

DRAWING ON CONTEXT:
Proposing a Hybrid Design Process for Textured Concrete

by

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Figure1 Top pattern on icing sugar drawing

“Make your own tools. Hybridize your tools in order to build unique things. Even simple tools that are your own can yield entirely new avenues of exploration. Remember, tools amplify our capacities so even a small tool can make a big difference.”

(Mau 2000, 89)

Abstract This thesis argues that making architectural representations using combinations of different mediums and tools offers greater material awareness, which opens the possibility of closer engagement with the site and its program. Specifically, the first chapter compares the strengths of digital and non-digital drawing mediums in order to develop an architectural theory that promotes the development of hybrid representations. The second chapter is a case study relating the method of drawing and translation to construction of two projects that use textured concrete. The third chapter details how a hybrid representation is used to design an addition to a culinary academy in the city of Cuenca, Ecuador. Finally, the research concludes that the process of making a hybrid representation takes advantage of the strengths of digital and non-digital mediums creating a closer relationship between materials and site.

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Introduction

Among the many design tools at the disposal of the architect the drawing represents one of the most significant. From the sketches that define early ideas to the final construction drawings, one of the fundamental roles of the architect is to make drawings of things to be built. The concept of the drawing in this thesis refers to an expression of design intentions overlapping ideas, modifications and design developments.

Architectural representation as well as translation to matter has changed with the introduction of digital tools, but non-digital mediums have not been replaced by digital representation, nor has construction been displaced by digitally controlled manufacturing. At the same time, new technology for graphic production has been widely accepted by students and practitioners and it has become the standard in architecture. Digital representation has been recognized for its power to directly manipulate digitally controlled fabrication machines, and they are often seen as the answer to the process, but they can also be restrictive because they facilitate certain aspects of drawing and fabricating more than others.

While the digital drawing has become very common, it does not mean that it must be the only medium in the design process. The same thing is also true in the fabrication process. The qualities of non-digital mediums of representation have many benefits for architects that can still be of use in combination with the strengths of digital tools. This thesis argues that by combining digital and non-digital mediums into a hybrid design process it is possible to create a closer relationship between materials and site.

The following research explores the hybrid design process in three ways. First, it compares the strengths of digital and non-digital drawing through line-making and hatching. Second, it analyzes two case studies where each approaches the drawing and translation to building using a different method. The Art and Architecture building designed by Paul Rudolf in 1964 is an example of the use of non-digital drawing and construction while the Edison Residence designed by KANVA architects in 2014 is an example of design and construction primarily by digital mediums. These case studies offer insight into their specific drawing and construction methods, and aspects of each are applied in the final design project. Finally, the design project develops a hybrid design process through the construction of a drawing tool, and the juxtaposition of digital and non-digital mediums.

1 Chapter Non-Digital and Digital Features of Drawing

1.1 Line-Making

Expressing ideas in architecture takes many forms. Line making for example, is the way in which the translation of ideas and the use of the media give shape to different geometric expressions on the page or on the screen. Professor Paul Emmons says that “architectural drawing is a unique mode of active thinking, a fertile wellspring where the design emerges from within the effort of drawing” (Emmons 2014, 536). In these terms, line making involves translation of ideas, construction of relationships and sensitivity to the context. However, these are not the only features that the drawing possesses, material expressions are also involved. Professor Robin Evans suggests that the combination of these traits—ideas and material expression—emphasize the abstract dimension of the drawing and the corporeal properties of how things are made (Evans 1997, 161). By comparing non-digital and digital aspects of line making with reference to fluidity, layering, and visualization, the process of design by combining mediums reveals new connections between the drawing and the fabrication.

Fluidity

Between digital mediums and non-digital representation, the fluidity of the drawing motion presents points of comparison. Beginning with the sketching phase of design, hand drawing has the potential to be loose and free compared to digital drawing that often requires commands and order to produce images. Architect David J. Lewis makes use of hybrid methods of representation to develop the design in his practice. He says “in the case of

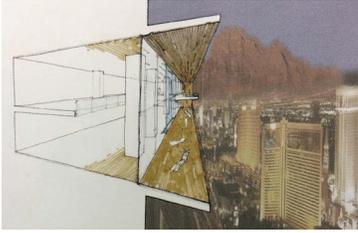


Figure 2 David Lewis Vegas 888 hybrid design drawing (Lewis 2008, 176)

representational drawings, we build this through a method that relies equally on complex modeling software and 4H lead pencils on Mylar, tactically using aspects of each. The speed and fluidity of one method of design are augmented and counterbalanced by the slowness and accuracy of the other” (Lewis 2008, 177).

The fluidity of non-digital drawing is also seen in architectural sketching where different parts of the project are depicted at different scales. The non-digital drawing makes it easier to work on a single surface where it is quick to overlap lines and blur images to develop new ideas. Because all of the sketches are visible all the time across a surface, it is much easier to make associations between the various drawings. Carlo Scarpa made use of this technique in many of his drawings such as the 1975 project for the museum of Santa Caterina.

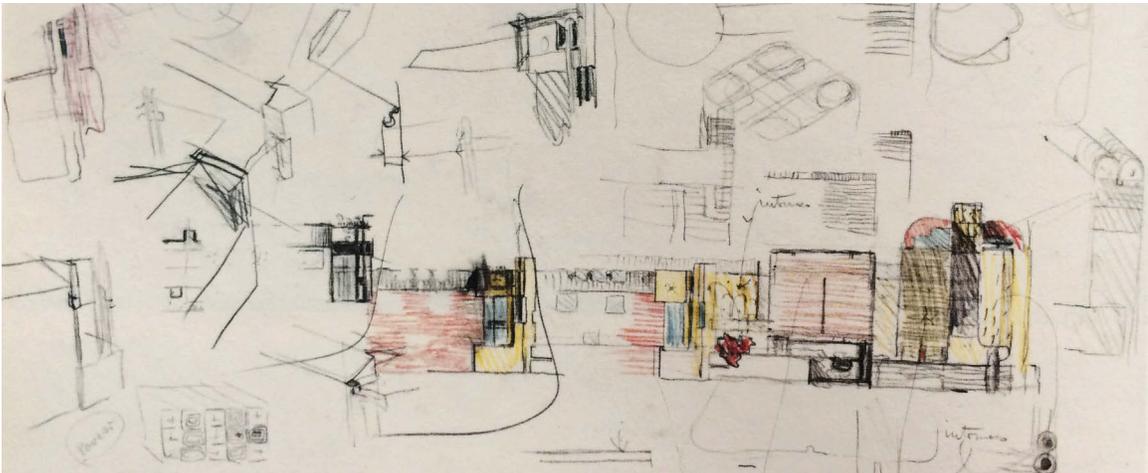


Figure 3 Carlo Scarpa studies for modification to the new gallery block (Scarpa 1984, 117)

When drawing on the computer, because of the physical construction of the screen and the possible views in the software, there tends to be a separation between stories, elevations, sections and details because of the interface that is split into windows and layers and this condition makes it difficult to keep a record of the development of the design.

By contrast, hand drawing offers a certain advantage for speed and fluidity for working through design ideas, while using digital tools tends to favor established designs.

One of the major differences included in the digitalization of tools is the change of drawing fluidity related to the haptic sense of the design tool. “The use of digital technologies once again suggest an answer to the question of how we design, as both the boundaries of feasibility and pathways of imposing material form that characterized the traditional design tools have been completely redrawn by the digitalization of those tools” (Gänshirt 2007, 96). There is a physical connection to the tools while drawing, and the architect has available different kinds of tools for non-digital drawing like pencils which help to connect the idea to the quality of materials through their physical nature. “Some architects have developed rich techniques for working building materials from how they worked their pencil lead. Louis Sullivan, who drew primarily with lead pencil, made pointillist black pencil marks on top of light construction guidelines to create a sparkling effect of highlights and shadows. These marks are seeds planted in the vibrant whiteness of paper corresponding to his transcendentalist view of the vital life of nature. The black spots translate into the shadows and white paper the highlights of the glazed terracotta ornament of his buildings” (Emmons 2014, 552–53).

Compared to the relatively sanitized experience of designing with a mouse and monitor, the computer suggests a different interface in the design process. While digital drawing seems to offer similar visual effects to drawings made with non-digital tools they provide a different haptic experience. For example, the dirtiness

of working with non-digital drawing tools connects well with the real dirtiness of constructing buildings. Emmons highlights how construction tools became the architects drawing tools during the Renaissance. The translated tools included the compass, T-square and triangle, and just as importantly the paper sheet became the construction site (Emmons 2014, 538).

Each hand drawing instrument has a unique haptic quality presenting a different relationship to the fluidity of design, but the mouse introduces uniformity to the design process by removing the difference in input and reducing the process to a single physical interface with the drawing software like the mouse or stylus. Where hand tools present a wide variety of unique feels, each providing a different result on the page, the homogeneity of the mouse is a different experience. The ability to draw smooth, accurate, detailed curves using non-digital drawing tools takes a lot of practice but is relatively easily achieved using digital drafting. This is not always translated to construction, but graphically becomes much easier when the lines are by nature being calculated instead of drawn.

In conclusion, each hand drawing tool provides a slightly different haptic sense and fluidity for the design development, while also reflecting the tools used on the construction site. The mouse introduces uniformity and simplifies geometric constructions, while at the same time digital drawings make it much easier to create accurate, complex geometries that are supported by digital analysis and a connection to fabrication tools. Together the combination of their qualities can benefit the selection of materials and techniques for the design process.

Layering

The concept of layering in architectural line work can mean many things. It relates to building up lines on a single surface, but it also refers to the idea of working simultaneously in a set of architectural drawings on separate layers of paper. Both digital and non-digital mediums offer something unique for visualizing ideas across the layers.

In non-digital mediums, using layers of tracing paper helps to develop the design because it's possible to see sketches and drawings in different media juxtaposed against one another. It also permits a designer to add details by building up layers of line work and complexity of relationships through color, scales, weight etc. across the different sheets. By contrast, digital drawing works this quality by changing opacity of the drawing interface. This gives a similar visual quality but is very difficult to work between the strengths of different software programs. For examples, Photoshop enables drawing using free style sketching through layers, but becomes difficult to overlay in the line work of a drafting program. Bringing a Photoshop sketch into AutoCAD is a tedious process, while working on trace paper over a drafted plan is much quicker and facilitates construction of ideas in a vertical dimension.

Visualization

A third concept relating digital and non-digital line making is visualization which has changed significantly with the introduction of digital images and mapping. The tools and the software enables architects to see a design from different distances that supports the understanding

of concepts, relationships and sensitivity to the material differently than they would using a non-digital medium.

Zoom in line making of hand drawing is achieved by the depiction of objects at different scales, while zoom in the digital drawing is achieved by scrolling in and out of a view on a monitor. It is a different kind of visualization because it narrows the view of an image, whereas in non-digital mediums it is much easier to see the bigger picture all at once across different scales. This is significant because all the images hand drawn are always in relation to the size of the hand and the tool, but in the digital drawing images are reduced to the width of the window on the screen.

Visualization and scale take on different meanings in the different mediums. There is not really a similar zoom in hand drawing, while one focuses in on a part of the whole with focused vision you need to imagine it by drawing at different scales, whereas the digital drawing presents everything uniformly, but the ability to scroll in and out allows an actively dynamic perspective during the design process. This idea is present in mapping where Google maps has become widely accepted and enables the user to zoom in to any place in the world at the street view level and similarly, and opposite, out to the scale of the planet or the universe. All of this exists within the fixed frame of the computer monitor.

There are examples of architectural drawings that experiment with this idea and translate it to façade surfaces in a number of unique ways. For example, in the surface of the Young Museum of Art in San Francisco (2005) designed by Herzog and de Meuron, they used the zoom quality which was translated to panels that reproduced the pixels of the landscape. These panels were produced



Figure 4 Image of canopy trees from the area by architects (Zahner)



Figure 5 Childrens Entry (Zahner)

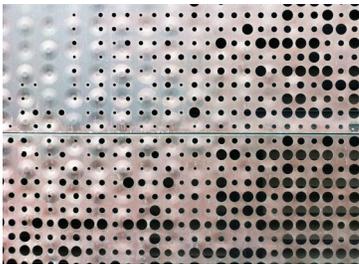


Figure 6 Copper Sheet (Zahner)

using blown up images of canopy trees from the area. “To synchronize the production reality with the design intention, an algorithm was created to interpret and convert the images into a matrix of circles. The circles were of different diameters that corresponded precisely to a gray scale image of the trees. The position of each circle and its diameter were then directly related to a machine stamping process – the copper sheets were stamped outward or inward to nine different levels of predetermined depths” (William 2008, 70). The screen itself is not a drawing of the surrounding environment but makes reference to the process of capturing, modifying and ultimately fabricating abstracted digital representations of the trees in an effort to illustrate the design concept of camouflage.

