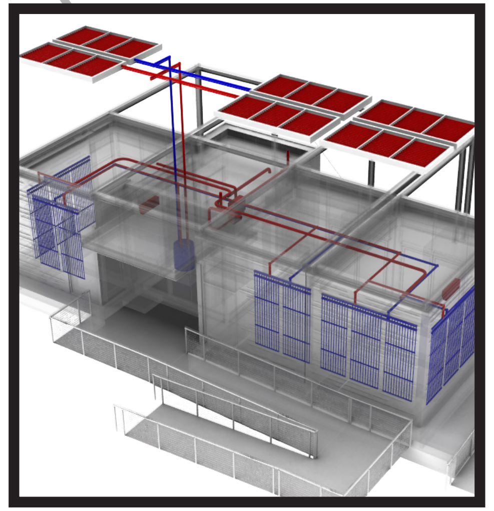
North facade faces the street; thick concrete walls create aural and visual privacy



Building envelope integrated with passive and active systems and designed to Passivhaus standard

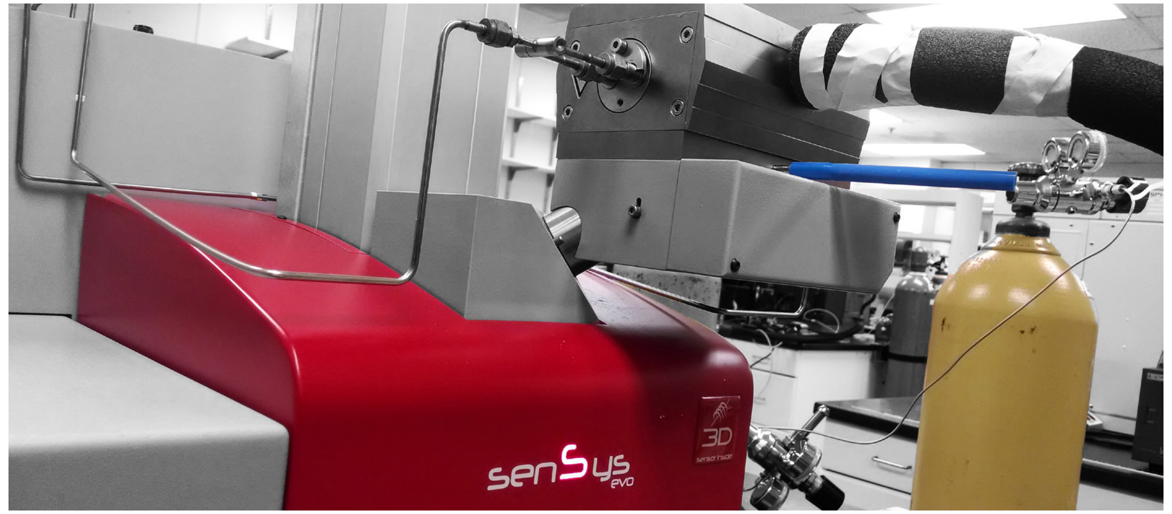
Living room entertainment center opens to create guest sleeping area outfitted with Murphy bed...

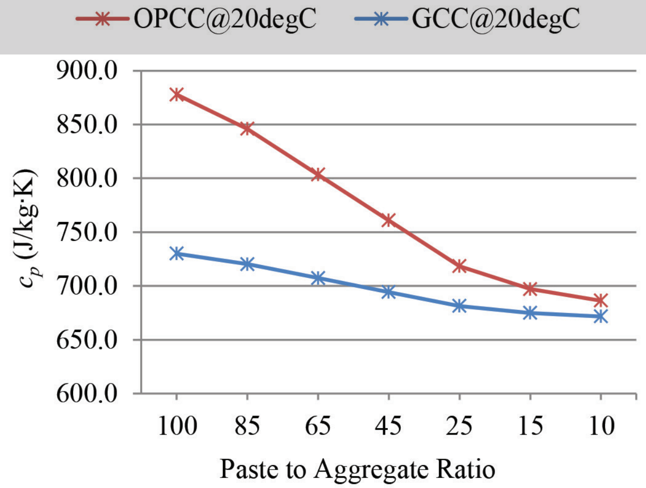
...and living room moves outside. Outdoor rooms double square footage of living space with living walls and movable PV array shading device.

