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SALTYGLOO

Project Date: 2013
Project Team: Ronald Rael, Virginia San Fratello, Seong Koo Lee, Eleftheria Stavridi

The Saltygloo is an experiment in 3-D printing using locally harvested salt from the San Francisco Bay to produce a large-scale, lightweight, additive manufactured structures.

The Saltygloo takes its clues from the Inuit Igloo, both in form and concept. In the landscape of the San Francisco Bay Area natural power from the sun and wind, produce 500000 tonnes of sea salt each year. The salt is harvested from 109-year-old salt crystallization ponds in Redwood City. These ponds are the final stop in a five-year salt-making process that involves moving bay water through a series of evaporation ponds. In these ponds the highly saline water completes evaporation, leaving 8-12 inches of solid crystallized salt that is then harvested for industrial use. From this landscape, Rael and San Fratello theorize a new kind of architecture created through the lens of 3D printing and computer-aided design. The Saltygloo is made of a combination of salt harvested from the San Francisco Bay and glue, a "salty glue", which makes an ideal 3D printing material, one that is strong, lightweight, translucent and inexpensive.

To build the Saltygloo, 336 translucent panels were 3D printed using this unique material invention. Each panel recalls the crystalline form of salt and is randomly rotated and aggregated to create a larger structure where all tiles in the structure are unique. The form of the Saltygloo is drawn from the forms found in the Inuit Igloos, but also the shapes and forms of tools and equipment found in the ancient process of boiling brine.

The panels are connected together to form a rigid shell that is further supported with lightweight aluminum rods flexed in tension, making the structure extremely lightweight and able to be easily transported assembled in only a few hours.

The translucent qualities of the material, a product of the fabrication process and the natural properties of salt, allow for natural light to permeate the space and highlight the assembly and structure and reveal the unique qualities of one of humankind's most essential minerals.

The Saltygloo is on display at the Museum of Craft and Design in San Francisco as part of the New West Coast Design Exhibit.



boiling brine



crystallizer in Redwood City





SALT-Y-GLOO under construction



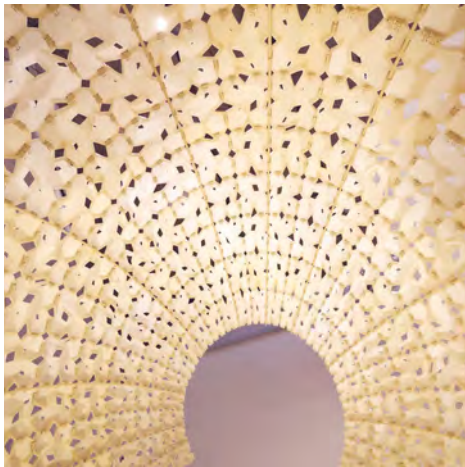
Construction in the studio



Single tile



Interior view



Interior



Single salt tile



SALT-Y-GLOO at the Museum of Craft and Design

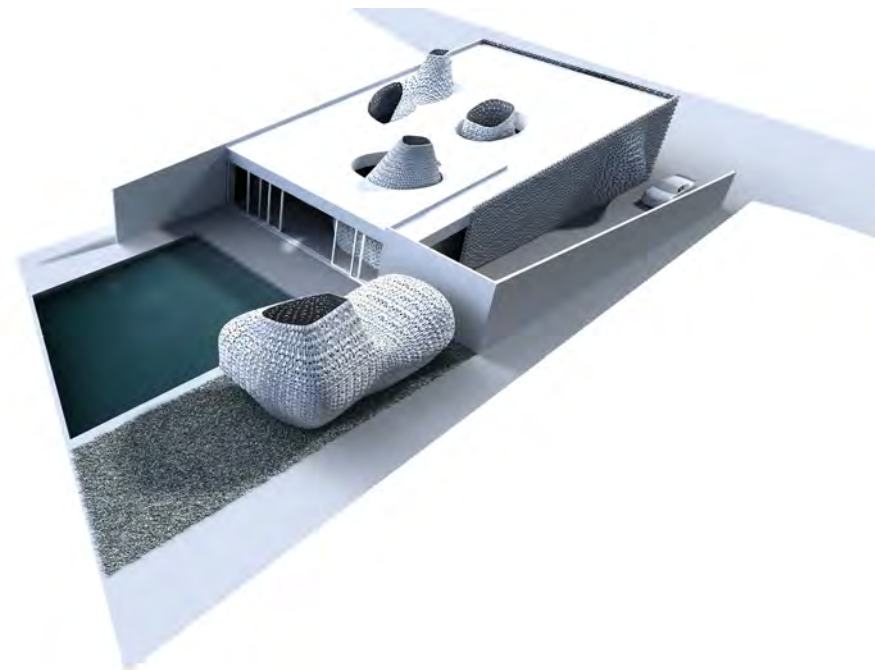
YINSHUA DASHA / 3-D PRINTED HOUSE

Project Date: May 2013-October 2013
Project Team: Ronald Rael, Virginia San Fratello, Seong Koo Lee, Eleftheria Stavridi

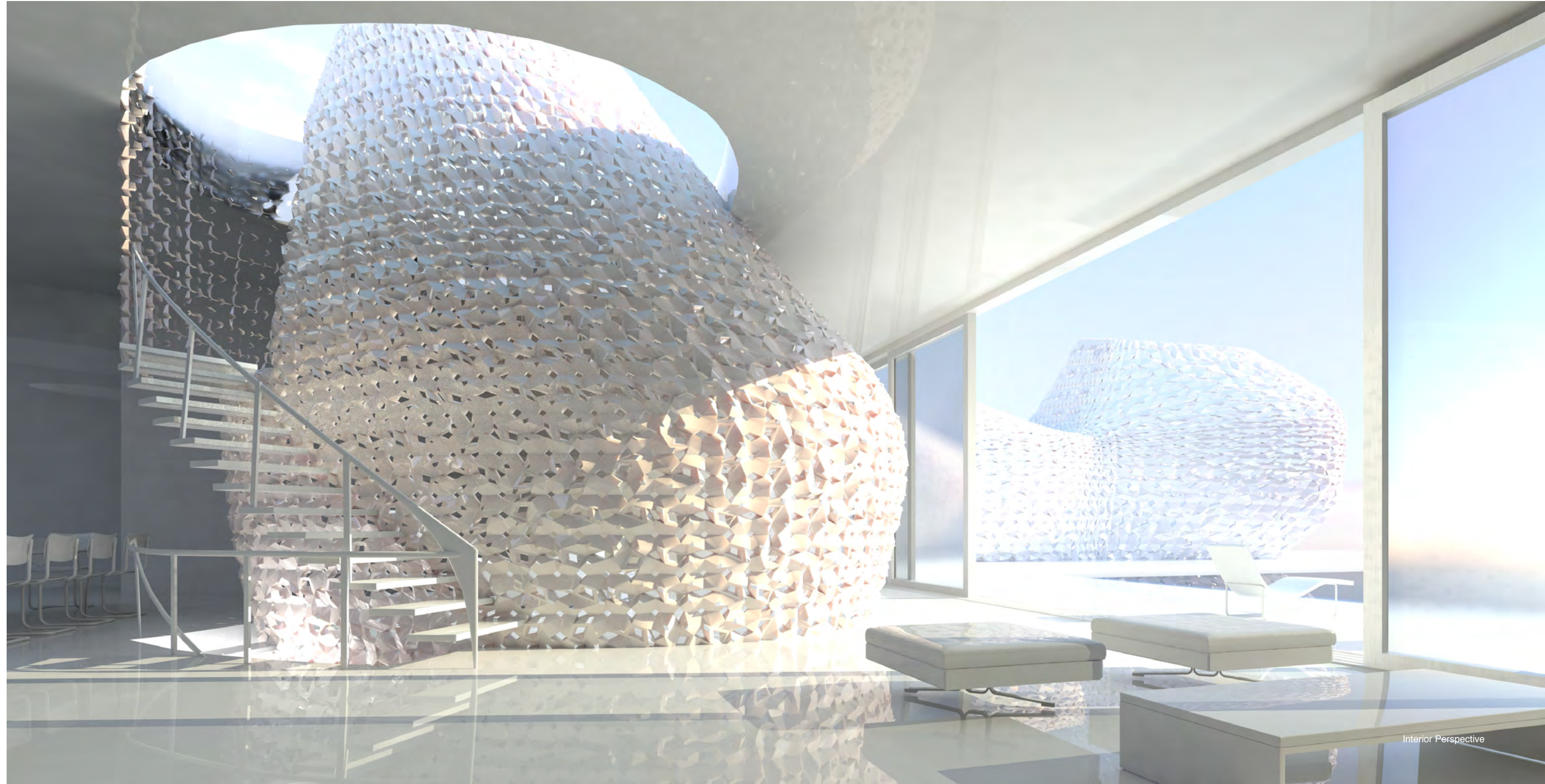
The Yinshua Dàshà is a case study in 3D printing major components of a house. The exterior walls of the Yinshua Dàshà will be constructed of concrete, pastered white, with portions of the exterior cladding that are 3D printed using a black foundry sand. Inside, the private spaces of the house—the bedrooms, bathrooms and family dining room are housed in translucent 3D printed double height and two story tall vessels constructed of salt. Outside, adjacent to the pool, is a free standing 3D printed pool cabana.

The house explores juxtapositions between traditional construction methods and 3D printed manufacturing. It also explores relationships between public and private within the organization of the program of the house.

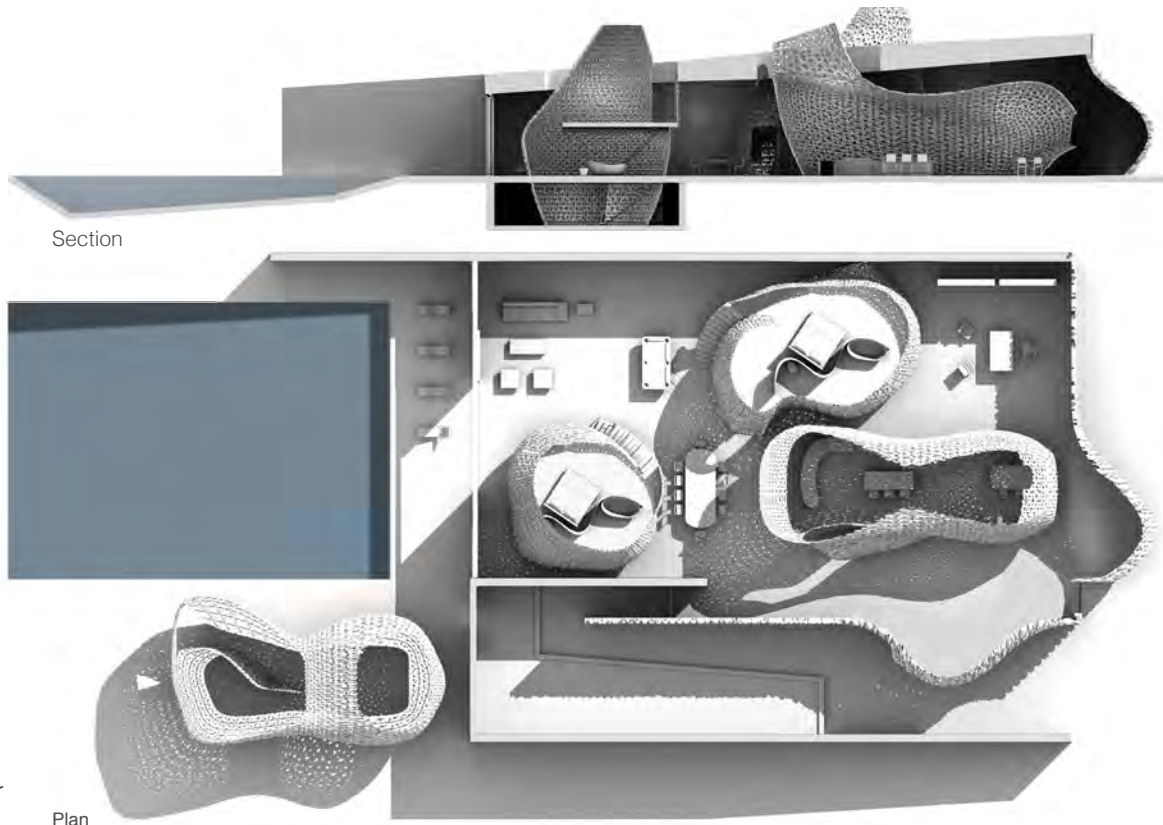
Translucency, porosity and openness are all tested in the different material conditions and inform the optics, lighting, views and thresholds between adjacent spaces.



Site Plan



Interior Perspective



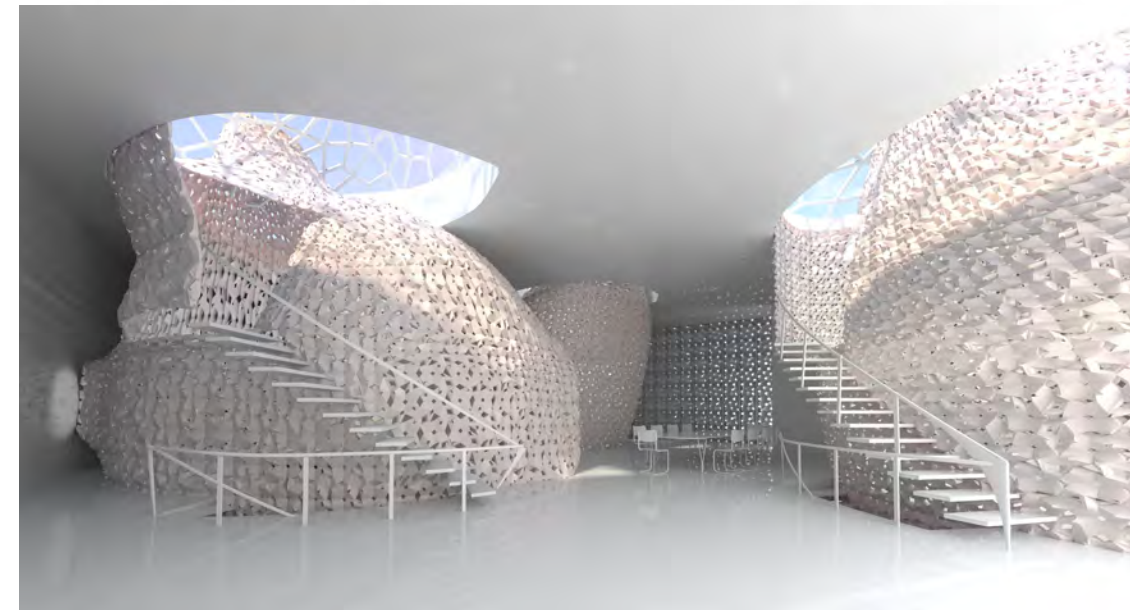
Section

Plan

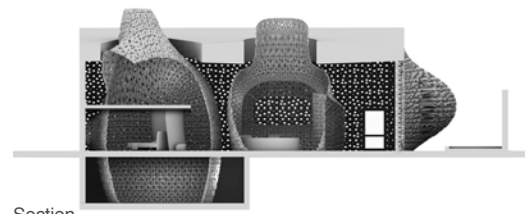
The Salt-Y-Gloo acts as a prototype for the interior volumes within the 3D printed house. Material development, manufacturing techniques, fabrication assemblies and material effects have been explored through the prototype and found to have desirable results for use in the interior of the house.



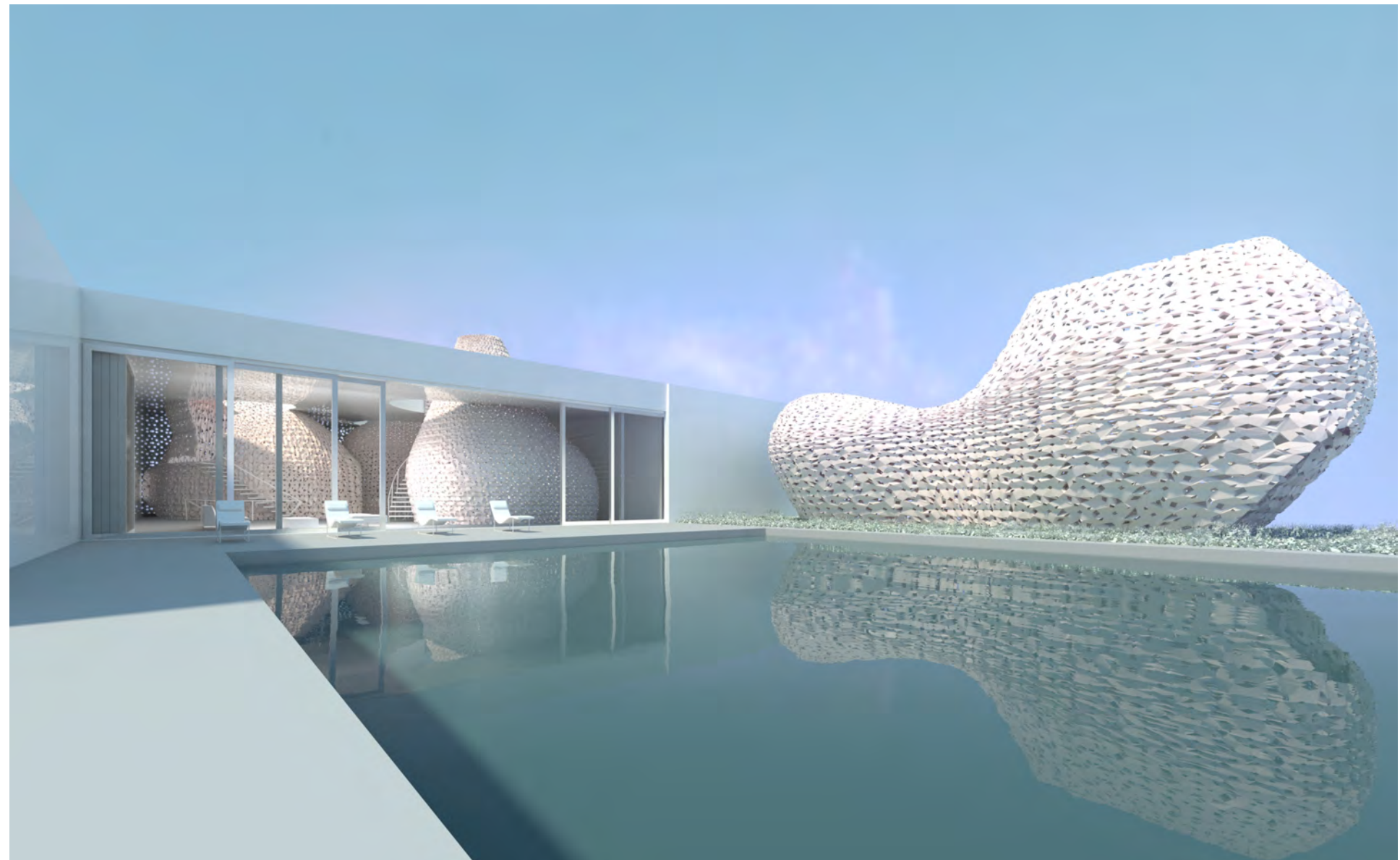
Photograph of 3D printed interior



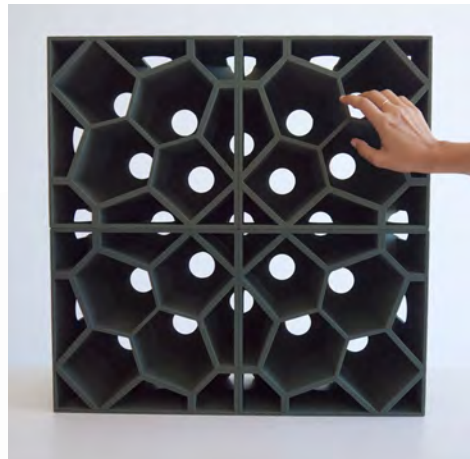
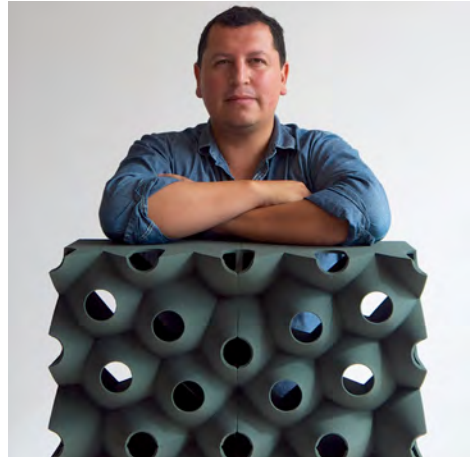
Interior Perspective



