Foundation of design based on material research and craftsmanship

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Foundation of design based on material research and craftsmanship

by

Velimir Manjulov

A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF ARCHITECTURE

Major: Architecture

Program of study committee:
Jason Alread (Major Professor)
Karen Bermann
Tomas Leslie
Christopher Martin

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This is to certify that the master's thesis of

Velimir Manjulov

has met the dissertation requirements of Iowa State University

Signatures have been redacted for privacy
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ABSTRACT

As I have worked closely with different materials over the course of architectural studies, I’ve realized their great potential in design. I have discovered that my fascination with materials has to do with how they influence design process.

The major interest of this study is exploring the nature of materials and building methods in design. In order to narrow this field of study, my thesis research focuses on material research and design conducted in a woodshop environment. Considering the thesis question “materiality and crafts within design” I will examine related case studies. I will conduct a research by observing, experimenting and analyzing materials. These experiences I will implement into workshop design projects.
CHAPTER 1
INTRODUCTION

Design in relation to material research and crafts

The physical act of making, building or constructing in Architecture is related to the architect’s investigation of the materials they use for construction. This relationship is enriched by knowledge of using tools and building techniques on one side, and understanding design process on the other. One way of understanding materiality in architectural design is through craft. In turn a way to know “how” in design is through the physical act of making by use of materials.

The intent of this thesis is to understand how materials influence architectural design through the processes of making. I want to understand a mechanism behind this framework, and the relationships between material research and craft activities. The framework is based on problem solving in design, and the intent of this thesis is to study its potential as a generator for design. How should the relationship between material and craft in design be explored? What are creative ways in which materials and crafts inform design processes and design projects? What are the ways in which this relationship leads to innovation? How are design components shaped, constructed and assembled based on the relationship of materiality and craft?

History and culture can be investigated through crafts. Historical and cultural artifacts consist of objects and tools, which preserve information on material transformation through handcrafting.¹ Architecture concerns the designed environment, and these artifacts are case

studies to an earlier culture’s analysis of material and problem resolution. Exploration of materiality and craft activities through case studies is an effective means for understanding design.

Craft experimentation follows materiality. Crafts are used as means to investigate the potential materials have for solving design problem. The craft experiment begins with molding, assembling, model making, building or constructing. Design starts when one has to observe, touch and feel material - “play with it”. Materials attract one’s attention and become the object where thoughts and feelings are projected. Our understanding of materiality leads to “making” in design. The hands-on approach in an act of making creates a dialog with the material. This kind of a dialog becomes the vehicle for design. It is a source of creativity, exploration and discovery in design.

An artist who explores materiality through handwork is Andy Goldsworthy. In his artwork, he manipulates material with his hand or with the use of simple tools. Goldsworthy created “Sweet chestnut horn” (Figure 1) as continuous spiral where each leaf is laid in the fold of another and is then stitched with thorns. By observing the material, Goldsworthy found the “mode” under which the material behaves. He used this material characteristic with another of stitching bent and folded leaves using thorns, which is similar to the craft technique of weaving. “Sweet chestnut horns” were done in early summer and autumn. The spiral form grows naturally from the relationship of material and handcrafting method. The design becomes evident through the connection detail used, the simple joinery, and between the physical relationship of leaf and torn. Form was not imposed upon object, but it results from structural characteristics of leaf and thorn discovered in the process of material

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observation and investigation. This moment of realization must have brought joy to the artist as it does the viewer. Material perception seen through craft leads the artist to discovery on the nature of leaf and thorn. The artist learns from his work, and the work itself clearly communicates the design process, which is innovative. Andy Goldsworthy shows that his investigation of materials is sensory and intuitive, rather than intellectual, and fundamentally is an outgrowth of material observation. The process can be learned through design study and craft activity.

Over the centuries, architects have explored design through craft and material relationships. The education in the Bauhaus school was based on a “learning by doing and making” method in craft exercises and activities. The Bauhaus based the foundation of design on the relationship of arts and crafts. The school revolutionized art training by combining teaching of arts with the study of crafts. The Bauhaus had many physical workshops. The metal shop, woodshop, textile and ceramic workshops were seen as places that harbor collaboration among disciplines. A strong handcraft ethic, rooted in national traditions, was the basis for the school’s design foundation. The hands-on approach to workshop training made students stay in touch with material throughout the entire process of production. Student assignments were more technologically advanced, moving from manual work to machine work, as seen over the short existence of the school. Bauhaus design expressed the nature of the materials and methods of construction (material honesty). The practice of the Bauhaus school showed that crafts permit us to learn and discover through direct contact with materials. The Bauhaus demonstrated that the success of design lies in full exploration of materials and respect for their limitations. Many design schools of today base

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large portions of their curriculum and pedagogy on the Bauhaus design foundation.

