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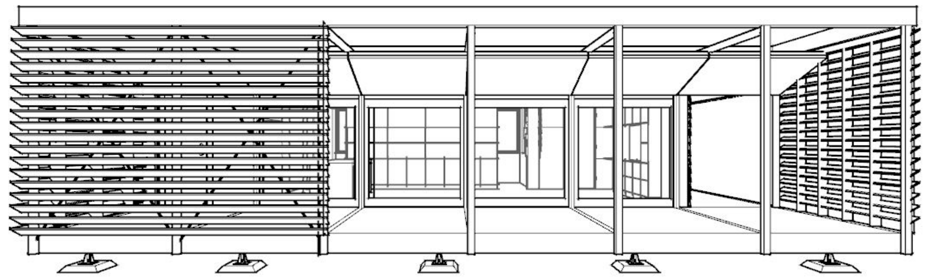
The SU+RE HOUSE installed at Solar Decathlon competition site



Sustainability and Resilience as Design Constraints

In October 2012, Superstorm Sandy, the largest Atlantic hurricane on record, pummelled the East Coast of the United States. In New Jersey alone, Sandy caused US$30 billion in damages, killed 39 people and left 2.7 million homes and businesses without power, 350,000 of those needing repair or reconstruction. The Federal Emergency Management Association (FEMA) responded with regulations that mandated construction above the floodplain. This was a sensible technical solution, but disastrous from an architectural and social standpoint in that it would lift many buildings well above street level, disrupting longstanding existing neighbourhoods with entrenched and vibrant living patterns.

A small group of architecture and engineering students led by faculty from Stevens Institute of Technology in Hoboken, New Jersey countered with the SU+RE House, a new paradigm for coastal housing and the winning entry in the US Department of Energy's 2015 Solar Decathlon competition.

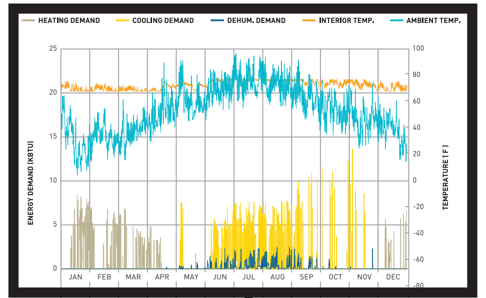
Hoboken sits on the Hudson River across from Manhattan and in 2012 Sandy had flooded the city. Just months later Ecohabit, Stevens' entry in the 2013 Solar Decathlon, was being built by students in a parking lot adjacent to the Hudson as a storm threatened to flood the river again. As an emergency measure, the building had to be craned out of the danger zone. When Stevens decided to enter the 2015 Decathlon and utiliz ed the same parking lot for construction of the SU+RE House, it seemed clear that the design challenge had to be an intelligent, replicable response to Sandy.

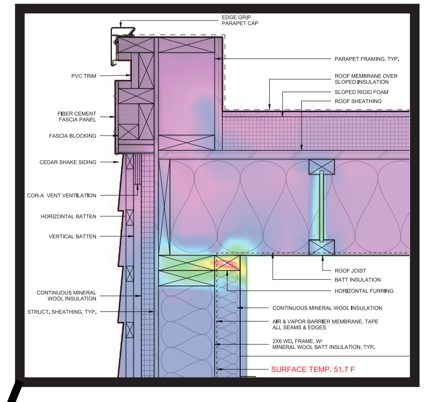
The result was the development of a building system that allows for construction in the floodplain, thereby reclaiming a densely populated site condition currently being lost worldwide to more frequent and severe flooding. Through conscious envelope design, the house also requires only a fraction of the energy to run compared to its conventional counterparts, its roof-mounted photovoltaic system producing considerably more power than the building requires. During a storm-induced grid failure, the system 'islands' itself to continue producing power, becoming an oasis of energy to supply standby electricity to the neighbourhood.

The project is now a permanent exhibit at the Liberty Science Center in Jersey City, New Jersey and documented in an edition of AD, "SU+RE: Sustainable and Resilient Design Systems", edited and contributed to by project faculty.

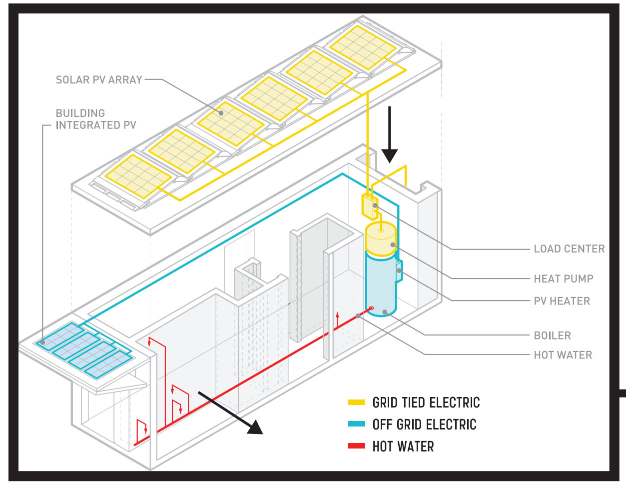
Resilient PV system engineered to produce energy for the neighborhood in the event of power outages.

Building operational loads extensively modeled to inform solar control and building envelope design...

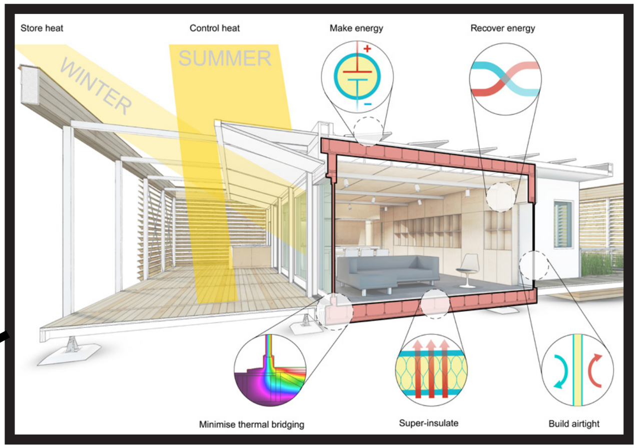




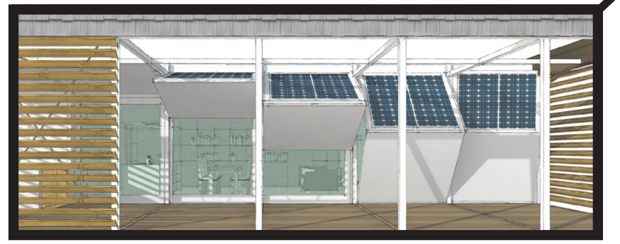
...then modeled interatively in tandem with architectural design to mesh performance with form.



Two distinct PV arrays: one grid tied, the other directly heats water through a resistance element creating a heat storage battery for use whether grid power is available or not.



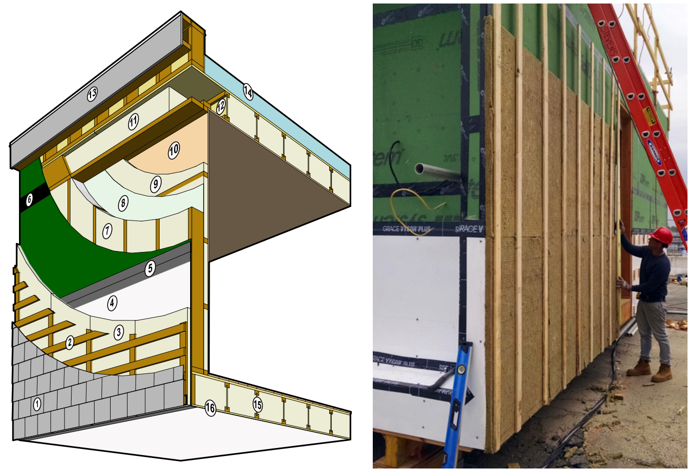
Final envelope system delivers over 90% reduction in modeled energy usage compared to standard buildings in target market. Actual usage in operation tests tracked modeled data accurately.



Composite bi-fold shutters are solar shades when open, closing to protect the building during flooding...

...part of a resilient desing strategy to allow the building to be constructed in a backbay floodzone as an answer to FEMA's changes in regulations after Superstorm Sandy.

A model of the first envelope design direction: composite SIPs. This solution eventually fell prey to code restrictions.



The final building envelope is essentially a reorganisation and amplification of a well-established low-energy system...

...with flood-proofing added in a layer on the underside of the floor system and continuing up the lower portion of the wall exterior extending above the base flood elevation.

Low-tech Adaptation Combined with Plug and Play Innovation

The SU+RE HOUSE project design constraints defined the envelope as a hybrid combination of existing low-energy building and marine industry materials and methods. It was noticed that a boat hull is a structural insulated panel (SIP), a well-established assembly for creating low-energy building enclosures. Building SIP skins are most often wood-based sheet goods, while in boats they are glass-fibre laminates. When used in buildings, the foam cores of SIPs are excellent insulators, while in boats they are part of an efficient buoyant waterproof shell. In both instances, the foam sandwiched between and bonded to continuous skins uses similar structural principles to create very strong panels. Therefore, to deliver flood-proofing, why not simply build a boat configured to perform as a very low-energy house?

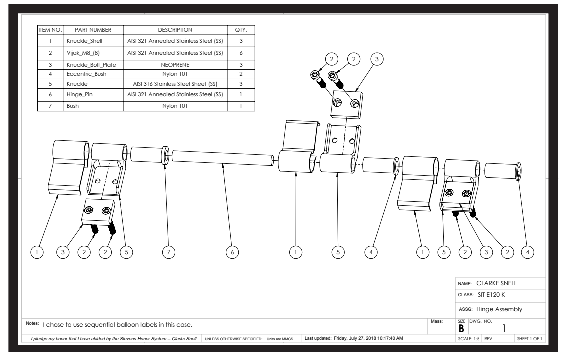
This design thread provided many potential advantages including unbroken insulation, integral rather than applied flood-proofing, standard methods for perfect joint-sealing against air and water leakage, and simple adjustment of insulation thickness for different climate zones. The biggest problem encountered was finding structural and fire code equivalence between glass-fibre composite panels and wood-panel-based SIPs designed for buildings. Used ubiquitously in craft designed for water, air and space travel, the technology was clearly there for the composites, but the regulatory infrastructure was not. A case in point and a cautionary tale for design processes that prioritize innovation.