Working with a micro visualization and precision is possible with a digital drawing and is reflected in the surfaces produced by using digital tools for fabrication. The theoretical micro zoom precision of the algorithm has a direct relationship to programming the digital tools. In the case of the hand drawing, this feature is difficult to reproduce, because our physical visual perception possesses a different zoom quality than digital mediums; we see all scales at once but not beyond the limits of our eyes.

As a counterpoint, working with physical materials as opposed to digital models with the understanding that they will later be digitized frees the designer to work at any scale that is comfortable. This is particularly helpful when modeling because the models can be adjusted in the digital modeling software while maintaining the details and physical material nature of the original model. Frank Gehry most notably developed a design workflow using

physical models and digitization as a key to his process. For example, in the Walt Disney Concert Hall project “Gehry physically models his conceptual designs by shaping into desired forms the ‘developable’ strips of paper or metal. These forms are digitized and the resulting surfaces are then analyzed in CATIA software and converted into digitally developable surfaces” (Kolarevic 2003, 46). By using a hybrid process Gehry takes advantage of the freedom of form and scale in the physical model and translates that to full scale material form using the power of the computer to analyze the structure and control the fabrication machines.

1.2 Hatching

Hatching further develops the relationship with line making between digital and non-digital mediums by creating relationships with the physical building through the depiction of material conditions and qualities of its surfaces. These traces are commonly recognized as adding texture to the drawing, or introducing hatchings that are more than just symbols representing materials. Emmons states that “they are related to constructive material understanding with long traditions. As iconic indices, constructive drawing is a form of imaginatively constructing buildings. In constructing drawings that are metonymic with constructing buildings, the story of the materials and methods of making become integral with the concerns of the form of the design” (Emmons 2014, 547). This is significant because the depiction of the hatching precedes the actions of the construction and the drawing technique becomes integral to the final shape of the building.

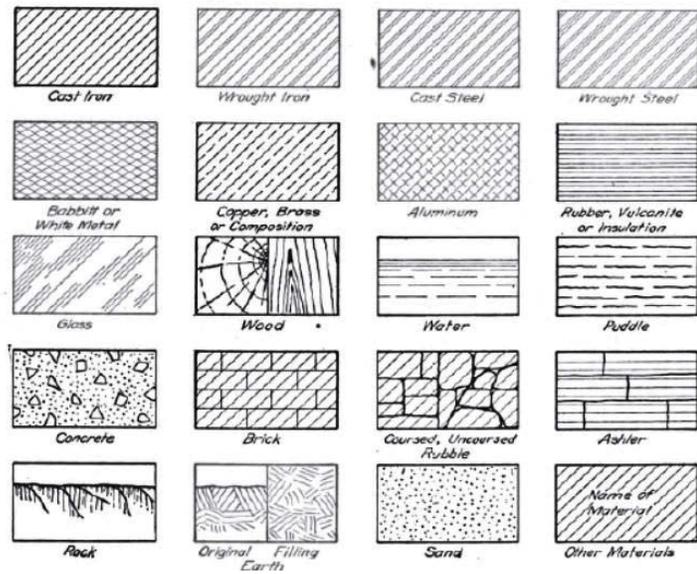


Figure 7 Symbols for materials (French 1911, 318)

Drafting Speed

The first aspect of comparison between digital and non-digital hatching is the speed at which the hatch is applied. Hand drawing demands a lot of time to apply hatching. As an innovator in the field of digital programming for architectural drawing, Mark Burry says “when I studied, it was the late 1970’s, we spent a lot of time hatching—I remember spending at least several days hatching on my final project! There has been an incredible productivity gain through CAD, but what are we doing instead with the time we have saved in studio? ...In this case there must be a lot of room for a completely renovated architectural education” (Burry 2003, 69).

Hatching by non-digital drafting used to take a lot of time and careful application, but with the introduction of digital drafting this practice has been reduced to the application of a pre-established texture that can be easily edited in a number of fields including scale, line weight and color. This results in time saving during drawing production but can also be seen as a reduction of an

imaginative constructive element to a material symbol as Emmons suggests.

Translation of Hatch to Building

Building on the imaginative qualities of the hatch, there is a complexity inherent in the translation of a hatching pattern to material because it requires reciprocity. As the project advances the relationship between a drawing and the construction matures through iterations. The translation is a process of testing, evaluation and creation of methods that work with the drawing and the material qualities. Professor Goffi states that “the process of making, whether drawing or building, is not just imposing the idea on material but growing through it so that material influences the result rather than merely receiving it” (Goffi 2013, 61). In these terms, various testing procedures, tools and materials support the translation but the material reacts in different ways to each one. In the A&A building of Paul Rudolph, the contractor Charles Salomon did around three dozen tests of the formwork to examine the visual qualities between the design of the formwork and the material (TIME INC 1964, 81). Rudolph’s drawings were not simply a set of exact orders for material execution, but rather a visual guide to be interpreted between architect and builder.

In translating the hatch to the material, it is important to develop the drawing with careful consideration to the material, but the introduction of digital tools have changed this condition in part because of the new complexity of building surfaces. Antoine Picon has classified the surfaces into three classes: texture, pattern, and topology emphasizing how technology has produced new types of

surfaces based on digital images and fabrication techniques (Picon 2013, 27).

In traditional non-digital representation and construction there were a much smaller pool of standard materials to choose from than are currently available. New complex building surfaces are constantly evolving in material and structural nature and thus require new material representation. Materials such as fiberglass, polymers and foams, rarely used in the building industry are well suited to digital drawing as it relates to fabrication because they can be molded to any shape (Kolarevic and Klinger 2008, 8).

Working with digital tools supports new uses of traditional materials but they are also well suited to forming new materials into non-traditional forms. On the other hand, non-digital representation works well for interpreting existing buildings and evolving construction as well as designs for new buildings. Together they offer a complementary set of qualities for working with various forms of construction.

2 Chapter Case Studies

The two case studies selected for comparison include the Yale A&A building by Paul Rudolph and a student residence at McGill University designed by Kanva architects. Other case studies considered included the Eberswalde Technical School (1999) by Herzog and de Meuron that features a screen printing on concrete around the exterior and the Museum of Architectural Drawing (2013) by Speech Architectural Office covered with architectural sketches cast in concrete. In the case of the Yale School of Architecture (1964) and the Edison Residence (2014), their respective textures correspond in that they both respond to specific techniques of representation and a particular treatment of light that enhances the texture. Paul Rudolph in 1964 used a unique hand rendering technique that was learned through engraving methods and then translated to the casting molds. More recently, KANVA architects in 2014 used digital tools to arrange movie frames in a repetitive sequence along the façade and then digitally fabricate the casting molds.

2.1 Non-Digital Mediums: A&A Building -1964

Project Information

Designed by: Paul Rudolph (1918-1997)

Education of Paul Rudolph: Harvard University under Walter Gropius and Marcel Breuer

Build by: Charles Salomon at George B. H. Macomber Co.

Years of building: 1961-1963

Area: 117,575 square feet

Location: New Haven, Connecticut

Orientation: It faces East and West

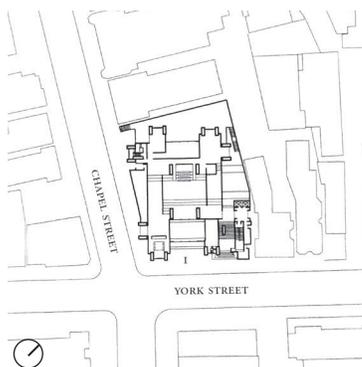


Figure 8 Project Location (Rudolph and Stoller 1999, 86)



Figure 9 Yale School of Architecture and Louis Kahn's Art Gallery from Chapel Street (Rudolph and Nagy 1970, 123)

Concept

The Yale school of architecture was inspired by the idea to furnish a single roof to house architects, planners, painters and sculptors. In these terms, the interior comprises 36 floor heights between 6 stories that provide communication between disciplines and the most desirable light to work. For its part, the exterior breaks down the horizontality of the building through vertical sections that are arranged to take out the weight of the corner and communicate with its immediate context, the Louis Kahn's Art Gallery and Chapel Street (Rudolph 2008, 98).



Figure 10 Entrance to the School (Rudolph and Stoller 1999, 35)

Project Description

After the turn from Chapel Street to York Street, the access is located through a series of steps that guide the visitor to the third floor. From this point, the visitor has access to the vertical circulation (on the right) or the third floor (to the left) where the main hall is located. The main hall is a large room for expositions and a mezzanine for administrative offices. Below the main hall there are two levels where the mechanical rooms, lecture hall, graphic arts and sculpture studios are located. Above the main hall planners and architecture students are located in separated areas but connected by a bridge. In the last floors there are the painting rooms and a penthouse for visiting critics (TIME INC 1964, 66).

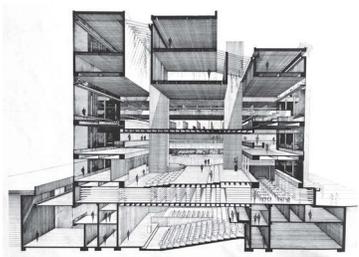


Figure 11 Cross Section from Chapel Street (Rudolph and Nagy 1970, 130)

Drawing and Construction

The drawing technique of Paul Rudolph derives from a technical treatise from the 1940's called the Scratch Drawing. The treatise features methods from wood cutting and fine art engraving techniques. One of these methods

involves applying a layer of ink over a white surface and then cutting it away using an engraving tool (Rohan 2000, 90). Even though the methodology was not originally intended to be applied to architectural drawings, Rudolph translated the method of holding the engraving tool and the method of cutting into the reproduction of parallel lines for the drawings of the A&A building. The drawings created by this method were easier to reduce and enlarge because they do not lose a great amount of detail in printing, which provides an advantage for reproduction in architectural journals (Rohan 2000, 89).

Based on his drawing technique, Rudolph explains in his essay *From Conception to Rendering to Building* how the development of the construction technique came together:

“Some construction materials are easier to depict through rendering than are others. This probably accounts for some of my interests in concrete and highly textured surfaces in general. The technique of rendering to create line and shadow suggests certain linearity in the texture of walls which sometimes influences the choice of materials. For instance, the development of textured concrete, as used in many of our buildings, probably started... with the concept of rendering and how to make buildings conform more exactly to the image depicted” (Rudolph 1972, 7).

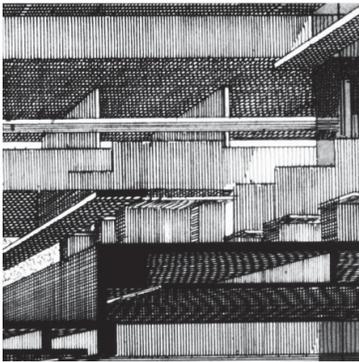


Figure 12 Perspective section by Paul Rudolph (Rohan 2000, 90)

To translate Rudolph’s drawings in the concrete, the contractor Charles Salomon from the George B. H. Macomber Constructions was the key. Salomon made



Figure 13 Construction worker hammer the concrete (Paul Rudolph 2008, 70)

around three dozen casting samples before agreeing to the technique that better represented Rudolph's drawings (TIME INC 1964, 85). The construction of the reinforced concrete and the definition of its surface started with the construction of the wood forms. Strips of wood of 1 ½ inches deep and 1 ½ inches wide and a slope of ½ inch in the side of the strip were cut and then nailed to plywood panels of 2 x 4's. The plywood panels were made up in 2 foot widths of varying lengths. When the forms are ready a generous amount of oil was applied and then they are set in place to pour the concrete. The stripping of the forms was made the same day when the concrete was poured or the next morning, and after that, men knocked the top of the ribs with three pounds hammer (Allen 1962, 35).