Cabinetry is a craft of woodworking. Carlo Scarpa so valued the craft and ideas of cabinetmakers that they were a regular part of his practice. Collaborative work between Scarpa and cabinetmakers and metalworkers was accomplished by communicating via models and drawings (sketches and working drawings).

“Drawings plans and models leave no doubt about close cooperation between Scarpa and Anfodillo cabinetmakers. The drawings are expressive working drafts having nothing in common with the austere neatness of architectural designs meant for presentation or to be put up for a sale. In his characteristic technique, Scarpa meticulously prepared every single part of his designs. He often used crayons to correct his first rough sketches that were just to convey the gist of it. Scarpa corrected even the blueprints in different colors, adding handwritten comments on the plans, and thus imbued the sober copies with life. The models evidence that Scopa studied the effect even of single architectonic elements in wooden miniatures before he started to realize his designs.”

“... He once said that he made drawings because he wanted “to see things,” and there was nothing else he could rely on.”

Collaborating with cabinetmakers and metal smith workers Carlo Scarpa developed a unique design process communicating through drawings and models. This demonstrated that Scarpa had a profound respect of materials. Scarpa designed through series of drawings, which helped him revise his designs, communicate with craftsman and make decisions for design. When he designed a stand for the display of “Ivory Madonna”, Scarpa expresses the process of making by placing notches in the ring of bronze. The notch celebrated the first drill hole made in metal to cut a right angle joint (Figure 2). The brass ring has no structural role. Drilling a hole is the step in machine metal processing that precedes circular metal cutting. The decision was not made in the drawing phase, but in the process of metal

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armature production. In his designs, Scarpa values the nature of materials and demonstrates these in the process of making.

The work of Andy Goldsworthy, Carlo Scarpa and the Bauhaus school exemplify discovery to design through the exploration of materiality through craftwork. Craft activities are creative activities. They offer opportunities for problem solving and growth through the exploration of materiality.

**Diploma project**

My 2004 Diploma project dealt with building on site-specific locations. The design project was located on a traditional Midwest prairie. Midwest prairie grass areas are preserved and restored to show Iowa’s flora and fauna origins before agriculture took over the land. One of the prairie areas (not accessible) protected by the city of Ames is positioned in a park near University Campus (Figure 3, 4). The walking paths lead to a unique stretch of prairie landscape. The grass grows as high as 9’ over the course of the year. The design questions this space posed were:

What would it be like to experience the space “in” and “above” the area? How would one access the area during construction and in use of the space, without disturbing the prairie extensively?

The design solution was found in a pavilion type of structure. Building a pavilion in this preserved area would require a special approach. A typical park structure with concrete footings was not an option. Excavation work for foundations had to be minimally invasive to the soil, and this required construction to be less extensive and intrusive to the site. The pavilion and its pathway were designed with a number of light units that could be easily transported and installed at the site (Figure 5). Each unit is anchored with a wooden column
that works as a friction member to the soil. The pavilion units don’t require fixed connections between each other. They are designed with a rubber connection or “kissing joint” on each side. Walking on top of it, one can feel deflection which became part of the overall experience of the pavilion. Construction is imagined to happen in the wintertime when the field is more accessible, because the grass is dry and low, and the ground is covered with snow. This would make pavilion slide into place. In the pavilion one can sit or swing. The result of such structure came from an understanding of the site conditions and seasonal changes. There are no manmade objects around the site and the project doesn’t refer to an urban context. The site characteristics reflect on the pavilion’s solution for structure and materiality. A study was done on integration of design components, which features variety of “off the shelf” materials (Figure 6). The structural choice of materials is made through use of: steel for beams and bracing, laminated wood for supporting structure, wood decking, corrugated metal for roofing, bamboo handrail and rubber connections. The pavilion becomes integrated with the site due to its material, structural, and minimally invasive aesthetics. The diploma project demonstrates an early exploration between the relationship between materiality (of the site and pavilion structure) and crafting methods as a generator for design.

Since the diploma project is not built, many questions concerning the relationship of materials and building techniques remained unanswered. The diploma project is convincing enough to communicate the reality of building on the specific locations, but it lacks the experience of working in direct contact with materials as suggested by models and drawings. Materials and crafts inform the design process directly, and their relationship leads to solutions that are creative and innovative. This framework set the study on exploring the mechanisms behind the relationship of materiality and crafts in direct contact with the final
product. Looking for place to gain technical skills and knowledge needed for material exploration I looked over the university agenda. The underlined portion of the Bachelors of Architecture program (below) taken from the Iowa State University Catalogue highlights the learning objectives of an education in the discipline of architecture.

The Department is committed to the study of architecture as a cultural discipline in which issues of practice, of the multiplicity of social formations in which buildings exist, and of environmental effect are enfolded with the subject matter of building design - construction, space, material, form and use. Architecture arises from the aspirations that diverse individuals and groups have for their physical environment, and from the social enterprise of designing and fabricating the landscape we inhabit. It involves individual and multiple buildings, the spaces within them, and the exterior landscape.