The eventual solution went to the other end of the project material pallet spectrum. A conventional stick-frame envelope was modified to deliver required thermal resistance, air tightness, and resistance to buoyancy forces with flood-proofing applied as a layer in the floor and wall assemblies. Joint-sealing detailing was borrowed directly from proven marine practice. Performance enhancements were therefore accomplished through rearranging ubiquitous materials in existing construction details. The sage design advice of not fixing what isn't broken was followed as proven durable, and easily repairable vernacular beach exterior and interior skins were employed. The result was an effective low-energy, flood-proofed envelope that motivated contractors and tradespeople could build with a limited learning curve.

To complete the flood-proofing, barriers protecting fenestration from water, wind and flying debris needed to be devised that could quickly be deployed as a storm approaches, locking the house down while the occupants find safety off-site. This task required higher levels of innovation, so the team developed standalone products that could be applied to the existing envelope, thus enabling continued development towards a commercial product beyond the scope of this single project.

A large expanse of southern glazing created a transition between indoor and outdoor rooms. As part of a Modernist tweak on classic passive solar design, the glass needed a large overhang to maximise winter and minimise summer solar gains. Movable bi-fold shutters were designed that when open provide this overhang. In the event of a storm, the shutters can be quickly closed and locked, compressing their gaskets against a structural frame. Marine hardware, gas springs, and a 6:1 mechanical advantage pulley system allow two people with limited strength to close the large foam core glass-fibre composite panels. Fibre-laminate schedules were customised in each panel to balance weight and strength: the lower panel heavy and stronger to withstand the lateral and uplift forces of flood waters; the top panel lighter to allow for easier movement of the assembly.

Custom glasfiber laminates were engineered and manufactured for specific flood loading...

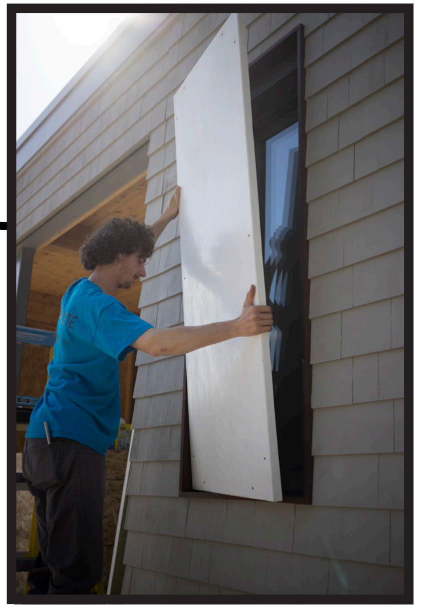


...some hardware was customized

...most was off-the-shelf marine industry parts: pulleys, ropes, cleats, compression latches and gas springs.

Panel gaskets compress against steel columns to create water-tight seal. Integrated solar panels are part of a direct DC water-heating system that supplies hot water even during a grid power outage.

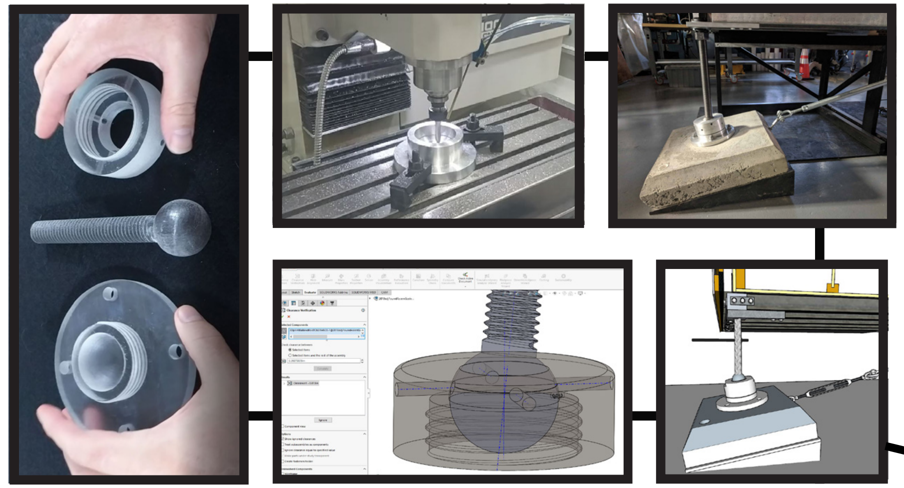
Shutters act as solar shades when open, and flood-proofing when closed.



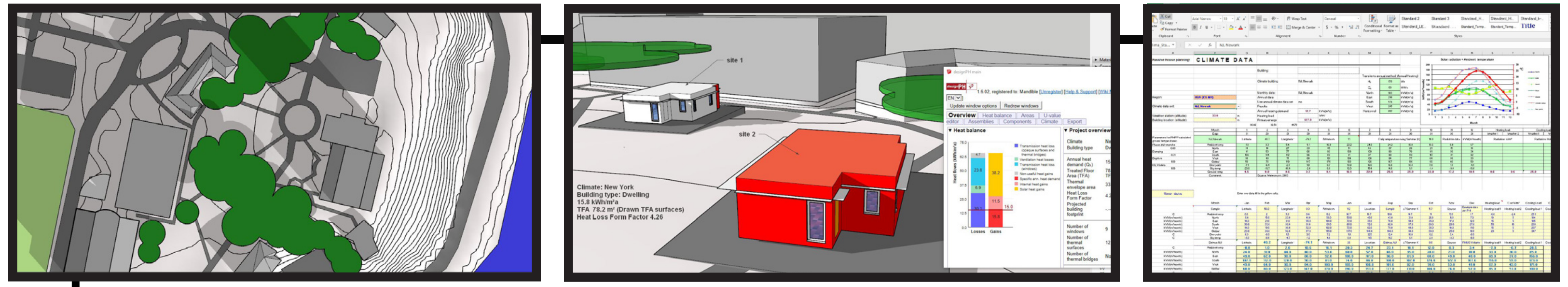
The same composite-panel technology used for the shutters was re-engineered to create strong, lightweight window plugs. A thin profile allows for easy storage, and simple hardware enables quick installation in response to a coming storm.

CROSS-PLATFORM MODELING

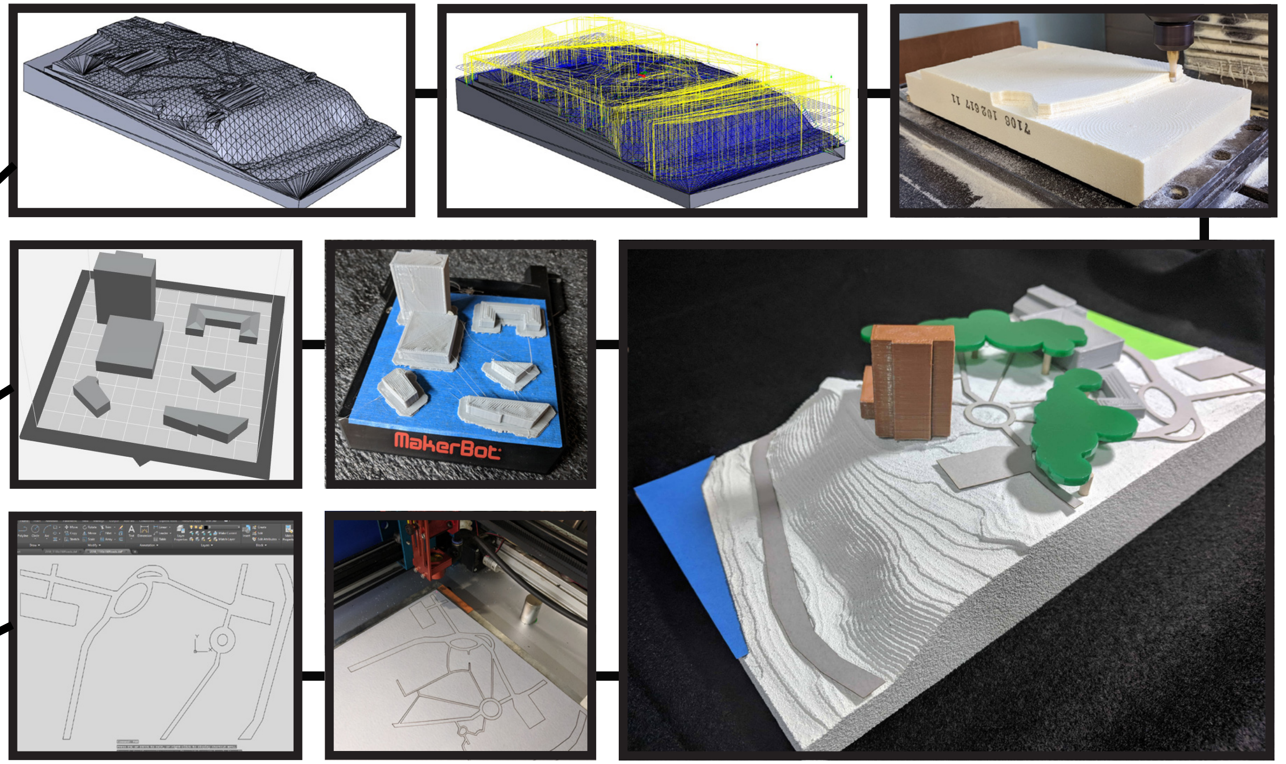
Iteration as a constant. Successful, buildable sustainable/resilient designs require that performance and form take shape together. Therefore, an iterative design process in which technical and architectural forces can inform one another is essential. Cross-platform modeling is a process by which the outputs of one model type are the inputs for the next. This is not a linear or binary process, but one in which any number of different modeling platforms communicate in an iterative loop.



Design, scaled physical, and full prototype modeling of project components starts in the schematic model and remains tied to it so that what is learned through protoypying re-informs the full design.