Section



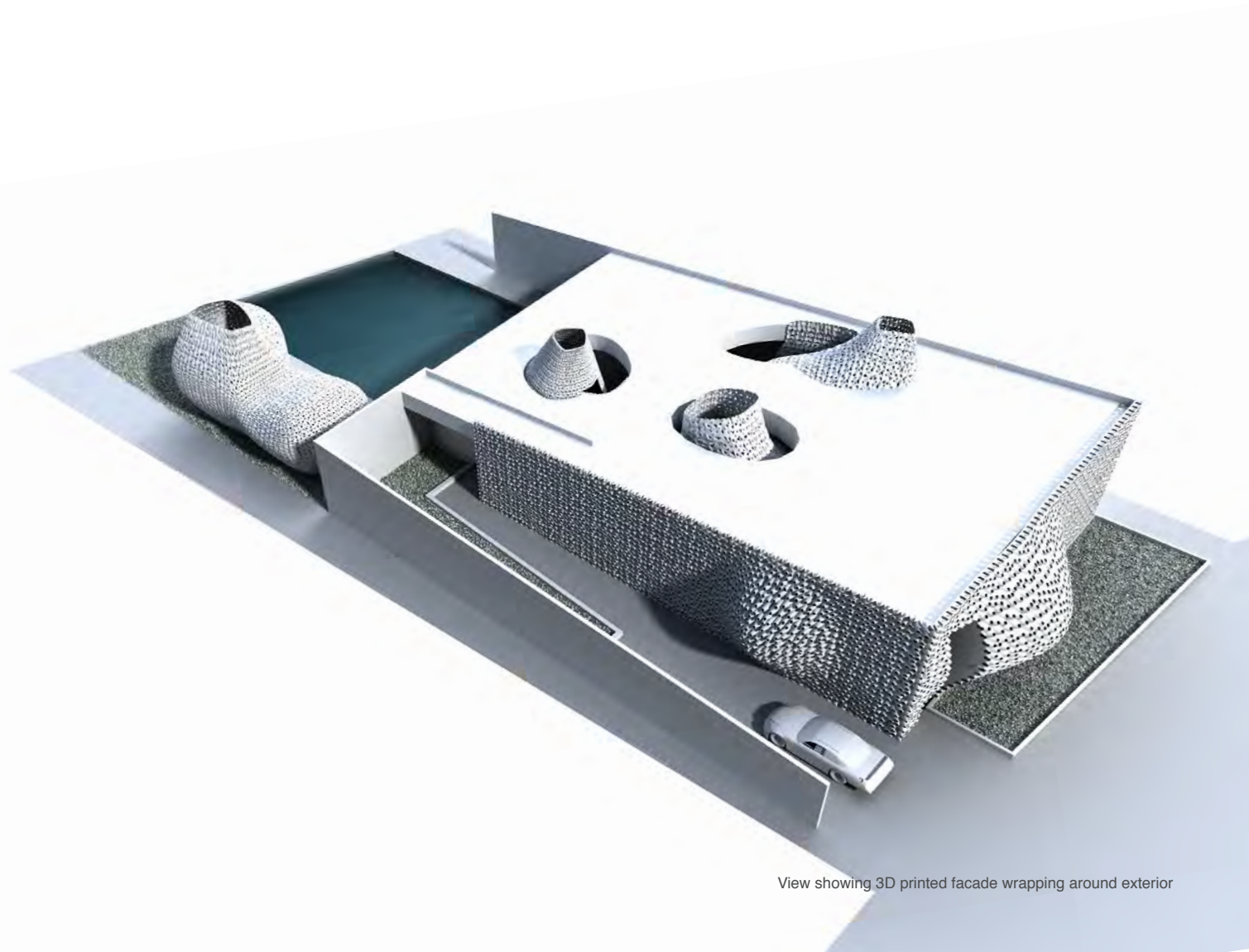
Exterior View



Interior side of 3D printed block



Close-up of PicoRoco Block used on exterior cladding



View showing 3D printed facade wrapping around exterior



3D printed prototype of building facade

SOL GROTTO

Project Date: 2012

Project Team: Ronald Rael, Virginia San Fratello, Bryan Allen, Chase Lunt, Dustin Moon, Kent Wilson, Bridget Basham

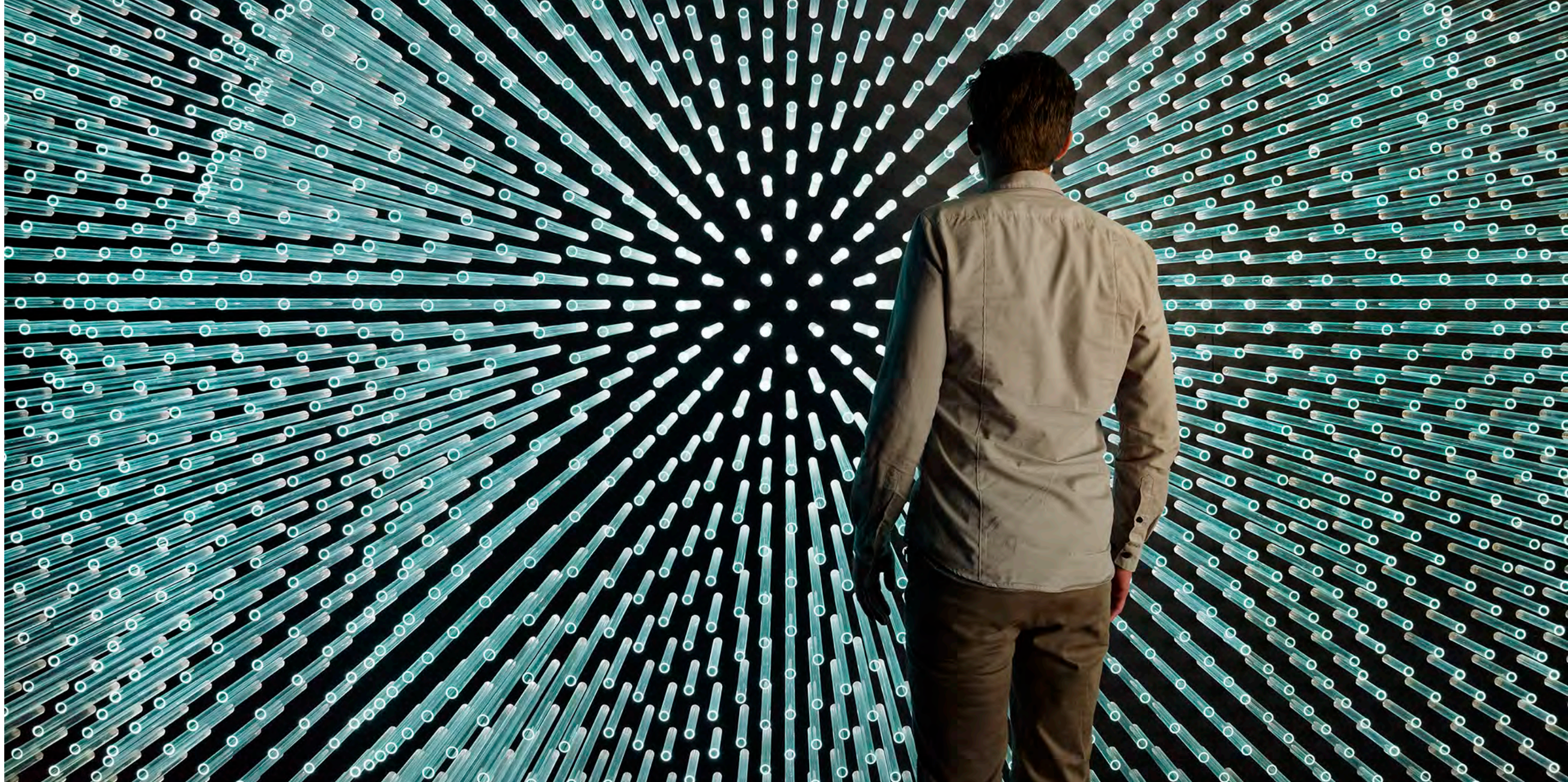
SOL Grotto is a spartan retreat—a space of solitude and close to nature where one is presented with a mediated experience of water, coolness and light . The SOL Grotto also explores Solyndra's role as a company Sh*t Out of Luck. 1,368 of the 24 million high tech glass tubes destined to be destroyed as a casualty of their bankruptcy, are used in the installation.

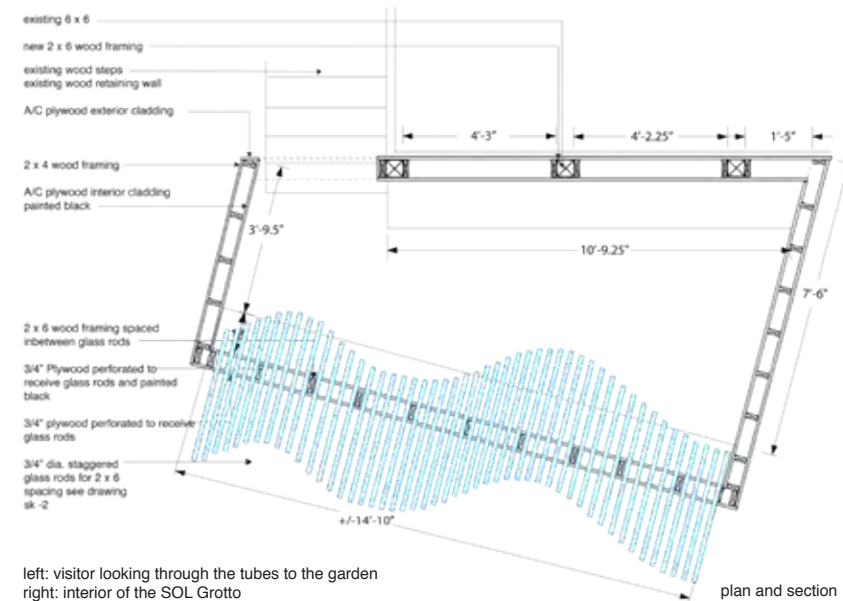
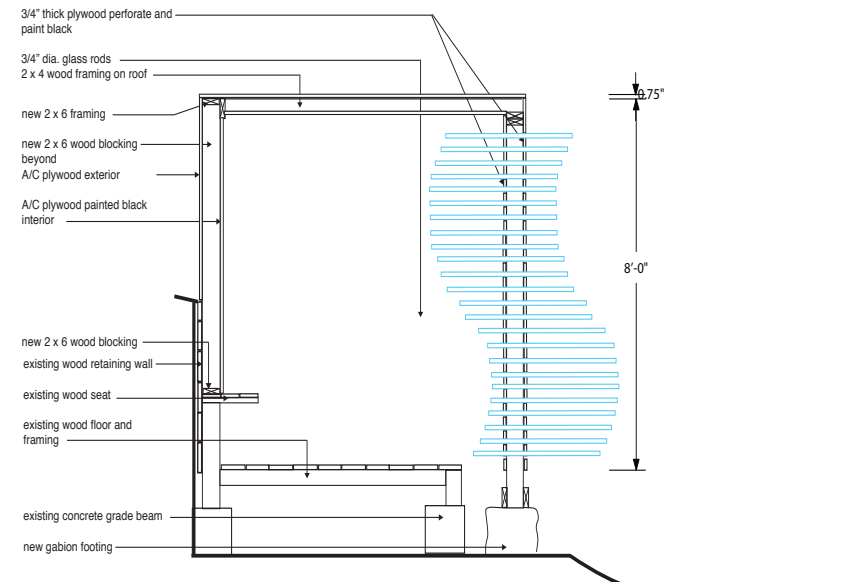
The project is located in the Berkeley Botanical Garden alongside Strawberry Creek in the California Native section as part of the exhibit Natural Discourse, which is a collaborative project between The University of California Botanical Garden at Berkeley and a multi-disciplinary group of artists, writers, architects and researchers who have been invited to spend time in the Garden's extraordinary collection of plants, engage with the horticulturists and develop new site specific work.

The tube's original role as a light concentrating element is extended to transmit cool air into the space via the Venturi effect, to amplify sounds from the adjacent waterfall via the vibrations of the tubes cantilevering over the creek, and to create distorted views of the garden.

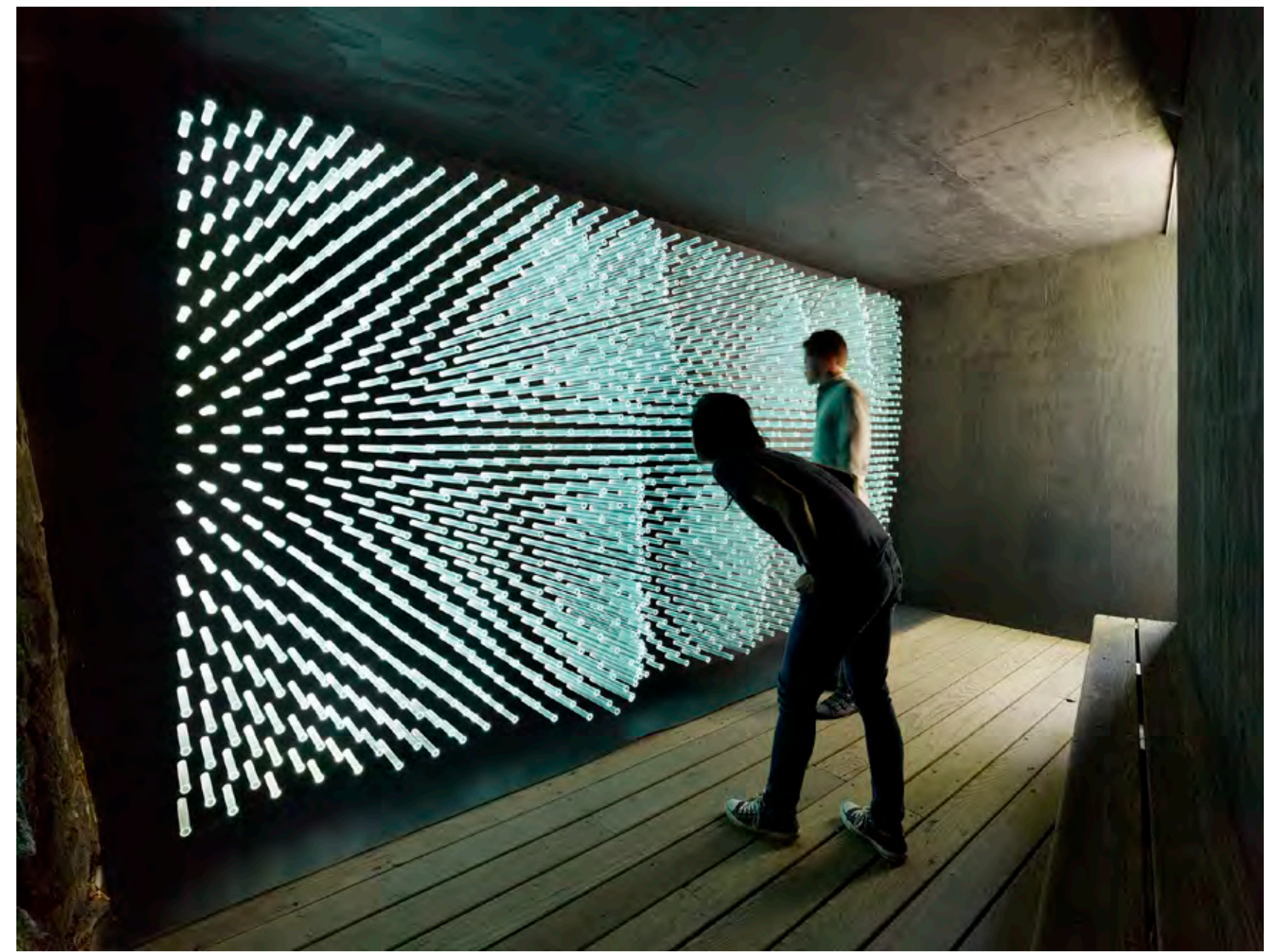
The glass tubes are illuminated electric-blue naturally from the direct and ambient light that is conducted through the glass causing each tube to change in intensity throughout the day. Collectively, the tubes take on the form of a cave wall or a waterfall, evoking Plato's Allegory of the Cave where shadows, light and sounds call reality into question. The view through the rods is simultaneously kaleidoscopic and mesmerizing and has become home to several insects found in the garden. The sound of a waterfall is present inside The SOL Grotto and the combination of sound, light, views and coolness filtering through the cracks in the flooring creates a highly sensorial space.