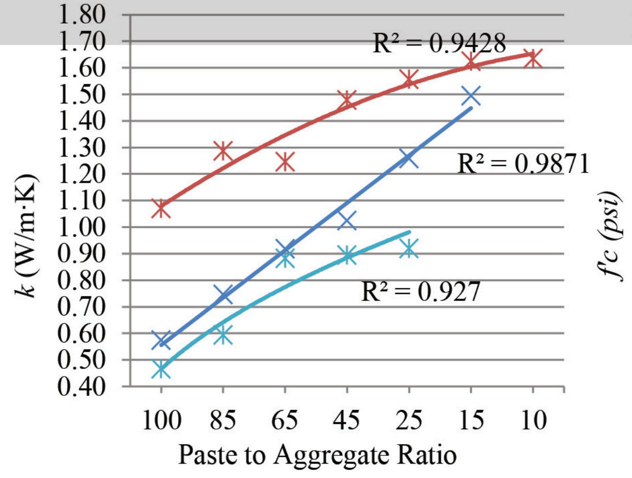


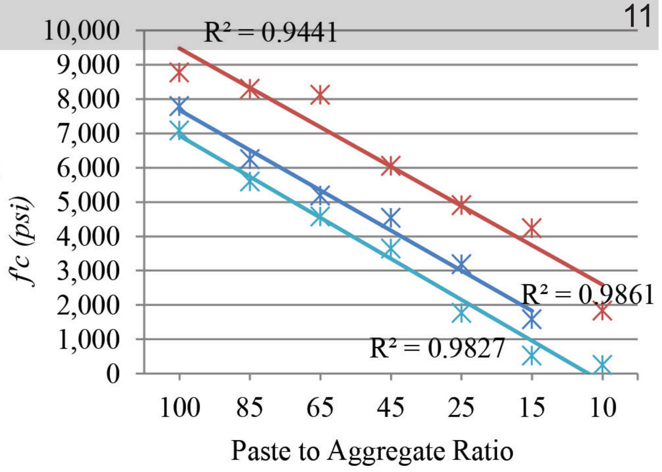
Hydronic capillary tubes emebedded in the geopolymer cement concrete walls and plumbed to heat exchangers for low-energy radiant heating/cooling (See “passichanical wall system” above.)

TESTING. Compressive strength: axial load application (left); thermal conductivity: modified transient plane technique (right); specific heat: differential scanning calorimetry (below)

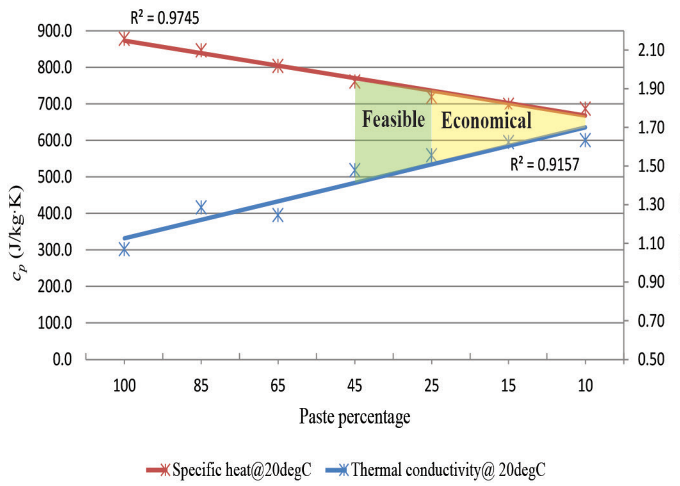


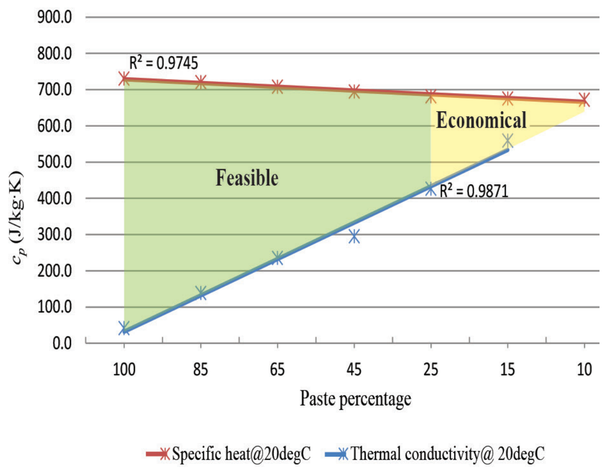






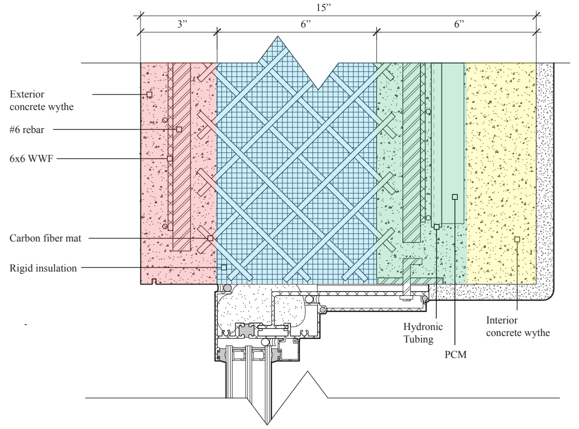
GCC's have lower specific heat capacity... *...thermal conductify...* *... and compressive strength than OPCC's*





Simple physical differences make the feasible mix range for GCC's broader giving them more thermal flexibility.

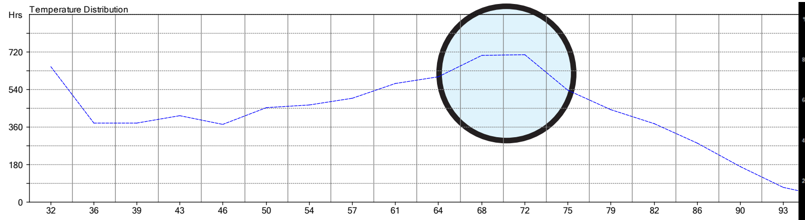
THERMAL OPTIMIZATION OF CONCRETE FOR HIGH PERFORMANCE BUILDING ENVELOPES. Humans have been mixing concrete for thousands of years and are adept at controlling structural and finish characteristics through mix design. At the same time, concrete has been consistently used as a thermal material in buildings, both to store heat energy and to resist its movement, but it seems that designing concrete to maximize these performance parameters has not been considered. I have been studying the potential efficacy of defining the specific heat capacity and thermal conductivity of concrete through adjusting paste to aggregate ratios. My initial results indicate a potential range of about 30% for specific heat and over 200% for thermal conductivity through such a mix design approach. I also posit based on the data from this study that geopolymer cement concretes (GCC) show more promise than portland cement concretes for thermal optimization.