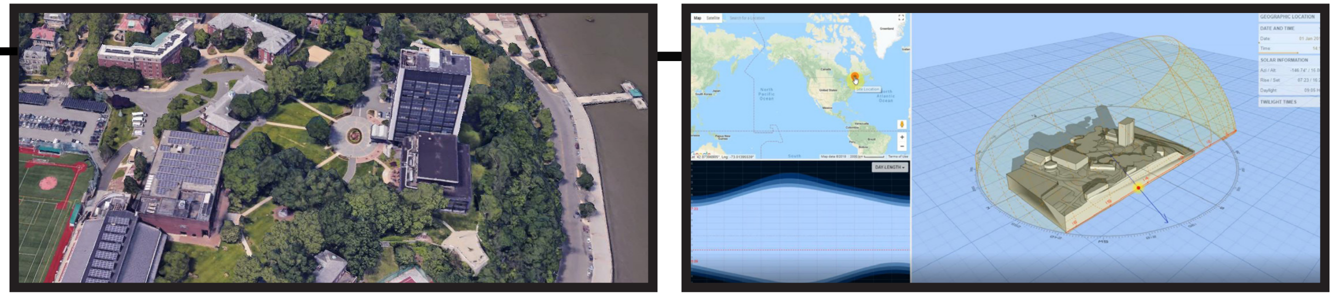
Climate data and 3D spatial context are inputs for energy modeling that immediately feed envelope design and siting options in an instantaneous feedback loop with architectural form generation.



Model components can be selectively output for fabrication (CNC milling, 3D printing, laser cutting,...) to quickly and inexpensively create a scaled, physical schematic model for presentaions and analysis at any point in the design process.

In a teaching context, all projects are conceived as design/build. From the outset, modeling is simultaneously playful and detailed, moving from parti through schematic design, rendering, construction detailing, into construction with iterative feedback the only constant.

The schematic model is geolocated allowing for immediate and robust definition of macro and micro climatic factors through access to readily available solar and climatic data. Detailed site selection is developed in real time as form and performance are in discourse with multiple site options investigated simultaneously through the model.

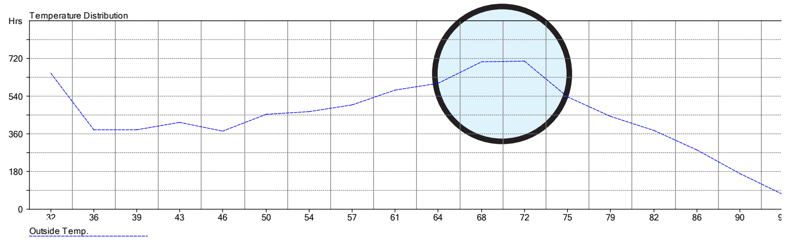


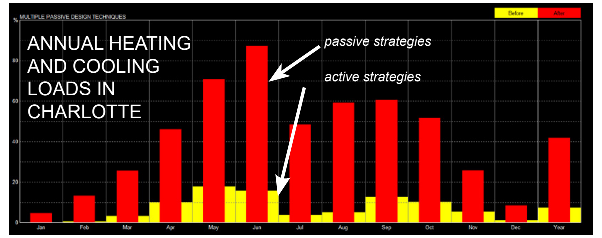
Macro site selection drives the initial schematic model, but at any point the context model can be output for comparative study of sites anywhere in the world.

High Performance Envelope Design Methodology. Design exercise toward integrating energy performance concerns with a formal and programmatic design process.

Case Study: basic climate and comfort analysis of site presents an interesting design challenge. Can we create a commerical building in a mixed humid climate with considerable heating and cooling requirements that would have most of its loads provided through passive means?

1. Climate and Comfort

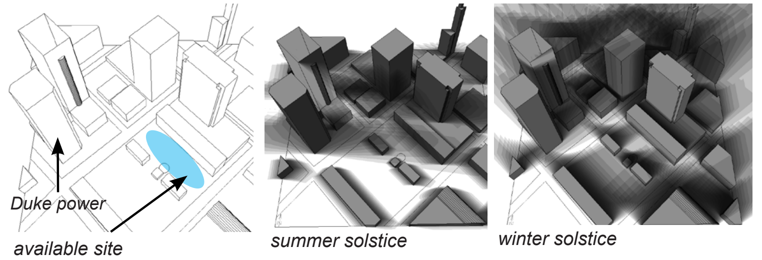


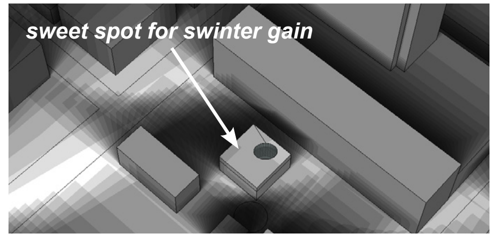


Though most commercial buildings in the southeast are designed as though cooling loads predominate, often the opposite is the case. For example, Charlotte NC has almost twice as many heating degree as cooling degree days and s significant percentage of annual ambient air temperatures are within the psychrometric comfort zone.

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

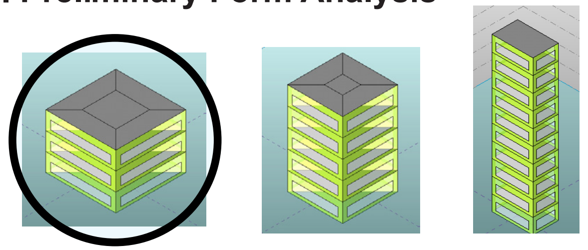




Based on this initial analysis, it makes sense to look for a spot on the site that maximizes winter solar exposure while offering summer shade. Butterfly shading analysis of the nearby uptown site uncovers a tight zone that fit the bill. Available wind data does not offer any useful data for design.

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

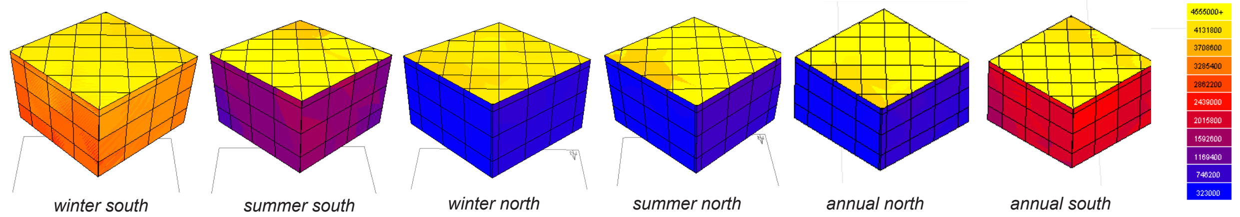
3. Preliminary Form Analysis



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

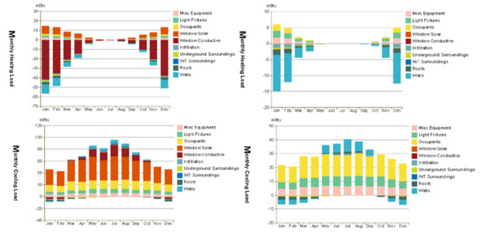
VISARI		Variable Maximized	Source EUI (kBtu/sf/yr)	Annual Energy Consumption Elect(kWh)	Fuel(Therms)	CO2 (tons/yr)	AnnEnergyCost ($)
Form 1							
Floor area (sf)	10,092						
Ext wall area (sf)	10,440						
		Code	73	166,676	1,600	50	$15,562.00
		Wall insulation	69	166,031	1,348	46	$15,106.00
		Slab 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

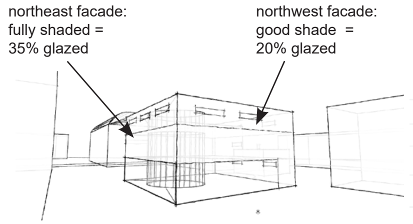


This basic formal concept is combined with the preferred siting to generate a solar insolation analysis to inform the building envelope design. The NE facade of the building is well shaded by a nearby building and receives little direct sun throughout the year. The NW side is more exposed but shaded by the building form due to the trajectory of the solar path. The SW 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 SE buildng face receives almost as much SIR but more during colder months when its effect is desirable.

5. Envelope Design



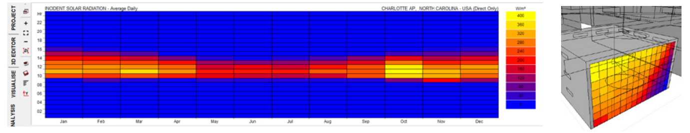
Energy analysis of similar buildings indicates that overglazing is a central issue. For this and programmatic reasons, the decision is made not to utilize a curtain wall. Instead a well insulated envelope is designed in combination with a storefront glazing system.



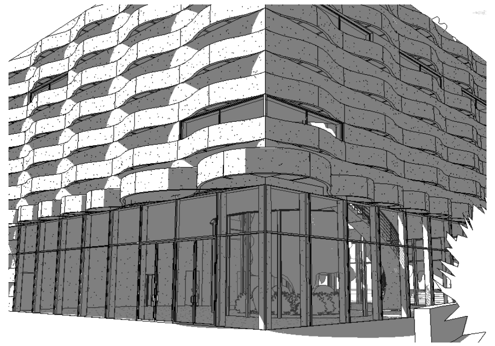
	Variable Maximized	Total EUI (kBtu/sf/yr)	Annual Energy Consumption Elect(kWh)	Fuel(Therms)
1	Base case (zoned with all non-glazing variables maximized; double pane low SHGC glazing)	80	188,372	1,521
2	Base case + max South shade + 2ft West overhang	80	186,570	1,553
3	Base Case + max South shade + all 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	189,663	1,410

Based on the SIR analysis window to wall ratios are 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. Different glazing types are modeled and preliminary specifications determined.

6. Integrated Shading Design

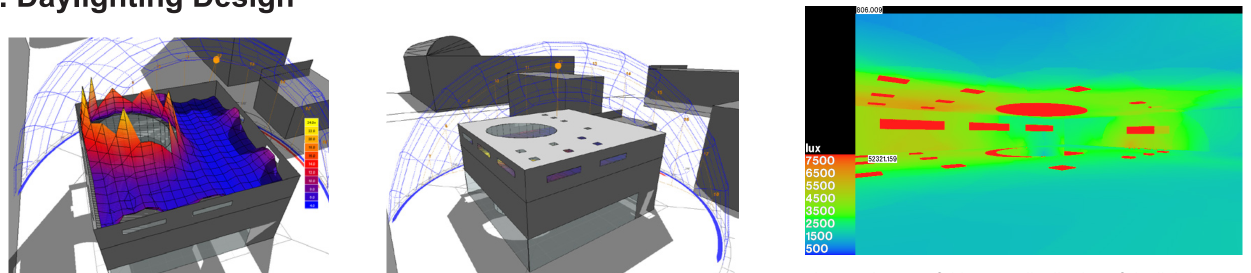


Window to wall ratios for performance are balanced with programmatic concerns. A storefront system is planned for the entry level assembly space that concentrates most of the building glazing in large areas of the first 15 feet of facade on three sides. Shading options for this glazing are studied and analyzed. The main benefit is realized with combinations of three and six foot horizontal overhangs above the storefront that eventually are 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.