It is our intent: that our students develop the skills with which to critically assess and research architectural questions and to invent architectural designs through which those questions are addressed; that they develop a working method for designing and that they have the communication, graphic, modeling and computational skills to support design exploration and to represent their design ideas to others; that they gain knowledge of architectural technologies through which buildings are given form, of which they are constructed and by which they are environmentally tempered; that they understand architectural history, that they understand the theoretical and diverse cultural underpinnings of the discipline of architecture, that they are able to reference architectural precedents and know how to utilize all of these in the development of their ideas; and that they have grounding in the ethical and practical aspects of the architectural profession in society.5

The diploma project suggested that answers could be found in the basement dwelling tool-equipped workshops of our department. Material exploration would be possible through manipulation of material by craft activities.

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5 Iowa State University. "Undergraduate and Graduate Courses and Programs 2005-2006". 2005.
CHAPTER 2
EXPERIMENTS, ANALYSIS AND OBSERVATIONS

Woodshop and material exploration

The woodshop is a material exploration area that focuses on furniture making and gaining technical skills in work with wood and other materials. In a woodshop environment it is possible to use tools to create different apparatus, which can be used to test materials on their inherent properties and characteristics. The woodshop is a place where a dialogue with material is made through craft activities.

The goal of conducting experiments, analysis and observations was to determine inherent material properties on bending for the purpose of lamination.\(^6\) This approach requires thorough documentation, analysis and comparison of results. Collection of information used in experiments is saved in the form of photo-documentation. Photographs are documenting steps in the process of material testing. The collection of work in this chapter represents one possible way of ordering and organizing results of research done in this design lab.

Experiments, analysis and observations are done with wood and wood composite products. Materials are tested on their physical characteristics and properties: strength by application of load and pressure (compression, tension, bending) and durability by application of heat and moisture absorption. Experiments present a record of the design research.

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\(^6\) Working as a research assistant over graduate studies I was part of on Biocomposite Research “Farm to Form-Applied Design on Biocomposite Materials” run by professor Jason Alread. In this chapter are presented findings and results of Biocomposite Research for relevant to conducting thesis study. One of my roles as research assistant was to find lamination technique for producing curved shapes of chair components. This material research required testing materials on bending properties for the purpose of lamination.
process and are documented by: description of tools and apparatus used in each experiment, by specific dimension of sample, by period of exposure to load, heat or moisture, commenting on durability, aesthetic qualities, etc.

The goal of material research was to understand the potential of materials for use in design. Material investigation starts from tactile analysis of material and observation. It goes through process of material manipulation by conducting experiments. Pushing the limits of materials during the experiments caused material failure. These failures are important in understanding each material and knowing its limitation for use in design.

**Wood veneer observation**

In furniture making, veneer is largely used as a covering and decorative surface. It comes in different patterns and colors depending on the type of wood. Veneer is very tangible material in the longitudinal direction, because of the strength of its wood fibers. Glued together at right angles, veneer creates plywood, which has more structural integrity than solid planks or veneer laid with the same grain direction. Veneer bends well along the fiber direction, but creates uneven structural characteristics.

Observations were made to test veneer on bending and lamination. Several thin layers of veneer have been glued together, and then bent over to form a rigid body - Mobius strip (Figure 7). The veneer’s strength was achieved by the process of lamination, which is an additive process. This simple observation suggests that the process of lamination is a basic process in achieving structural integrity in working with wood products. It also demonstrates many possibilities of achieving curved forms, both two-dimensional and three-dimensional by the lamination process.
Medium-density fiber board (MDF) and particleboard experiments

Medium-Density Fiber board is a wood composite panel made of wood fibers and resin under high pressure and temperature, which causes stiffness of the board. Compared to particleboard, MDF has no internal voids. Particleboard is also a wood composite product made of larger flakes and chips of wood. It has no uniform texture compared to MDF. Because of these characteristics both MDF and particleboard are used in construction for sheathing. A typical method of connection is bolt screwing. They are also easy to machine cut. The MDF board soaked in water swells and looses its hard-cut edges, it resist keeping its structural integrity. After soaking it retains moisture for a long period of time. MDF board “peels” irregularly causing material failure (Figure 8).

MDF and particleboard have no bending characteristics since they are designed with stiffness as a primary characteristic and are intended for use in construction as sheet product.

Masonite experiments

Masonite is a wood composite board product. It is made of long fiber wood chips, which were steam blasted, pressed, heated and formed into boards\(^7\). The long fibers give masonite a high bending strength, tensile strength and stability. Masonite doesn't absorb water even if soaked for a period of 24 hours. It is widely used in construction for sheathing and roofing.