Zone	Type	P/A Ratio	c	k	f'c	Application
1	GCC	1	730	0.53	7,784	microclimate temperature stabilization; strength
2	GCC (foamed)	1	high	low	high	theoretical foamed mix based on low k value of 100% GCC paste
3	GCC	0.15	675	1.49	3,184	maximize efficiency of hydronic and PCM systems
4	GCC	0.65	707	0.92	5,183	balance thermal storage with need for efficient heat transfer to hydroncis and PCM; high compressive strength

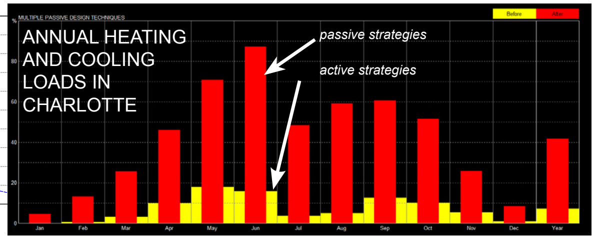
Application of this thermal optimization methodology to a high performance envelope.

1. Climate and Comfort



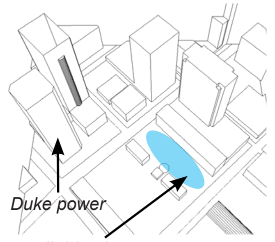
Though most commercial buildings in the southeast are designed as though cooling loads predominate, the fact is that often the opposite is the case. For example, Charlotte NC has almost twice as many heating degree as cooling degree days and the lion's share of the time the air temperature is within the psychrometric comfort zone.

Basic climate and comfort analysis presents an interesting design challenge. Can we design a commercial building that would have most of its loads provided through passive means?

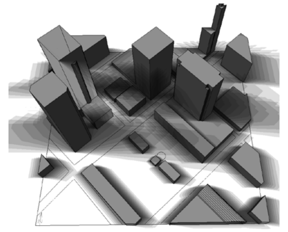


Good annual solar insolation along with a predominance of diurnal temperature swings above and below the desired indoor temperature allow the potential for almost all heating and cooling loads to theoretically be supplied through passive means. This chart combines passive heating, shading by building elements, high internal mass, and night flush strategies.

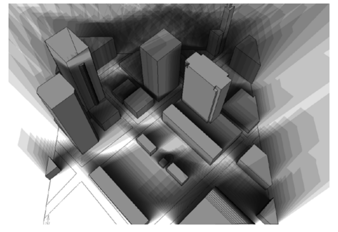
2. Preliminary Site Analysis



available site

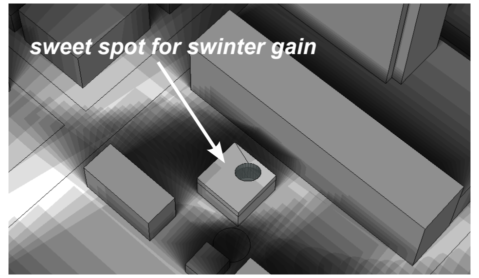


summer solstice



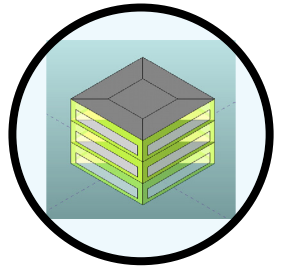
winter solstice

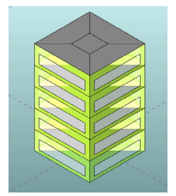
Based on this initial analysis, it made sense to look for a spot on the site that maximized winter solar exposure while offering summer shade. Butterfly shading analysis of the available uptown site uncovered a tight zone that fit the bill.

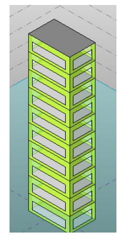


Annual consolidated shading profile. Tall buildings to the east block most cooling season morning sun leaving only the southwestern facade exposed to intense sun. Southeastern facade gets decent sun for potential winter gain to help meet passive load goals.

3. Preliminary Form Analysis



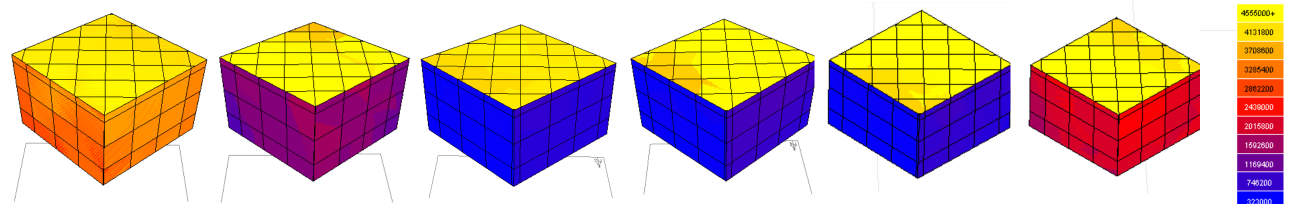




A performative study was undertaken testing a variety of simple forms with the same square footage of useable space. The forms were kept simple so that the performance consequences of changes in length and width could be clearly studied. Based on this analysis the decision was made to start the design process with a simple form that maximized floor area to exterior surface area.