7. Daylighting Design

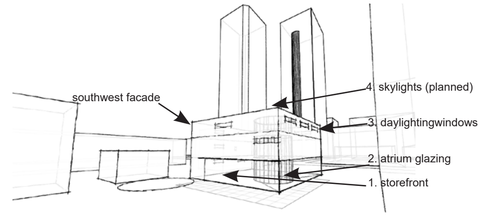


Without skylights the third floor is very dark.. *Skylights were added based on space usage patterns...* *the result was a fairly even distribution of daylighting at tasklighting levels for much of the year*

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

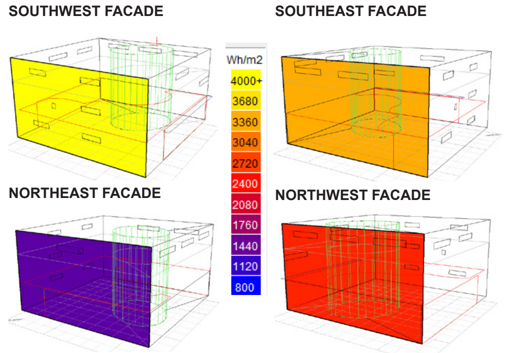
8. Materials Specifications

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



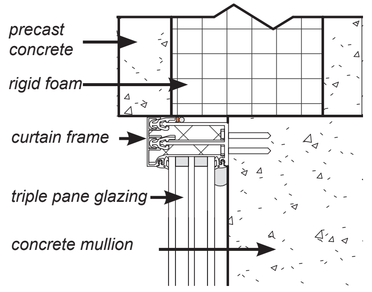
Façade Glazing Specs	Description	U-factor (Btu/h-ft2-F)	SHGC	VLT
1- Storefront NW, NE	Triple IGU (2 lowE;krypton)	0.11	0.36	58%
1- Storefront SE	Triple IGU (2 lowE facing	0.17	0.55	61%
2- Atrium	Triple IGU (2 lowE;krypton)	0.11	0.36	58%
3- Daylighting (all faces)	Triple IGU (1 lowE, air)	0.22	0.36	67

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.

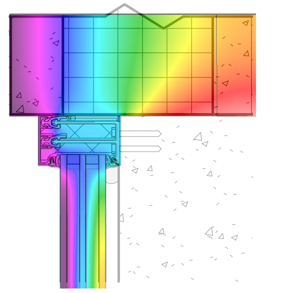


Average annual daily incident solar radiation for all four building faces.

9. Assembly Performance Maximization



Detail at curtain wall



Analysis of heat flow through assembly

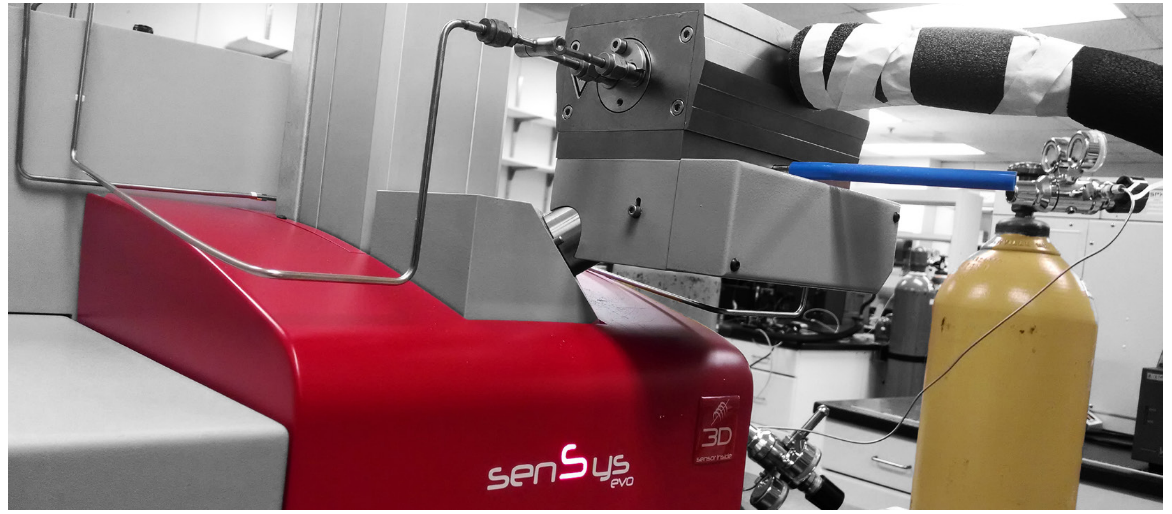
Weighted Area Calc for Glazed Portion of Wall System

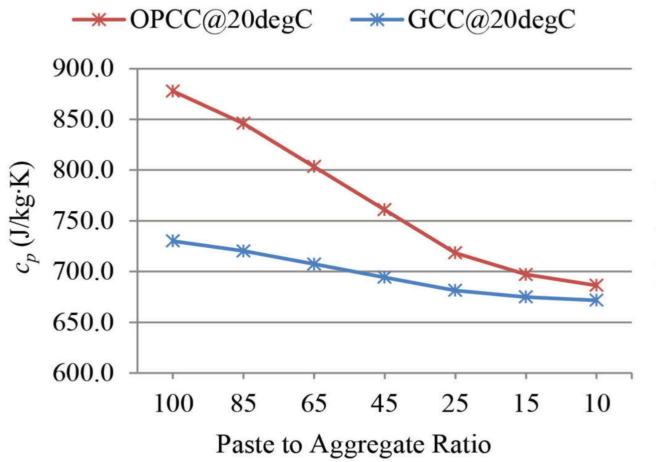
Descr	Area (sf)	%	U-value (Btu/h-ft2-F)	Weighted U-value
Total	95.00			
Frame	17.56	18%	0.45	0.08
Edge	7.88	8%	1.06	0.09
Glazing	69.56	73%	0.31	0.23
			Assembly U-value (Btu/h-ft2-F)	0.40

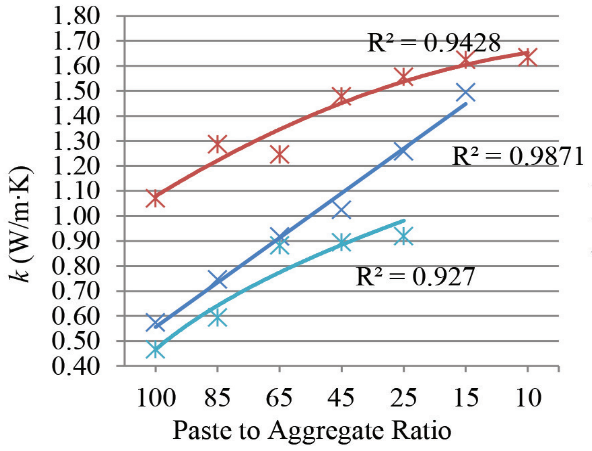
Assembly U-value calculation

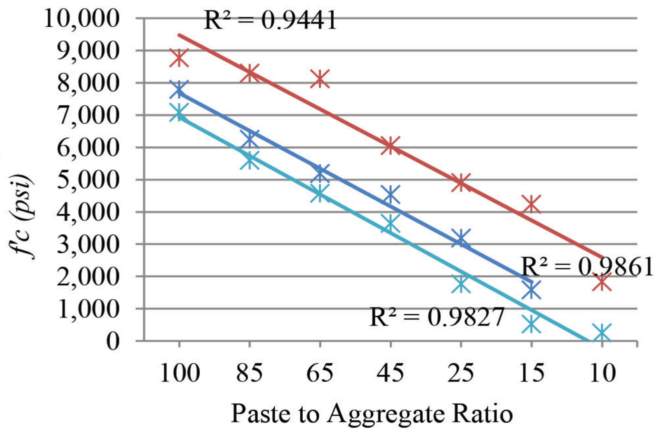
Now that all the programmatic and analytical information has been applied to the design, the performance of the full assembly can be modeled and tweaked based on comfort and performance goals for the project.

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

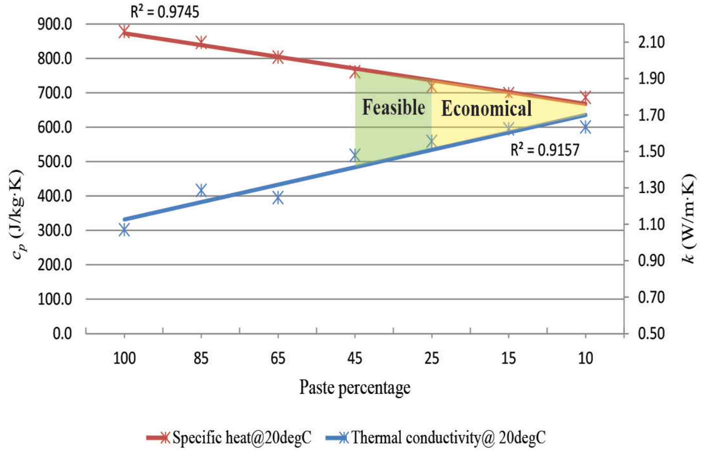


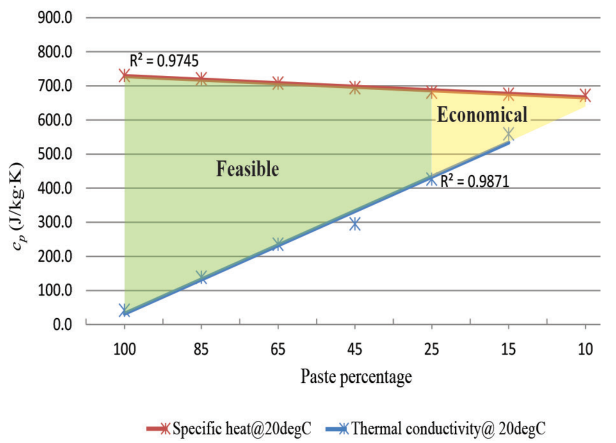




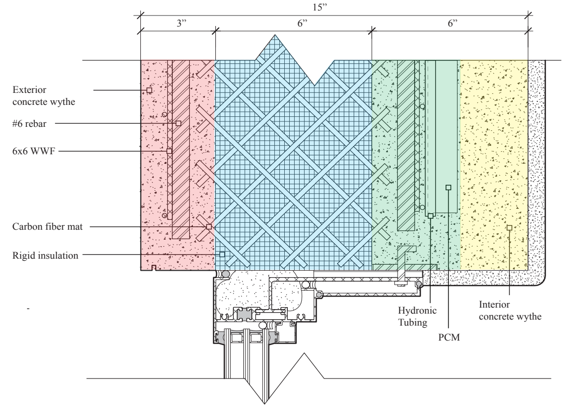


GCC's have lower specific heat capacity... ...thermal conductify... ... and compressive strength than OPCC's