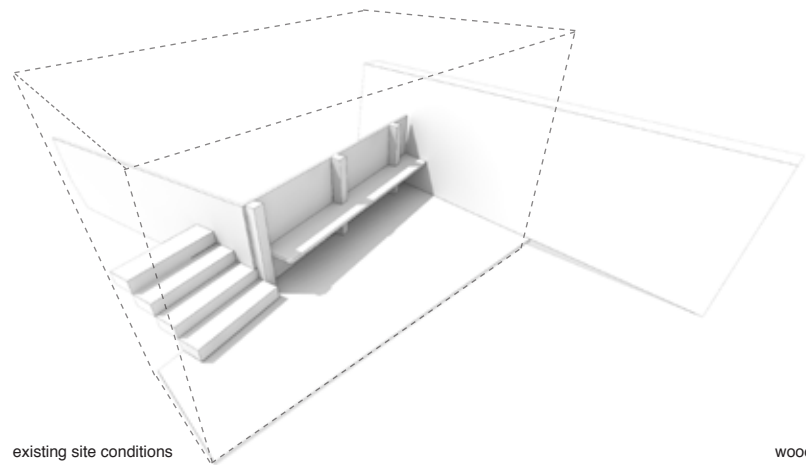
right: elevational view of SOLYNDRA tubes



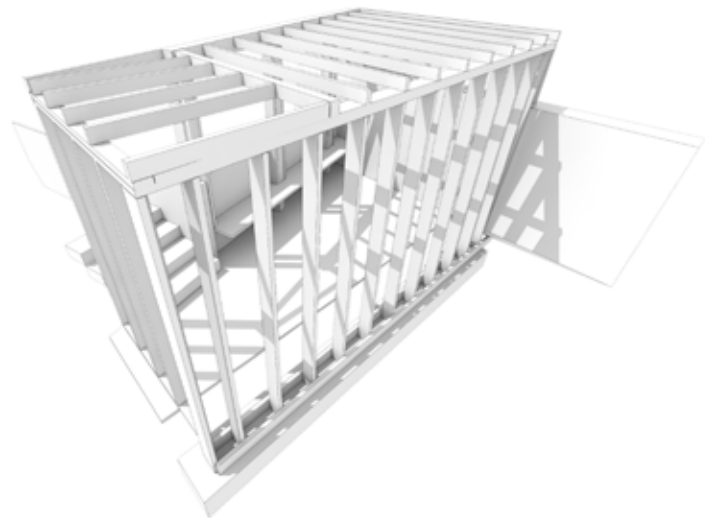


left: visitor looking through the tubes to the garden
 right: interior of the SOL Grotto

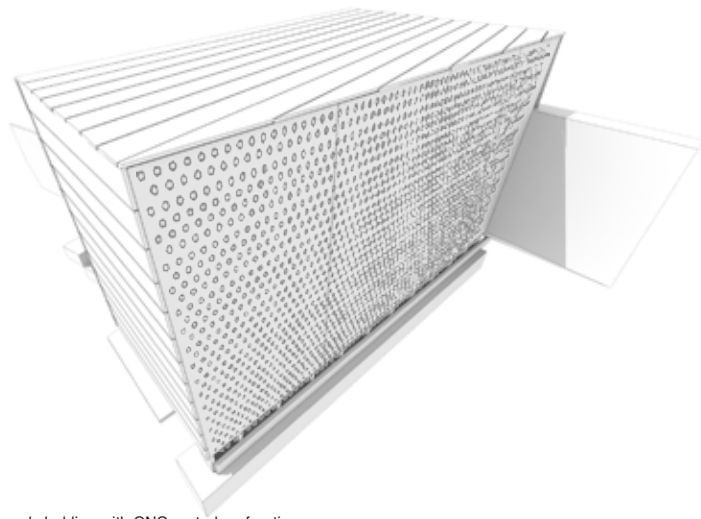




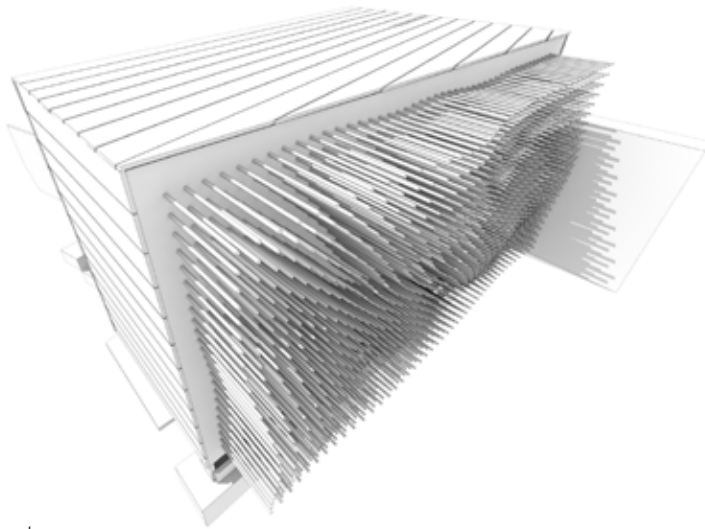
existing site conditions



wood frame



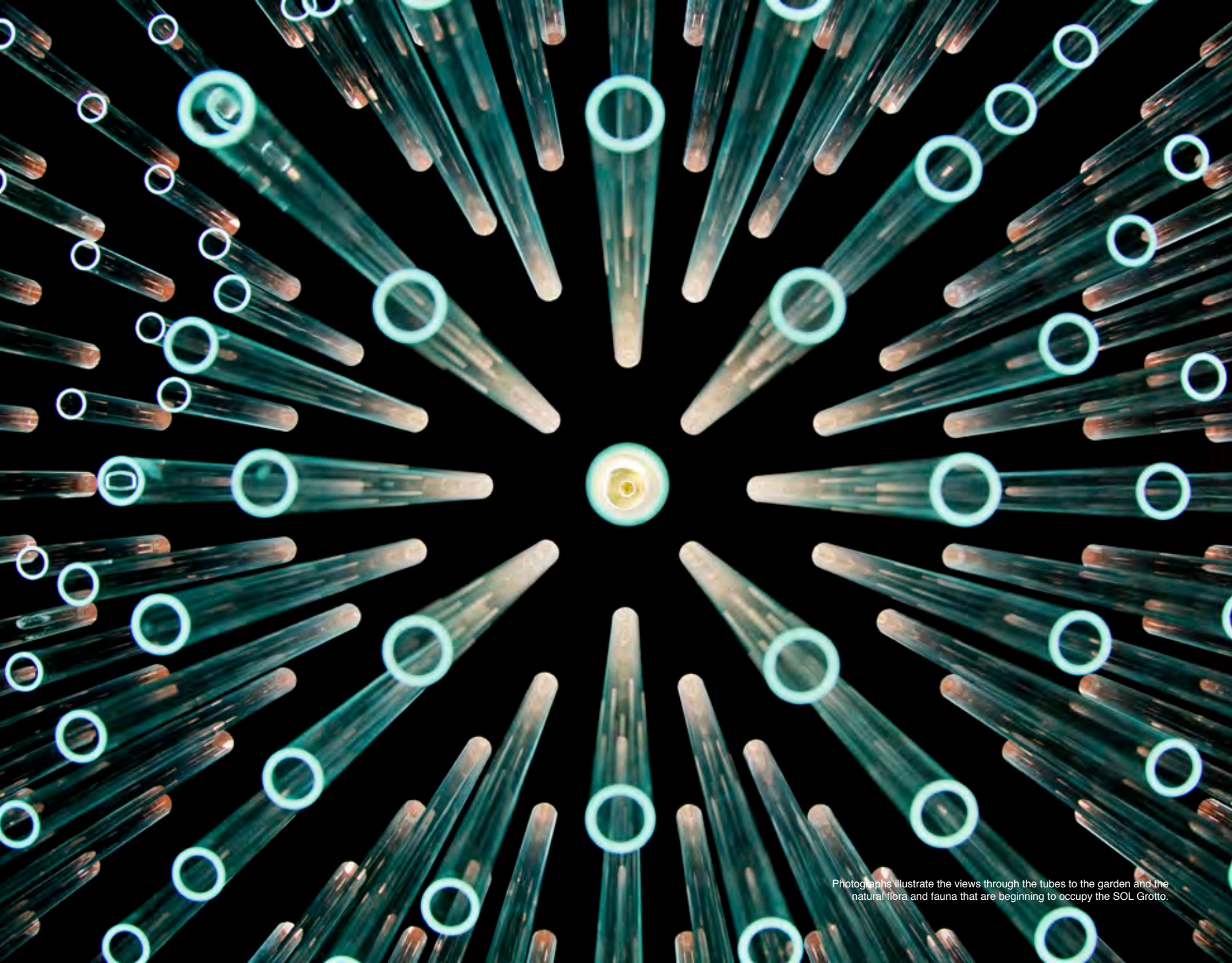
wood cladding with CNC routed perforations



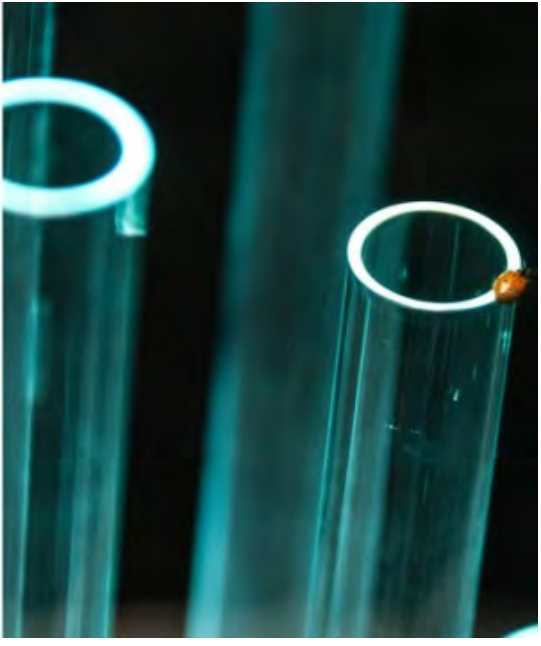
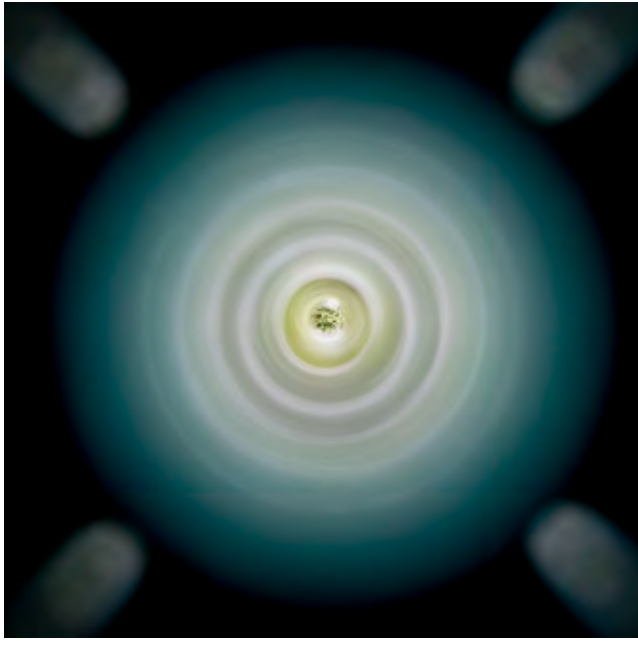
SOLYNDRA glass rods



right: SOL Grotto in the Botanical Gardens at dusk



Photographs illustrate the views through the tubes to the garden and the natural flora and fauna that are beginning to occupy the SOL Grotto.



STRAW GALLERY

Project Date: 2011

Project Team: Ronald Rael, Virginia San Fratello

The Straw Gallery was designed for HEDGE Gallery for the 4th annual sf20/21 San Francisco Art and Design Show held at the Festival Pavillion, Fort Mason Center. The temporary gallery was on display from September 15th through 18th opening with a benefit for the San Francisco Museum of Modern Art's educational programs.

The gallery is an aromatic, enveloping, and raw space in contrast to the refined and modern elements that are displayed within. The gallery consists of three unfinished, blackened steel display niches interwoven within the walls of straw bales. Each niche is an excavation that is filled with HEDGE's highly edited visions of 20th and 21st century design, art and craft, presented at different levels relative to the eye and the hand of the visitor.

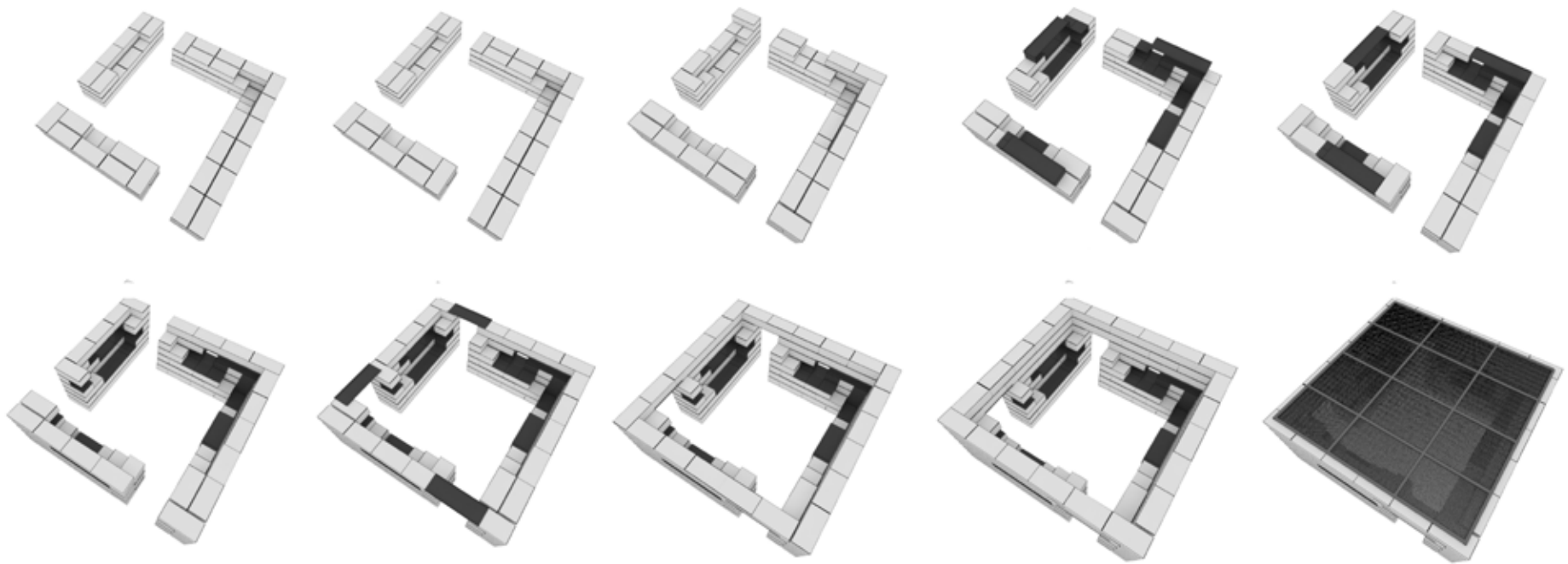
The juxtaposition of the two materials, steel and straw— one industrial and the other representing a storied agrarian history—heightens the tactile sensibilities as one navigates between the richness of the hay and the clean surfaces of the steel compartments. Straw is an incredibly effective acoustic buffer and the walls are in most places two bales thick and placed strategically to block views to the exterior as you enter the space. The experience within Straw Gallery is one of quiet, calm and focused observation in contrast to a busy exterior.

The several hundred wheat straw bales, an agricultural by-product used for bedding, roughage and fuel, used to construct the gallery were returned to the feed store. The steel shelves were recycled and will be used to construct furniture and shelving in San Francisco.



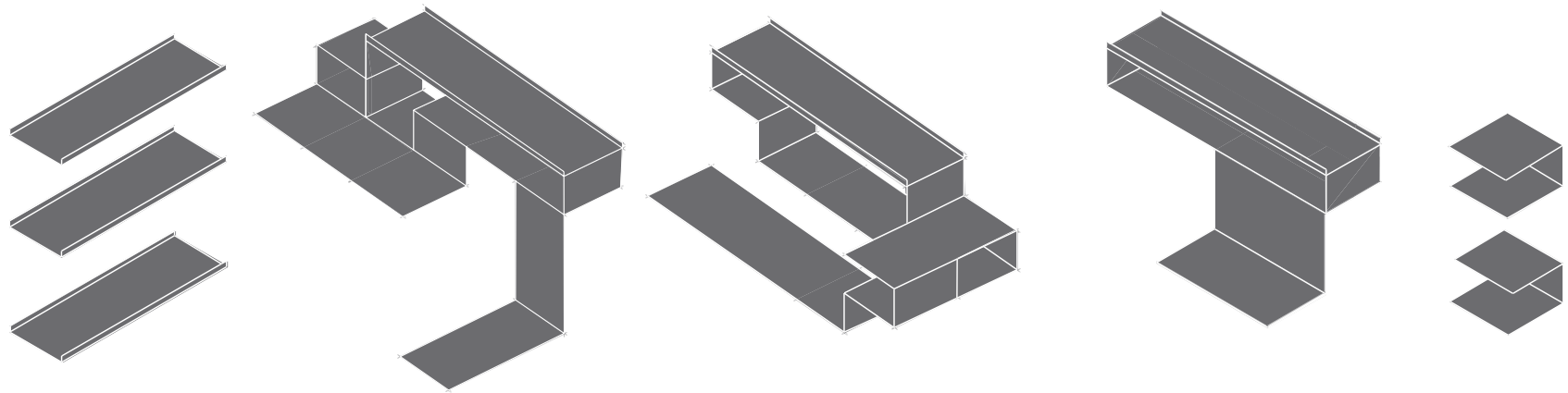
above: ceiling perspective and floorplan right: view from the exterior





above: stacking sequence
right: elevational view of straw gallery in site





above: steel shelves
 below: details of steel inserted into the straw
 right: view of the interior showing the display of objects on straw and steel shelves



“This project reinforced something for us as architects,” said Rael, a professor at U.C. Berkeley. “Our designs can send a social and political message, which is often hard to deliver. Clients don’t hire you to make social commentary, but we had the chance to express that through our work.” Inspired by a mosque made entirely of cardboard that Rael and San Fratello discovered in a Yemenite refugee camp a few years ago, the “Sukkah of the Signs” boasted roughly 280 signs, covering a 10-foot wooden structure of lumber pieces. The signs came from throughout the Bay Area, mostly in San Francisco. Rael and San Fratello drove down Van Ness, stopped at freeway exits and wandered through the Haight District. Sign bearers led them to others in Golden Gate Park. Rael even put an ad on Craigslist to get more.

“You see these guys on the streets all the time brandishing these signs,” Rael said. “We thought they were amazing and beautiful works of art.” Convincing the homeless of that took some time. Rael remembered how awkward it was initially approaching their subjects to ask for their signs — in many cases, it was all they had. He gradually learned that listening to their stories, coupled with an offer to buy the sign for a couple bucks, usually translated to success. Rael met people of all ages, races and religious backgrounds. They clutched signs that were humorous, serious, thought provoking and strange. One woman held a sign that said: “Need money for a new pair of shoes.” She didn’t have legs.

He approached people who couldn’t talk or write, grasping signs that made no sense as an act of desperation. In the bowels of



Examples of signs collected from San Francisco, Oakland, San Jose, San Diego, Los Angeles, Venice, Las Vegas and Denver

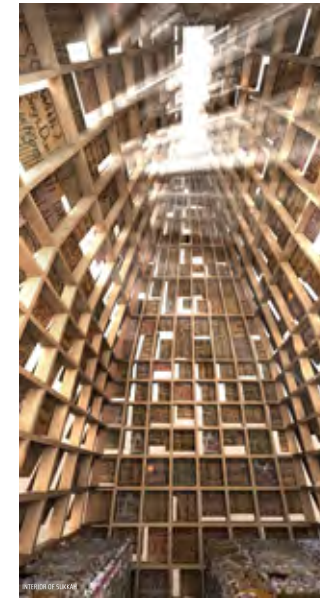


Above: People who contributed their sign to the project
Below: Homeless man in Union Square Park in front of Sukkah of the Signs

Golden Gate Park, he talked to individuals who lost their jobs and couldn't make rent, stuck in a vicious cycle they could not escape. "I was already empathetic toward people on the streets," Rael said. "To a greater extent, I understand the reasons of why they are there. Some accuse [the homeless] of being lazy or wanting to be on the streets, but so many have no choice."

Creating the "Sukkah of the Signs" inspired Rael and San Fratello to start the Homeless House Project, whose aim is to bring attention to homelessness in America. Rael hopes to publish a book with images of the signs used in the sukkah. "When we learned about the concept of the sukkah, it was a nice way to think about the contemporary issues of homelessness in the U.S. and the interesting stigmas that arise," Rael said. "In a sense we were waiting for a project like Sukkah City. We had the signs and it was a good opportunity to marry the two projects."