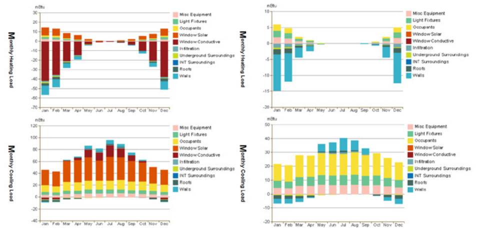
VISARI		Variable Maximized	Source EUI (kBtu/sf/yr)	Annual Energy Consumption		CO2 (tons/yr)	AnnEnergyCost ($)
				Elect(kWh)	Fuel(Therms)		
Form 1							
Floor area (sf)	10,092						
Ext wall area (sf)	10,440						
		Code	73	166,676	1,600	50	$15,562.00
		Wall insulation	69	166,031	1,348	46	$15,106.00
		Slab insulation	69	165,481	1,328	46	$15,125.00
		Roof insulation	69	165,688	1,245	46	$15,065.00
		Glazing performance	62	146,981	1,127	28	$13,385.00
		Glazing area reduction	52	133,223	744	-5	$11,805.00
		Glazing shading	51	126,612	779	22	$11,287.00
		Air tightness	51	126,627	812	22	$11,320.00
		HVAC	44	124,764	172	18	$10,566.00
Form 2							
Floor area	10,013						
Ext wall area (sf)	13,425						
		Code	84	185,928	2,084	77	$17,453.00
		Wall insulation	79	182,369	1,722	71	$16,818.00
		Slab insulation	79	182,681	1,705	71	$16,828.00
		Roof insulation	79	182,599	1,656	71	$16,775.00
		Glazing performance	68	157,434	1,478	47	$14,511.00
		Glazing area reduction	56	139,642	845	4	$12,436.00
		Glazing shading	53	130,278	862	37	$11,670.00
		Air tightness	53	130,354	893	37	$11,706.00
		HVAC	45	127,764	193	30	$10,838.00
Form 3							
Floor area	10,028						
Ext wall area (sf)	19,000						
		Code	113	237,787	3,190	117	$22,810.00
		Wall insulation	105	232,780	2,615	110	$21,856.00
		Slab insulation	105	232,878	2,605	110	$21,855.00
		Roof insulation	105	233,061	2,590	110	$221,856.00
		Glazing performance	90	197,414	2,250	76	$18,565.00
		Glazing area reduction	71	170,682	1,257	13	$15,409.00
		Glazing shading	65	155,506	1,221	47	$14,109.00
		Air tightness	66	155,588	1,261	48	$14,187.00
		HVAC	54	153,266	193	39	$12,963.00

4. Combining Form and Site

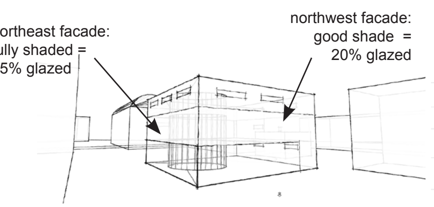


This basic formal concept was combined with the preferred siting to generate a solar insolation analysis to help inform the building envelope design. The northeast facade of the building is well shaded by a nearby building and receives little direct sun throughout the year. The northwest side is more exposed but shaded by the building form due to the trajectory of the solar path. The southwest facade is very exposed and receives a lot of SIR, much of which is during hotter months in the afternoon so has the potential to penetrate deep into the building. The southeastern buildng face receives almost as much SIR but more during colder months when its effect is desirable.

5. Envelope Design



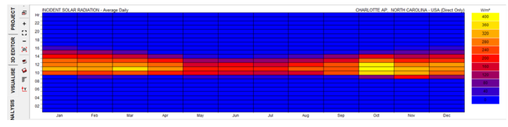
Energy analysis of commercial buildings with similar programs to the project indicate that it's all about the glazing: how much, what kind, and where it is. For this and programmatic reasons, the decision was made not to utilize a curtain wall. Instead a well insulated envelope was designed in combination with a storefront glazing system.

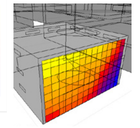


	Variable Maximized	Total EUI (kBtu/sf/yr)	Annual Energy Consumption	
			Elect(kWh)	Fuel(Therms)
1	Base case (zoned with all non-glazing variables maximized; double pane low SHGC glazing)	80	188,372	1,521
2	Base case + max South shade + 2ft West overhang	80	188,570	1,553
3	Base Case + max South shade + all other facades 2ft overhang	80	189,124	1,430
4	Base Case + Quad pane + #3 shade configuration	79	197,438	1,121
5	Base Case + Quad pane + #3 shade configuration, change to 4ft overhang	80	190,863	1,410

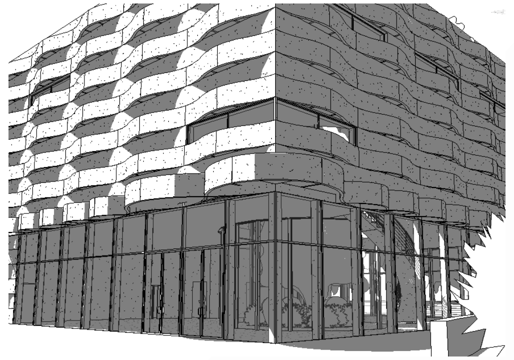
Based on the SIR analysis window to wall ratios were adjusted on each facade in line with the specifics of site conditions. The hot southeastern facade is the service core and has only 5% glazing for daylighting stairs and bathrooms. The cooler northeast facade has 35% glazing while the northwest and southeast facades each have about 20% glazing.