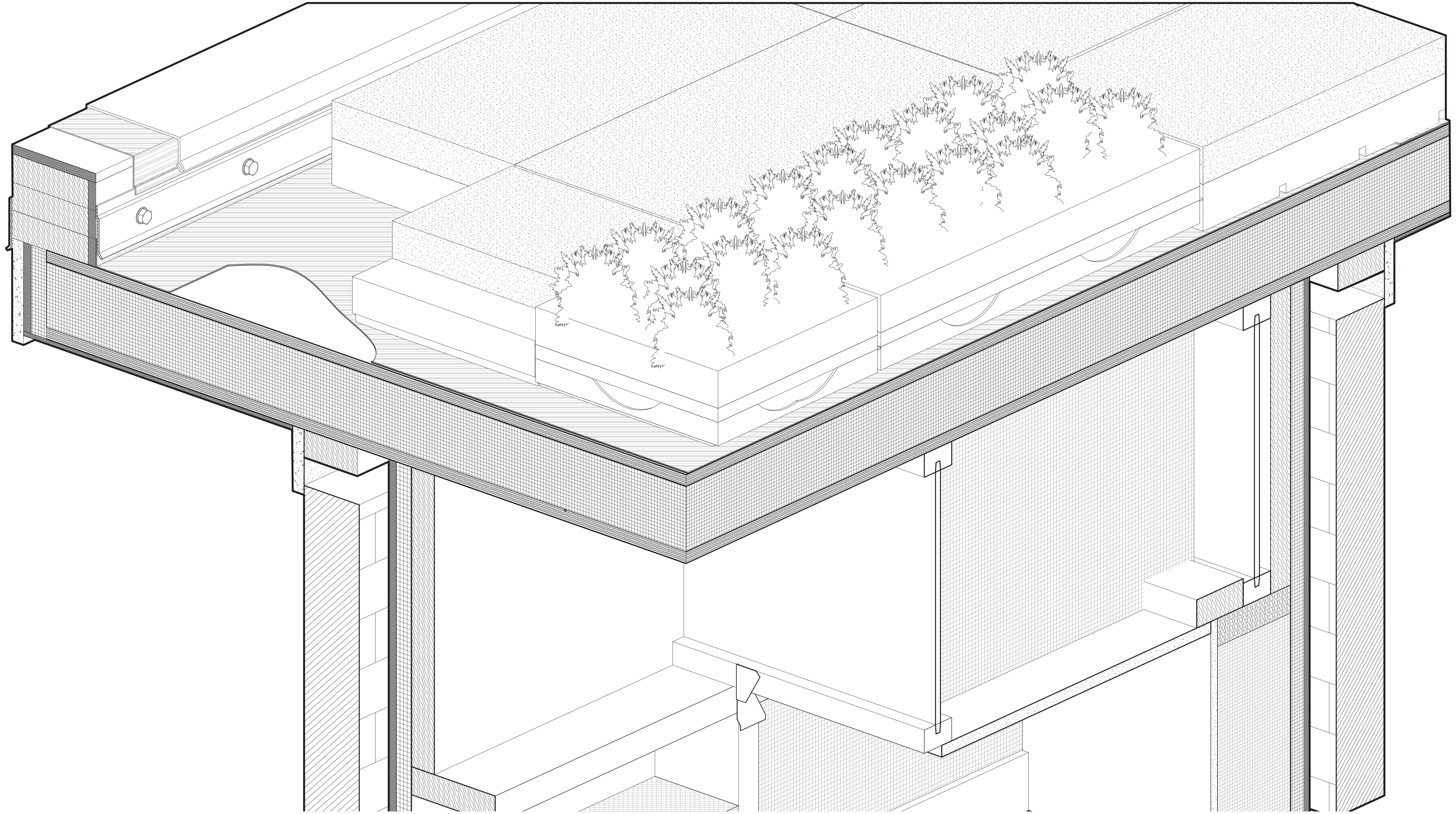
Simple physical differences make the feasible mix range for GCC's broader giving them more thermal flexibility.



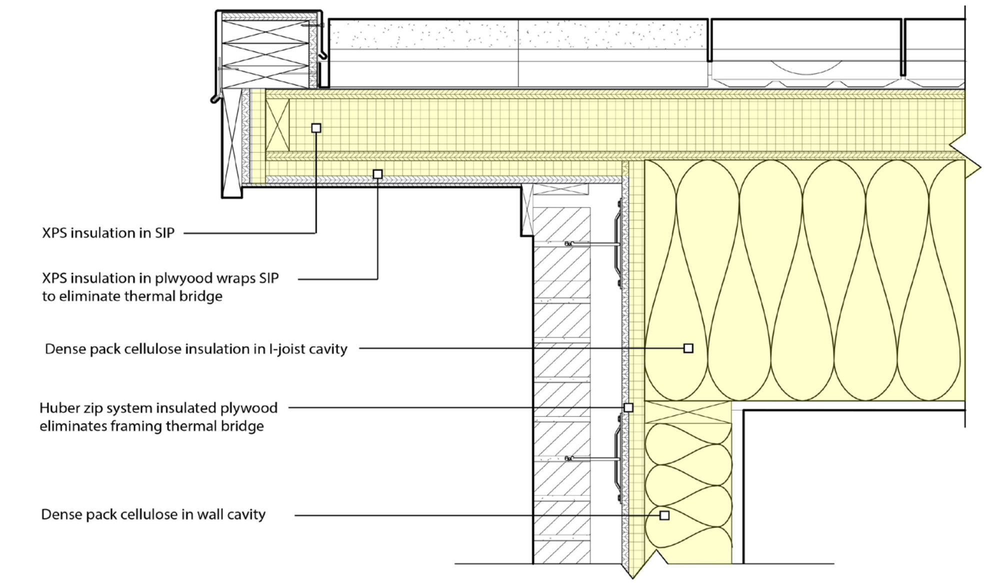
Zone	Type	P/A Ratio	c	k	f'c	Application
1	GCC	1	730	0.53	7,784	microclimate temperature stabilization; strength
2	GCC (foamed)	1	high	low	high	theoretical foamed mix based on low k value of 100% GCC paste
3	GCC	0.15	675	1.49	3,184	maximize efficiency of hydronic and PCM systems
4	GCC	0.65	707	0.92	5,183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

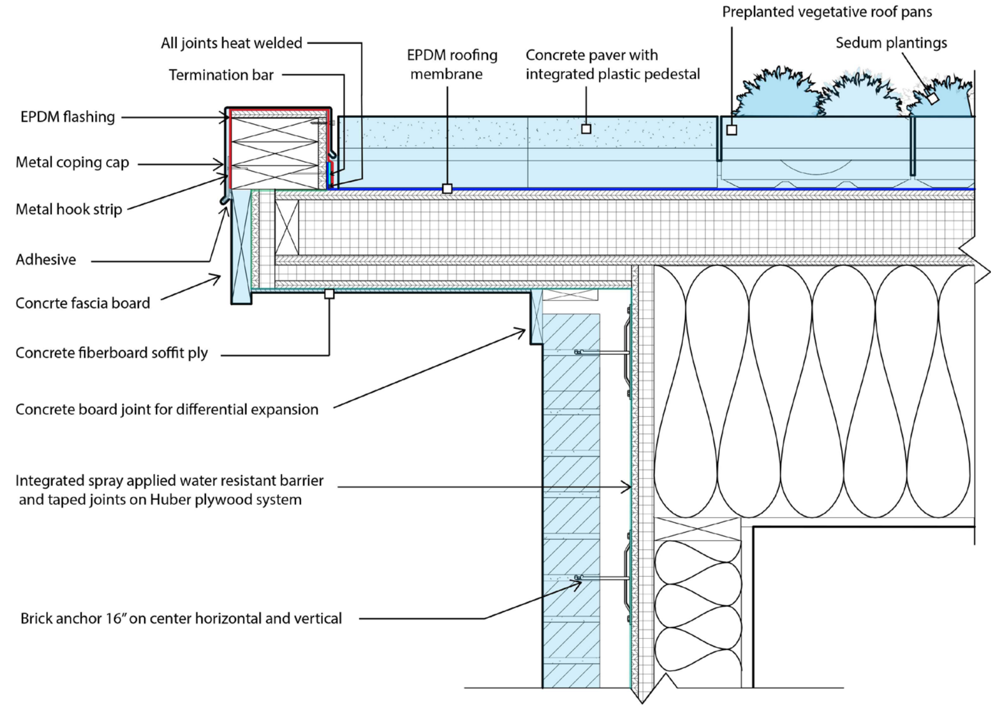
Thermal Optimization of Concrete for Low Energy Building Envelopes. Humans have been mixing concrete for thousands of years and are adept at controlling structural and finish characteristics through mix design. Concrete has also consistently been used as a thermal material in buildings, both to store heat energy and to resist its movement, but it seems that designing mixes to maximize these performance parameters has not been generally considered. In this study, the potential efficacy of defining the specific heat capacity and thermal conductivity of concrete through adjusting paste to aggregate ratios was investigated. Results indicate a potential range of about 30% for specific heat and over 200% for thermal conductivity through such a mix design approach. Geopolymer cement concretes (GCC) show more promise than portland cement concretes for thermal optimization. A zoned thermal wall assembly was designed to prototype application of study results in a low-energy building envelope. This research was published in the Journal of Architectural Engineering.