A steaming box was made in order to test bending characteristics by applying steam and heat. The steaming box was made of plywood and connected with a propane tank, which was used to create steam in the whole volume of the box. The inside of the box steamer was

water sealed with rubber tape and coated in order to keep the steam, heat and pressure in the box constant. A steamer this size couldn’t create enough heat for the masonite sample to cause material failure. Steam was focused on the center of the sample with an idea of applying one-point pressure to the centerpiece of the sample in order to test its bending characteristics (Figure 9). After 45-minute exposure to steam and heat the sample board bent well. When kept under the constant pressure, masonite board results in a failure by breaking during its cooling under room temperature, which demonstrates that masonite doesn't handle bending well. Masonite board is made under high pressure and temperature, so its fibers bond well and do not allow great bending. Tight curvatures are not possible to make with masonite. It bends well with minimal curvature and it is sometimes used for canoe making, which shows that masonite does not absorb water. One way to achieve greater structural integrity is to flat laminate it, which is tested by using a low curvature mold (Figure 10).

**Plywood experiments**

Plywood is a high-performance composite wood that has replaced traditional solid wood in most high strength sheet applications. Plywood is made of layers of veneers (plies) glued together with the direction of each ply’s grain differing from its neighboring layers by 90°. The plies are bonded by heat and pressure with strong adhesives (Figure 11). It has great bending characteristics and it is widely used in furniture making and construction.

Experiments are made by using simple tools and by building special apparatus for testing the bending characteristics of plywood. The steam box was used to steam, heat and moisturize plywood samples. Bending plywood was much easier after keeping the sample in the box over period of one day. This experiment demonstrates that plywood bends easier and
with greater curvature after heat and moisture exposure. When laminated together, plywood sheets achieve a greater bend. In cases of extreme bends, with a radius less than 2 inches, plywood sheets will fail to laminate and cause breaking on the maximum bending curvature (Figure 12). Failures happened during the process of drying when additional moisture coming from wood glue penetrates the plywood sheets and makes it too weak to bear the pressure.

The steamer required fine-tuning in order to distribute moisture and heat uniformly throughout its volume. Some experiments showed that, if not applied uniformly, heat will cause de-lamination when layers of plywood veneers wrinkle and peel, and where heat and steam cause material failure (Figure 11). Keeping the steaming box apparatus in the right balance of heat is a delicate and hands-on process. The exposure of material to steam at the right distance and position over period of time requires number of tries, great precision and fine-tuning of apparatus. The duration of the steaming process is essential for the success of the experiment.

**Bending & lamination**

The Eames Office experimented extensively on molded plywood. For that purpose they built the “Kazam” machine, a bladder press that would accept various forming molds they constructed. Experiments on their prototype seat established the basic techniques for molding plywood into three-dimensional compound curves. For the Eames studio, the goal was to devise a system for mass-producing high-quality and low-cost furniture. Charles Eames spoke about his work on series of experimental chairs:

”The idea was to do a piece of furniture that would be simple and yet comfortable. It would be a chair on which mass production would have anything but positive influence; it would have in its appearance the essence of the method that produced it. It would have an
inherent rightness about it, and it would be produced by people working in dignified way."

"Chairs made of separate components emerged as the best candidates for mass production- the production of separate elements was easier and more economical; parts could be joined in more combinations, and if a seat or back was broken, the loss was not as dramatic as the loss of an entire chair."

The Eames Office was successful in bending and laminating plywood three dimensionally. A strategy for the Biocomposite Research Team was to learn by repeating experiments by the Eames Studio on bending plywood while working on the LCW (Lounge Chair Wood) chair (Figure 13). An experimental design lab was conducted following the experiences of the Eames Office on their lamination study. The chair design is conducted with a focus on the arrangement of components and their connections. Various study models show the variety of chair diagrams, suggesting chair production with a different number of bent components, their connection points, and also chair performance. The woodshop was the experimental studio for this project. The results of experiments with various materials were implemented in study models to find a design solution for the chair project (Figure 14).

Molds were used for making the chair parts. Molds investigate negative space around each chair component. Careful measurements of the LCW were made and its curvature was studied both through drawings and by building molds. Shapes of individual seat and back components were three-dimensional compound curves and their molds were complicated to control by building a male-female mold (Figure 15, 16). This was due to a difference in tension and compression along sections of the shape required to bend and laminate. The chair legs and base of the LCW were two-dimensional curves and their production was easier to control in the process of lamination with use of molds. Their design was important because they transfer load in order for material to be laminated properly. Different materials were

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9 Biocomposite Research “Farm to Form” is led by professor Jason Alread
molded: plywood, cardboard and chipboard (Figure 17, 18). Different results came when different materials were used in the same mold. This is evident in the production of the back of the chair with plywood and chipboard. The mold’s big curvature caused a plywood failure (Figure 19). Great tension and compression on the plywood laminate sample caused cracks, even if plywood was sitting in water for period of a day. Chipboard showed better response on bending and lamination. Chipboard molded components were not stiff enough to be used for sitting. They served to study and prototype the shape of laminated and molded components (Figure 20). After the molding process, bend-laminated chair components were trimmed and their edges were cleaned (Figure 21). Assembly processes followed with implementing a study on the “body in seating position” (Figure 21, 22). Revisions, adjustments, and refinements of the chair design were taken into consideration. This resulted in many versions of chair components (a seat and a back) exploring bend-lamination techniques. Two approaches to seat and back designs offered increasingly minimal solutions (Figure 23, 24).