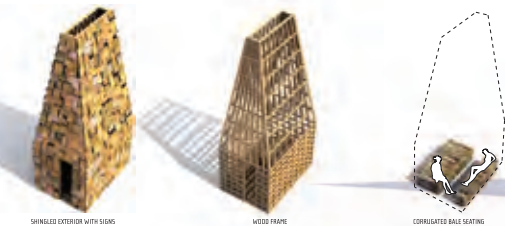
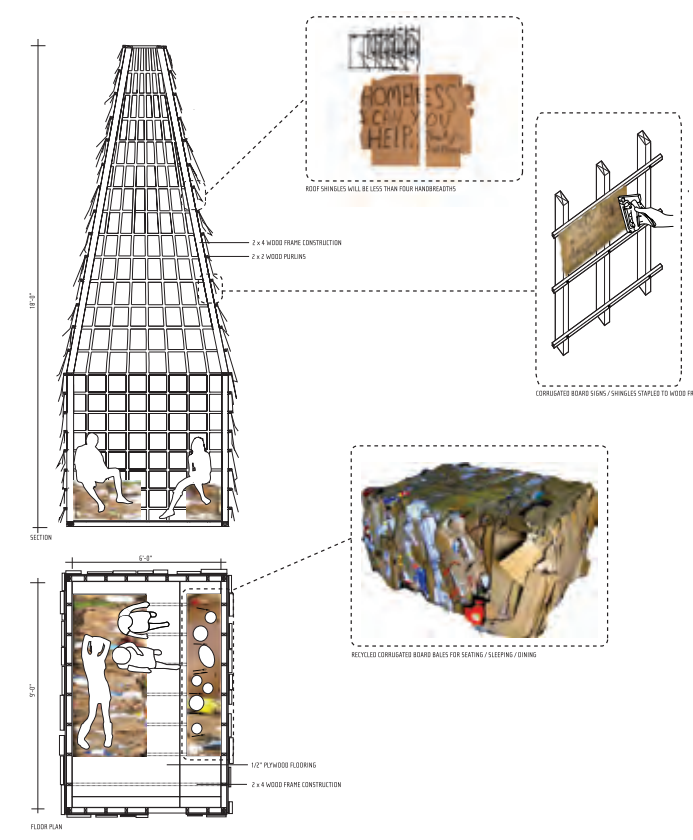
Erected for one week each fall during the festival of Sukkot, the sukkah is traditionally a space for sharing meals, entertaining, sleeping and rejoicing. Its construction must adhere to precise parameters: the structure must be temporary, have at least two and a half walls, be big enough to fit a table, and have a roof made of shade-providing organic material through which one can gaze at the stars. "We've inherited this tradition of sukkah building, but very few of us know the real rules or even build them anymore," said Reboot Executive Director Lou Cove. "For those who do it's very nice, but it's not a widely shared creative enterprise. The idea of making the sukkah an architectural piece was a way of reinvigorating that tradition." While the sukkah's religious function is to commemorate the temporary structures



INTERIOR OF A CARIBBEAN SUKKAH AT A SOMALIAN REFUGEE CAMP IN YEMEN

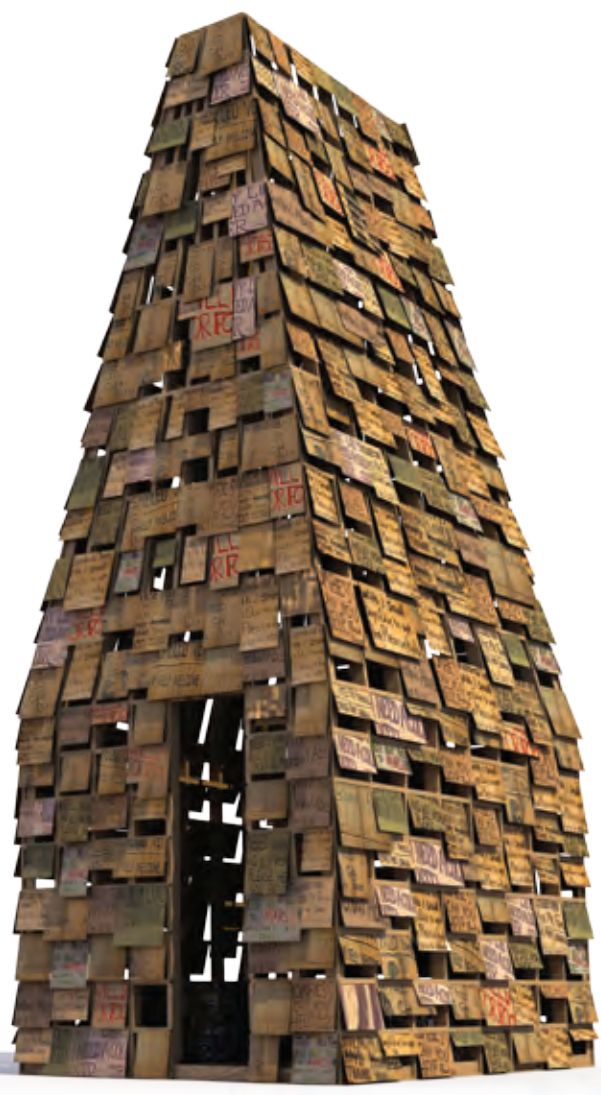
CONCEPT:

Just as the sukkah commemorates shelter provided during the forty desert-wandering years of Exodus, the design for our sukkah brings attention to the contemporary state of homelessness and wandering within the United States and is clad with signs made by the homeless and destitute. By purchasing homeless signs, from the individuals who made them, we are also contributing to a need for someone who might not otherwise be able to eat today in honor of the primary and traditional role of sukkah, which is a feast of bounty, of hospitality, and of welcoming strangers. Additionally, the corrugated board shingles are made of the fibers of hand-cut trees, therefore one could equate them to the historical use of branches on the sukkah roofs. The frame of our sukkah tapers as it moves up toward the sky to draw the eye up and also to provide a smaller framework for the shingles that are less than 4 handbreadths—reaching directly to the presence and scale of the hand in each of the handmade signs. This sukkah, if built for Sukkah City, will be auctioned and the funds donated to a homeless shelter in New York City.



STATISTICS:

—It is estimated that between 40% and 50% of homeless single adults residing in the municipal shelter system have a chronic mental illness.
 —Approximately 90% of homeless New Yorkers are black or Latino, although only 53% percent of New York City's total population is black or Latino.
 —Almost 17% of residents of the single adult shelter system are employed.
 —Each year 100,000 New Yorkers experience homelessness.
 —Each night, over 38,000 homeless individuals sleep in the New York City shelter system. This includes more than 16,000 children and 8,000 single adults.
 —Nearly 1-in-20 New York City residents have experienced homelessness.
 —There are over 1,000 soup kitchens & food pantries in NYC and 2,700 in NY State serving 2 million New Yorkers annually. They will serve 60 million meals this year to hungry men, women & children.
 —Families make up 70% of New York City's homeless shelter population.
 —More than one-in-four children in NYC live in poverty. A typical homeless child is under 5 years old.
 —Over half of homeless mothers in New York City have a history of domestic violence.
 —Nearly one-in-five homeless parents were in foster care as a child.



WHO IS HOMELESS RIGHT NOW?

Daily Census for July 29, 2010
 —8,087 Families With Children
 —1,310 Adult Families
 —7,376 Single Adults
 —35,148 Total Individuals are homeless in NYC today
<http://www.nyc.gov/html/ohs/html/home/home.shtml>



in which the Israelites dwelled during their exodus from Egypt, it is also a symbol of the transience of life as expressed in architecture.

Contestants did not have to be Jewish. The teams behind the 12 finalists received guidance from Judaic experts on how to craft a kosher sukkah. Neither Rael nor San Fratello are Jewish, but that didn't matter. "At this point, I think I'm much more familiar with the rules of constructing a sukkah than a lot of Jews," Rael said with a laugh. "Learning about lesser-known traditions of Judaism was really interesting." From dawn until dusk Sept. 19 to 20, nearly 200,000 passers-by wandered through Sukkah City in Union Square Park to marvel the sukkahs. "It turns out that architects viewed Jewish law in a way we could not anticipate," Foer said. "Working with the design constraints handed down for thousands of years was inspiring. They immediately understood how many levels of residence there are in the sukkah — what it means to be impermanent or homeless, to the role it plays in reconnecting Jews with their agricultural past. "All that is bound up with esoteric rules, some of which are playful," he continued, noting that a sukkah may be built out of an elephant's skeleton but no other animal's. "If that's not an invitation to do something weird, then I don't know what is."

Excerpted from the article, "A booth with a view: Oakland architects build sukkah using signs from the homeless" by Amanda Pazornik. J! Weekly, Thursday, September 23, 2010.

Photo: Nate Levy
Sukkah City, NY



PRADA MARFA

Project Date: 2008

Project Team: Ronald Rael, Virginia San Fratello

On July 13, 2005, 22 miles north of the U.S./Mexico border, patrol agents from the Marfa Sector of the United States Border Patrol surrounded five people traveling through the Chihuahuah Desert in West Texas. Suspecting illegal activity, the agents had been informed that illegal immigrants were detected by the tethered aerostat radar system hovering overhead that provides counter-narcotics and border crossing surveillance and can distinguish targets down to a meter across at ground level.

It is not uncommon that coyotes, smugglers involved in the profession of human trafficking, drive the desolate roads searching for “wets”, the derogatory term for illegal immigrants, in the vast desert expanse surrounding Marfa. When the five suspects were questioned on the nature of their business the answer was not so clearly comprehended by the Border Patrol. The suspects were a gallery curator, a photographer, an artist, and two architects who were discussing the selection of the future building site of Prada Marfa, a minimalist sculpture that replicates the luxury boutique where the Fall 2005 line of Prada shoes and bags were to be displayed.

The juxtapositions between the United States and Mexico, or between wealth and poverty, that are clearly evident in the Big Bend region of Texas define a landscape charged with contrasting conditions in which Prada Marfa is built. The immense ranches that comprise the area, each several thousand acres or larger, often appear to be abandoned, but are owned by many of the wealthiest people in the United States. Most of the ranch owners have ties to oil, and more recently, dot com wealth, including a ranch owned by Amazon.com CEO and founder Jeff Bezos, where he has announced plans to construct a spaceport just down the road from Prada Marfa. Just as each of these polarities are somehow equally at home and “foreign” to this environment,

so to is Prada Marfa, with its delicate interiors and massive walls, schizophrenically positioned in the geo-political and cultural framework in which it is built. In fact, the process of building the project is as simultaneously contextually grounded and extrinsic as the work itself.

The primary building material used to construct Prada Marfa is dirt. While it may seem odd to construct a building with soil, particularly one with the associated title Prada, building with earth is actually quite common. It is estimated that currently 1/2 of the world’s population, more than 3 billion people on 6 continents, lives, works, or worships in buildings constructed of raw earth. This makes fragmental soil, not to be confused with other materials that come from the ground, such as stone, cement, or metals derived from ore, the most ubiquitous building material on the planet. Earth buildings can also be found in almost every climatic zone on the planet, from the deserts of Africa, Australia and the Americas to England, Denmark, China and the Himalayas.

Whereas earth is a material that westerners commonly perceive to be reserved for the small, humble structures of developing countries, there are earth buildings of almost every architectural type in use by every economic and social class. Examples of churches, hospitals, museums, embassies, and even an airport demonstrate the wealth of earth building types found throughout the world. Typically, earth is also considered to be a building material only used in rural environments, but earth architecture can be found just as easily in contemporary urban environments. The world’s first skyscrapers, 11 story buildings first constructed over 500 years ago, continue to be constructed entirely from mud in the dense cities of Yemen. Perceived as a material of low quality, earth buildings also represent the oldest extant buildings

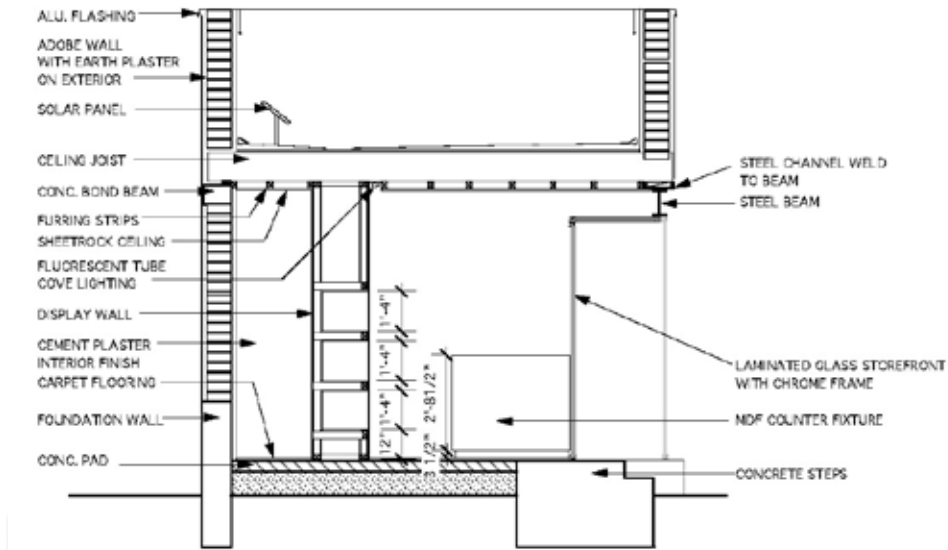
right: Prada Marfa at dusk



on the planet. Using approximately 7,000,000 mud bricks, the Ziggurat at Ur dates back to 4000 B.C. Taos Pueblo constructed between 1000 and 1450 A.D., in New Mexico is the oldest continuously occupied dwelling in North America and was also constructed from raw earth.

While earthen architecture is often considered the building material of the very poor, many wealthy residents inhabit the vast mud brick suburbs of Santa Fe, New Mexico. Ronald Reagan's former Ranch House (also known as "The Western White House") in California, Saddam Hussein's childhood home in Iraq, and Chairman Mao's childhood home in China were all constructed of mud brick, which speaks to the great breadth of ideological extremes represented by this omnipresent material. Now we can add Prada Marfa to this "A-List" of earthen architecture – the first Prada related building constructed of mud.

A large percentage of buildings in the region surrounding Prada Marfa, are also traditionally constructed of mud brick. Often made directly from soil excavated from the build site, mud brick, called adobe in Texas, is a brick made from soil mixed with water and straw and left to dry and harden in the sun. Historically, this was the traditional construction method used by the Mexican and Mexican American population. In the case of Prada Marfa, the 2,500 mud bricks used to construct the building were made by machine and express shipped to the site from a mud brick yard in Alcalde, New Mexico, over 500 miles away. Not unlike the luxury goods that fill the faux-boutique, the mud bricks arriving from this adobe yard are primarily manufactured to supply a growing population of southwestern affluence enamored with the romantic notion of living in a house constructed of earth. Increasingly, the demands made by wealthy interstate immigrants longing for mud brick residences have had a dramatic effect on the cultural and built landscape.



left: adobe bricks and concrete mortar walls
right: 2005 collection of Prada shoes and purses

At one time, buildings made of earth were looked down upon, and ultimately made illegal to construct for several decades. Today, however, mud brick's increasing popularity has created a demand for the material that has transformed it into a status symbol in the southwestern United States. The humble earthen houses that comprise Marfa's residential district now fetch several hundred thousand dollars from New Yorkers, Houstonians and Los Angelenos. Thus, what was once a vernacular tradition has transformed into a capitalist driven process that often leaves the traditional descendants of earth dwellers unable to afford mud, forcing them to switch to an ironically more affordable consumption of prefabricated mobile homes and concrete-block houses. Much like the knockoffs of Prada bags that are a consequence of the high price tag of authentic Prada merchandise, adobe knockoffs, faux-adobes, are the preferred style of manufactured southwestern homes.

Unlike traditional mud brick buildings, whose bricks are laid in an earthen mortar, the mud bricks used to build Prada Marfa were set in a cement mortar. The juxtaposition between the industrial material of cement and the traditional mud brick could be read as a nod to Donald Judd, but the combination also represents the bipolar nature of the context in which it is built. In Marfa the use of industrially produced cement, introduced by the U.S. military

— each leaving built traces in the landscape that are evident today. By crossing a border between art as commodity and commodity as art, Prada Marfa offers a conceptual interpretation of the latest wave of occupation in the region - Judd and the gentry of gallery owners, artists and art lovers who are his followers. It also raises questions regarding the consequences of this history.

While Prada Marfa was not constructed with illegal labor, mud brick construction is labor intensive and labor provided by illegal aliens is cheap. The demand for inexpensive labor in America coupled with a search by immigrants for higher paying jobs work hand in hand to prompt people to cross the desert by foot. Although it is difficult to know exactly how many immigrants cross the border in the Marfa sector each year, in 2005 there were

10,536 illegal border-crossing apprehensions and approximately 12 migrant border-crossing deaths. Most of these deaths are attributed to heat stroke or hypothermia. From a distance, illegal aliens walking through the desert at night might perceive the illuminated building to be a possible source of water or shelter. However, upon closer inspection, Prada Marfa reveals an irony that connects the history of the region while also offering a prognostication. It is not uncommon for one's shoes to wear out during the arduous journey across the desert. In a desperate attempt to protect tired feet from the rough terrain, immigrants are known to try to fashion shoes from the only material available — the yucca plants that dot the landscape. The contrastingly opulent presentation of meticulously organized shoes and bags housed within the familiarity of mud brick walls also foretells the future — a growing socio-economic polarity at a local and, indeed, global level. — From the essay "House of Prada / House of Mud", Prada Marfa Catalog, Ronald Rael
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left: Boyd Elder visiting Prada Marfa

NOWHERE

Project Date: 2013

Project Team: Ronald Rael, Virginia San Fratello

The Museum of Nowhere is a remote frontier for art, design, craft and architecture. NOWHERE's aim is to recognize that in a century where greater than 50% of the population of the planet is migrating to cities, a rural community can also be a SOMEWHERE of rich cultural, geographic, historic and aesthetic importance. NOWHERE (or NOWHERE as the locals like to say) demonstrates this by combining the work of internationally recognized artists with local artists in the small town of Antonito, Colorado (pop. 779).



Nowhere sign by Golden West Sign Arts



Interior: installations by Ehren Toole, Elmgreen + Dragset, Future Farmers and Stephanie Syjuco among others

The museum is located in an abandoned building that was previously the town drugstore. Rael San Fratello purchased the building, demolished the interior and completely transformed the space into a typical modern gallery interior. A director was installed during the summer of 2013 who curated bi-weekly performance pieces, a museum shop and gave tours. NOWHERE asks the question, "Can art be a seed for economic development in a small town?"



Performance piece by Chloe Rossetti



Local visitor examining ceramic cups by Ehren Toole



THE MUD HOUSE

Project Date: 2008

Project Team: Ronald Rael, Virginia San Fratello,
Jeremy Chinnis, Natalie Gambill

The Mud House is located in the high West Texas desert in the town of Marfa, TX. The house is inspired by the landscape, traditional building practices and the contributions of Donald Judd and is situated in a landscape of ocotillo, mesquite, yucca and sotol with a view to the Davis Mountains in the distance.

The Mud House is a large earthen box, designed to be easily constructed of mud brick and plastered with local soils mixed with cactus mucilage, horse manure and straw on the interior and exterior, and contains a smaller box inside that houses the major utilities of the house.

Radiant heating in the floors warms the body in the cool winters and the massive earthen walls store the heat minimizing energy costs. The sun also enters the space in the winter months through a courtyard that connects the house to the sky and outdoors directly from the living area. The contrast between the thick, earthen walls and the concrete lintels that interpenetrate the façade to create openings, as well as the use of stainless steel in contrast with the earth, create a tension between old and new, rough and smooth, and the industrial and non-industrial.

In the summer months, a subtle overhang over the courtyard entrance prevents direct sunlight from entering the house and the mud walls and high ceilings keep the interior cool. The clients, who are art lovers, selected works that are complimented by the earthen walls such as Kiki Smith and Susan York.

The entrance to the Mud House is through a slit in the earthen wall adjacent to a concrete pool that fills with water from the desert rains that is filled via the large scupper extending from the roof.