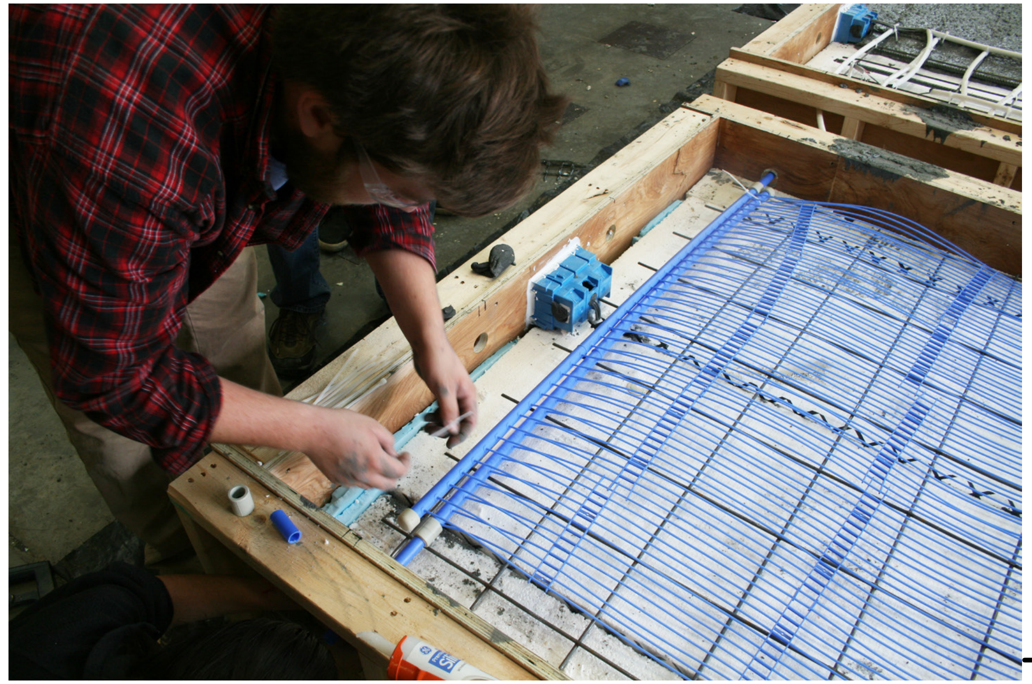
BIM Construction Detailing.
Ongoing experimentation in drawing through modeling components first, assembling them into systems such as the model at left, and then mining documentation directly from the model such as the sections at right. This work is part of long term project to develop a library of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



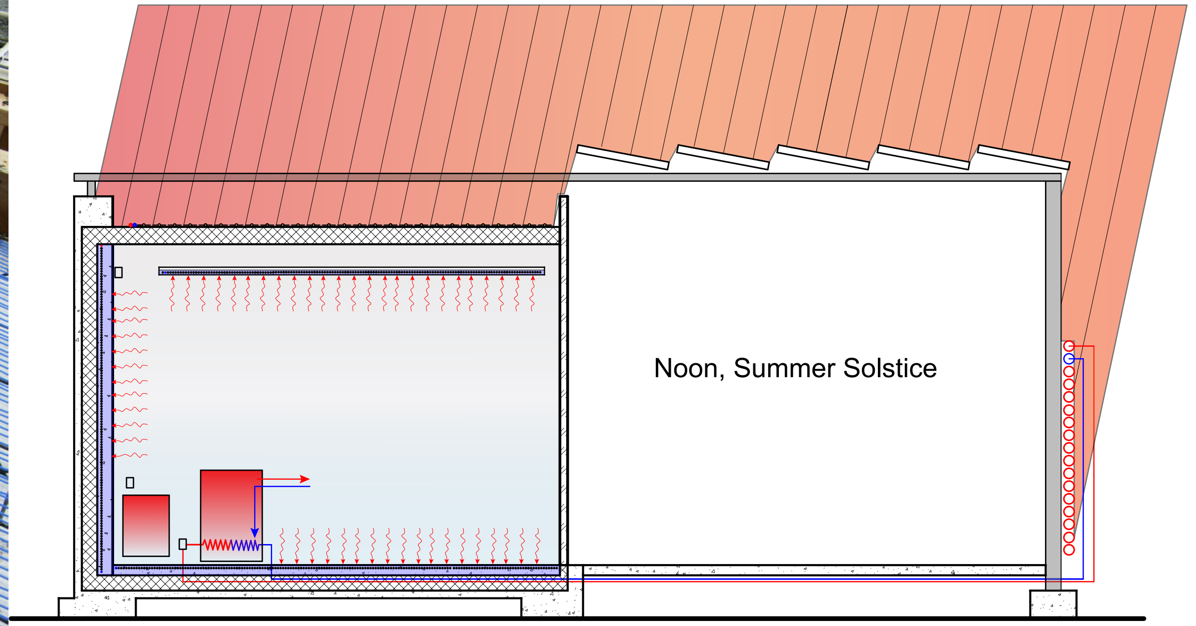
2 Horizontal Section - THERMAL
1" = 0'-6"



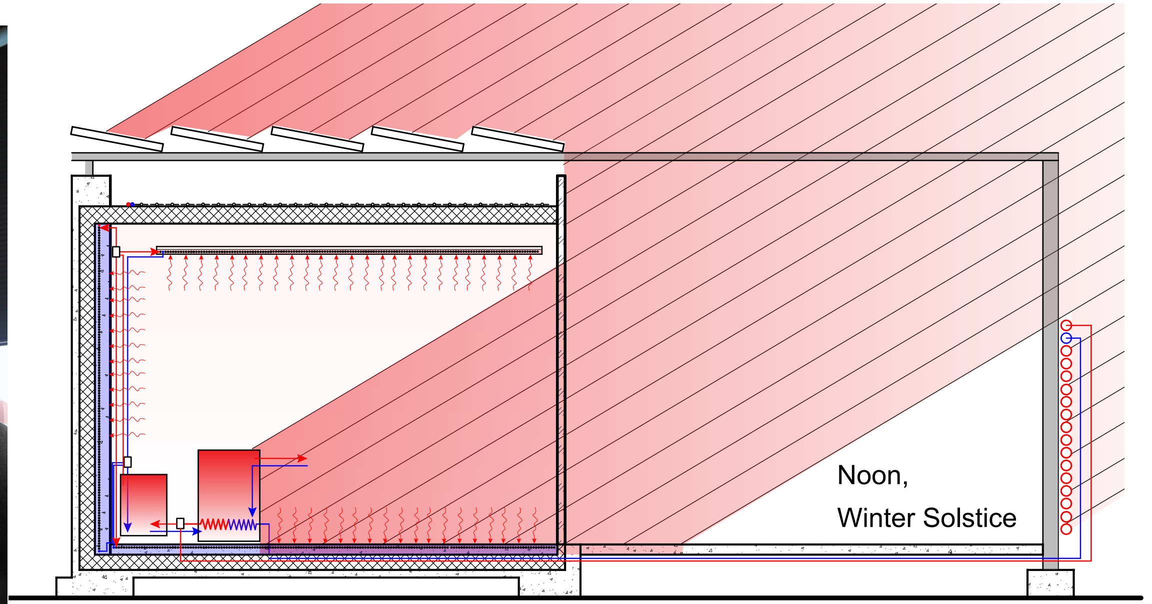
4 Horizontal Section - PRIMARY SEAL
1" = 0'-6"



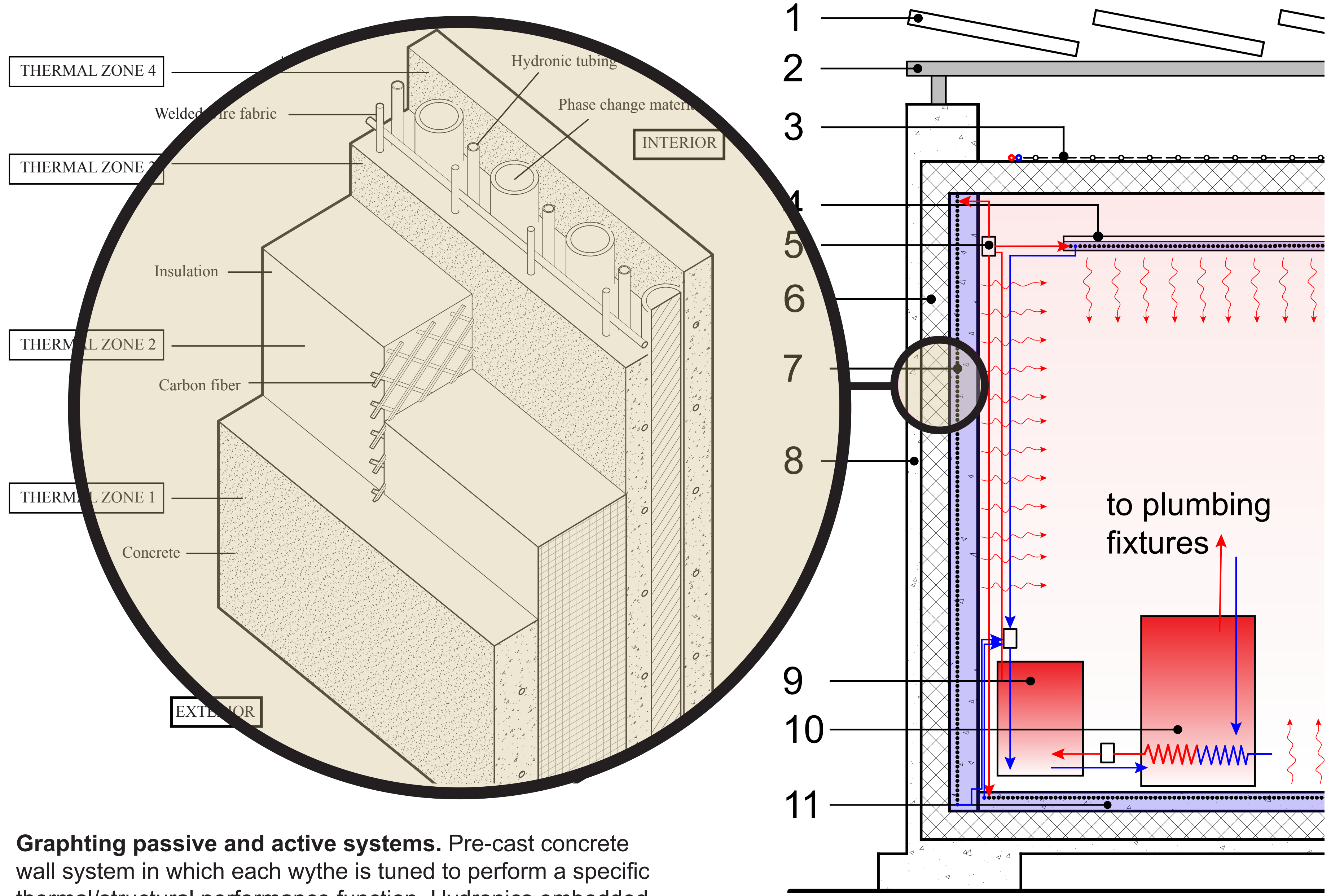
Annual Hybrid Passive Radiant Heating/Cooling Cycle



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.