6. Integrated Shading Design

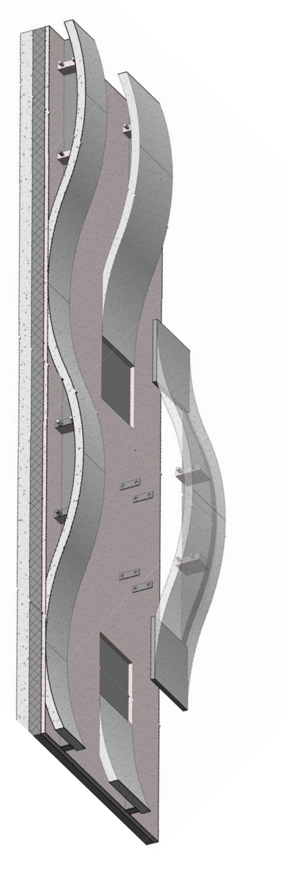




Window to wall ratios for performance were balanced with programmatic concerns. A storefront system was planned for the entry level assembly space that concentrated most of the building glazing in large areas of the first 15 feet of facade on three sides. Therefore, shading options for this glazing were studied and analyzed. The main benefit was realized with combinations of three and six foot horizontal overhangs above the storefront that eventually were integrated into the facade design.

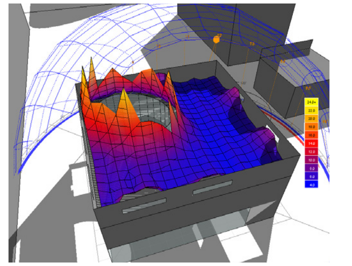


On August 30th at 1:00 the stationary horizontal overhangs fully shade the storefront glazing. This is the hottest time of the year in Charlotte 1 1/2 months after solstice with the sun well below it's apex.

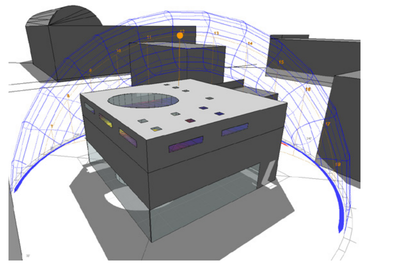


modular concrete precast planter system to allow for microclimatic adjustment at wall surface

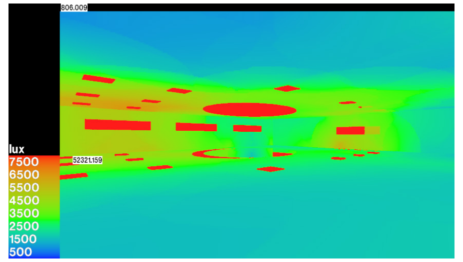
7. Daylighting Design



Without skylights the third floor is very dark..



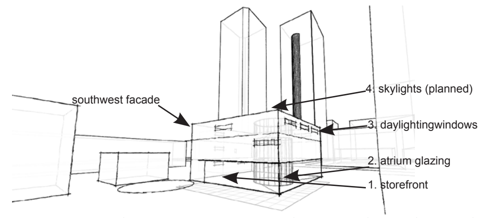
Skylights were added based on space usage patterns...



the result was a fairly even distribution of daylighting at tasklighting levels for much of the year

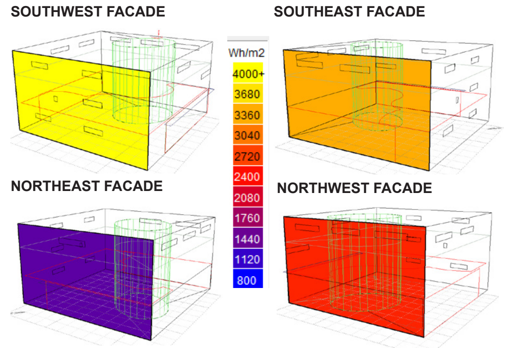
By adjusting glazing amounts and employing simple stationary shading devices based on site conditions, much of the heat gain from glazed openings was eliminated. But one of the biggest energy loads on commercial buildings is heat gain from lighting. For this and other reasons, daylighting studies were conducted and it was determined that a skylight system would be useful for daylighting the third floor office space.

8. Materials Specifications



Façade Glazing Specs	Description	U-factor (Btu/h-ft2-F)	SHGC	VLT
1- Storefront NW, NE	Triple IGU (2 lowE krypton)	0.11	0.36	58%
1- Storefront SE	Triple IGU (2 lowE facing	0.17	0.17	61%
2- Atrium	Triple IGU (2 lowE krypton)	0.11	0.36	58%
3- Daylighting (all faces)	Triple IGU (1 lowE, air)	0.22	0.36	67

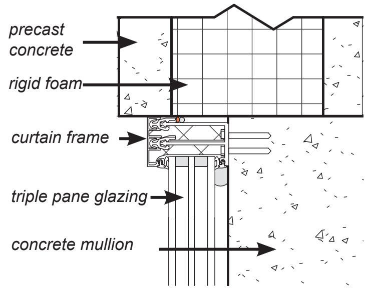
Glazing assemblies chosen based on insolation data. High visual transmittance for daylighting. Higher SHGC on southern facade for winter heat gain. Low U-values all around.