In an interview with Rudolph in 1988 for the 25th anniversary of the completion of the project, Rudolph explained the reasons behind hammering the concrete. He explained that the construction technique was not only aligned with its drawing technique but it displays a deep understanding of how concrete weathers, the aggregate and its color. In this way, the channels are made for the staining to occur and that would weather much better with the concrete (Rudolph 2008, 144).

Learning by Making

To understand how the concrete surface was made in the A&A building, I had to research Rudolph's drawing technique and the construction system. For the construction system, two publications were very helpful. The first was the magazine called *Contractors and Engineers* (1962) and the second was a publication called *Architectural Forum* (1964). Both magazines have detailed descriptions about

the construction process along with the major challenges that the contractor faced in the project.

My first test considered how to make mortar, how to balance the ratio of the materials and the casting system. Four wood forms of 10 x 15 cm were made and sealed with silicone in the interior and with duct tape on the exterior. For casting the surface, construction foam, Vaseline and a mortar 1:2 (cement-sand) were used. The wood form and the foam were stripped after 24 hours but some of the mortar remained trapped in the foam. This test defined the basics of mixing the materials including details like how to add water during the making of the mixture. Even though there were ratios established for the materials, the water changes the consistency of the mortar and therefore it is not always easy to mix exact proportions; the ratio is often modified based on the consistency of the mixture.



Figure 14 First test of mortar, construction process (Author)



Figure 15 Final Results of first test of mortar (Author)

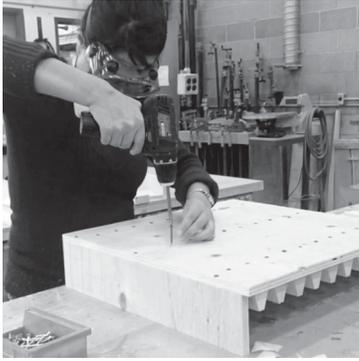


Figure 16 Construction process of Paul Rudolph concrete (Author)

For the reconstruction of Rudolph's section, a sheet of plywood was used for the mold. The sheet was cut to form a mold of 50 x 50 x 10 cm. For the strips, one pine plank was cut in strips of 1 ½ inch by 1 ½ inch and 50 cm of length. The strips also had a lateral cut of ½ inch. After cutting the parts for the mold, the strips were marked with pen on the board, and then attached with a double-faced tape. This worked like a guide to screw the strips from the back. The mold was ready and a great amount of oil was applied in the interior before screwing down its lateral side.

For the concrete it was necessary to make 0.025 cubic meters. The concrete ratio was 1:2:4 (cement – sand – gravel). The mixture was made by hand and then poured into the mold. The mold was released after 24 hours and then the concrete was hammered. The process of hammering the concrete was the most difficult part because of the amount of strength that is necessary behind each strike of the hammer.

Building Paul Rudolph's surface concrete revealed the relationships between the drawing and the building. The lines of his drawings were translated in vertical shadows and the interstices between lines were translated to protruding channels. The process of translation also shows the communication between architect and contractor. The contractor performed many tests for the architect and together they figured out the best system to work with the characteristics of the material. The project demonstrates a growing process for the drawing, the construction system and the material.



Figure 17 Paul Rudolph concrete of Yale School (Author)

2.2 Digital Mediums: Edison Residence -2014

Project Information

Designed by: KANVA architects – Tudor Radulescu and Rami Bebawi

Education of KANVA architects: McGill University

Build by: KI

Concrete supplier: Reckli, Solubrik, Saramac

Years of building: 2013-2014

Area: 9,000 square feet

Location: 3525 rue University, Montréal, QC - North of McGill University

Orientation: The building faces the south west



Figure 18 Location of Edison Residence (Author)



Figure 19 Edison Residence (Author)



Figure 20 Entrance to Edison Residence (Author)

Concept

The design of the Edison Residence was inspired by the proximity to McGill University in Montreal and the historical context of the site. The building comprises thirty student units and common areas such as a kitchen, lounge and living room (Solkoff 2016). On the exterior, the building integrates with the height and materiality of the heritage neighborhood, which was restricted to three levels and the use of masonry.

Project Description

Vertically the project keeps the proportions of wall and window from the adjacent constructions though façade modulation and materiality. When students arrive at the building they are guided through a corridor on the right side of the building which evokes Montreal's traditional method of building for horse carriages (Solkoff 2016). After entering the building, they find the common areas on

the left, which face the front façade, and the rooms in the right side, which face the back of the building. The level underground has six rooms, the laundry and the storage area. The first level has eight rooms and lobby. The second level has another eight rooms and the kitchen, and the third level has eight rooms and the living room. There are two washrooms per floor with the common areas, so all rooms have close access.

Drawing and Construction

The drawings of the project were made using a Building Information Model. The program helped with the arrangement of images in the front façade and the corridor in the ground level. The images selected were twenty frames of the movie *Montreal Fire Department on Runners* (1901) by Thomas Edison. The movie shows the chief of the fire department, his driver and the equipment carried by horses to stop a fire of early 20th century where the existing stone house of the lot was flattened (Solkoff 2016). The sequence of images, which is repeated three times, was organized from top to bottom and crosses different materials such as the concrete panels and the glass windows (Theodore 2016).

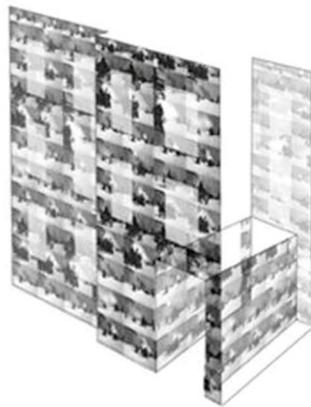


Figure 21 Arrangement of pictures in the facade (Solkoff, 2016)

The construction of the concrete panels were manufactured by the firm Reckli which has its main office in Germany and has been working with concrete since 1968 (“RECKLI Company History” n.d.). For the translation from image to concrete, the first step was to scan the pictures and then run an algorithm of 256 shades of grey. The algorithm provides a file of lines with different depths. The depth of the lines depends on the particular shade of grey. This means if there is a grey area close to white there

will be a minimal depth change, but if there is a grey close to the black the depth will be significant. After defining the image in grey-scale, the file was run by a CNC machine and the first negative mold was made. The negative mold was used as the master in order to cast the elastic form liners (positive mold) and then the concrete was poured over the elastic molds.

The procedure involves a double casting, from CNC mold, to an elastic mold and then to the concrete. Reckli indicates that the purpose of this procedure is for the reuse of the elastic molds, which in the case of the Edison Residence fits well because each panel is produced a minimum of three times.

Learning by Making

To reproduce the concrete surface of the Edison Residence, research into the building system of Reckli was done as well as making a number of visits to the site for documentation. During the visits to the site it was observed that shadows were visible if the person is located at 45 degrees from façade in the direction opposed to the sun. During a winter morning the sun is in the South-East and the observer needs to be in the North – West at 45 degrees from the façade. By contrast, during afternoon the sun is in the west and the observer needs to be in the South-East at 45 degrees from the façade.

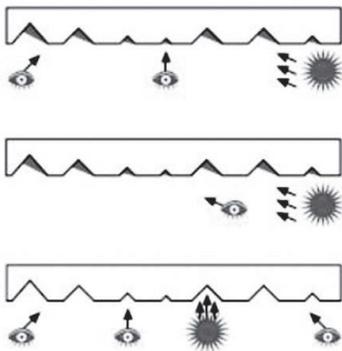


Figure 22 Diagram of concrete facade and sun (Reckli Company)

In order to reproduce the effects of the concrete façade a 3D model was built based on photogrammetry and the measurement of the panels. Between the digital drawing and the measurements, it was understood that the variations of grey oscillated between 1 mm and 3mm in depth. The white surfaces will be depicted with a 1 mm

and the black surfaces with a 3mm. A frame of the movie was then selected and the lines were traced in AutoCAD.



Figure 23 Construction process, from building to drawing (Author)

With the digital drawing the second step was to translate to the first mold. In the CNC three kinds of blades were tested to reproduce the effect of the shadows. The blades were of 45, 60 and 90 degrees. The first blades were very narrow and they did not reproduce the same effect. Only the 90 degrees could reproduce the same effect. Along with the different blades, various densities of foam were tested as well. The tests were cut with low, medium and high density foam. The purpose of testing with different foam density was to find which of them have better results with the silicone casting.



45 degrees blade and low density foam

60 degrees blade and medium density foam

90 degrees blade and high density foam

Figure 24 Test of blades and foams (Author)

On the foam molds several layers of silicone were applied. This was a process very slow. The first layer of application is the most important because it needs to be done very carefully in order to avoid air bubbles. Only when the layer is dry, the next layers can be applied. This is a repetitive process that could be accelerated with the use of a hair drier and a fan. The construction of the silicone mold was built during three days and twelve layers. On the fourth day the silicone molds were peeled and the foam with higher density produced a better casting of the silicone mold.

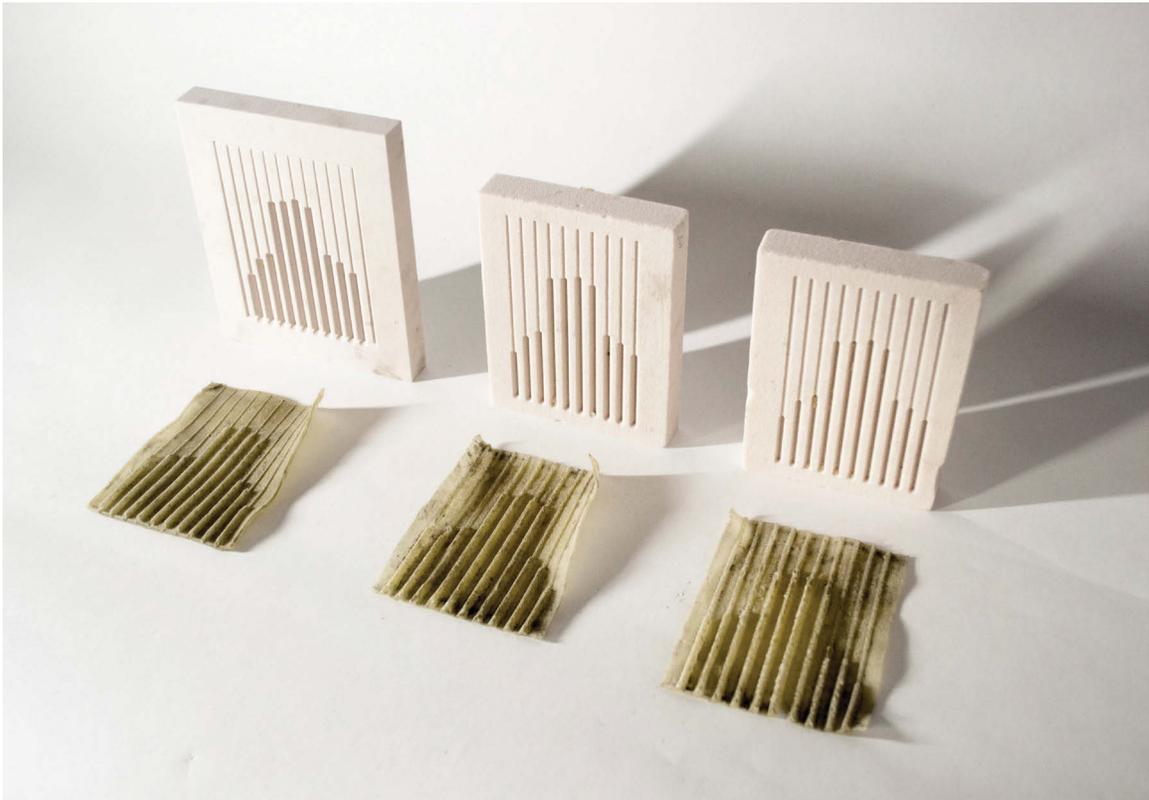


Figure 25 Test of foams and silicone. From left to right, high density-low density (Author)

For the last step of the production, the silicone molds were put in wood containers and oil was applied in the surface, then a mortar 1:2 was applied. After 24 hours the wood container and the silicone molds were removed. The best definition of the surface was arrived at though the hardest foam and a blade of 90 degrees.

The research and reproduction of this surface was a learning process. On one hand, the surface is a medium to reveal the history of the neighborhood through shadows; on the other hand, the process of manufacture with digital mediums establishes a layering process between programs and materials. The process of translation from representation to building introduces a third subject between architect and contractor, who is the CNC technician. The technician operates between the scan and the pouring of concrete, and this is a new figure for the building process.