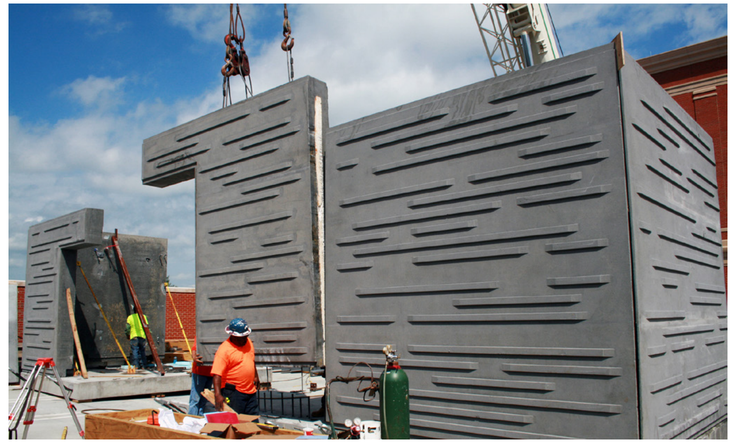
In the winter, the PV array is moved over the main roof allowing the low southern sun to reach deep inside the house where the geopolymer concrete floor, walls, and cloud store the heat. The solar thermal collectors heat water for domestic use and additional solar energy from the collectors is transfered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



Graphting passive and active systems. Pre-cast concrete wall system in which each wythe is tuned to perform a specific thermal/structural performance function. 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 glaizing 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 (above) and as constructed on site for the competiion in California (below).

Carbon Reduction Through Fixing Concrete.

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.

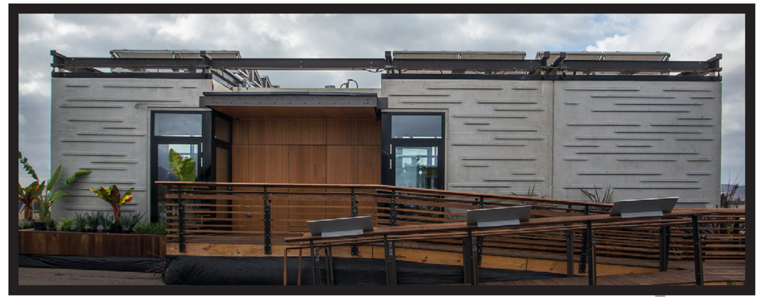
Architecurally the project concept was to create a better urban living context through crafting a space that blurs the line between inside and out. A series of connected indoor and outdoor rooms combine into a single healthy environment: the interior completely adaptable to maximize comfort year round 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.

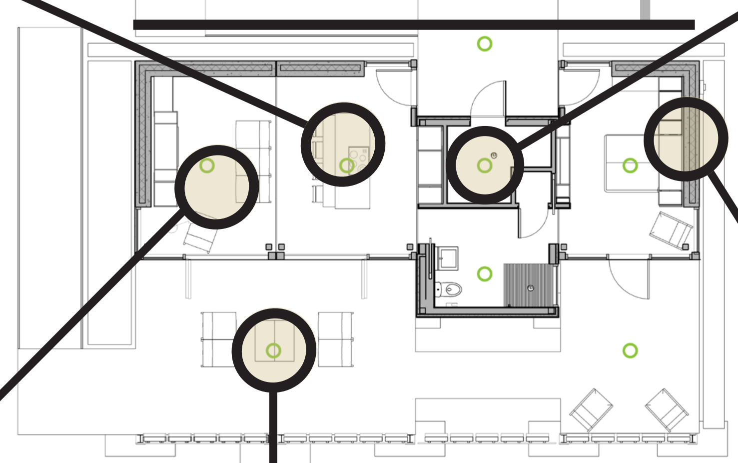
Transition between these interior and exterior living spaces is provided by a high performance floor to ceiling glass wall that allows for exacting interior environmental control while maintaining a constant and seamless connection to the outside. Public and private spaces are defined formally as essentially 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.

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

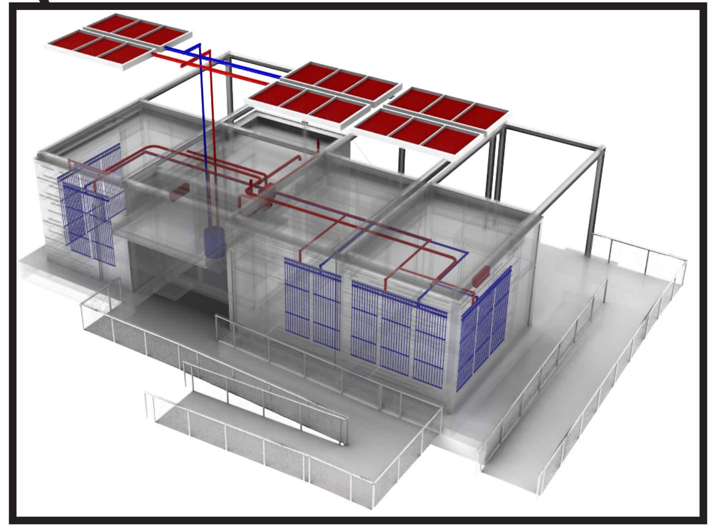


North facade faces the street; thick concrete walls create aural and visual privacy

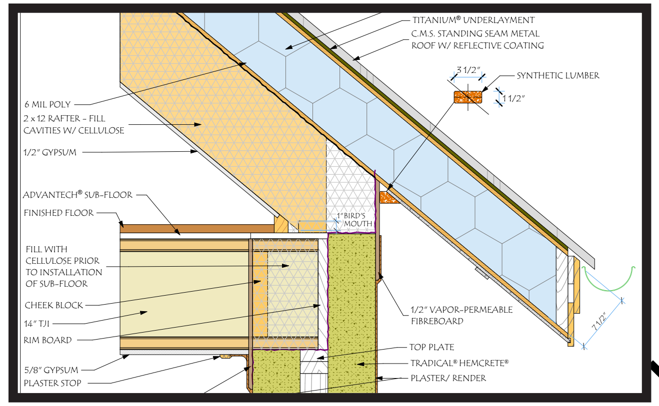


...and living room moves outside. Outdoor rooms double square footage of living space with living walls and movable PV array shading device.

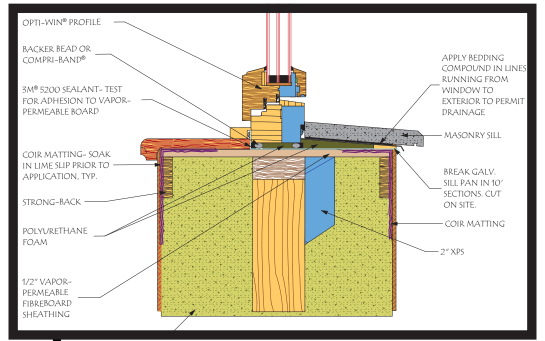
Building envelope integrated with passive and active systems and designed to Passivhaus standard



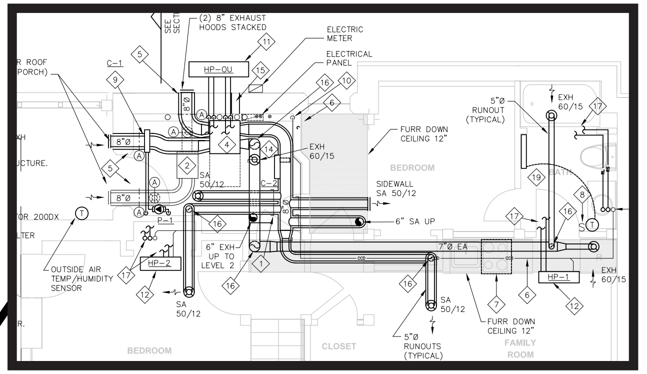
Hydronic capillary tubes emebedded in the geopolymer cement concrete walls and plumbed to heat exchangers for low-energy radiant heating/cooling (See "passichanical wall system" above.)



Ultra low energy building envelope featuring innovative assemblies that marry site-made and industrial materials...

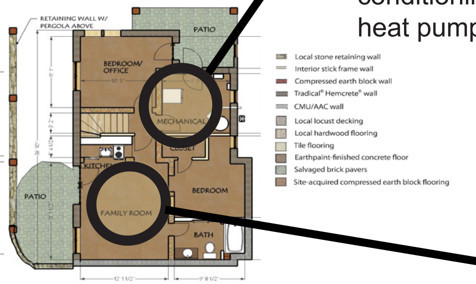


...with airtight construction methods utilizing porous hygroscopic materials

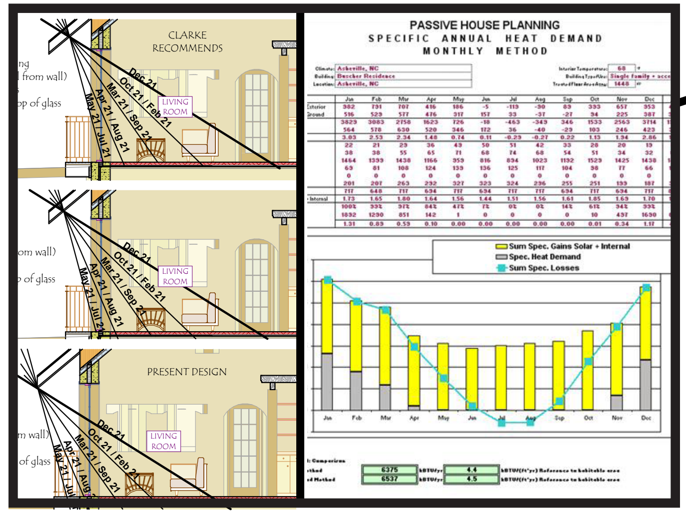


Mechanical system including ERV intake pre-conditioning coil, domestic water waste heat recycling, heat pump hot water heater, and ducted mini-splits.