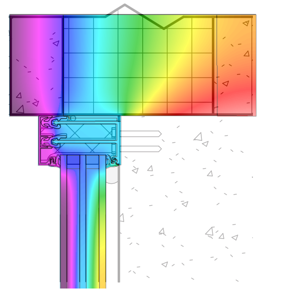
Average annual daily incident solar radiation

Now that all the base elements of the building were placed to maximize performance in line with program, a return to insolation data helped in the specification of glazing for the different applications and site conditions. The opaque envelope had been specified as part of the modeling done during envelope design (#5 above)

9. Assembly Performance Maximization



Detail at curtain wall



Analysis of heat flow through assembly

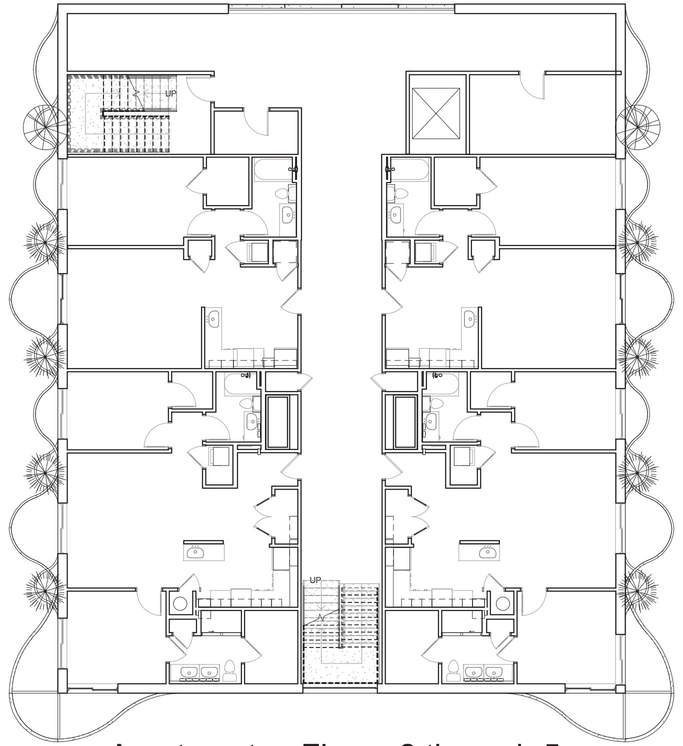
Weighted Area Calc for Glazed Portion of Wall System				
Descr	Area (sf)	%	U-value (Btu/h-ft2-F)	Weighted U-value
Total	95.00			
Frame	17.56	18%	0.45	0.08
Edge	7.88	8%	1.06	0.09
Glazing	69.56	73%	0.31	0.23
			Assembly U-value (Btu/h-ft2-F)	0.40

Assembly U-value calculation

Now that all the programmatic and analytical information has been applied to the design, the performance of the full assembly can be modeled and tweaked based on comfort and performance goals for the project.

HIGH PERFORMANCE ENVELOPE DESIGN METHODOLOGY OUTLINE. Design exercise toward a methodology for integrating energy performance concerns with a formal and programmatic design process.

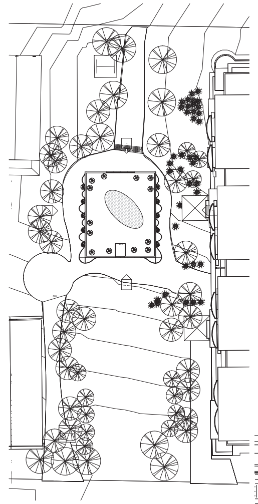
Modeling tools utilized: Weather Manger, Ecotect, Radiance, Vasari, Therm,Revit, and SketchUp.