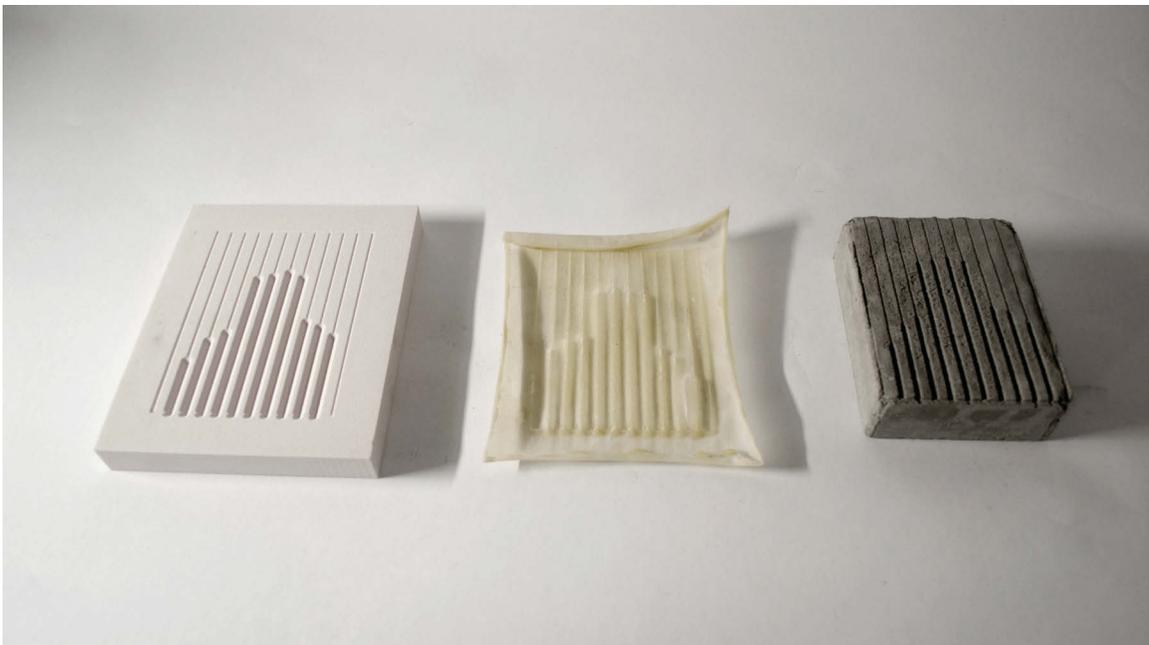


Figure 26 Concrete casting with 90 degrees blade and high density foam (Author)

3 Chapter Testing Hybrid Drawing in a Design Process

Taking into account the analysis of non-digital and digital features of drawing and the case studies, it can be said that non-digital representation has the strength of freedom in line-making, layering and diverse haptic sense of media. Meanwhile, digital representation possesses strengths such as micro and macro visualization, calculation of complex shapes and a direct link with fabrication tools.

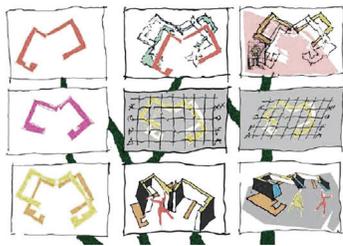


Figure 27 The family tree of a hybrid drawing (Fracari 2011, 116)

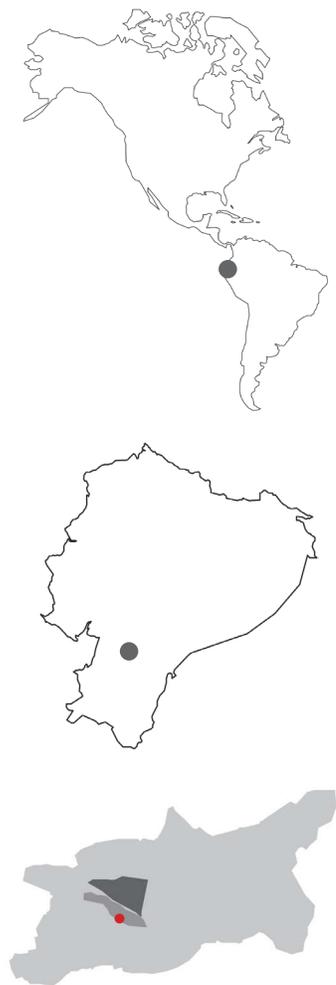
Professor Frascari in the book *Eleven Exercises in the Art of Architectural Drawing* states that the hybrid representation is not the final phase of a representation; it is the history of conversion between mediums that provides the name hybrid to the drawing technique. The representation can start on paper or any preferred medium, and then it can be edited in a digital tool or vice versa as many times as necessary to engage the imagination. The hybrid representation enables a sensorial relationship with the material construction and sensitivity to the creation of form (Fracari 2011, 114–15).

Kieran and Timberlake present a vision of architecture that is significantly different from the hybrid process where the value is placed in the vertical organization of production of elements for new buildings. They prioritize the digital model and preplanning all elements of the building so that the final construction is an assembly of parts delivered prefabricated to site (Kieran 2004, 157-173). This departs from the hybrid method of representation that captures the focus of the architect and the values of the site over time, including overlapping modification, changes and developments.

Even though digital representations sometimes appear to reproduce characteristics of non-digital, the

hardness of the work interface (mouse, screen, and keyboard) and the complexity of the drawing methods sometimes restrict the material imagination. A hybrid approach to drawing as explained by Frascari offers the combination of strengths of digital and non-digital mediums and suggests a sensible and sensitive working process with materials and the site context.

Through the design project located in Cuenca, Ecuador this thesis proposes a unique type of hybrid design process connected to the history of the site, the present use, and the heritage values of the city. The existing buildings on the site are the first examples of modern architecture in Cuenca. The buildings were an orphanage for fifty years and five years ago were transformed into a cooking school.



Legend

- Cuenca until XIX century
- South Growth of Cuenca at the beginning of XX century
- Cuenca in 2018
- Project Location

Figure 28 Design Project Location - Cuenca, Ecuador (Author)

3.1 Description of the Site

The city of Cuenca is located in the south of Ecuador between the highlands at about 2500 meters above the sea level and was designated as a Heritage Site by UNESCO in 1999. Cuenca was founded in 1557 by Spanish conquistadors, who organized the city with a regular grid of 84 meters by 84 meters. The city grew slowly until the first quarter of the XIX century when the exportation of coffee, cocoa beans and straw hats activated the economy of the country (UNESCO World Heritage 2018). Cuenca was the major exporter of straw hats and with this production the city grew to the south. In the south, farming areas were replaced by buildings for social use such as a hospitals, schools and nursing homes.

In order to organize the southern growth of the city the architect Gilberto Gatto Sobral designed the first urban plan in 1947 (Tello, Astudillo, Cardoso 2009) as well as

some buildings in Cuenca and Quito. Between the buildings that Sobral designed in Cuenca around the 1950's was the orphanage called Tadeo Torres. The orphanage was located in the southern area of expansion and was organized to contain a set of buildings that were connected by corridors. The design contained classrooms, an administration area, bedrooms, a cafeteria and a playground in the back of the buildings. Due to the lack of budget for the construction of the project only two buildings were built in 1950, the administration and the bedrooms.



The orphanage was used between 1956 to 2007 and during this period the lot grew smaller because the administration of the orphanage sold parcels to private investors. From 2008 to 2011 the building was used by city hall for offices. During 2012 the building did not have any use and in 2013 a cooking school called San Isidro occupied the building. Currently the cooking school has been active for five years with a certificate program of 3 years. There is only one class per year with 15 students which gives a total of 45 students in the school. The cooking school uses the two buildings built in 1956 but they have a limited area for cooking and no formal dining area.

- Legend**
- Administration building
 - Bedrooms
 - Playground
 - Kitchen/Cafeteria
 - Orphanage Lot
 - Lots

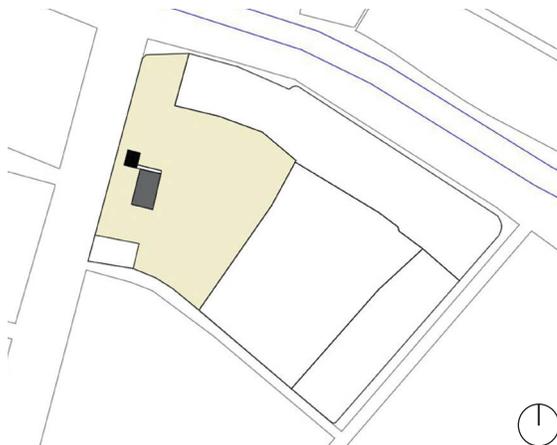


Figure 30 Orphanage and lot in 1956 (Author)



Figure 31 Orphanage and lot in 1973 (Author)



Figure 32 Orphanage and lot in 1979 (Author)



Figure 33 Orphanage and lot in 2007 (Author)

3.2 Values of the Site

The value of the site is present in two categories: one is the urban value, and the other is the building value. Central to the urban value is the block where the building is located that represents the first extension to the south of the city. This zone was primarily dedicated to farming until the 19th century, but as the city grew it became increasingly dedicated to social uses.

The zone has further significance to the city as it is surrounded by important aspects of the city landscape such as the change of topography levels, the river and a set of vegetation around the block. The vegetation of the area is the same kind that follows the lines of the river which integrates the landscape of this block with the change of topography.

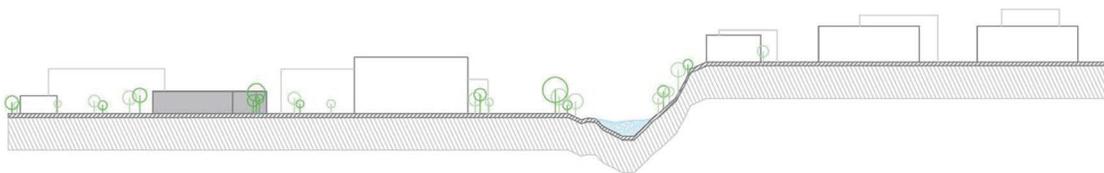


Figure 34 Context of the site and section (Author)

The building value resides in the characteristics of its architecture. The two blocks connected by a corridor is the first attempt of Modern Architecture in Cuenca. Further, it is the only building in the city designed for an orphanage use, and it is embedded in the memory of the city as a building of social care because it maintained its use for 51 years. On the site, only the first building was designed and built by the architect, while the second building was designed and later built by a developer. This second building has a pitched roof finished with clay tiles that changes the overall reading of the complex.



Figure 35 Orphanage in 1960's
(Central Bank of Ecuador)

3.3 Design Process

Sun Study

The orientation of the sun at different times of year played an important role in defining the location of the new buildings. Because the city is located at the equator, the sunrise and sunset has very little variation over the course of the year. This variation is between ten to fifteen minutes. During the summer the sun travels east to west at an inclination of 30 degrees to the north and during the winter it is the opposite; 30 degrees to the south.