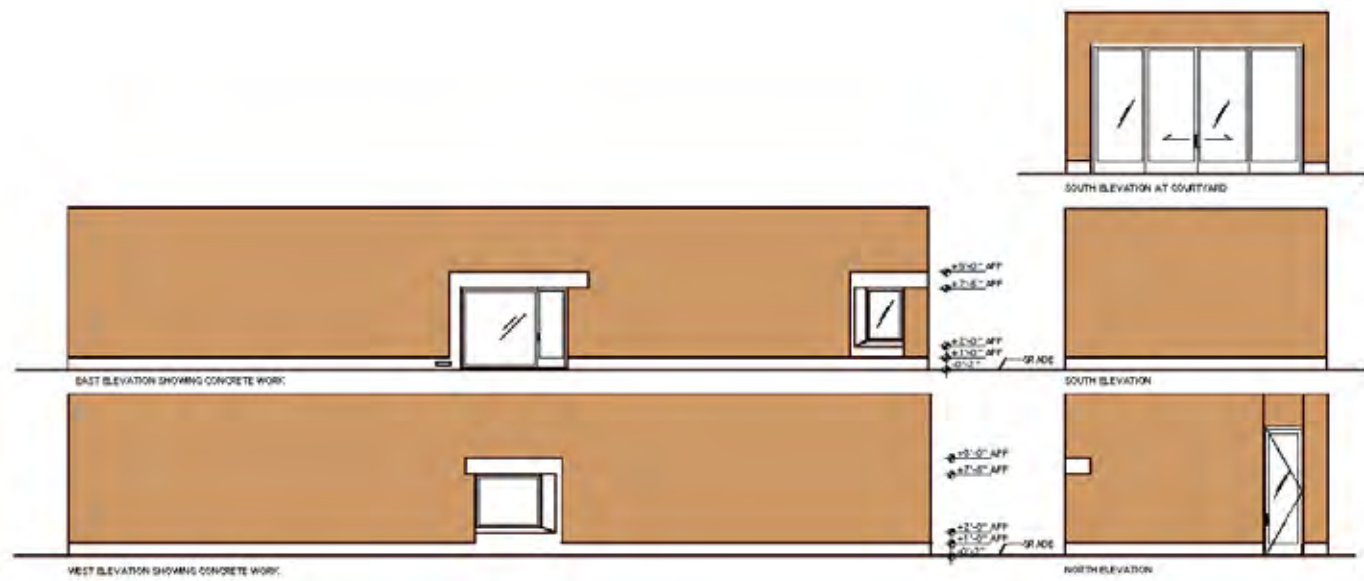
view of the big window





Inside, a large courtyard opens to the interior and to the sky, bringing in vast quantities of light, while shielding the desert sun.





Donald Judd aluminum box



Interior perspective showing aluminum box and ceiling and changing reflections and light



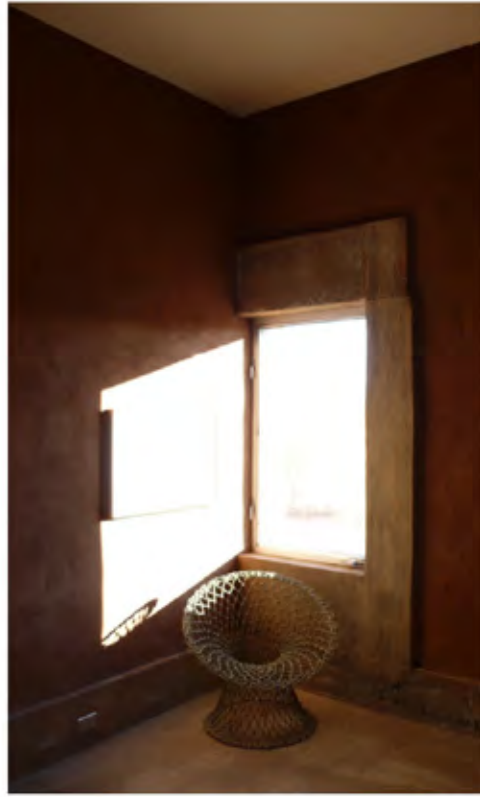
View of Haystack Mountain from big window

right: view of the mud plastered interior and big window





Two types of mud bricks, or adobes, were used in the construction. The lower portion has adobes made in New Mexico that possess a higher compressive strength and resistance to water. Towards the top of the wall, adobes made in nearby Ojinaga, Mexico were used that are lighter in both weight and color. The mud used in the plaster is from Van Horn and has a beautiful reddish tint.



this page: concrete lintel and window in the bedroom



right: north wall with scupper



BORDERWALL: ARCHITECTURE, INFRASTRUCTURE AND SOUVENIRS

Project Date: 2009-2013
 Project Team: Ronald Rael, Virginia San Fratello, Brian Grieb, Nicholas Karklins, Emily Licht, Plamena Milusheva, Colleen Paz, Molly Reichert, Aine Coughlan, Kent Wilson

Recuerdos (Souvenirs) is a journey documenting a series of scenarios, real and imagined, along the U.S.-Mexico Border Wall. It is a story that must be told, for it is an account of the largest construction project in 21st century Usonia. Almost exactly the distance of the Grand Tour, the migratory route for upper-class European men that went from London to Rome, this journey stretches along the southern border for 1,931 miles. This Nuevo Grand Tour traces the consequences of a security infrastructure that stands both conceptually and physically perpendicular to human migration. Whereas the artifacts Grand Tourists would return with (art, books, pictures, sculpture) became symbols of wealth and freedom, the border wall is a preventative measure against Grand Tourists from the south.

On this journey, the collected experiences are accounted for in the form of stories, drawings, images, postcards, key chains and snow globes: souvenirs, or recuerdos—a Spanish term that defines both the trinkets one might purchase at tourist shops, and memories—in this case declarative memory that is both semantic (independent of context) and episodic (particular to context). The recuerdos gathered are tragic, sublime and absurd, occasionally hyperbolized, but in all cases based on real experiences and events existing in the liminal space that defines the southern boundary of the United States.



RECUERDOS, {Souvenirs}

Ronald Rael & Virginia San Fratello
 RAE SAN FRATELLO ARCHITECTS

But when one draws a boundary it may be for various kinds of reasons. If I surround an area with a fence or a line or otherwise, the purpose may be to prevent someone from getting in or out; but may also be part of a game and the players be supposed, say, to jump over the boundary; or it may show where the property of one man ends and that of another begins; and so on. So if I draw a boundary line that is not yet to say what I am drawing it for. — Wittgenstein¹



Fig 1. Teeter Totter Wall Section
 Fig 2. The trade and labor relationships between the U.S. and Mexico are in a delicate balance, as witnessed in the Teeter Totter Wall
 Fig 3. Cross-border volleyball game at Friendship Park, CA and Tijuana, MX

RECUERDOS, {Souvenirs}

On this journey along the border, a series of souvenirs, or *recuerdos*, a word which has the dual meaning describing both the tangible objects and the images we store in our memory, are collected. The liminal spaces that forged these moments along the wall were created by The US Secure Fence Act of 2006, which funded the single largest domestic building project of the twenty-first century. It financed approximately 800 miles of fortification dividing the US from Mexico at a cost of up to \$16 million dollars per mile.² The construction of this wall has transformed large cities, small towns, and a multitude of cultural and ecological biomes along its path. The wall was envisioned for a *tabula rasa* defined by former Department of Homeland Security Secretary Michael Chertoff who was given the unprecedented power by President George W. Bush to waive any and all laws to expedite the wall's construction.³ Ultimately, 30 laws were waived or suspended for the construction of the wall, including important environmental, wildlife, and Native American heritage protections. Ignoring the diverse contexts found along the border raises critical questions of ecology, politics, economics, archaeology, urbanism, and eminent domain, and radically redefines the territories of the *frontera*.



Fig 4.5. In 1891, prior to the construction of the wall, a boundary commission was created to assume the task of re-marking the border with a series of monuments. Border Monument Keychains, for which there is no key, were collected along the journey.

Fig 6. Excerpt from the postcard series

Fig 7. Map of existing fence types along the U.S. - Mexico Border

TYPLOGIES

The over 800 miles of U.S. - Mexico border wall is organized in eight, double, triple or more layers depending on the topography, incidence of crossing, and available ground resources. The wall is fabricated from steel, wire mesh, concrete and other materials as constructed in a proposed timeline see: An Ficus landing strip. It makes use of high-tech surveillance systems - sensor blimps, surveillance probes, and laser sensors. Walls can be defined by the following typologies:

- Visual Wall (proposed)**
Constructed to prevent pedestrian crossing and often has a high transparency for surveillance.
- Vertical Wall (proposed)**
Designed to enforce the respect of a large vehicle, often with a heavy concrete base.
- Vertical Wall (proposed)**
Custom features of both pedestrian and vehicle walls.
- Visual Wall (proposed)**
Used along rivers to control flooding and prevent illegal crossings.
- Vertical Wall (proposed)**
Kites, balloons, temperature balloons, rough terrain are all considered natural barriers.
- Vertical Wall (proposed)**
Employ technologies such as motion detection, radar, laser, infrared, wall and photography.

Fig 8. Special wall types along the U.S. - Mexico border.
Fig 9. "Welcome Wall" border barrier commission and road construction.
Fig 10. Planning and construction of a common/monumental of the border.

The coverage of "national security" grows as and reduces dimensions and design of the wall as the nature of the wall has been measured in the numbers of intercepted illegal crossings. However, the wall, as such project, should be thought of not only as security, but also as production of infrastructure - as the very backbone of a borderland economy and ecosystem. Coupling the wall with visible infrastructure, forcing an aware, site energy, and other national infrastructures, is a pathway to an energy and safety in border communities and the nations beyond them. This proposition is for a wide array of retrofit and new typologies for the U.S. Mexico border wall that build on existing conditions and work to anticipate problems created by the physical border.

DESIGN

In the most part, architects and designers have stepped away from the border security issue. Border fence projects, "It's a silly thing to design a roadblock. You might as well leave it to security and engineers." "I am frustrated, who created the barrier wall, made the following observations:

"The wall was not really a single object but a system... it was not wall that always assumed a different condition."

This is also true for the US-Mexico wall. It has created a paradoxical territory of border, border nation, and flow, far as a much larger scale to border rivers, farms, forests, public lands, cultural sites, wildlife reserves, and migration routes, and was planned to go through a territory.

While the wall is always constructed on US soil, in many places it is constructed as far as two miles away from the actual territorial border. Removed from the nation's economy, this land is between the political boundary of the United States and the security barrier fence its production value. Estimates suggest that there are approximately 40,000 acres of US land that will be on the Mexican side of the border wall - an area equal to twice the size of Manhattan. To ensure this economically reworked land, the security infrastructure must be put to work through contextual engagement and awareness.

Fig 11. Robert Chertoff, then and former DHS secretary, proposing

OBSERVATIONS

On the journey along the wall, it is documented that the wall is higher with a wide range of uses beyond a security infrastructure because:

The wall is constructed with three when special law goes into effect. The wall is built to allow the property on the other side. Although each wall has two sides, along a wall on one side and after the wall and the cross on the other side.

The wall is an attractor. The current border wall is meant to keep people out and away, but instead, it attracts an attention for other people both sides in a common dialogue.

The wall is a way of life and is connected with the construction that it will eventually be constructed. Constructing a post-border wall requires that some control of the border space is more defined.

Over 100 miles of border have been constructed since 2006 at a cost of \$3.4 billion. Additionally, the wall has already been breached over 3,000 times, resulting \$4.4 million in repairs. The construction and maintenance costs are estimated to exceed \$40 billion over the next 25 years and there are several hundred more miles of wall construction recently proposed. While recent statistics show a 10 percent drop over the past few years in the number of people caught illegally crossing the United States from Mexico, human rights groups and the number of deaths along the border crossings in its highest since 2006 - almost 6,000 deaths have occurred since 1994.

Fig 11. The construction of the border walling the United States - Mexico border. Photo provided courtesy of a photo documentary series.
Fig 12. Transformation through the border. Photography of daily routine.

"The \$40 million 'floating fence', or 'sand fence' is built atop the sand dunes in the desert but land between Yuma, Arizona and California. The sand built up along its edge instead of fence can be lifted by a machine and placed back on top of the sand, so the fence never loses its height or its almost seven miles of floating fence cost about \$6 million per mile to build."

WATER INFRASTRUCTURE

The border wall has already proven to be an effective, if accidental, water collection system. Water from desert rains typically drain across the border—yet in areas such as the port of entry at Sonoyta and Organ Pipe Cactus National Monument, or in the Ambos Nogales, the fence acts as a dam, causing flooding and environmental damage. Border walls also block animals from food and water sources, which leaves them especially vulnerable in times of drought. When water collection is considered proactively, it can become a system with transformative consequences for the desert communities along the border.



Fig 14, 15. Trough Wall and Aqueduct sketches

Fig 16. Deer are blocked from their natural migration routes in search of water near Arizona's Riparian National Conservation Area

Fig 17. Flooding in Nogales, AZ and Heroica Nogales, MX



WATER TREATMENT (ALBUQUERQUE, NM)

The New River consolidated the most polluted water in the United States. It flows north from Mexico and crosses the border at Cameron. New River toxicity is composed of chemical runoff, pesticides, herbicides, insecticides, and herbicides, which are the border challenge for several US Mexico treaty laws. The New River flows through the Imperial Valley, which is a major source of water for agriculture, citrus, and grain. While the San Juan National Monument is a major source of water for the Imperial Valley, it is also a source of water for the New River. The New River represents a far more dangerous flow north from Mexico to need of treatment.

A wastewater treatment wall located in the 100-mile-long watershed that buffers Mexico from the Imperial Valley is a solution to the "illegal entry" of toxins to the US.

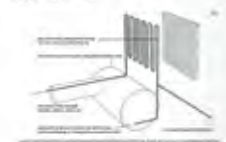
The pollution problem is expected to increase as Mexico's population, already at 1.1 billion, continues to expand with our adjacent infrastructure. For \$1.5 billion, the same cost as the wall that borders California and Mexico, it is possible to construct a wastewater treatment facility with the capacity to handle 20 million gallons per day of effluent from the New River. This proposed facility is composed of a lower-level filtration and purification system, creating a secure border infrastructure. The by-product of the water treatment facility would include methane and water, a combination that could power a series of 16, green gardens, creating a healthy, social infrastructure that could just cross the growing border zone.

Fig 18. Wastewater treatment plant structure from the New River



WATER COLLECTION (ALBUQUERQUE, NM)

In urban environments, the border wall can be created with the water production, allowing low-cost additional resources that supplement the infrastructure of nearby growing border zones. The massive steel walls are enormous heat absorbing agents, and they could easily be replaced with panels that produce hot water, which is a much-needed energy in border zones. The hot water could then be used in markets, hotels, hospitals and schools.



LIFE SAFETY (MEXICO CITY - MEXICO)

When water collection is coupled with solar energy, it also offers a key component for the sustainability of life safety because along the border. The principal cause of death among migrants attempting to cross the border illegally is dehydration. Solar generated electricity could power lanterns that in some border patrol of both immigrants or American citizens who find themselves in danger in the harsh conditions of the border deserts. The photovoltaic panels would also be designed to collect water runoff to power automatic water sensors, or to pump water from wells or rivers that could be stored, bottled and dispensed as needed to dismount migrants in the desert. Engaging the water dispenser, or water-sensing the life safety lantern would alert border patrol. Such devices could also provide the information that migrants have an ability, who find themselves unable to reach their intended route in search of water.



Fig 21. Life safety structure system

SOLAR INFRASTRUCTURE

Building upon the installation of photovoltaic along the border, it is important to note that the most compact potential for solar development in the United States lies along the US-Mexico border. Solar farms, in some way tightly across international borders, could provide a source of energy and improve the border wall for the construction of energy infrastructure along the border zones. In many instances, solar farms are more efficient than the existing wall, and solar technology provides solar energy to the Southwest. The stretch between Nogales and Douglas over 87 miles of border wall construction at a cost of \$225 million, while the largest solar farm in the world, the Colorado Renewable Park in Spain, cost \$325 million for 1775 million, 34 miles of photovoltaic solar farms could be constructed at 80 feet wide, generating 40,000 households.



Fig 25. People, Solar Wall along



According to the U.S. Dept. of Energy, One square foot of land along the U.S.-Mexico border can generate up to 260 kilowatts of electricity in one year - enough to power a household dishwasher for a year.

SOCIAL INFRASTRUCTURE

While some of this journey has been focused on public, urban-style recreation, the experience of social infrastructure along the border should be centered. Exercise and walking, for example, are social activities where networks between people with common interests are formed. Social capital, a concept that refers to the value of social relations and the role of cooperation and contribution to achieve collective or economic results, can be produced by such networks and is a core element in the fabric of communities and capital. The practice of safety, familiarity and community, risk-taking and economic value. One view, social capital builds "social infrastructure," in the form of parks and other public amenities - a key element in the health of communities. One of the most devastating consequences of border wall recovery is the erosion of communities, cities, neighborhoods, and families in the erosion of social infrastructure. Despite this, there have been a way to cope with the realities of the wall.

TOYAMA WALL, TOKYAMA, CA | TOYAMA, WA

"Show me a 50-foot wall and I'll show you a 50-foot ladder." - James Hoffmann

This community has become a model for climbing the fence's requirements as well as the fences are used to connect the wall. Aerial wall climbing has become a social activity. James Hoffmann, "crossing border" - designed to help it. Legal immigrants require the sometimes deadly services they experience when crossing the border from Mexico to the U.S. Various methods of climbing a fence have also been used to allow cars to drive over the border fence. With the Climbing Wall the act of climbing the fence has become an act of faith, but also a challenge, as it brings back climbing wall practice with various routes and grading.



Fig. 01. The Climbing Wall connects challenges with faith in community. The fence.
Fig. 02. Aerial view of the wall and border crossing.
Fig. 03. Aerial view of the wall and border crossing.

LINEAR PARK, GARDNER, CA | BERKLEY, WA

Using the border as an amenity for a linear urban park through various urban programs could offer pedestrian and bicycle routes through the city. The linear park, or town, could increase adjacent property values and the quality of life on both sides of the border while providing an important green corridor through the city. Border towns lack the infrastructure that allows them to be livable, healthy cities and a border wall that integrates pedestrian transportation benefits with the city, all the surrounding border security and decreasing automobile emissions. Traffic support to active lifestyle that improves health. Physical activity helps prevent heart disease, diabetes, osteoporosis, obesity, stress, cancer and depression. An increase in physical activity can save millions in health care spending. Tourism and recreation-related spending on items such as bike and water shoes are just a few of the ways a linear park wall can positively impact community economic health. Some of the social infrastructure proposals presented thus far could also be integrated along the park.



Fig. 01. Aerial view of the park and border crossing.
Fig. 02. Aerial view of the park and border crossing.
Fig. 03. Aerial view of the park and border crossing.



THE WALL, ENROUTE, WA | TOYAMA, WA

Canal exchange is not uncommon across the border wall. In the past, it was one of the few ways on the border where people from Mexico and the U.S. could meet and talk across the fence. Families would set up beach chairs on both sides of the fence for picnics, beer and food. They would bring the kids and eat. Some families would bring their dogs. Through holes in the fence could occur. Commercial exchanges did not stop, when legally, even between family and business. U.S. Border Patrol agents and family would sometimes on the other side. The Toyota Wall is the name given to the 14 mile section of wall between the Clay Mesa Border Crossing and the Pacific Ocean. Sections of the wall accommodate land cars built over the wall. The proximity to the wall and the security parking areas (sheds being or built over the wall and fence, construction or a 10-foot wall can build across the border.



Fig. 01. Aerial view of the wall and border crossing.
Fig. 02. Aerial view of the wall and border crossing.
Fig. 03. Aerial view of the wall and border crossing.



Fig. 01. Aerial view of the wall and border crossing.
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Fig. 03. Aerial view of the wall and border crossing.



THE WALL, ENROUTE, WA | TOYAMA, WA

The Treaty of 1848 went on to require that attention to the border had to result from gradual natural causes. This provision followed the long established doctrine of international law that when changes in the course of a boundary river are caused by a deposit of alluvium, the boundary changes with the river, but when changes are due to erosion, the old channel remains the boundary. The river eventually shifted south between 1852 and 1866, with the most natural shifts in the river occurring after a flood in 1864. By 1873 the river had moved approximately 400 yards, cutting off land that was in effect made United States territory. The newly acquired land came to be known as El Chorro, and eventually the land was settled and recognized as part of El Paso, both Mexico and the United States. The land for 1881, Mexico citizens filed suit in the United States Court of Claims to reclaim the land. The Young Wall allows participants riding the way to cross back and forth across the border, but all other remain securely on their respective sides.