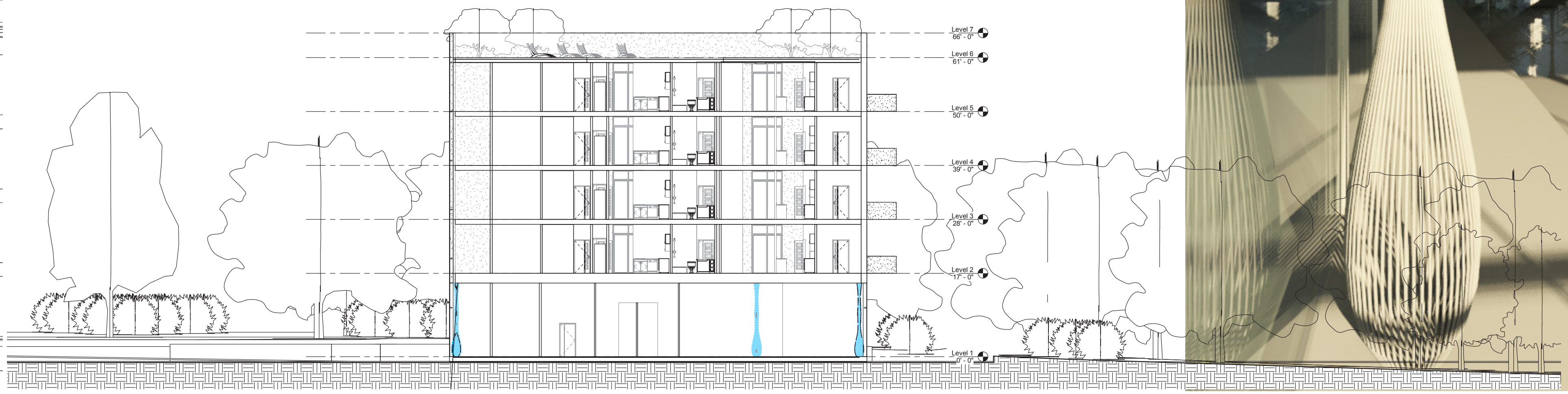
Apartments - Floors 2 through 5

First floor pool

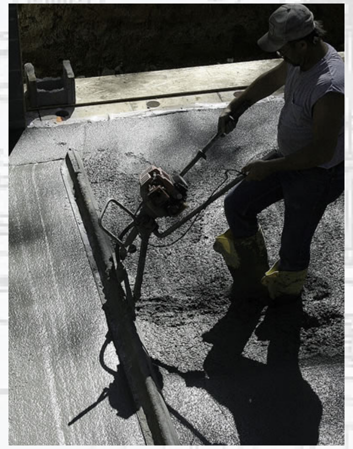
Site Plan

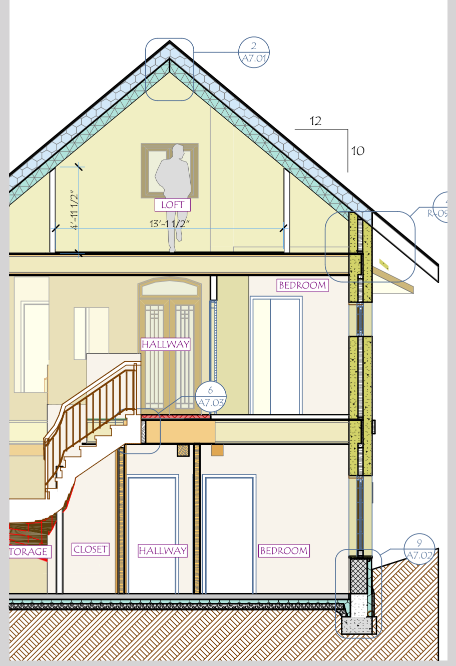


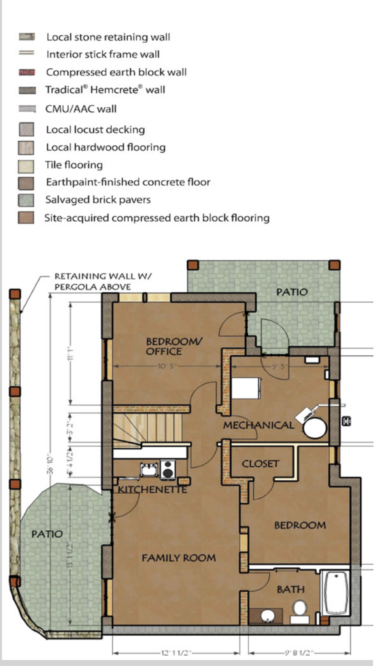
North/South Section through both Units

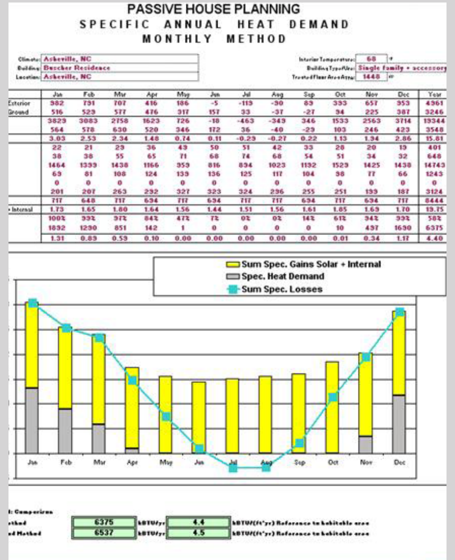


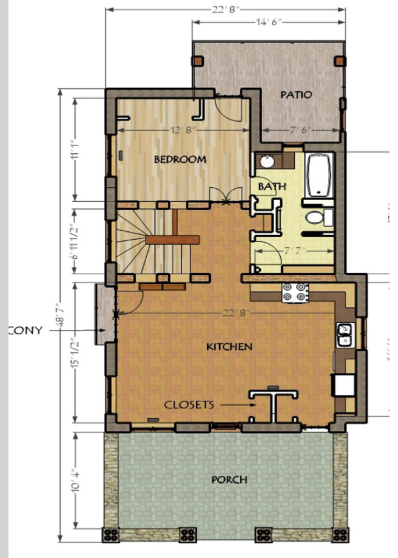
CHARLOTTE CONDO PROJECT. Academic exercise in advanced BIM design. Model built using custom parametrics families including adapative component, curtain panel pattern based, and other family types.