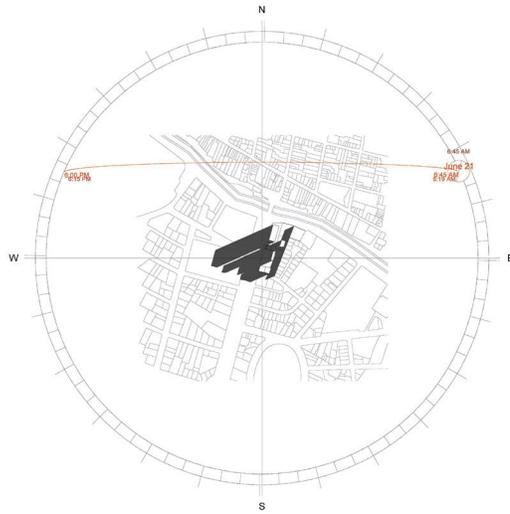


Figure 36 Sumer Solar Path in the Site
(Author)

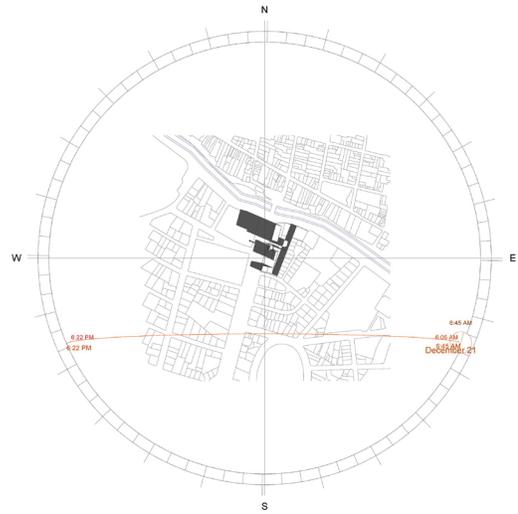
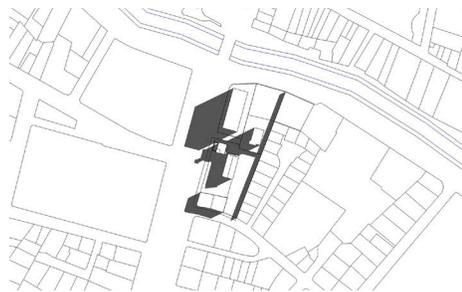
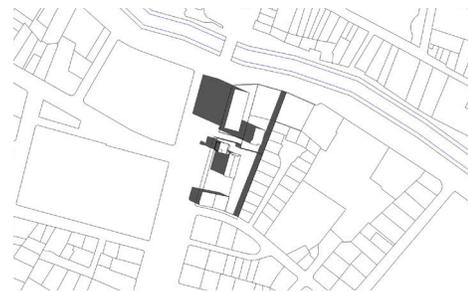


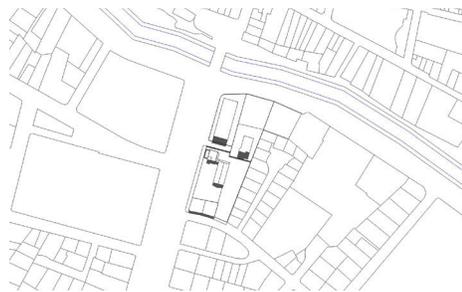
Figure 37 Winter Solar Path in the Site
(Author)



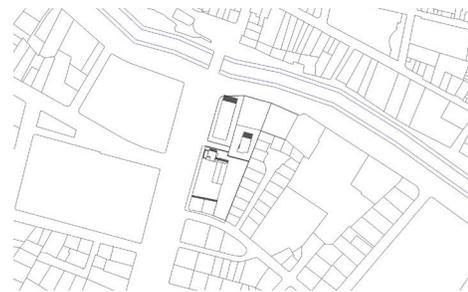
Sumer Solar Path - 9 am



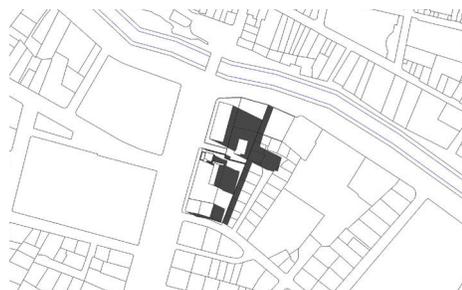
Winter Solar Path - 9 am



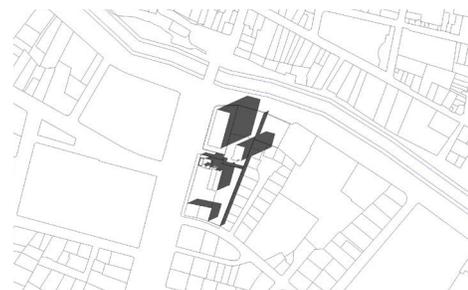
Sumer Solar Path - 12 pm



Winter Solar Path - 12 am



Sumer Solar Path - 5 pm



Winter Solar Path - 5pm

First Ideas

The proposed buildings and their location began with models of wood, paper and sketches that organized the first ideas about the program. It was important to find out that during the years that the orphanage was in use, the people in charge built a cafeteria, a kitchen and a playground to provide the kids with facilities missing from the existing buildings. Taking into account this consideration and the sun study the facilities for the cooking students will reintroduce some aspects of its historical context.



Figure 38 Wood models (Author)

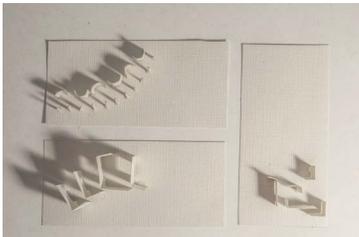


Figure 39 Paper models (Author)

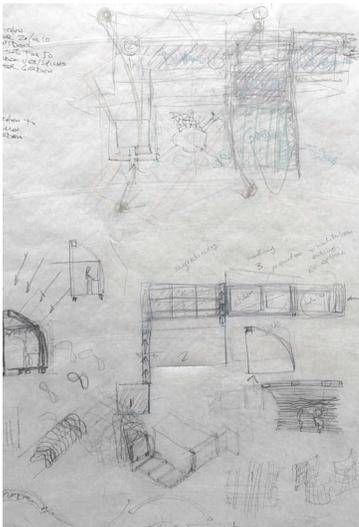
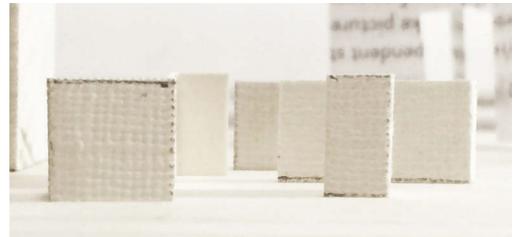
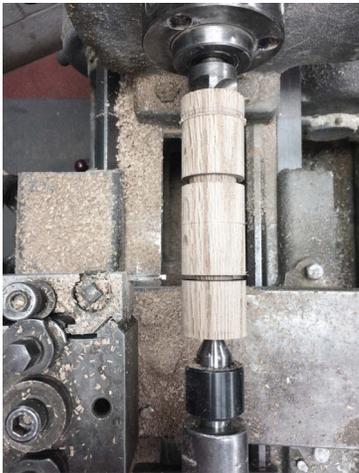


Figure 40 Sketches (Author)



After making some sketches on trace paper, and building a number of small massing models, the idea connecting how the kids used the back area was considered. In the playground it was possible that the kids would play traditional games like football, hopscotch, or the spinning top. Contrasting the games with the current use as a cooking school there was a natural connection to make between the cooking ingredients as a drawing medium and the playground games.

The top is a very popular traditional game, not only in Ecuador but around the world, and the idea of recording the motion of the top on a surface that has the ability to capture the movement provides a way to link culture, food, and the historical context. This process was inspired in part by the scratch board drawings of Paul Rudolph; where he cut lines on the paper, the top cut lines through the icing leaving behind the architectural traces.



Top Fabrication

The first step in creating the drawing tool was to fabricate a top. The measurements were taken from childhood memory because growing up I used to play this game with my brothers so I was very familiar with the toy. The top was carved from a small piece of oak in the shop on the lathe. From the raw materials we cut a piece roughly 20x5x5cm and marked a 6cm section in the middle from which the top was to be carved. Inside the 6cm section the head was notched at 0.5cm, the first part of the body at 2.5cm, and finally the 3cm length of the narrower base leading down to the tip.

We began cutting by roughing away the corners from the block turning it on the lathe. Then, with two

Figure 41 Fabrication of drawing tool/ top (Author)

different blades, one flat edged blade to rough the fatter part on the body, and a second angled blade to carve down the narrower neck of the top. The process required a delicate touch holding the carving blade while the wood spun on the lathe. With the same blade and a drill, we cut a hole at the tip to make a place to seat the metal tip.

The metal tip was a 6mm piece of steel rod cut with a hack saw. In order to make the angle on the metal tip we used the same angled metal chisel used to carve the narrow neck of the top. After shaping the tip, the rod was inserted into the nose of the top.



Figure 42 Drawing tool/top (Author)

Making the Drawing

Following the fabrication there were weeks of practice re-learning how to throw the top. The technique that worked best was one of the least complicated. Beginning by making a loop with the string around the tip, the string is passed around a small knot at the end and returned in the opposite direction. The first two laps around the tip need to be tight to hold the remainder of the string as it's circled around the body. After the string is wound around the body of the top, you must pass your middle finger through the loop. At this point it's time to throw the top. It does not have to be thrown hard to stand up properly. Once it's released from the finger tips it will unwind down the string like a yo-yo, but at the end will release and continue to spin on the ground.

After that it was necessary to figure out which drawing material would receive the marks left by the top. The first consideration was to imagine a surface where the moving top could be cast. In the same way Paul Rudolph learned from scratch board drawing, a paper covered



Figure 43 Steps to throw the top (Author)



Figure 44 Top on charcoal surface
(Author)

with a layer of charcoal was used. The top was thrown across it, but no traces were visible. Other materials included pastels, color pencils and crayons, but none of them retained enough of the movement to make a drawing possible. Looking at the results, it became apparent that a surface material that could do a better job of recording the movement was required.

Inspired by the program of the new building, it was necessary to look at different cooking ingredients that might better capture the movement of the top. Some of the choices included flour, butter, and icing. Flour was too light and did not hold on the drawing surface well. Butter was too oily and wet, and melted at room temperature, but icing had a smooth consistency at room temperature and held the shapes at each throw of the top.

The first attempt with icing was on a sheet of paper. The icing was applied with a spatula, and during application the resemblance to plaster and trowel became apparent. After a few attempts, the icing began to dry but it stayed creamy and able to cast a number of tries. After seven successful throws, a picture of the icing was taken and the shapes were traced in AutoCAD from the image. Then, the digital tracings were imported into Rhino and the lines were cut by a CNC mill in plywood. Each of the lines produced in the icing by the top were cut in plywood using a different milling bit. Tracing is important but is only one part of the drawing process where the final drawings capture and reflect the overlapping methods and mediums of design development.

At this stage the exercise was done in order to see which milling bit would best resemble the shapes drawn in the icing. Unfortunately, after the CNC cutting test it was clear that the material qualities of the icing were being lost.

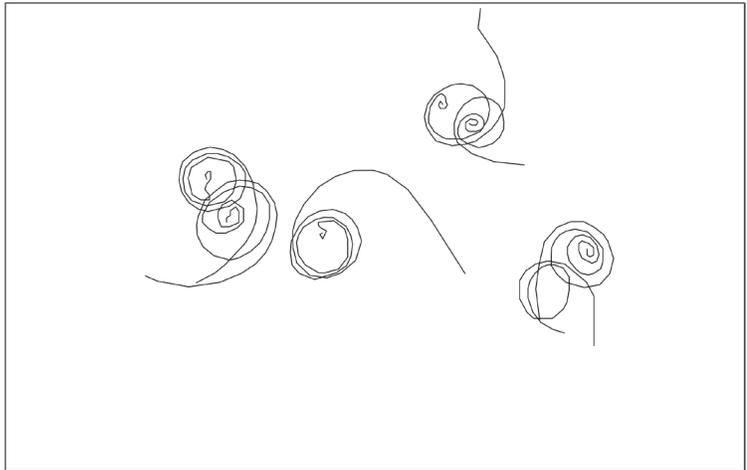


Figure 45 First test of top over icing sugar and transalton to wood by different CNC bits (Author)

After the first trial attempts on paper, a second and third drawing were made on foam board. The process was recorded using a Zeitdice time lapse camera set at 5 seconds per frame. Further, each stage of the drawing was captured using photogrammetry. This method of the recording the drawing across time was inspired by the work of Kanva where they display individual frames along the façade of the Edison Residence.