Fig. 01. Aerial view of the wall and border crossing.
Fig. 02. Aerial view of the wall and border crossing.
Fig. 03. Aerial view of the wall and border crossing.



The Billioteca Binacional in Pos Ampos Nogales allows transnational exchanges of books, ideas and knowledge in this cross-border book exchange program.



“What I seek to convey is the historic truth that the United States as a nation has at all times maintained opposition—clear, definite opposition—to any attempt to lock us in behind an ancient Chinese wall.” (Jan 6., 1941) — Roosevelt¹³

reTHINK BAY BRIDGE

Design Team: Ronald Rael, Virginia San Fratello, Frederick Schwartz, Marc L'Italian

On Monday, September 2, 2013 the new eastern span of the Bay Bridge opened to vehicular traffic, thus ending the 240,000 cars per day load to the historic, James "Sunny Jim" Rolph Bridge, east of Yerba Buena Island. In 2009, in anticipation of the new bridge, we proposed to repurpose, rather than destroy, the then to be abandoned bridge and imagined The Bay Line— an aerial garden, which would include housing, recreational and cultural facilities connected to a continuous, lushly planted, green strip, floating above the water as the region's newest park through which you could walk and wander and enjoy the most spectacular views of the bay.

Today the new bridge lies in the shadow of the abandoned span and new questions arise. Metropolitan Transportation Commission spokesman John Goodwin said the current cost forecast for the demolition project is \$233.7 million and will take about three years. Previous predictions of the cost of the bay bridge project were unpredictable, resulting in the bridge being several billion dollars over budget and many years behind schedule, so there is good reason to at least imagine what other possibilities might exist for the abandoned structure.

If we compare the \$233.7 million for the demolition to the cost of perhaps the most famous infrastructural reuse project, The High Line, the total cost of Section 1 and 2 of The High Line was \$152.3 million. The design and construction of the currently opened area cost \$86.2 million. Funding for the project came from multiple sources: \$112.2 million from the City, \$20.3 million from the Federal Government, \$400,000 from the State, \$44 million raised by the Friends of the High Line.

Does the possible investment in social infrastructure outweigh the cost associated with demolishing the bridge?



THE BAY LINE: Adaptive Reuse of the Bay Bridge

Project Date: 2009

Project Team: Ronald Rael, Virginia San Fratello, Emily Licht, Duncan Young

The Historic Bridges of the United States website lists 1,788 bridges that have been “closed” to traffic and 321 classified as “abandoned”. According to the website, “with all of the Federal stimulus money sloshing around, it’s no surprise that bridge replacement projects are quite common this summer.” Many of the bridges that have been neglected are largely former railroad bridges--a testament to the decline of rail as a means of freight and passenger transportation. Engineered as rail bridges, the structures have the capacity to support tremendous loads. The Bay Line imagines abandoned and closed bridges as sites of potential parks, cultural centers, and housing. The eastern section of the historic James “Sunny Jim” Rolph Bridge, commonly known as the Bay Bridge, in San Francisco/Oakland, which is currently being replaced by a new concrete bridge structure, serves as a prototype for considering the potential of re-utilizing bridge infrastructure to create new social, housing and sustainable infrastructures.

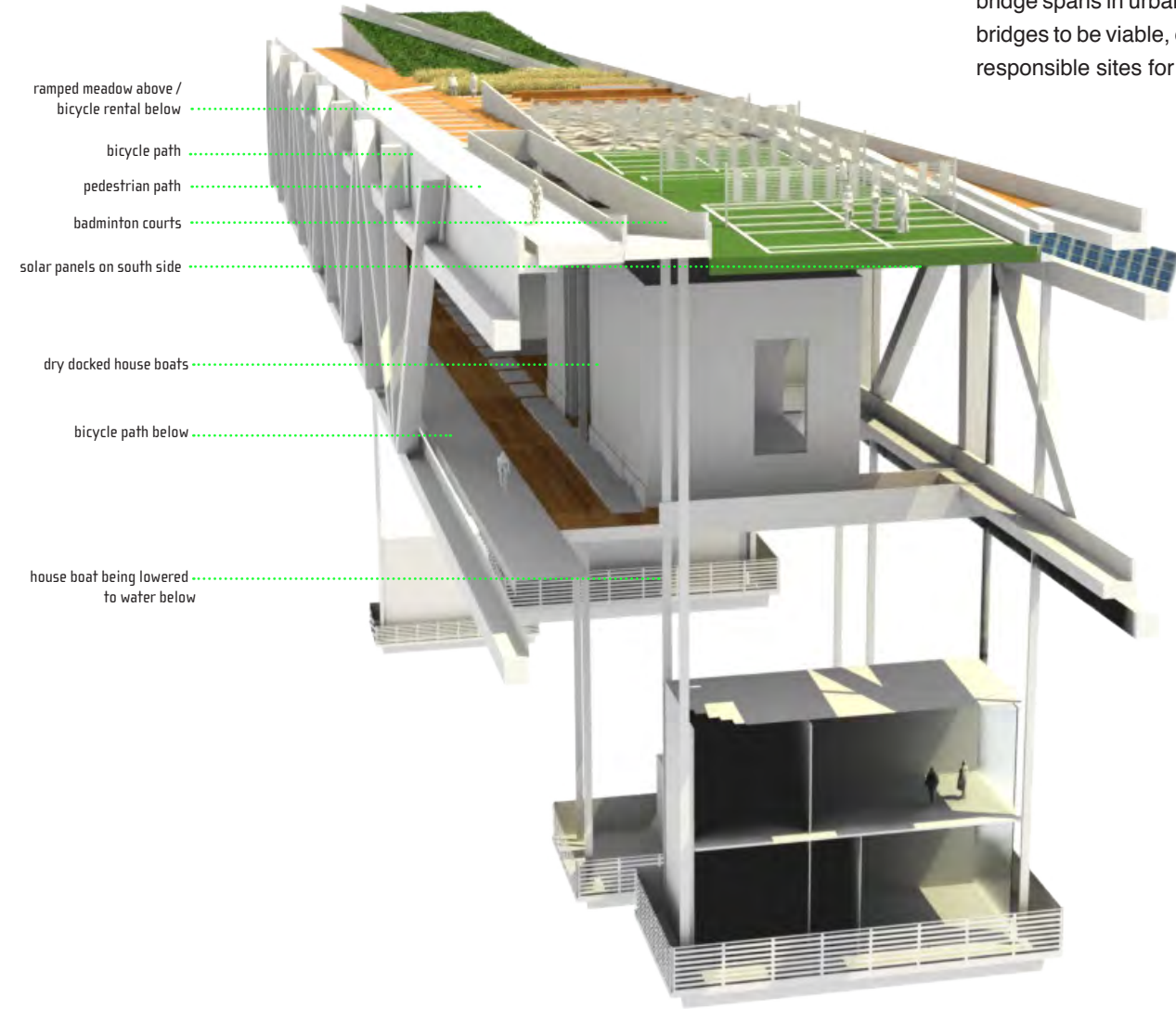
Both rural and urban areas have demonstrated an increased interest in converting abandoned railways into linear parks (best illustrated by the recent opening of the High Line in New York City). This proposal goes a step further in suggesting the possibility that housing be included in the re-thinking of abandoned bridges. The immense load bearing capacity of rail bridges suggests an “urbanization” of bridge infrastructure could be plausible. While the current economic climate suggests a surplus of housing, economic and ecological realities demand settlement patterns based on density. By using abandoned bridges in urban areas as the framework, we are creating opportunities for sustainable low-cost housing within the urban realm and opening up the potential for creative speculation



Current construction on the new Bay Bridge



San Francisco-Oakland Bay Bridge Plan



“Bridge housing” is not a new conception. The Ponte Vecchio in Florence, Italy, the pre 1756 London Bridge, the Chateau Chenonceau in France and the Pulteney Bridge in Bath, England are all historical and successful examples of inhabited bridge spans in urban areas. This proposal understands defunct bridges to be viable, cost effective, enterprising, and ecologically responsible sites for potential housing development.

CORE PREMISE AND OBJECTIVES

The specific objective of The Bay Line is to re-imagine the replaced eastern span of the Bay Bridge as a linear park with bicycle and pedestrian access, housing and cultural activities, such as theaters, commerce and museums, as well as 1.92 miles of bicycle lanes, sporting facilities, such as tennis courts, climbing walls, squash courts, and skate parks in addition to orchards, gardens and meadows, that are easily accessible and interconnected to the larger Bay Area. More broadly, we hope that this project is the genesis for creating a series of prefabricated prototypes and widely applicable concepts that can help others realize the potential in abandoned bridge infrastructure world-wide.



Hotel rooms + outdoor amphitheater



Dormitories + climbing wall



Bungalow house + tennis courts



Row houses + gardens



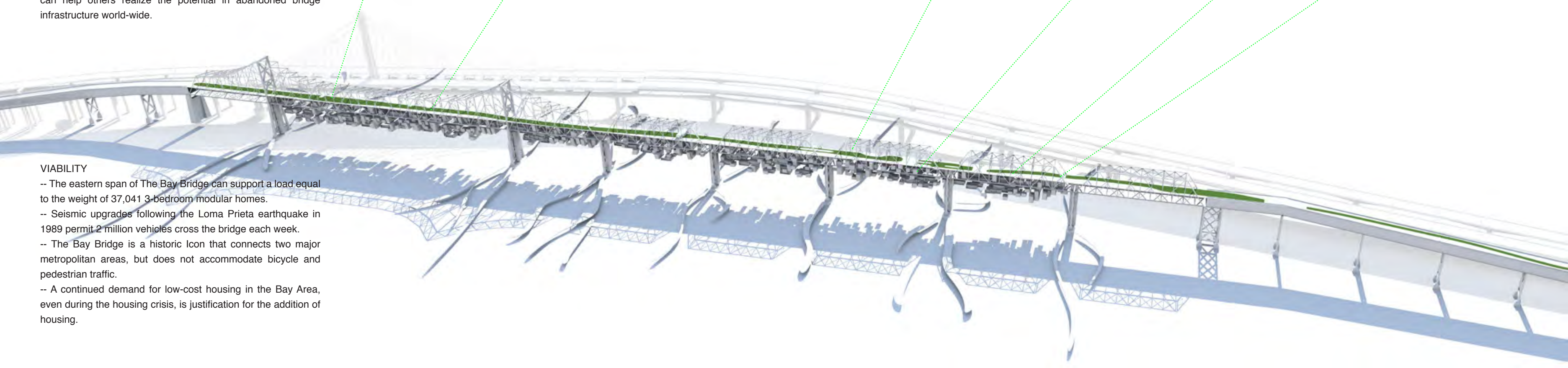
Live / work lofts + orchards



Condos + swimming pool

VIABILITY

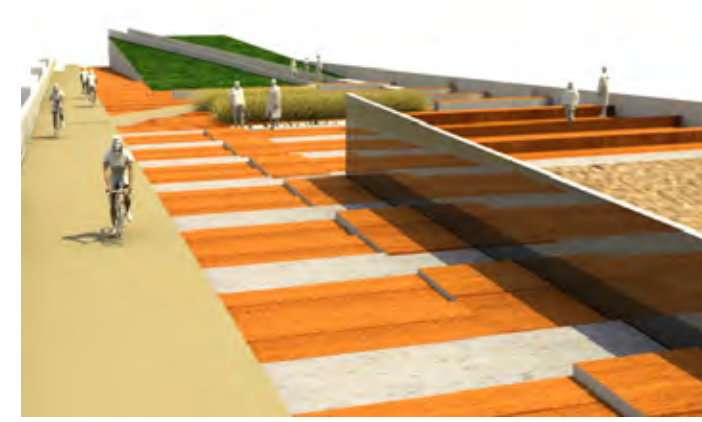
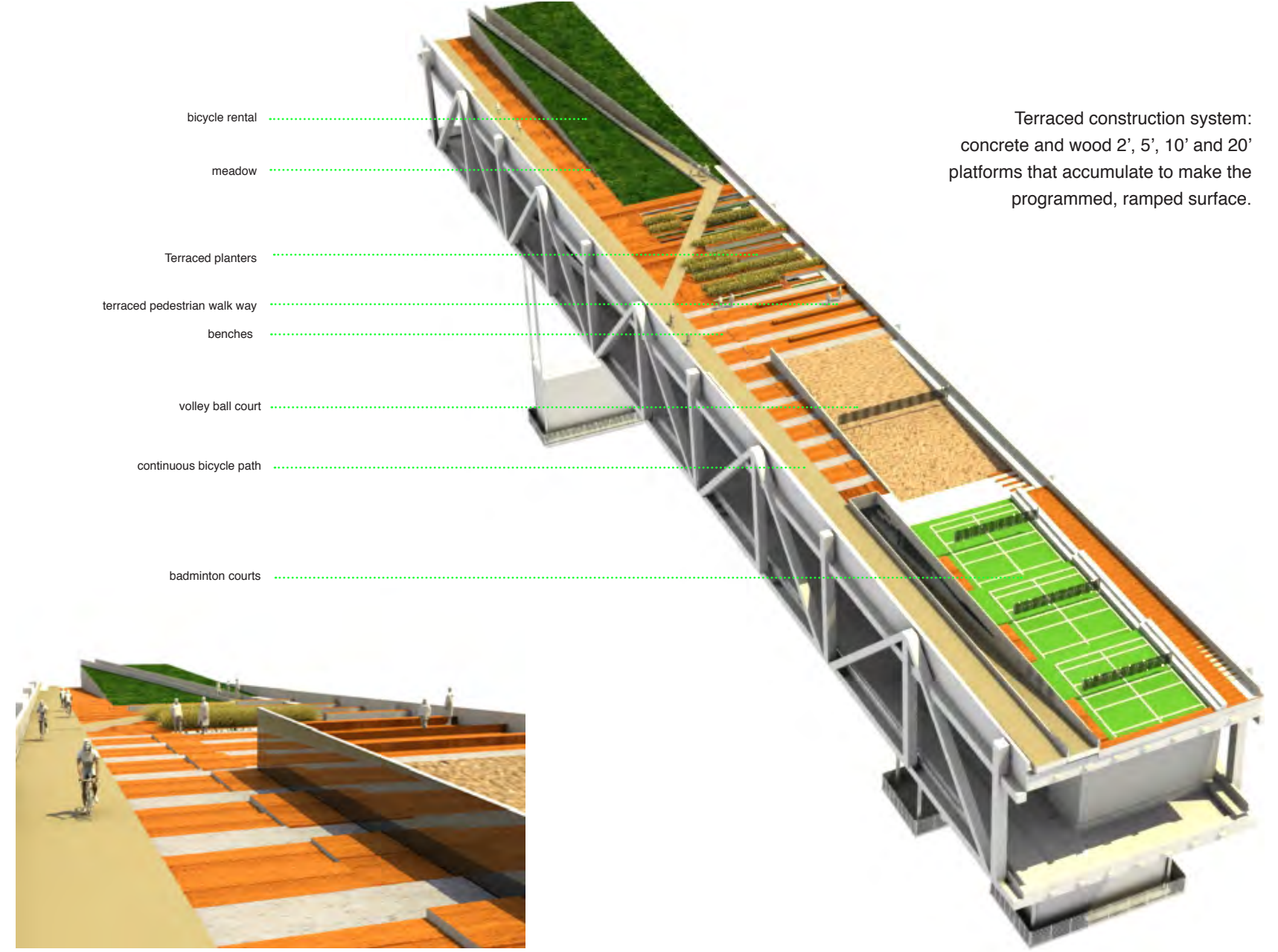
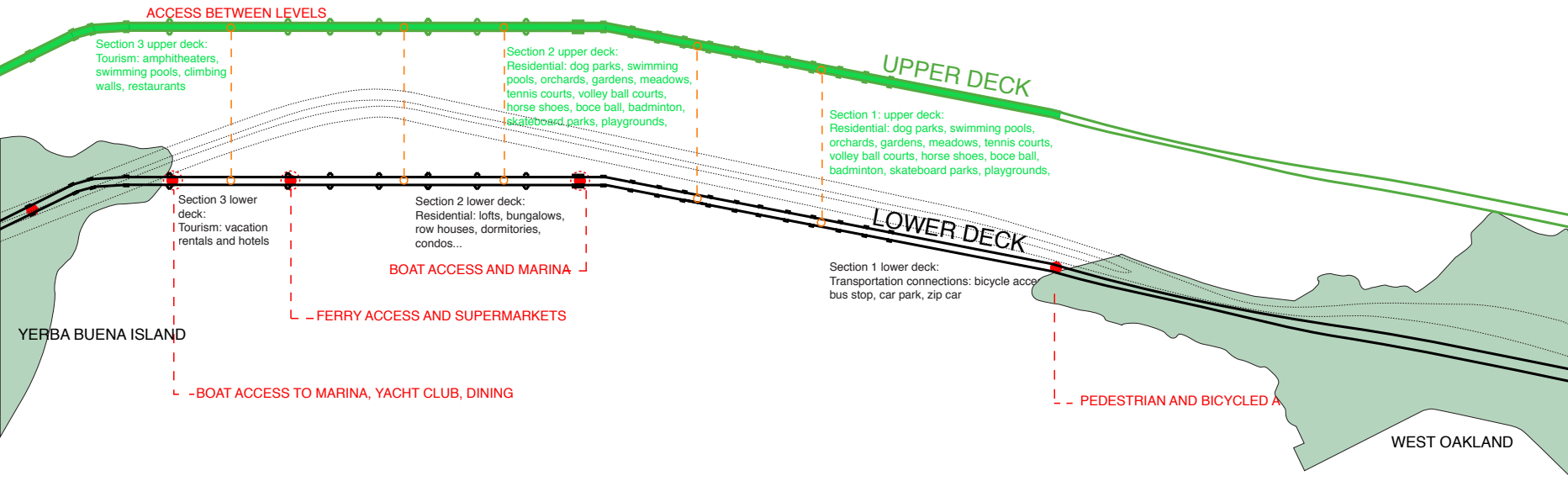
- The eastern span of The Bay Bridge can support a load equal to the weight of 37,041 3-bedroom modular homes.
- Seismic upgrades following the Loma Prieta earthquake in 1989 permit 2 million vehicles cross the bridge each week.
- The Bay Bridge is a historic Icon that connects two major metropolitan areas, but does not accommodate bicycle and pedestrian traffic.
- A continued demand for low-cost housing in the Bay Area, even during the housing crisis, is justification for the addition of housing.



LINEAR PARKS ALONG THE UPPER DECK

The upper deck of the Bay Line will be re appropriated as an urban park. The park will include sports facilities that are often quite difficult to find in dense urban centers such as tennis courts, swimming pools and skate parks. It will include edible gardens and orchards as part of the urban agriculture network established in the Bay area by organizations such as the League of Urban Gardeners, there will also be gardens, meadows and woodlands for leisure activities and amphitheatres and museums to support local culture. A system of prefabricated terraces will be constructed to build the different programs and to smoothly allow one program to sequeway into the next.

The recreational, cultural, leisure and agricultural programs will promote diverse user groups along the bridge. The continuous bicycle path that runs the length of the bridge will become a part of the growing bay trail which connects cities along the perimeter of the bay.