Working directly with materials one can learn a great deal in the experimental process. The role of experiments, analysis and observations is to understand the materiality and craft behind the lamination process and to derive bend laminated curves in design. This was possible through handwork in direct contact with materials. Experiments present a creative play of crafts, and they all inform the design. Experiments were done from the use of simple tools to building lab apparatus in order to test the limitations of material or learn about their characteristics. The chair project shows the possible use of thin sheets of various materials in bending for the purpose of laminating curved forms used in chair components. The Biocomposite Research demonstrates that production of chair components might be possible with use of an affordable material. This material research done by experiments,
analysis and observations influenced the design directly by observation of the material properties and lead to innovations and discovery only possible by learning first-hand. None of these technologies were new, but my direct experience with them determined the process and outcomes.
CHAPTER 3

WORKSHOP PROJECTS

"Materials are preexisting, but concepts are varied and individual to each specific project."

Shigeru Ban

Materials and crafts explorations are vehicles for design. These workshop projects present a collection of work done during a course on furniture making. The goal of my woodshop education was to gain experience and skill in woodworking. Projects demonstrate levels of craftsmanship starting from simple to more complex projects. The woodshop experience combines design and hands-on approach to material. Woodshop projects bring forward a set of issues relevant to thesis on: foundation of design based on the material-craft relationship. Besides woodworking projects, this chapter includes projects done during an independent course of CAD Design. This advanced course on woodworking allows the use of more sophisticated tools and equipment only available to students in this class.

Wood carving exercises

The intent of this exercise was to introduce elementary techniques of woodcarving. This exercise required no study model. A trim and chisel are used to shape a wood log into a spoon. Like in traditional handcraft this exercise refers to work with simple tools and basic handwork skills. Tools used to process wood define form in respect to grain direction. The spoon consists of two shapes merging together: the vessel segment and the handle of the spoon (Figure 25). They differ by function and shape. The vessel is concave and it was

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chiseled and carved out from the log, while the handle was trimmed from the log. Because of its varying shapes it required different tools, all in respect to the arrangement of the log’s annual rings. The process of making in this case is subtractive. Two possible modes of shape in sculpture are explored here: concave and convex space. The experience of creative manipulation of raw material grows out of the act of craftsmanship.

Another exercise required formal study through sketches and drawings. Blocks of wood were laminated, carved with a chisel, and finished with files and sandpaper. The design process was based on how tools define shape and inform each surface in respect to grain direction. A collision of two doughnut shapes allowed exploration of tools on concave and convex surface, using the maximum angle of the tools on a wood surface that defined the form of the sculpture (Figure 26).

In this exercise wood was an additive material through lamination, and subtractive by carving and filing. These exercises with simple tools stress the importance of woodworking along and against the wood grain. Also, sculpting from the wooden log or wooden block sets a dialog of convex and concave form with the tool. Making an object from a rough block of wood connects the craftsperson with the material.

**Mixed media**

This project introduces wood in combination with other materials. Hand tools are used for this project. A suggestion was followed to build a kite, a seemingly simple and familiar object that contains many complexities. The kite is a flying object made of light materials. The study focuses on the design of kite components and their connection all in respect to aerodynamics. There are many types and models of kites. Depending on the model of a kite, there are instructions and information given on its size and parts, frame
construction, type of paper or cloth used to cover, and strength of the string used to sustain in the air. Research was completed to build an “Eddy” model, which is a diamond shaped kite (Figure 27). Arms of diamond shaped kites are commonly made of lightweight hollow carbon tubes. Building it out of solid wood, the kite had to have longer arms in order to overcome the weight disadvantage for flight. A kite with arms this dimension reached the height and arm span of an average human (Eddy kite reached the proportions of Leonardo da Vinci’s Vitruvian man).

Because of the kite’s long arms and tail, a decision was made to build the kite so its arms are removable and the kite could be easily carried and assembled when needed. This caused a different strategy in design of its parts. Building the kite with removable arms meant that its parts are not glued but rely on dry friction joints. A kite raises, flows and flies because of the difference in air pressure below and above the kite. With diamond shaped kites the way to achieve this is by changing the angle of its arms to a 5° rearward sweep, so the kite becomes more of a three dimensional pyramid than a two-dimensional diamond shape. Introducing angle to its arms caused a bigger structural moment of arms and tail to the center connection of the kite. Building the kite with removable arms created a concern that was carried throughout the project, and in the first flying test caused a failure by breaking an arm.