Legend

- A** Application of icing sugar over black cardboard
- B** Wrapping the top with string
- C** Top over icing sugar
- D** Recording of drawing with photogrammetry

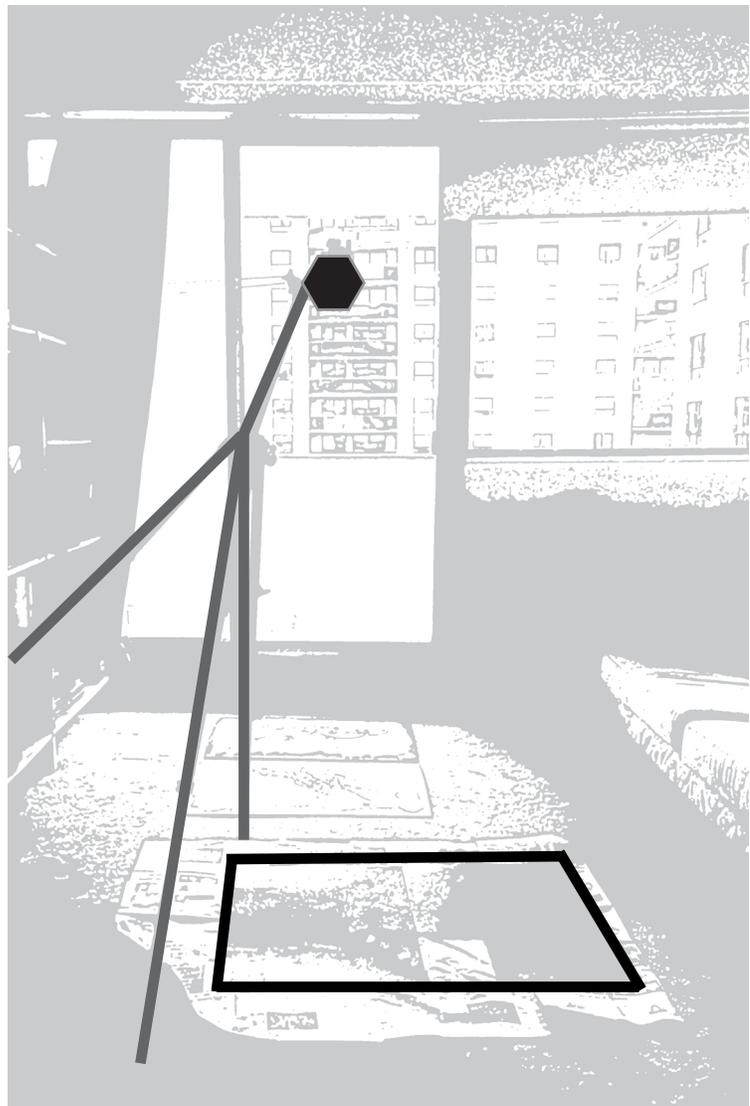
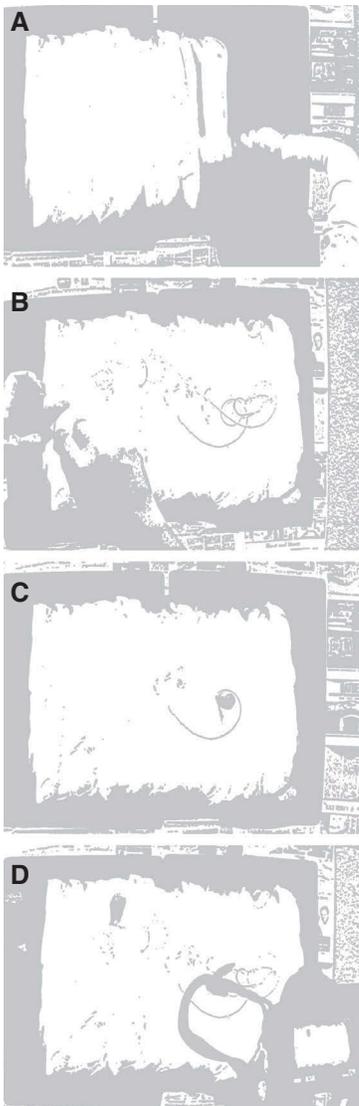


Figure 46 Left - Drawing steps recorded by Zeitdice Camera. Right - Drawing Scene (Author)



Figure 47 Second test of top over icing and white cardboard (Author)



Figure 48 Third test of top over icing and white cardboard (Author)

Digital Documentation and Fabrication

Photogrammetry is a 3D measuring technique developed from 2D digital photographs. Behind the software is the basic process that demonstrates that a point can be measured in an image if there are two images of the same location taken from two different points, the camera plane is parallel to the surface and the scale is known. The technology has a long history, but with the power of personal computers it is now possible to calculate millions of points of comparison between photographs to generate a cloud of measured points known as a point cloud. This point cloud can then be used to make a surface, or a mesh, by connecting the 3D measured points from the photographs. This whole operation is made possible by the development of easy to use software. One of the most common is AgiSoft Photoscan (“AgiSoft PhotoScan” 2018). To make the model, digital photographs are imported into the software, select the automated alignment tool, and then generate mesh. It is then possible to export the surface to other modeling or drawing programs like AutoCAD or Rhino to be cut using a CNC or any other fabrication machine.

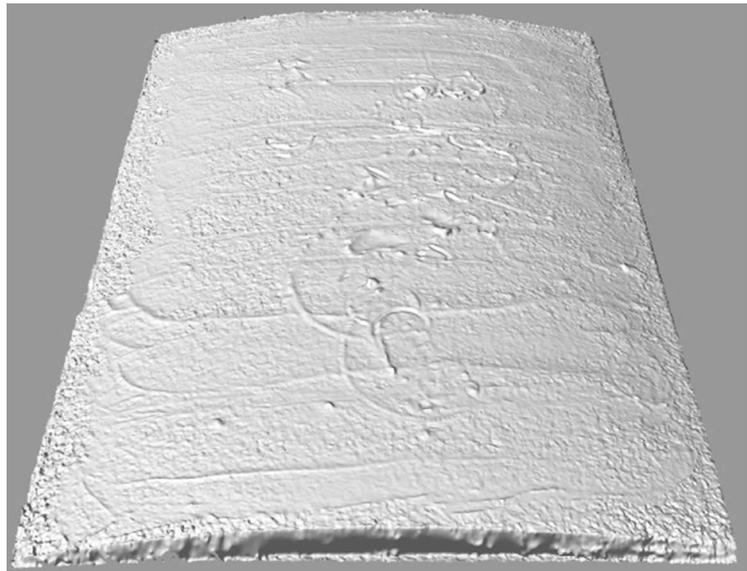


Figure 49 Photogrammetry of third drawing test (Author)

3.4 Final Design

The design has been motivated by the relationships between the history of the site, the formal qualities of the existing building, and the contemporary use. In these terms, the design of the new facilities for the students is arranged through a set of volumes and corridors that maintain similar proportions with the existing building and has a surface design that is inspired by the history of the site through the making of the drawing. This is evident in the choice of drawing technique related to the programs past and present.

The proposed facilities for the students include an outdoor cooking area, a dining room, reception, and an urban garden. This building will expand the program of the cooking school but also offers a dining area that is absent from the current facilities. The outdoor kitchen offers a unique area to re-examine traditional cooking in a modern environment using wood and charcoal. Because the climate in Cuenca is relatively warm all year, the building is only semi enclosed allowing the smells and smoke of the cooking to escape and circulate around the site.

The sun is important for the urban garden that serves as a teaching environment for the young cooks to learn about the sources of their ingredients, but it is also a source of fresh food for the restaurant. The organization of the site started around the location of the garden between the two kitchens serving as a buffer between the busy street and the teaching restaurant. The garden is aligned between the second building and dining area to help transition between the existing and new buildings.

Legend

- A** Existing Building - Administration
- B** Existing Building - Indoors Kitchen
- C** Urban Garden
- D** Reception
- E** Dining Room
- F** Outdoor Kitchen

Figure 50 Zoning of new facilities for the Cooking students (Author)

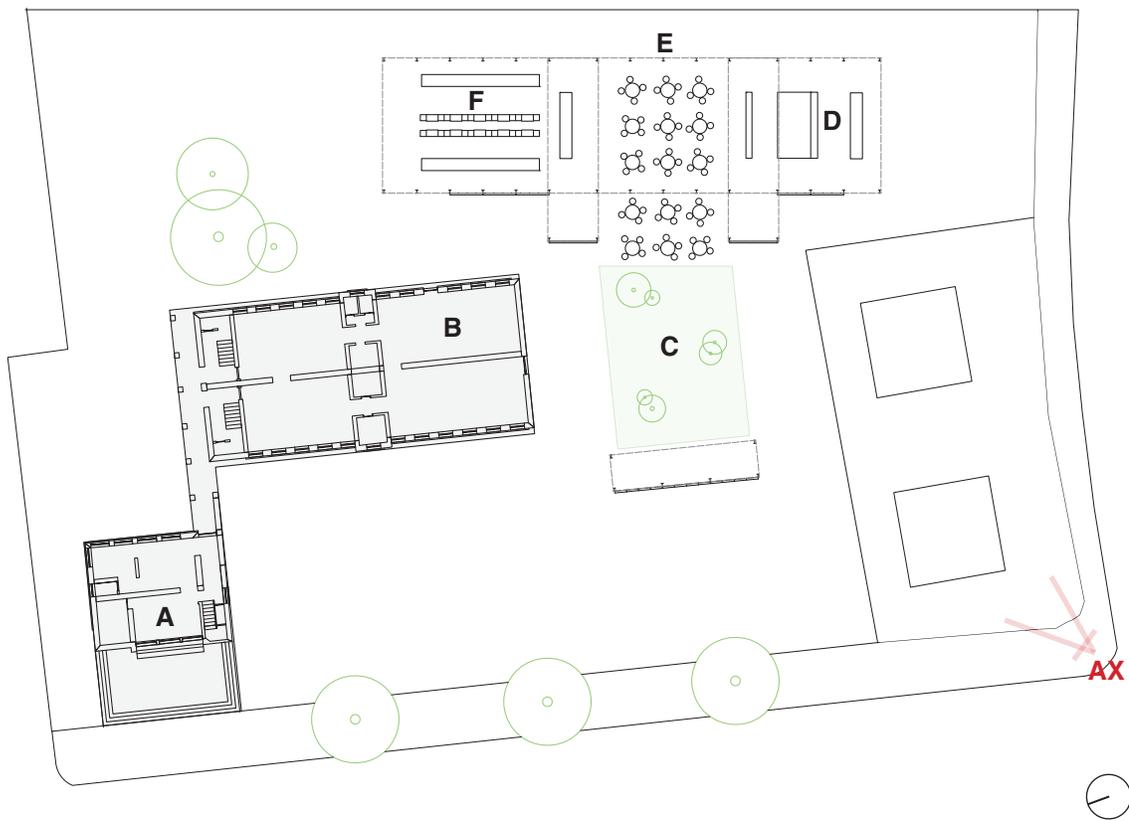


The new buildings for the students occupy the south east of the site where the orphanage playgrounds used to be. This area offers an independent entrance through a secondary street. From this access, the first area encountered is the reception followed by the dining area and finally the open kitchen. The dining area also faces the urban garden to the west which is screened from the main street by concrete panels.

Looking from the west side of the site the new building is located behind the two existing buildings. Its composition is formed from a set of concrete planes that define the different areas. From this view point the buildings are visually arranged to contain the program but disseminate the smoky smells of the barbeques and ovens. The kitchen is equipped with ten BBQ stations to accommodate one level of students. Behind the kitchen in the north east corner of the site is a rest area with benches for the students to relax.

The volumes of the new buildings share proportions with the first building designed for the site in 1950. This building was chosen because it was the only one designed and built by the original architect according to the original

vision, and it also has a higher heritage value than the second building added later. The proportions that were used refer to the original measurements of the ground floor of the first building which are 11mx11m. This measurement served as a module to organize the new facilities of the school. Each of the program parts are divided to fit in and around this subdivision. The proportions of the concrete panels draw on division of the 11x11 unit and vary it at different scales.