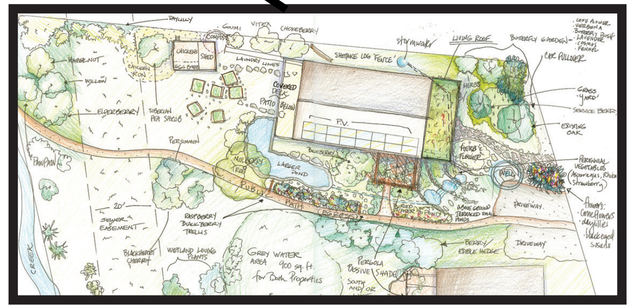
street level



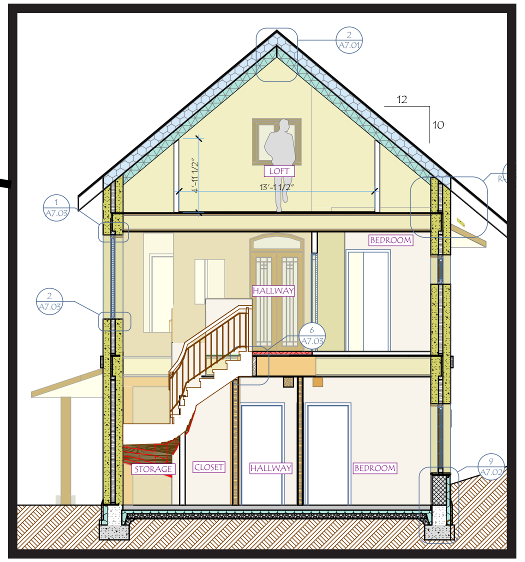
daylight basement



Performace modeling fed an iterative design process linking site, envelope, and mechanical systems.

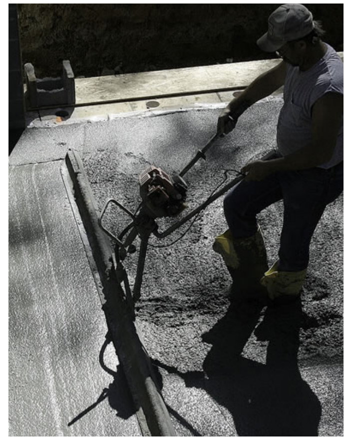


Permaculture design and outdoor room extends living space and is an act of repair in an urban environment.

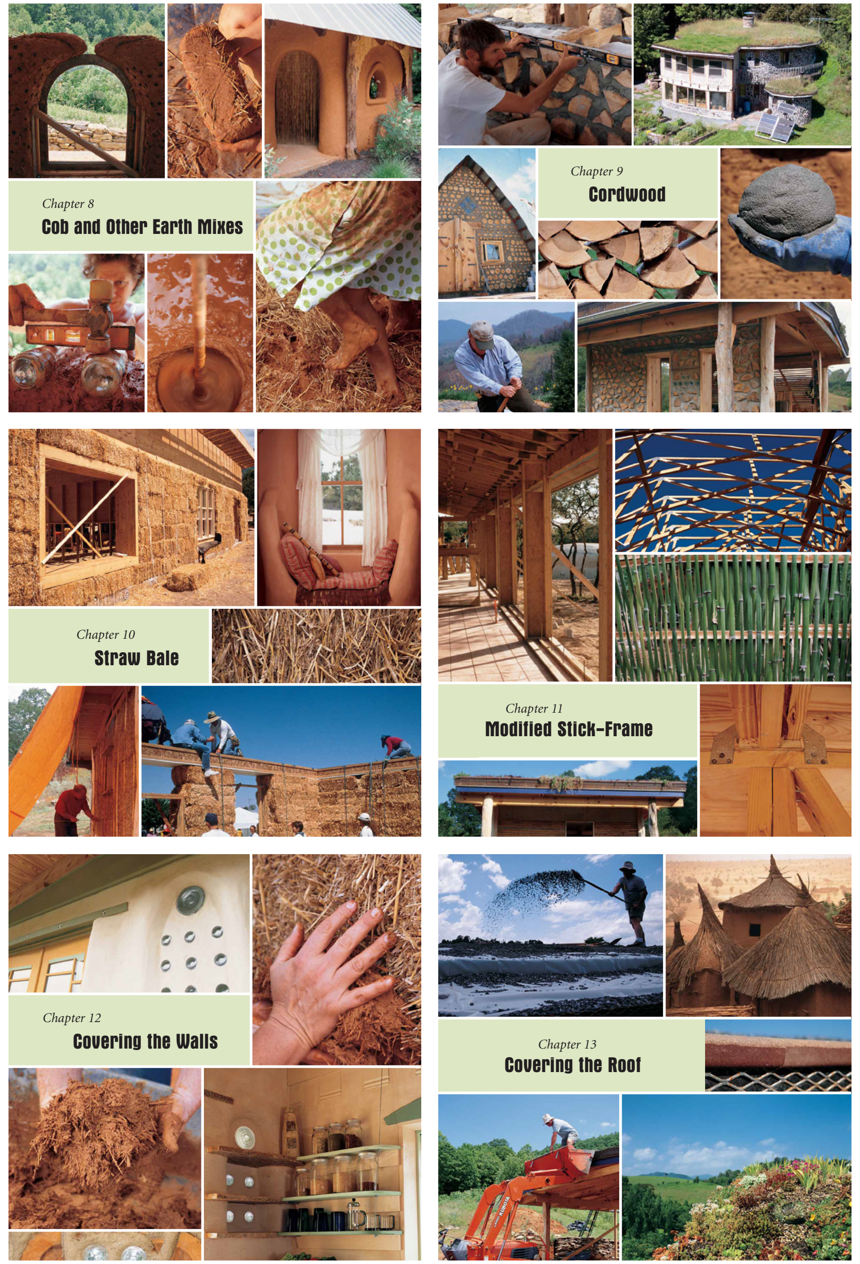


Loft and daylight basement maximize living space on a small lot and increase energy efficiency through an efficient interior volume to exterior surface area ratio.

Low-energy hygroscopic envelope. 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.



Juxtaposition of state-of-the-art building science and high performance industry products with site-made materials and low-tech methods. Compressed earth blocks, earthen plasters, hemp shiv, lime renders, living roof, polyurethane SIPs, closed-cell foam, triple plane glazing, air tight construction, passive coil thermal pre-conditioning for energy recovery ventilation supply. First hempcrete insulated building in the US.

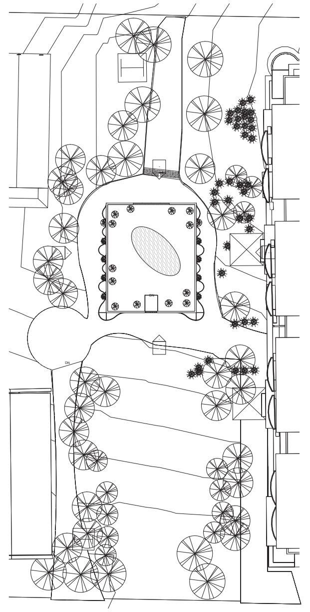


"Building Green" Cottage. Project purpose was to publish the results of research into application of traditional building systems in a comtemporary residential context. A demostration cottage was designed and built in which different material systems were applied based on their efficacy in the given microclimatic created by building siting.

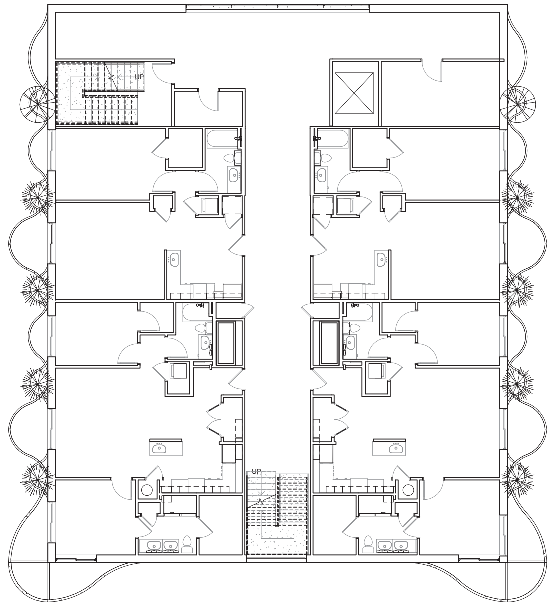
The design and construction process was documented in detail so that a series of how-to image sequences worked together with written and illustrated offerings on building science, architectural design, and other contextual information. Different materials and methodologies were compared and contrasted from performance, practicality, and aesthic standpoints.

CONDO PROJECT PROTOTYPE

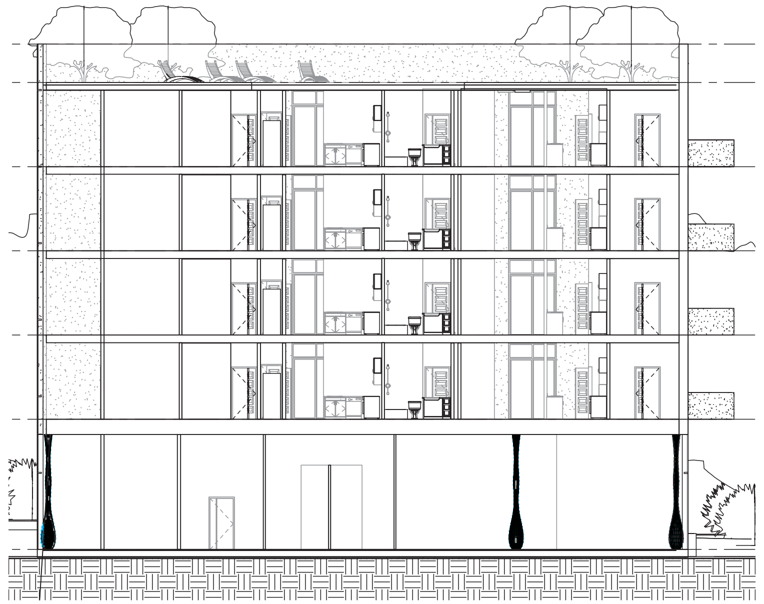
programming, 2D/3D modeling, rendering



Site Plan



Apartments



North/South Section

West Entrance

Lobby

Composite Column

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.

CLARKE SNELL

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