The center of the Eddy kite was built out of four parts precisely connected with a hardwood wood clip (Figure 28). All four parts are connected with the grain perpendicular to each other. The connection of arms and centerpiece were done with dry mortise and tenon joint connections. Two side arms are braced with a bow to compensate for the big moment on the centerpiece caused by wind pressure. In order to stabilize the kite in the air, the craft has to be done precisely and the entire assembly must be very well made. Extreme conditions of high wind required maximum strength and lightness. Walnut as a hardwood was used for
the kite’s body. In order to bring lightness to the kite the arms ends were shaved and trimmed. A thin, strong and durable plastic sheet is stretched over the frame. A light steel cable with miniature turnbuckles helped brace the wooden frame.

Ultimately the failure occurred because the joints were not deep enough, causing them to wear out quickly when dealing with strong winds. The final workable solution was to glue the arms to the centerpiece and to work on more sufficient bracing by lashing the joints together.

Wood in the case of the Eddy kite is used for making a flying object with extreme performance. The kite project introduces design through details requiring great precision. This project deals with integration of different material and an idea of easy assembly of its parts (kit of parts). The combination of kit of parts and precision assemblies influences later iterations of the thesis project.

**Joinery**

The goal of designing a round wooden three-leg table was to become familiar with the use of more complex building techniques and the introduction of power tools to the process (Figure 29). The power tools used for this project were a table saw, table router, hand router and wood spindle shaper. Instructions were given for each component of the table. Legs are connected by dovetail joints and the edge of the tabletop is routed. The design process in the round table project is made by formal study communicated by drawings and sketches. This project serves to attain the skill of traditional wood joinery using power tools. This exercise precedes the table project.
Table project

As I intended the table for my own use, one major concern I had was mobility for ease of transportation.

Unlike the case of the Eddy kite (extreme performance), where the object’s utility required a special approach, the dining table requires a much more integrated relationship with the user in the daily ritual of eating. The dining table is designed to accommodate six persons seated (Figure 30). The table had to be able to remove legs from the tabletop easily and to assemble itself easily. This way the volume of the table is reduced to a minimum depth for shipment. The study model, done in wood, shows the main focus of integrating the table legs (vertical members) to the tabletop (horizontal members). The wooden model also suggested an enormous weight of the tabletop if done in one piece out of solid wood. The second study model, done in chipboard, along with the sketches and drawings searches for a suitable construction method (Figure 31). It is a study on transfer of load from horizontal members to vertical. Also, the design focuses on integration of components. A solution was found in prefabricating the tabletop in a system of intersecting plywood ribs. The tabletop is constructed as rigid frame made of plywood ribs that support the tabletop board. The result was an integration of design components into a prefabricated tabletop box. The tabletop is a flat surface, which is structurally defined from the bottom side where the connection with the legs is made. Routing the tabletop board allowed plywood ribs to sit orthogonal to the tabletop and be glued to it. Routing weakens the tabletop, but the ribbed frame provides structural stability, where both work as fabricated box (Figure 32).

Precise drawings help define the construction method, specifying dimensions and positions of plywood ribs in routed tabletop. Drawings are also used to make full-scale templates for all curved table components. The dining table was built from the “bottom up”,
and was first flipped onto its legs after assuring that bolts were securing the position of the tabletop frame and legs (Figure 33). The table legs are made by laminating three maple boards together (Figure 34). Assembly of the tabletop and table legs was made possible by two bolts per each leg assuring secure connections. The bolts are exposed, contributing to the design by revealing how the components are put together. A natural ivory-white silk was stretched over the frame of the ribs. Silk’s role is aesthetic. An experiment was done to test the ability of silk to stretch (Figure 35). Silk was stretched over two points and coated with several layers of Polyethylene. After the silk was stretched, the frame was glued down to the tabletop. Several coatings of Polyethylene allowed the silk to stretch even more and to become translucent. This way the silk has been protected and becomes almost drum-thick. It also becomes translucent, so it could be used to reveal the ribs to tabletop connection. The silk becomes plasticized and this characteristic of the material helps to remove the joints where the wooden legs fit into the boxes (Figure 36, 37, 38).

The dining table design features many intricate details and introduces the idea of prefabrication where the production of each component is carefully executed (Figures 31). Working on the dining table project helped to develop many technical skills with the use of both manual and power tools. This project demonstrates discovery in design, communicating through drawings and model making. It also communicates through observations and experiments done with materials, investigating their limitations and possible use for the design. This table is unique to the purposes and material investigations being made, and its design comes from refinement drawings and study models, and though experimenting with material crafting techniques.
CAD fabrication

The laser cutter and laser printer are new technologies at Iowa State University. Laser technology is not a crafting tool in the traditional sense. It is seen as an extension and materialization of computer aided design. The medium for laser technology is CAD (Computer-aided drawing) 3D modeling software. A high-energy laser or router bit is used for cutting through material. Material melts in the laser chamber. There is no direct human contact with a cutting tool, and there are few nuanced craft skills to be studied.