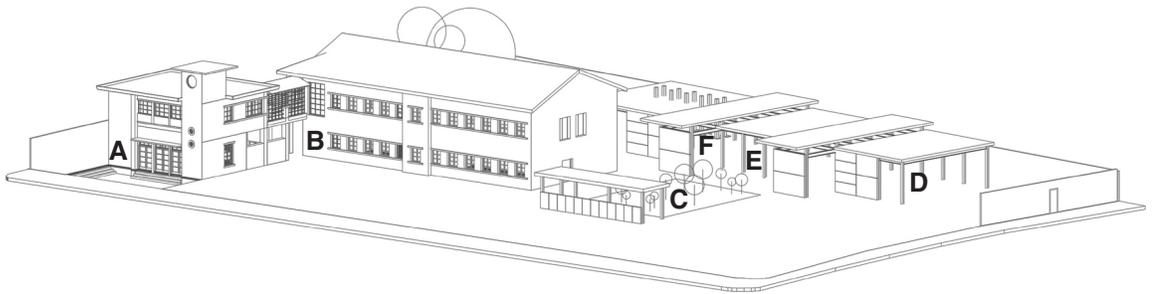
Legend

- A** Existing Building - Administration
- B** Existing Building - Indoors Kitchen
- C** Urban Garden
- D** Reception
- E** Dining Room
- F** Outdoor Kitchen

Figure 51 Ground Floor (Author)



Figure 52 West Elevation (Author)



Legend

- A** Existing Building - Administration
- B** Existing Building - Indoors Kitchen
- C** Urban Garden
- D** Reception
- E** Dining Room
- F** Outdoor Kitchen

Figure 53 Axonometric view(Author)

3.5 Translation of Drawing to Building

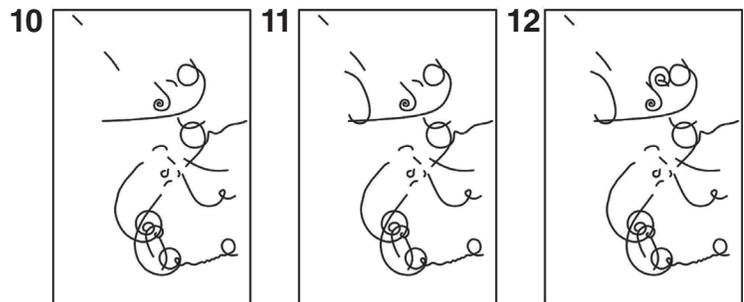
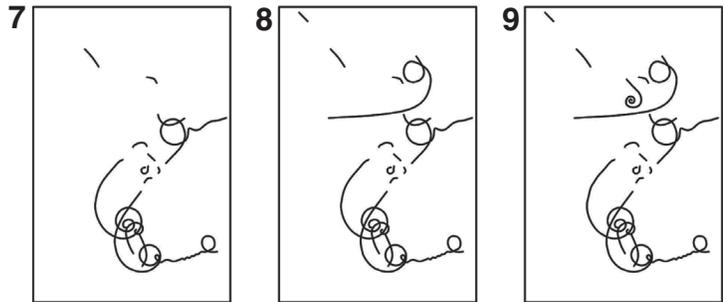
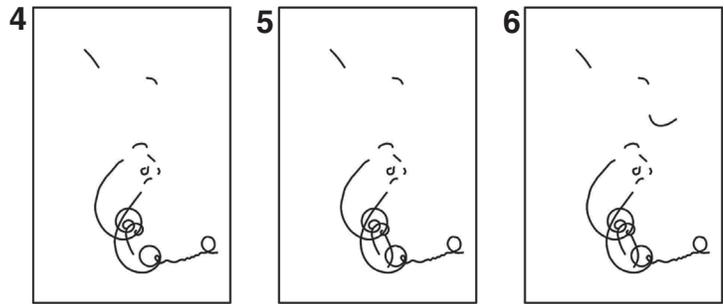
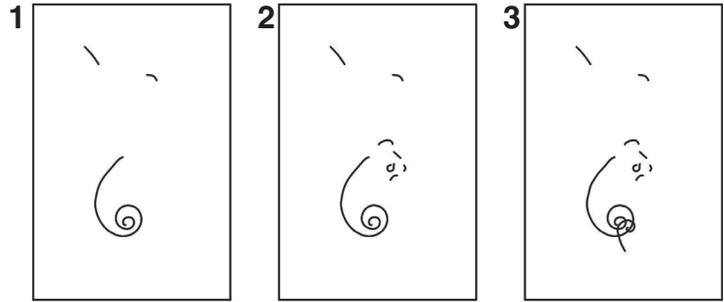


Figure 54 Traced images of Zeitdice camera in Autocad (Author)

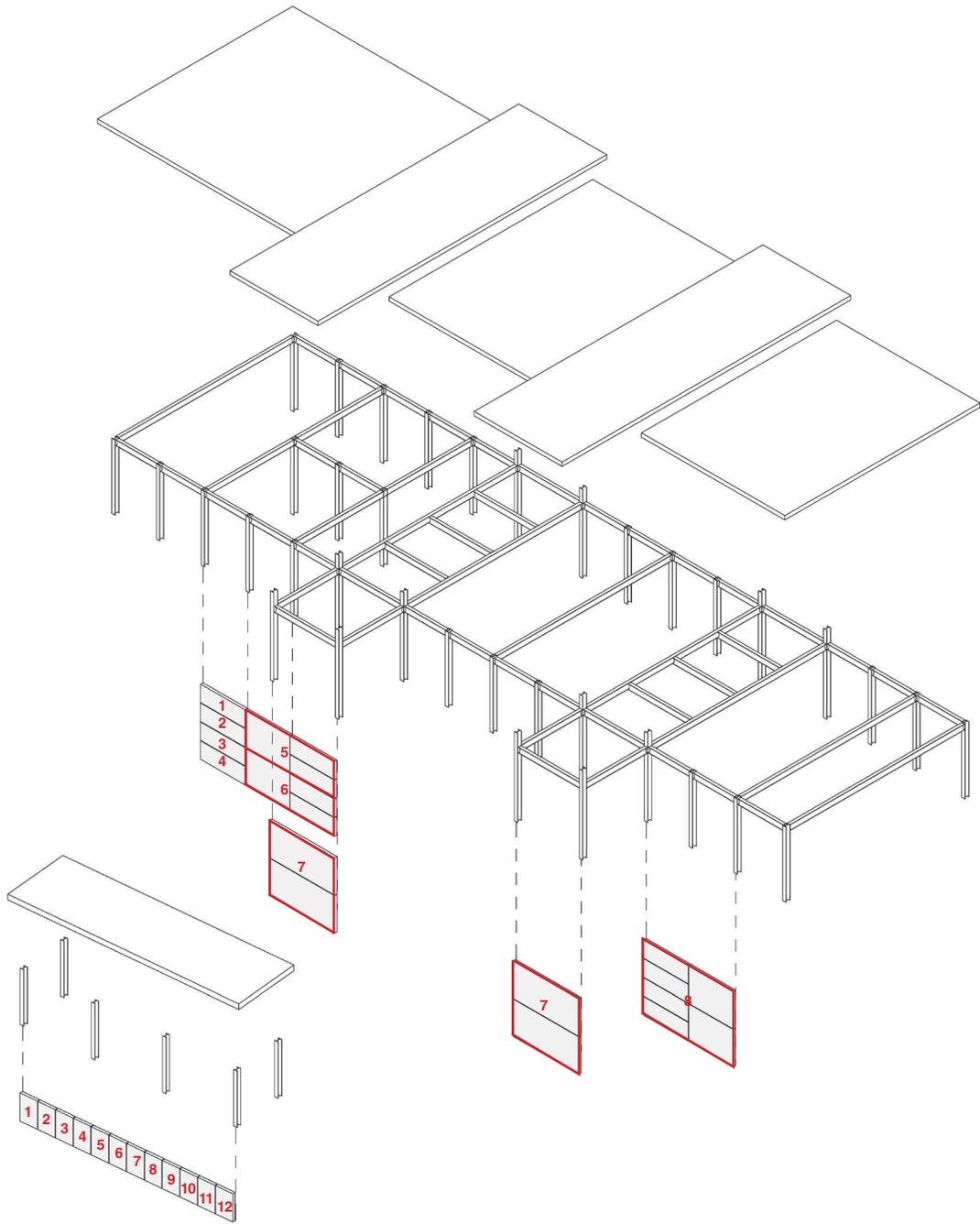


Figure 55 Concrete panels, structure and roof assembly (Author)

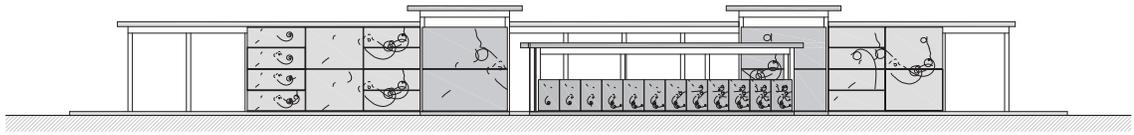


Figure 56 West Elevation of New Facilities - kitchen, dining and Reception- (Author)

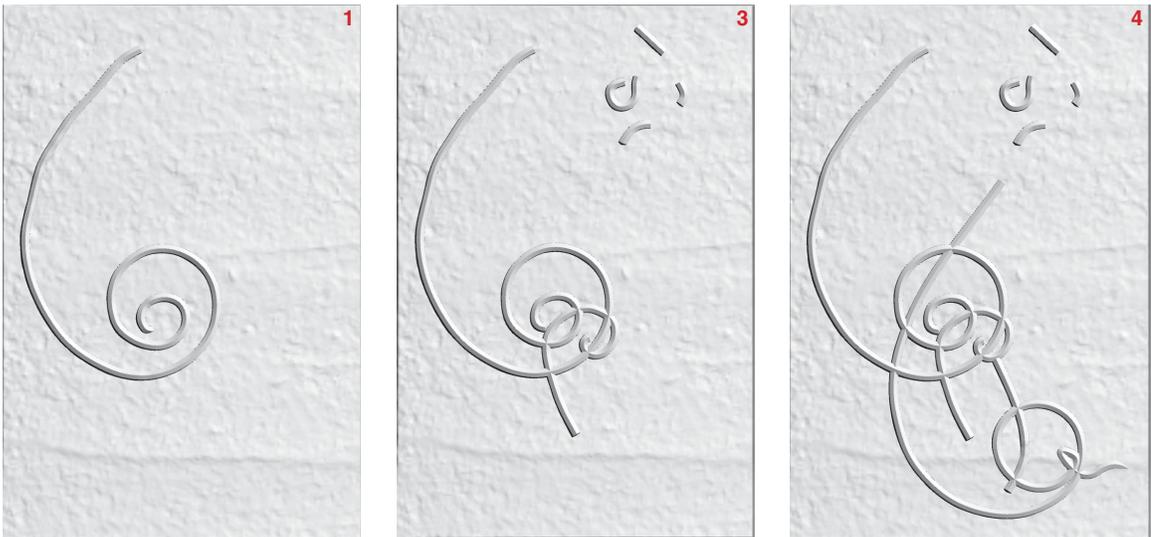


Figure 57 Photogrammetry mesh with a 3D model sweep (Author)