COMMUNITY: RECREATION AND SPORTS

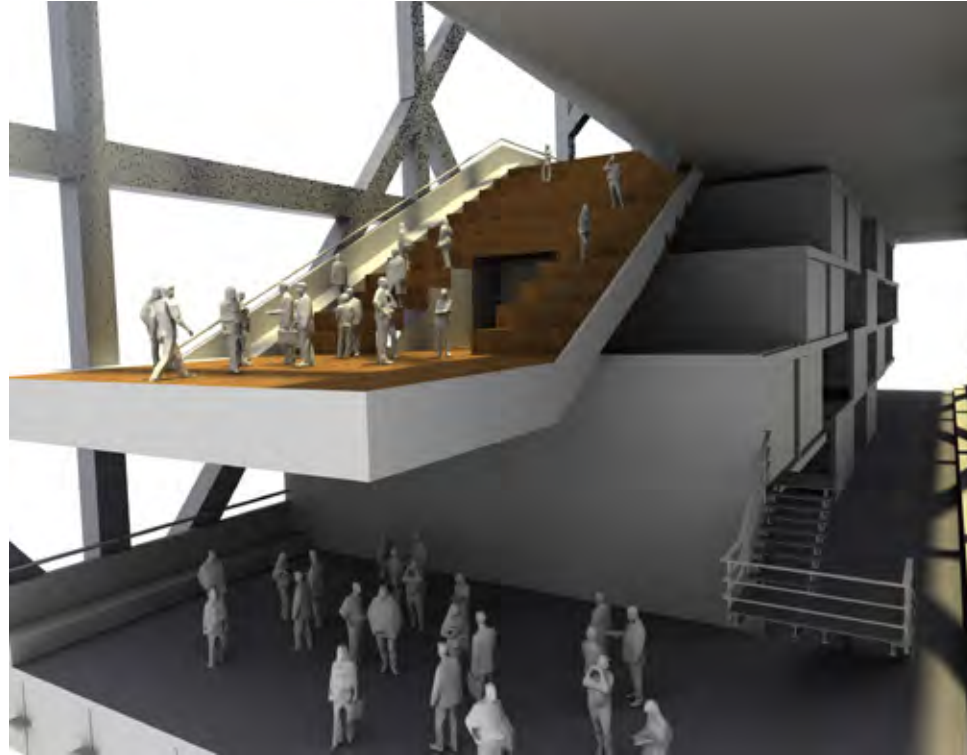
Sports are inherently very social activities where networks between people with common interests are formed. These networks form social capital which is the underpinning and core fabric of communities. Social capital has a stream of benefits, including safety and security, friendship and community, a sense of civic identity and economic value. Over time, social capital builds what may be termed as social infrastructure which is key for any successful and healthy community.

SUSTAINABILITY: GARDENS AND AGRICULTURE

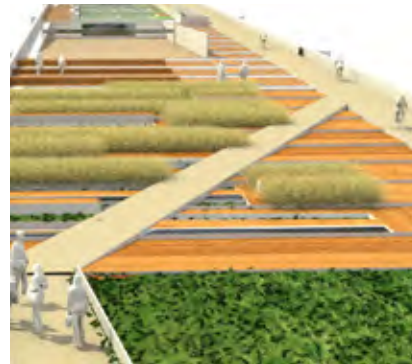
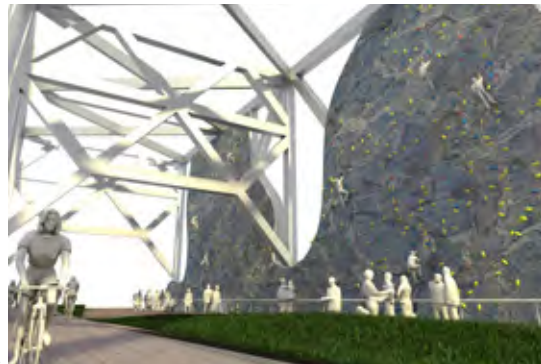
Recently there has been a large movement to bring agriculture back into the city. The Bay Line has up to 15 acres of "land" that can potentially be used for edible gardens and orchards. These gardens may be incorporated by institutions such or non profit community organizations such as SLUG (San Francisco League of Urban Gardeners) who currently run 40 small gardens in the city that generate it's \$1.6 million dollar annual budget. The gardens not only provide food but they are economically self sustainable.

PUBLIC PRESENCE: LEISURE AND CULTURE

Like the Golden Gate Park, the Bay Line would be a destination for tourist and locals alike. The Bay Line would be suitable for hotels, restaurants and museums as well as picnickers, walkers and kids in search of playgrounds.



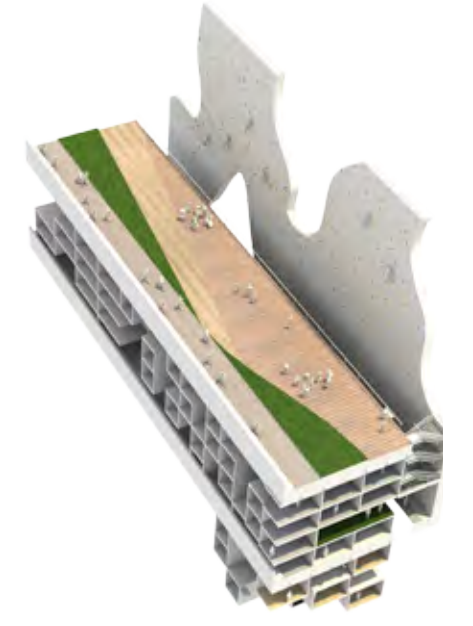
right: view showing auditorium, climbing wall and bicycle paths



CULTURE: outdoor amphitheater



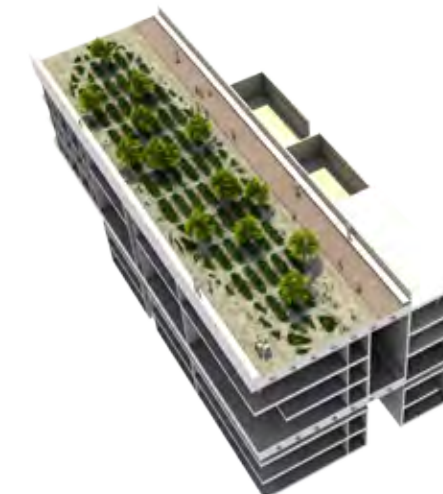
RECREATION: swimming pools



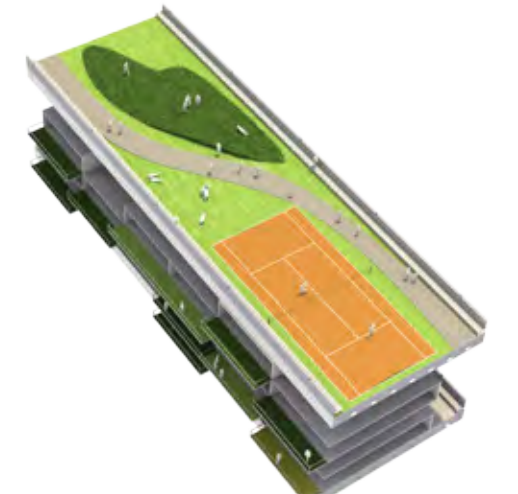
COMMUNITY: dog park



SUSTAINABILITY: urban agricultural plots



SUSTAINABILITY: urban orchards



RECREATION: tennis courts

EMERGING OBJECTS

Project Date: 2010 -ongoing
Project Team: Ronald Rael, Virginia San Fratello, Emily Licht, Kent Wilson, Nick Buccelli, Bryan Allen

MISSION

Emerging Objects is a pioneering design and research company that specializes in designing and 3D printing objects for the built environment.

ABOUT

Our research and designs focus on the development of innovative 3D printed objects that serve the fields of architecture, interior design, furniture design and product design. Our design research has served as the foundation for our consulting projects and we work with a range of industrial partners, nonprofit foundations and creative practices.

VISION

Emerging Objects is interested in the creation of 3D printed buildings, building components and interior accessories that can be seen as sustainable, inexpensive, stronger, smarter, recyclable, customizable and perhaps even repairable to the environment. We want to 3D print long-lasting performance-based designs for the built environment using raw materials that have strength, tactility, cultural associations, relevance and beauty.

Because the inherent nature of 3D printing opens new possibilities for shaping materials, this process will reshape the way we as a society think about manufacturing and construction. Though rapid manufacturing, geometries can be created that would be impossible to create by hand or require expensive machinery to produce or reproduce. Because additive manufacturing requires no dies or molds, products can be mass-customized, employing the flexibility of computer-aided manufacturing systems, rather than mass-produced, allowing design parameters to be quick. 3D printing is also a fabrication method that minimizes waste which makes it an environmentally conscious method of manufacturing.



3D Printed items in cement polymer, nylon, salt, wood and sand

EARTHSCRAPER:
Developing 3D printing for the rapid manufacture
of sand-based building components

Project Date: 2010

Project Team: Ronald Rael, Virginia San Fratello, John Faichney,
Maricela Chan, Chris DeHenzel, Emily Licht

SUMMARY

The creation of building components that can be seen as sustainable, inexpensive, stronger, recyclable, customizable and perhaps even reparable to the environment is an urgent, and critical focus of architectural research. In the U.S. alone, the construction industry produced 143.5 million tons of building-related construction and demolition debris in 2008, and buildings, in their consumption of energy produce more greenhouse gasses than automobiles or industry.

Because the inherent nature of 3D printing opens new possibilities for shaping materials, the process will reshape the way we think about architectural building components. Digital materiality, a term coined by Italian and Swiss architects Fabio Gramazio and Matthias Kohler, describes materiality increasingly enriched with digital characteristics where data, material, programming and construction are interwoven. The research aspires towards this classification through the use of parametric modeling tools, analytic software and quantitative and qualitative analysis.

Rapid Prototyping, which is the automatic construction of physical objects using additive manufacturing technology, typically employs materials intended for the immediate analysis of form, scale, and tactility. Rarely do the materials used in this process have any long-term value nor does the process, except in rare cases with expensive metal prototyping, have the ability to create actual and sustainable working products.

3D printed sand
display table



This research intends to alter this state of affairs by developing methods for 3D printing using concrete for the production of long-lasting performance-based components.

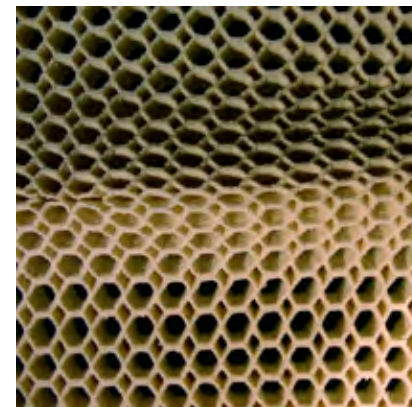
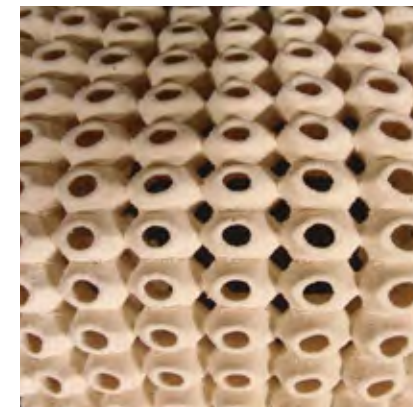
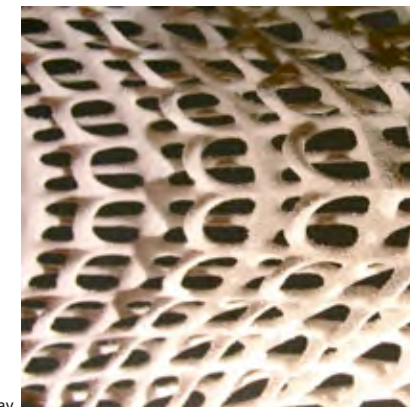
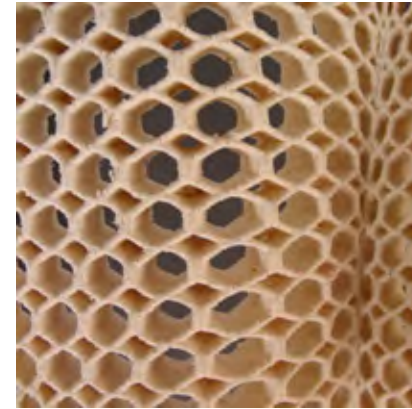
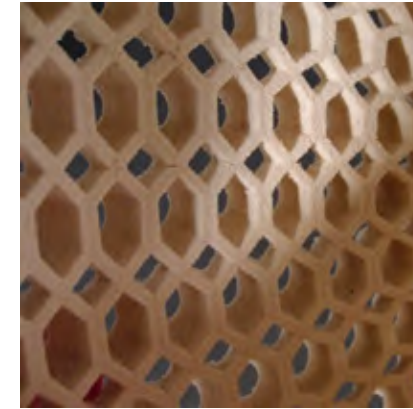
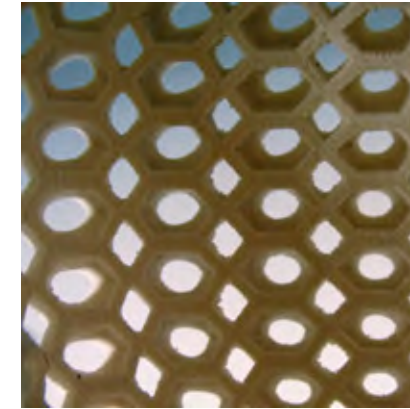
MATERIAL INFORMATION

The word concrete comes from the Latin word “concretus” (meaning compact or condensed), the perfect passive participle of “concreo”, from “com-” (together) and “creo” (to grow). The development of concrete has evolved for over two thousand years. The Romans used quicklime, pozzolana and aggregate or rubble to build concrete structures such as the Pantheon and the Baths at Caracalla. In 1756 John Smeaton rediscovered concrete by mixing hydraulic lime and powdered brick as aggregate. These mixtures produced concrete with a comprehensive strength comparable to the mixes that we use today. The mixes that we most frequently use today include:

Portland cement: which consists of a mixture of oxides of calcium, silicon and aluminium. Portland cement and similar materials are made by heating limestone (a source of calcium) with clay, and grinding this product (called clinker) with a source of sulfate (most commonly gypsum).

Water: Combining water with a cementitious material forms a cement paste by the process of hydration.

Aggregates: Fine and coarse aggregates make up the bulk of a concrete mixture. Sand, natural gravel and crushed stone are mainly used for this purpose. Recycled aggregates (from construction, demolition and excavation waste) are increasingly used as partial replacements of natural aggregates, while a number of manufactured aggregates, including air-cooled blast furnace slag and bottom ash are also permitted.



right: studies of 3D printed porcelain and ball clay

When initially mixed together, Portland cement and water rapidly form a gel, formed of tangled chains of interlocking crystals. These continue to react over time, with the initially fluid gel often aiding in placement by improving workability. As the concrete sets, the chains of crystals join up, and form a rigid structure, gluing the aggregate particles in place. During curing, more of the cement reacts with the residual water (hydration).

Concrete is inherently weak in tension as the cement holding the aggregate can crack. The addition of steel reinforcement to concrete in the 19th century solved this problem. In addition to adding steel reinforcing bars, we now add steel fibers, glass fiber, or plastic fiber to carry tensile loads. Thereafter the concrete is reinforced to withstand the tensile loads upon it.

The mix for use in the 3d printer is similar to yet varies in composition from the traditional mixes used. The traditional processes used vary dramatically, from hand tools to heavy industry, but result in the concrete being placed in a formwork where it cures into a final form. In the case of 3d printing concrete there is no form work or mould. There is however, the constraint that all binding particles used in the concrete mix must fit through a 35 picoliter print head and all cement, aggregate and reinforcement must be smaller than 0.010". The mix that is used in the 3D printer is made of:

- Portland cement
- Finely graded sand
- Powdered sugar
- Maltodextrin
- Rice wine
- Nylon fibers



below: 3D printed sand structure
right: Tower printed in 4 pieces and stacked together at interlocking sections



The Portland cement serves the same purpose as it does in a traditional mix. The finely graded sand, sugar and maltodextrin act as the aggregates. The rice wine is composed of 80% water and acts as the binder, although a slurry is not formed, and the nylon fibers serve as reinforcement.

HOW IT WORKS

The 3D printer lays down a thin layer of the dry, powdered concrete mix, then using an ink jet sprays the image of one 'slice' of the 3D object or in this case CMU (concrete masonry unit) onto the dry mix. The wet parts of each layer hydrate into rock-hard concrete, and the rest remains in a powder form which can be brushed off later. Because concrete cures via a chemical reaction – hydration- no air is required for curing, so the next layer can be deposited immediately.

The cycle of laying down concrete and binder with the rice wine is repeated over and over, stacking layer upon layer, building up a solid object inside the pile of dry, powdered concrete mix. The dry concrete mix acts as a support structure during the printing process, so objects may have undercuts which is unseen in traditional concrete casting.

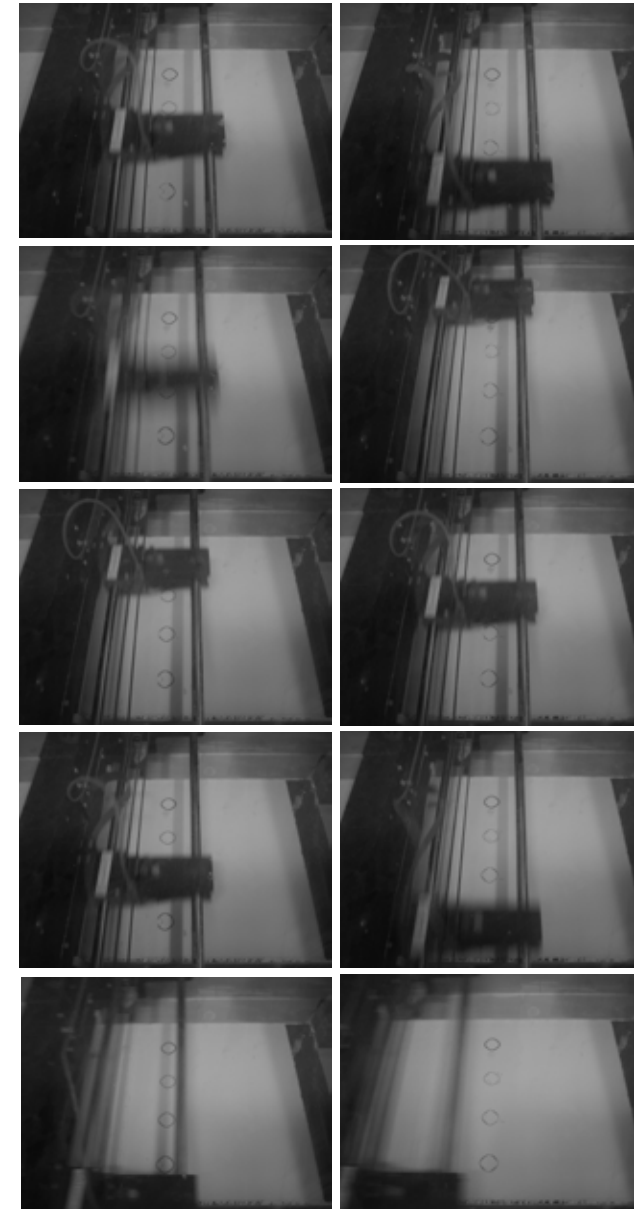
Once the concrete cures enough to handle, which typically takes about 12 hours, the finished object can be lifted out of the powder bed. The dry mix used to support the concrete object during printing can be recycled. Printing an intricate and unique concrete part would only consume a few dollars worth of material, would incur no cost for formwork and very little labor costs. Additionally compared to printing with z corps proprietary blend, the costs are considerably lower. The Z corp polymer / plaster powder, at it's cheapest, is \$3 a cubic inch and the 3D printed concrete costs mere cents per cubic inch.