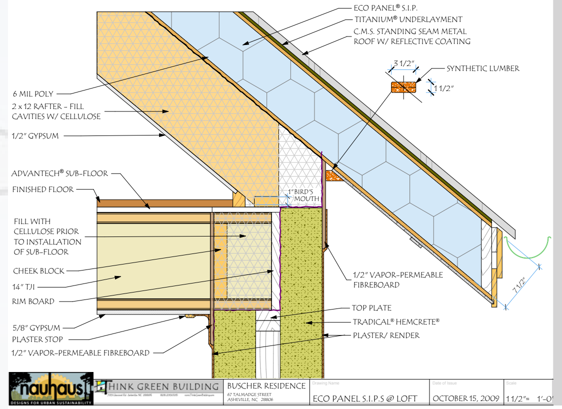


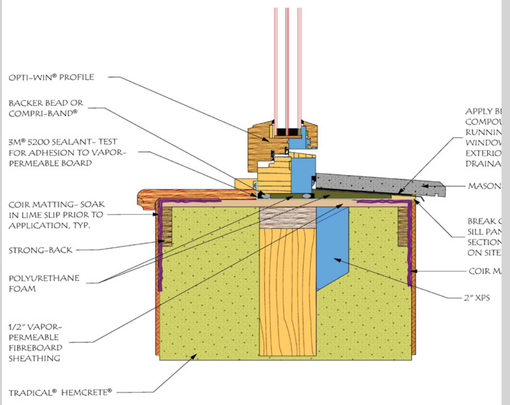










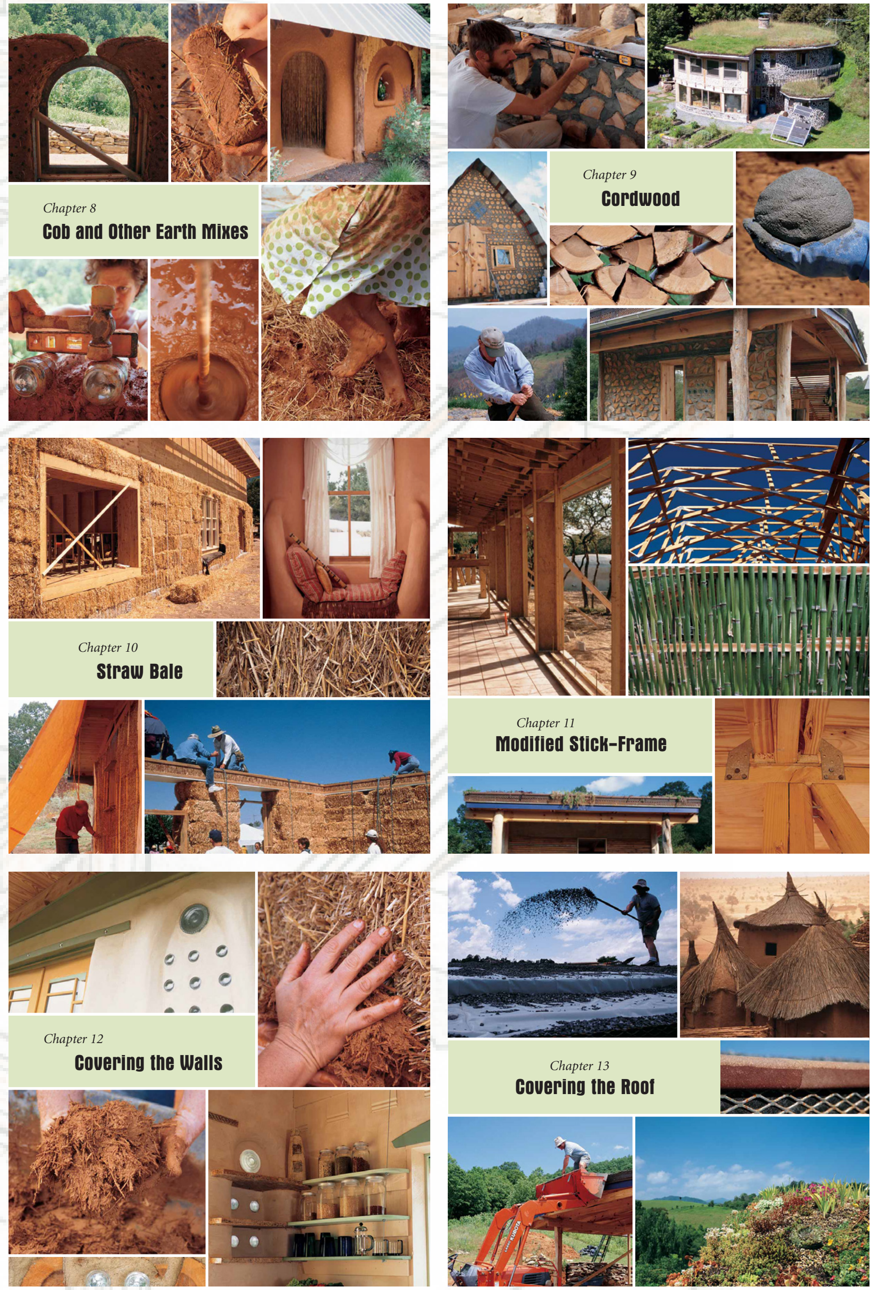


Juxtaposition of convention and tradition:

- 2x4 stick-frame; frame wrapped in hempcrete
- Foam on CMU; site-made earthplaster on hempcrete
- Concrete slab; site-made compressed earth block floor

The project had a research component juxtaposing the most exacting building science and high performance industry products with site-made materials and low-tech methods. Therefore, the design team needed to run the build. We utilized skilled subs, unskilled interns, and did much of the work ourselves. My experience is that innovation blurs the line between design and construction. When working out a new system or combination of materials, at some point you have to put down the pencil and pick up a hammer.

NAUHAUS PROTOTYPE. Intended as a carbon neutral prototype, the Nauhaus was designed to have a low embodied energy in construction through the use of site-made, local, and recycled materials and tiny operational energy loads through adherence to the Passivhaus standard. The architectural design incoporated extensive outdoor rooms to keep expensive interior square footage down and enable more time spent outdoors, both enjoyable and energy efficient because inhabitants do not need to heat or cool the indoors when they are living outdoors.



"BUILDING GREEN" COTTAGE. Project intent was to publish the results of research into application of traditional building systems in a comtemporary residential context. A demostration cottage was designed in which different material systems were applied based on their efficacy in the given microclimatic created by building siting. The design and construction process was documented in detail so that a series of how-to image sequences could work together with written and illustrated offerings on building science, architectural design, and other contextual information. The goal was to allow a wide range of readers to understand how the different materials and methodologies could be compared and contrasted from performance, practicality, and aesthic standpoints.

CLARKE SNELL

PORTFOLIO