Laser cutters are automated machines used for fabrication of components with great precision. CNC technology lacks the traditional “touch of the craftsman”. When parts are assembled there is no surface texture, or marks produced by hand operated tools to reveal handcrafting activity behind the design. This led to a study of finished fabricated parts and to consider their characteristics in design: thickness, translucency, ability to connect and assembly after processing, tactile qualities, ability to bear high temperature of the laser without melting material, etc.

CD tower

Over the course of an independent fabrication class, students were asked to explore the possibilities of 2D laser cutting with a given 11x17 inch sheet of Plexiglas, where spatial composition had to be assembled with no leftover (Figure 39). AutoCad drawings are the media for both the laser cutter and laser printer. The CD case tower was an idea that came from the study Plexiglas and the precision under which it is cut. The CD case tower, like the traditional CD case, is made of Plexiglas and this led to an analysis of material thickness in relation to a typical CD case. A solution was found in four interlocking plates. Only three
poly lines lead the laser point to cut through Plexiglas with maximum density of line, without melting the material. Because the CD tower units are done with great precision, they could be stacked on top of one other. Since it contains only three poly lines, the AutoCad drawing file is small and could be easily downloaded from the Internet (file size 135kb), in this way the CD Case Tower could serve as "print and build" object. A load of 50 CD cases with CDs is carried by single tower unit (Figure 40). This project demonstrates the relationship of thickness and strength of pre cut Plexiglas and the load of CD cases.

**Pen-thimble**

The pen-thimble project is a study of tactile interaction with a plastic used in 3D laser printing. The pen and thimble are studied as miniatures. The thimble is a pitted cap, used for protection, or covering the thumb used to push a needle in while sewing. The thimble is a tool, which is used in direct contact with a human finger and needle. This “action-reaction” relationship between thimble, finger and needle is essential. The thimble is used in combination with a pencil led point or fountain pen point. A fusion of these two is possible through the hybrid object “pen-thimble”. It results a new and unprecedented writing tool that uses ink from an inkbottle (Figure 40). Although there was no direct contact with the material while fabricating, a relationship was established by adjusting the vector-based model made by the Rhino software program (Figure 41). Several prints were made in order to adjust the thickness of the pen-thimble wall (Figure 42). Printing such an object takes approximately 30 minutes with today’s cutting edge laser printer. The material used for the pen-thimble project is under 1 dollar in cost.

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This project combines the study of 3D software, miniatures, anatomy of a finger, and thimble and fountain pen explorations. The study mediates between the use of software and 3D laser printer using plastic mass as a material (Figure 43, 44).

**Conclusion to the workshop experience**

These workshop projects are the results of exploring the relationship of materiality and craft. Material is of central importance to the design process I’m studying. Through the process of design it is possible to learn a great deal on the nature of materials. There is a pattern found in the design process, where every stage is informed by previous one:

- Experiments and Analysis; Investigation of material by observations,
- Acknowledging pros and cons of material
- Taking advantage of material characteristics found in experiments
- Addressing critical factors to material limitations
- Problem solving
- Formal studies – drawings and model making
- Design and production - based on adopted building method
- Design evaluation by testing and refinement

Design starts with an initiative in problem solving. Designing by craft is a creative and integral part of the process of making. It is important to know the medium and work creatively within it, exploring its potential. In the act of making, craftspeople derive joy and satisfaction. Dialog with a material is individual. The learning process is based on collecting information through successes, but more importantly - failure. The workshop experience helps a designer develop a “pallet of materials” and gain knowledge of technologies that process them. Woodworking and furniture making are activities where one can maintain control over a product from beginning to end. Material research and craft exploration define material limitations and potential use in design. The design practice depends on workmanship and a commitment to quality, with a deep understanding of the hands-on
design process and the decision-making behind it. Knowing how something works, what is it made of, or how it is put together can only be fully understood through the empirical process of learning.
CHAPTER 4

THESIS DESIGN PROJECT

Sideboard (1919) by Gerrit Rietveld

The thesis design project is conceived as the design and fabrication of a shelving unit. The theme of a display unit is a common exercise in advanced woodworking and furniture making courses.

The sideboard designed by Gerrit Rietveld in 1919 radically differs from similar items of furniture done at the time. Rietveld’s sideboard is famous for its ideological statement. It relates directly to the historical origin in Arts and Crafts tradition and the work of Frank Lloyd Wright. According to Daniele Baroni, Rietveld must have been familiar with the work of Edward William Godwin’s sideboard 1867 (Figure 45). Bruno Zevi also comments on Rietveld’s sideboard:

“In opening the doors of a cupboard by Rietveld one experiences an extraordinary pleasure which derives not only from its technical perfection, but from the natural process of retracing the history of its assembly, which can be discovered and brought to life, element by element, with amazing clarity”.  