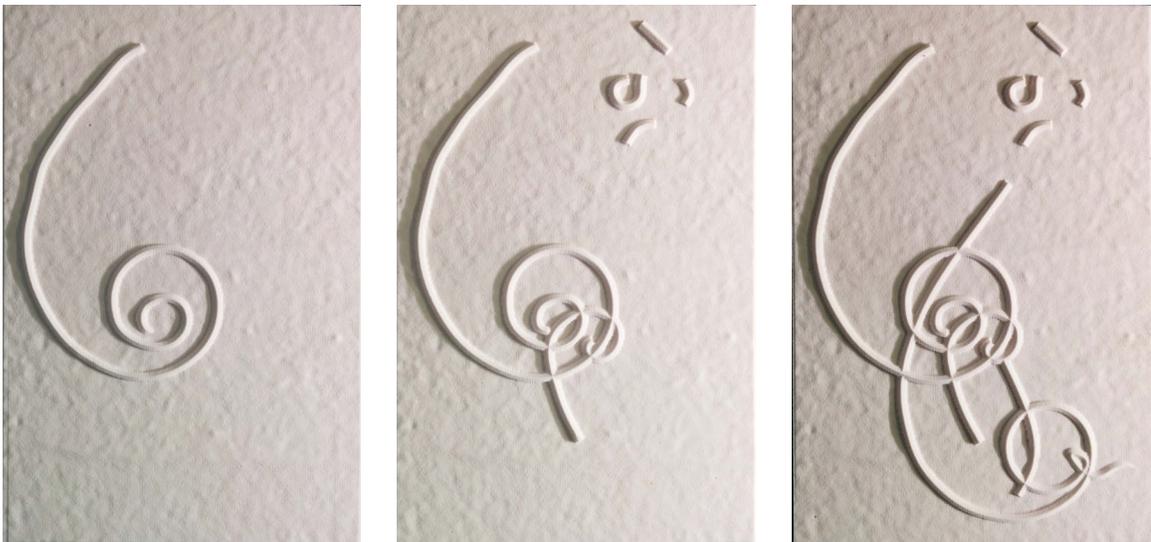
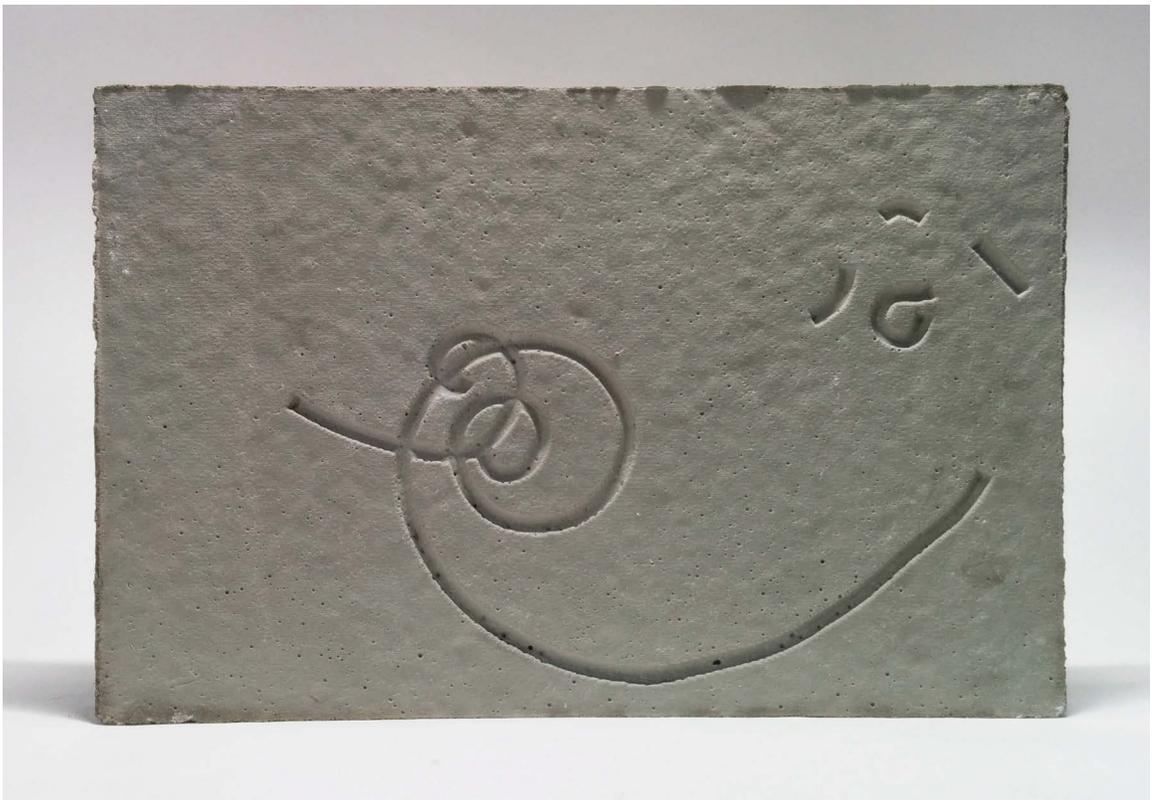
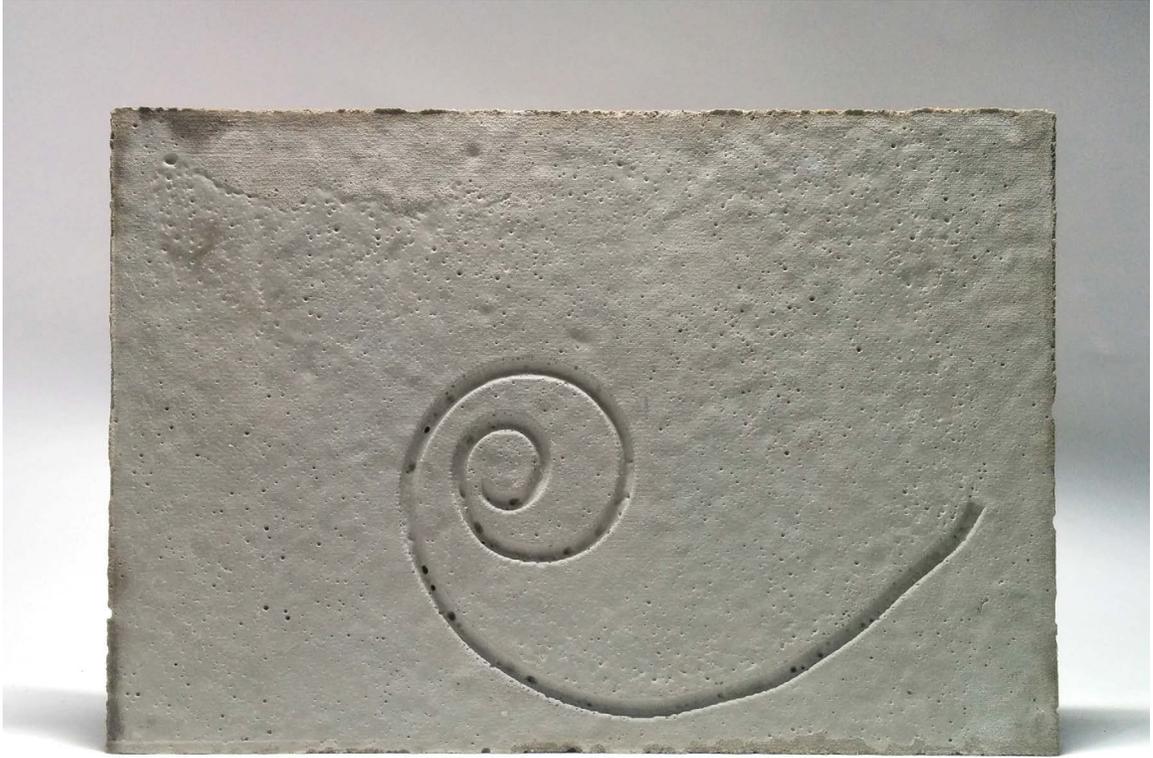


Figure 58 CNC milled foam with 3/16 bit (Author)



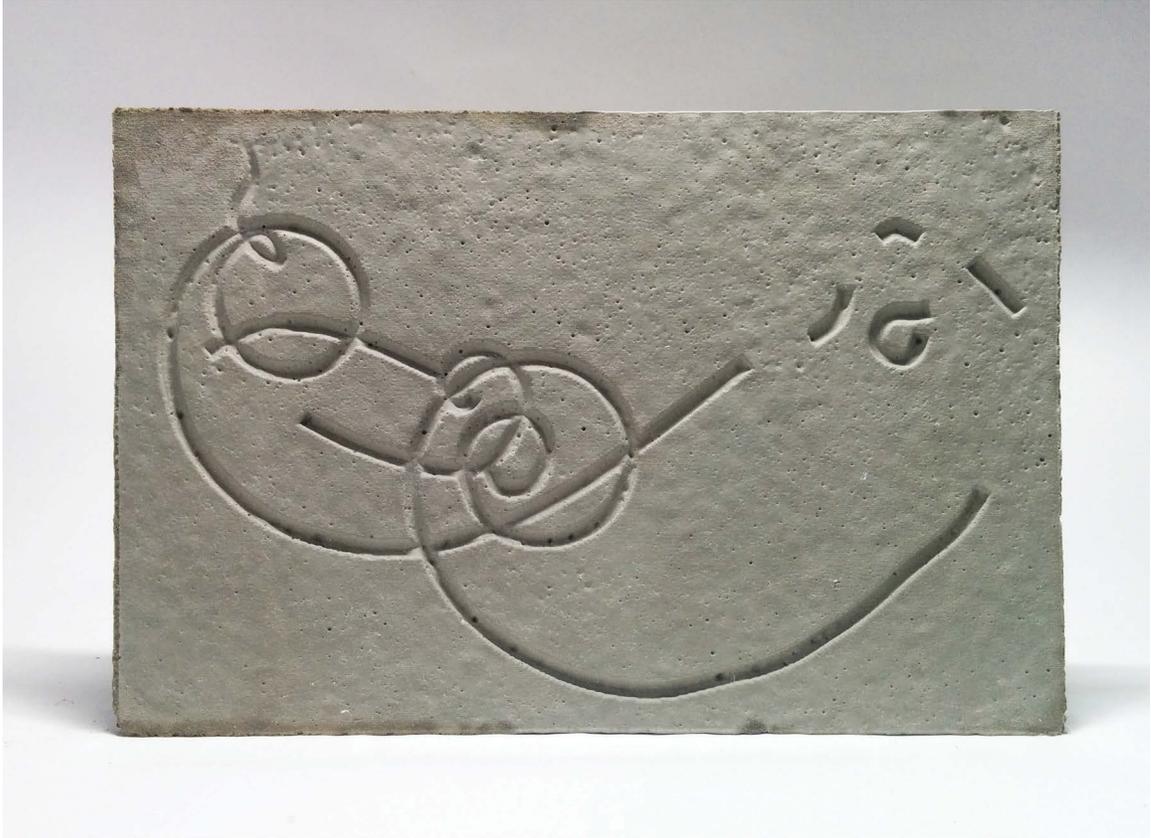


Figure 59 Final Castings in concrete.
Drawing 1, 3 and 4. (Author)

Conclusions

Casting the original drawing on concrete could have been a direct process of translation, however it is the transformation of mediums and the creative architectural development during each stage that has enabled a learning process in four areas: first, by improving the throw of the top over the icing and documenting each attempt I demonstrate the sequence of the drawing. Second, by the construction of the 3D model, the traces and different operations can be evaluated through the software. Third, understanding documentation as part of a creative process that can be used for prototyping and reproduction. Fourth, recognizing that each translation adds a trace and therefore the process of drawing to building opens the field of testing with different materials, techniques and tools.

Learning by making is the methodology of this thesis. It started with the reconstruction of the case studies, then the experience gained was applied in the design project and other iterations were developed during the progression of the project. The representation of the top over icing evokes the history of the site however its high level of unpredictability in the production of traces makes the documentation a fundamental step. When documentation by photogrammetry and video was added to the process it transformed the final graphic representation in a set of signatures that allows us to prioritize the iterative process and development over a final result. Taking into account this condition, the process creates an analogous connection between the methodology of this research and the purpose of the cooking school.

The 3D models constructed from the documentation process maintains visual similarity to the material qualities

of the icing and provides a platform for design decisions to evolve through the digital modeling. These includes scaling, copying, flipping and arranging the design and the traces of the drawing in several ways. In this case, the existing building is the first point of reference because of its position on the lot and its character defining elements. As the design of the new facilities advanced, in order to communicate with the existing building and provide complementary activities to the cooking program, the set of traces are evaluated and organized using different orders. In the volume closer to the main avenue (West) the set of lines generated by the top have a sequential order and in the further volume (East) the scale and orientation have been changed. For the observer this represents two sequences at different depths from the street.

Even though the documentation of the drawing was considered as a register of the unique traces that the top produced on the icing, it was after the design and arrangement of traces that it was seen as a tool for prototyping and reproduction. In this way the prototype required a 3D model with a higher resolution in order to reduce the digital noise of the first translation. The same condition was applied to the selection of the milling bit in the CNC. The 3/16 bit left subtler but still visible tool marks on the surface.

This methodology allows new mixtures of graphic representation to evolve which are closely connected to construction methods and are not limited to an established set of tools. The creative process exposed through making directly connects to the program of this building by critically questioning each tool through experimentation. By recognizing the historic and present programmatic

and material qualities of sites and buildings, they can be referenced and exposed in the construction of architecture. This is possible by learning through the currently available tools and experimenting with their possibilities. Each of the tools reveals its presence through its traces as the tools we use to design have an impact on the final design. The drawing suffers different transformations but each becomes visible to the observer through the layering of the final construction. Ultimately, the process of learning through making connects the larger history of the buildings to the present methods of fabrication.

Digital drawings have their own value, not necessarily only connected to the speed of production and fabrication. The unique ideas of each architect are represented differently by each in various balances and combinations. It depends on the focus generally but also specifically for each project based on the context and the brief. If one or the other better reflects the values of the project then they will assume a specific role. Both Non-digital and digital techniques have something to offer in the production and translation of the drawing. Frascari explains that “hybrid drawings are the result of continuous process alternating conversions and translations” (Frascari 2011, 114) that do not necessarily see both types of drawings equally at all times. The selection of the method can be connected to the design approach taking different significance in different scenarios and with different programs.

Finally, the hybrid processes described in this research offer a unique way of analyzing the program and creating relationships via drawing that sensitively reflect on the values of a site.

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