Concrete Media:

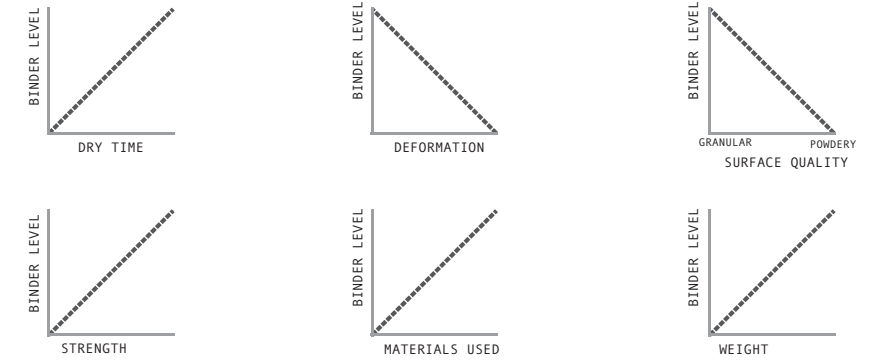
The initial impetus to work with concrete as a 3D printed material was driven by an installation we designed called Earthscapers. Earthscapers imagines the potential of employing Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) processes in the construction of a proto-architectural landscape—one where the building material source and the building itself are seamless. The project also imagines a future scenario for the material and the process as a scalable technology—one that also dissolves the role of the architect and builder. We imagined printing full scale buildings with in situ aggregates in a world where designer and geomorphologist merge.

The capability to 3D print at the scale of the building is gaining momentum and is certain to occur. Currently the largest 3D printer in the world is a 10' x 10' x 10' 3-D stereolithographic printer that creates models entirely out of artificial sandstone using CAD-CAE modeling technologies and CAD-CAM software to control the plotter. The printing proceeds in 5-10mm layer segments and, in the end, produces a structure that has strength characteristics reminiscent of standard Portland Cement. This printer can print a low resolution room.

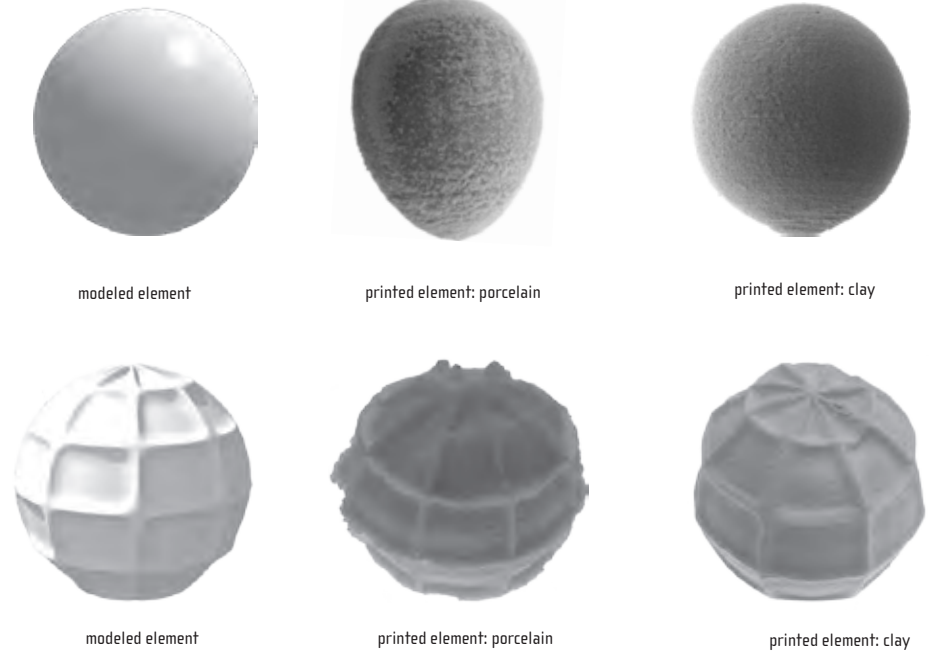
Dr. Behrokh Khoshnevis, of the University of Southern California has developed a different printing technique called Contour Crafting (CC). Contour crafting is a layered fabrication technology that has potential for automating the construction of whole structures as well as sub-components. Using this process, a single house or a colony of houses, each with possibly a different design, may be automatically constructed in a single run, embedded in each house all the conduits for electrical, plumbing and air-conditioning. They have recently collaborated with Caterpillar to fabricate a 6 foot wall.



EFFECTS OF BINDER LEVELS:



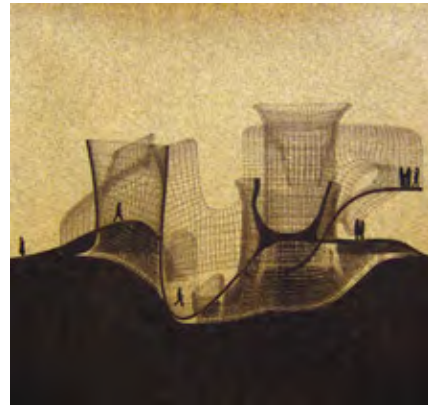
MATERIAL DEFORMATION



For the Earthscrapers exhibit we were uniquely interested in connecting the 3D printed material to the landscape therefore we started by printing various materials including clays, sands and ashes. Ultimately we decided to print a small amount of portland cement mixed with a large portion of sand. The resulting concrete prints proved to be very stable, strong and have the effect of looking like earth due to the amount of natural aggregate within the mix.

The plastic nature of both concrete and 3D printing offer up a powerful material solution to recent generative design processes in architecture, which often feature organic, doubly curved surfaces and complex ornamentation. The Earthscrapers exhibit explored a range of complexly curved forms. It also explored thinness and attempts to push the limits in terms of extracting thin surfaces and thin structural elements from the printer bed. Several of the complexly curved, fiber reinforced concrete prints were easily 1/16" of an inch thick which would be very difficult, if not impossible, to cast using traditional methods of mould making. Making the 3D printed models and objects that were on display in the Earthscraeper exhibit was an active process where software, geometry, material, fabrication and production were simultaneously linked. The complexity of form was limited by thinness and slump. If the form was not allowed to cure in the bed for at least 12 hours the concrete object would fail. The success of the mix depended on the amount of binder being laid down at each successive interval. For example, if the binder was sprayed at full capacity the concrete print would slump therefore the binder level should be set at .75.

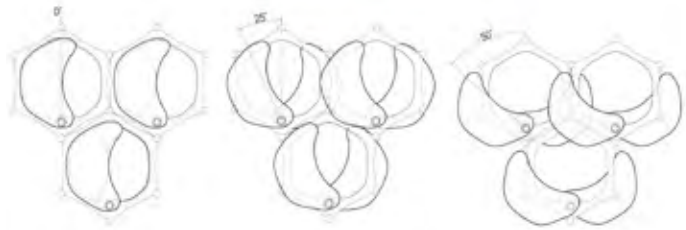
Drawings printed on sand paper



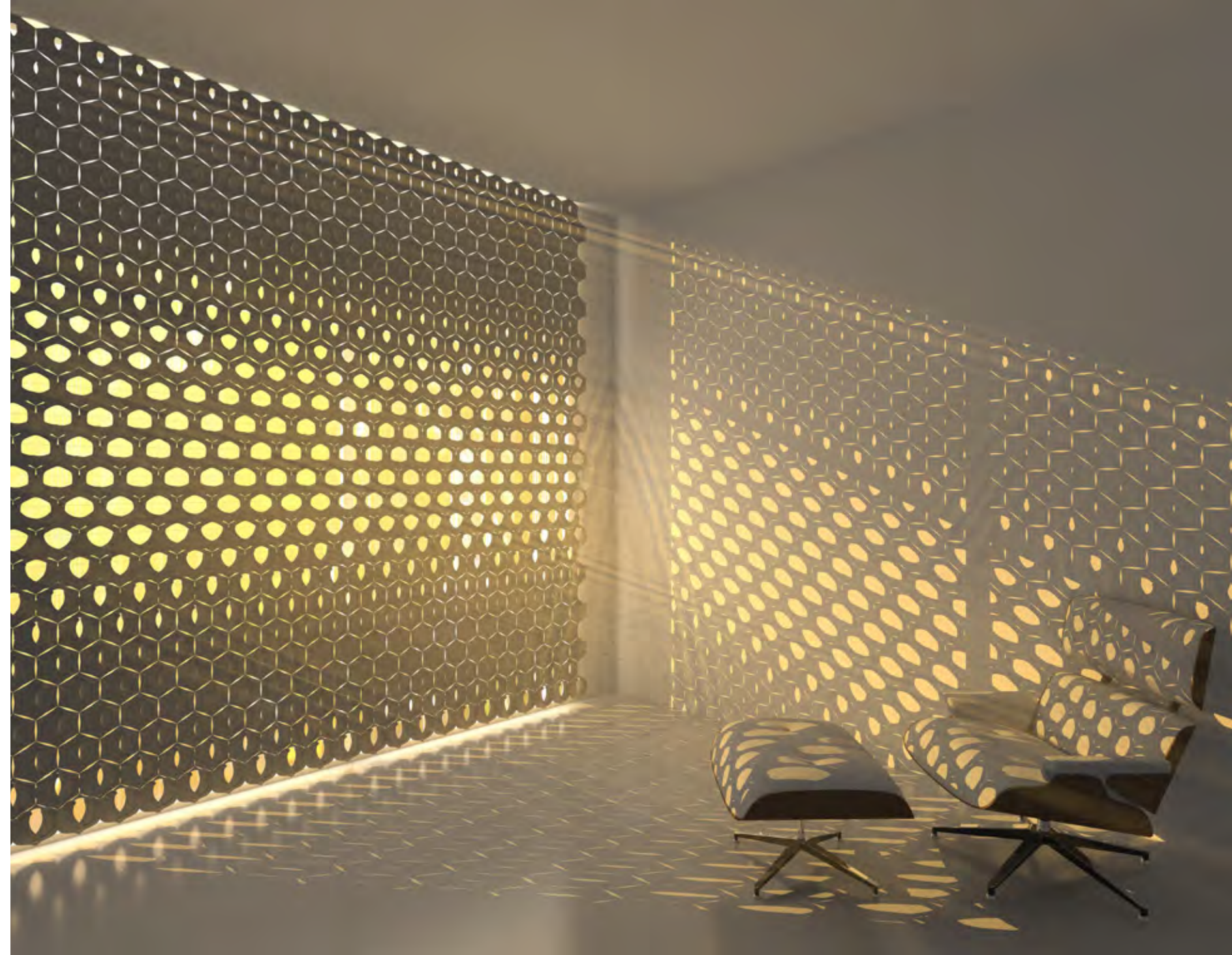
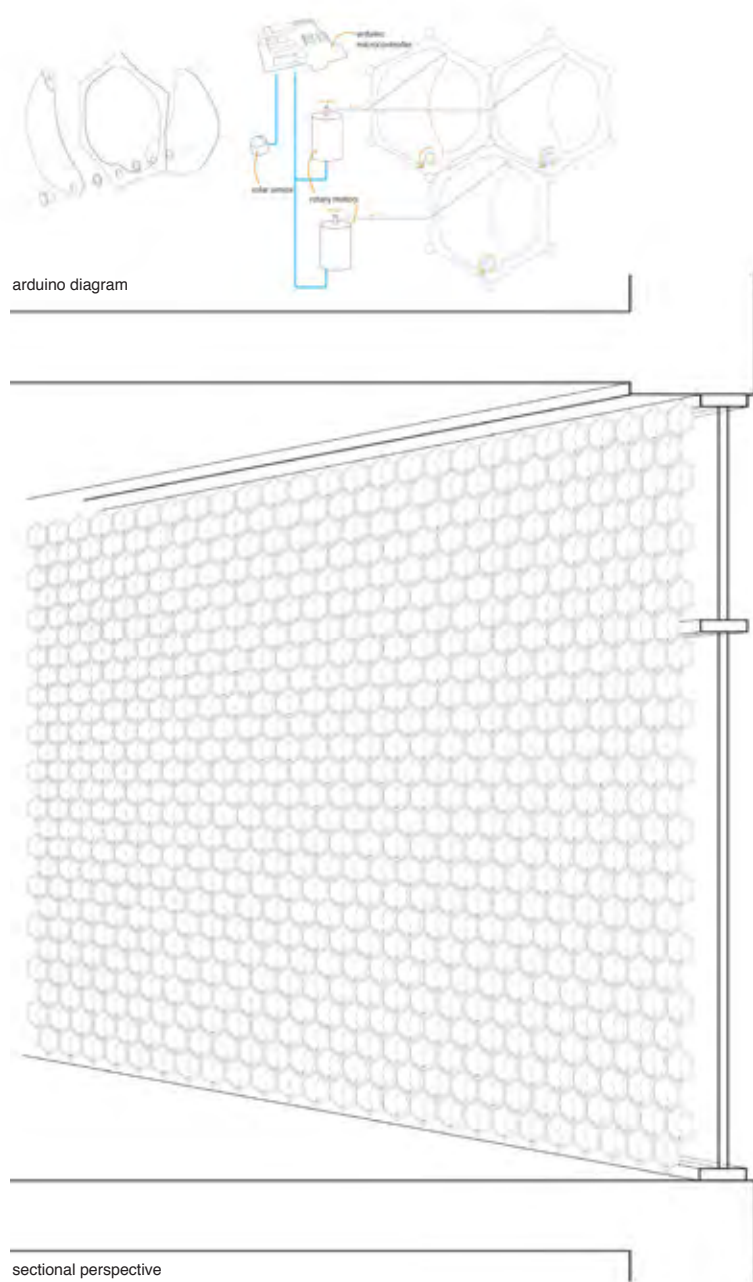
HEX CURTAIN: Developing 3D printing for the rapid manufacture of facade elements

Project Date: 2011
Project Team: Ronald Rael, Virginia San Fratello, Chase Lunt

The HEX curtain is designed to open and close automatically in response to natural daylighting conditions. Each row of the HEX curtain is composed of hexagonal shaped apertures that are covered by 2 operable shields. The shields have the ability to pivot open and closed. The shields are hinged at the bottom and threaded at the top. The top thread connects each shield to the one next to it. At the end of each row a rotary motor pulls the thread and slowly opens or closes the shields in tandem. The motor is driven by an arduino microcontroller connected to a solar sensor so on a sunny summer day the shields remain closed and on a sunny winter day the shields are automatically opened to allow sun to enter the interior and warm the space. The HEX curtain is constructed of laser sintered nylon and is 3D printed in 27" x 22" panels.



above: opening and closing sequence
below: 3D printed prototype



**PLANTER BRICK WALL:
Developing 3D printing for the rapid
manufacture of clay building components**

Project Date: 2011
Project Team: Ronald Rael, Virginia San Fratello, Molly Reichert

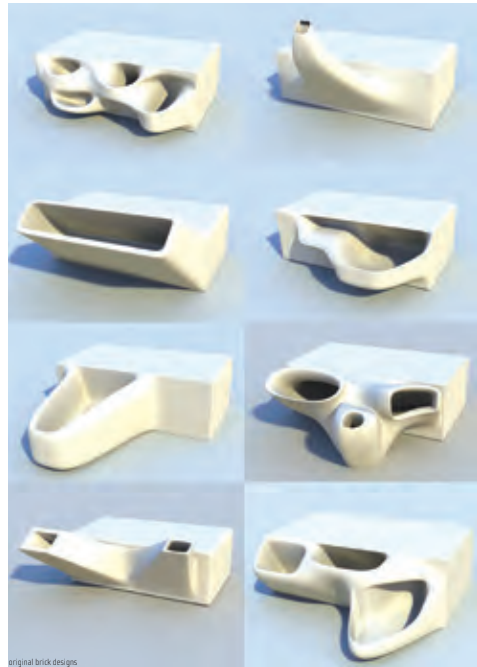
The planter brick wall is designed to be a combination of traditional masonry units combined with units that can hold plants and vegetation. Most plants do not need much, if any, soil but they do need water and nutrients. The plants held in the planter bricks will be fed water and nutrients through drip irrigation lines that are built into the cavity of the masonry wall.

The planter bricks have the potential to counter the heat island effect in big cities through evapotranspiration and pollution conversion and by the light, reflective color of the bricks. Additionally, edible plants such as rosemary and other fragrant herbs with shallow root systems may be planted in the bricks and accessed through openings in the wall. The plants in the bricks will help mediate the temperature of the microclimate surrounding the building, buffer sound and filter the air.

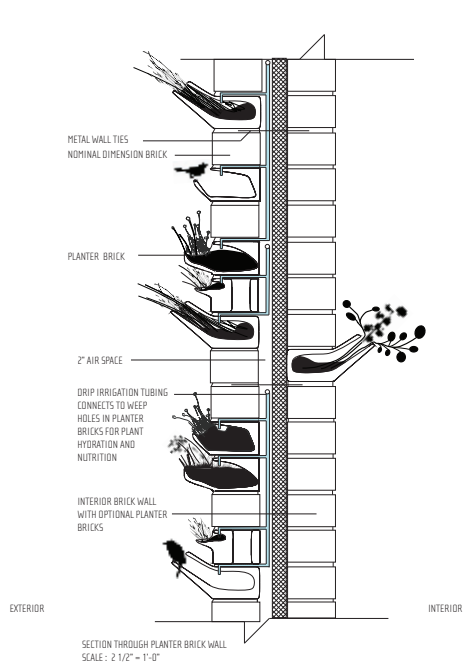
The planter bricks are made by direct digital manufacturing and rapid prototyping technology. Ceramic particles are printed and held together using an organic binder and then fired in a kiln just like traditional bricks. The bricks may be assembled in a load bearing cavity wall condition or installed as a traditional masonry curtain wall would be on a steel or concrete frame building and can be installed new or retrofitted.

The planter bricks shown here have all been 3D printed using direct digital manufacturing. The bricks are modeled in a 3D software application and the digital file is sent directly to the 3D printer for manufacture. This means a very diverse and infinitely unique selection of bricks can be manufactured based on the clients or designers desires for a particular application.

The bricks are manufactured with clay instead of more ephemeral powders that are typically used for rapid prototyping. The 3d clay prints are then bisque fired at cone 5 and glazed to make them waterproof.



original brick designs



3D printed clay wall assembly



3D printed clay brick glazed white

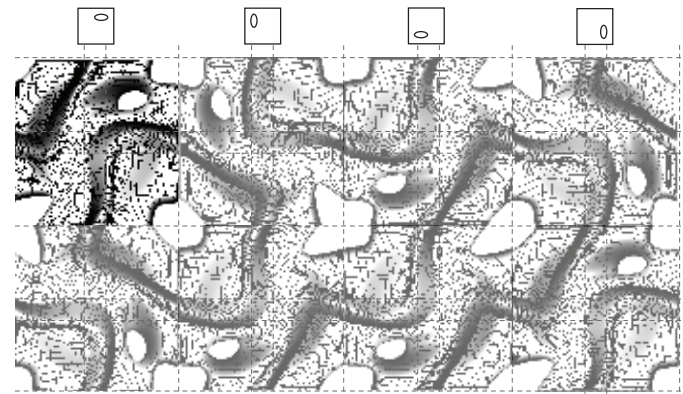
SEAT SLUG:
Developing 3D printing for the rapid manufacture of structural cement-polymer building components

Project Date: 2010

Project Team: Ronald Rael, Virginia San Fratello, Kent Wilson, Nick Buccelli, Emily Licht

RSF has developed a cement-based polymer and a new process that, for the first time, employs conventional rapid prototyping hardware to produce strong and durable building components that cost far less than conventional rapid prototyping materials—up to 90% less than comparable powder printing materials. The material can also reach strengths of up to 4,700psi in compression. This advancement in material output from digital modeling software ushers in a new era in building materials, and a new synthesis of design and production.

The SeatSlug, a biomorphic interpretation of a bench, demonstrates how this new digital output process generates end-product structural building components directly from 3D software models. The design is inspired by flabellina goddardi, the newest species of sea slugs discovered in California in 2010, and by the infinite tessellations of Japanese karakusa patterns. It is constructed of 230 unique rapid-manufactured components. The sinuous form, subtle translucency and glossy finish engage viewers with a memorable aesthetic experience—a tactile personal encounter with a technological breakthrough.



karakusa tiling pattern