Cabinet making involves appropriate joinery and shelving systems. Rietveld’s sideboard is elementary in structure and essential in form. Bruno Zevi credits Rietveld for his conceptual clarity, simplicity and essential representation in design. For that, Rietveld must have designed through a series of iterations, which helped him refine the conceptual scheme and present a single idea of joinery in its essential form. This joinery detail has been perfected through many other Rietveld designs. The result is a design in which the components are assembled with great simplicity and clarity. A didactic joy and pleasure

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comes from discovering and understanding the assembly process through examining relationships between components of the sideboard. Rietveld's sideboard broke conventions of fine cabinetry by expressing each joint, similar to the Arts and Crafts tradition, but with a goal of universal extension over simple expression. Wood is abutted to one another rather than joined by a traditional wood joint. None of the joints has been hidden, but rather overlap expressing the connection point and suggesting extension of the "XYZ" axis to infinity (Figure 46). The joinery results in a skeleton structure in which shelving and cupboards have been inserted. They are free from the base structure, but supported by it; they revolve along the skeleton where needed. This skeleton structure suggests that the sideboard could be enlarged into an almost infinitely repeated structure. The relationship of the structure to the inserted board is determined by the grain directions of the wood, which is always in a 90-degree relationship to each other. This concept is similar to Godwin's sideboard with the difference in conceiving a joint detail. They both present work of the early Modern furniture designers. In the case of Godwin's sideboard, wooden shelving components are inserted into the skeleton frame and in that way are integral with it. The relationship of joinery to the shelving is reflected in the overall structure. This relationship is more evident in his schemes with clarity between assembly components. Integration of components comes from conceiving joinery and shelving bound together. Rietveld represents his separations as fundamentally different from Godwin's by organizing his drawings in quadrangular sections projecting plan, front view and side view (Figure 46).

Both Rietveld's and Godwin's sideboards were machine fabricated. This fact informs the design of the sideboard components and they are executed with the simplicity of planar wood. In one version of his sideboard Godwin incorporates ebonized stenciled floral and
abstract ornament\textsuperscript{13} borrowed from Irish manuscript illustrations (Figure 45). Godwin was a leader of the aesthetic movement, during the period of England’s Arts and Crafts movement. He had aesthetic concerns towards design and they were manifested through decoration. Rietveld, on the other hand, was trained as a craftsman in furniture making and his roots were in popular art, not in folk art, so he rejects decoration and native tradition. Rietveld reduced his design to essential planes. This results in the abstraction of wooden boards to almost two-dimensional planes. His sideboard features plain wooden boards, and was constructed out of ordinary milled lumber. Rietveld represents “truth in materials” when he uses wood. Material and surface treatment are limited to a bare minimum. Subtle wood texture and light finishing of the surface brings grain and color of the beech wood forward. Joinery is revealed and allowed to show. Form and content become identical (Figure 47).

Using Rietveld’s sideboard one can retrace history of its assembly, and also a history of its component production. Materiality is emphasized through the mechanical production of wooden components. Wood processing is always completed in respect to grain direction. Many materials such as wood, wooden products, plastic, and metal that come in plank shapes typically bend easily under their own weight, due to exaggerated proportions between width, length and height. This is a restraint of material that should be incorporated and solved through the design process. When applied to a shelving unit; bending, sagging and torsion occur under the load and become integral concerns to the design.

There is an analogy between the sideboard and a typical building structure. Bending occurs when structural elements are subjected to load. The structural element in buildings subjected to bending is the beam. In order to span and deal with deflection beams are

positioned with the longer vertical axis in their section. The same is applied to other structural elements: girders, structural walls and columns (Figure 48).

**Shelving unit - precedent study**

David Chipperfield developed a composite material, which helped to solve the problems of a shelving system that had structural extensions (Figure 49). This composite material is made of light honeycomb plastic sandwiched between two sheets of aluminum. The aluminum is in both compression and tension, and the light airy honeycomb prevents bending and is in zero pressure. Both the aluminum and honeycomb material depend on adhesive used to bond their surfaces. This composite material is extremely light and gives a good strength to weight ratio, which allowed the shelving to span a long distance (Figure 49).

David Chipperfiled’s design of the shelving unit comes as a simple solution. The problem of shelving rocking and swinging is solved by bracketing the back of the self with a solid composite board, and with “L” shaped members, which deal with the moment created in corner joints.

The development of a composite material presents a special approach to cabinetry. Material design in cabinet making has a great potential for innovation and introduces a new set of technical solutions (and problems). The goal of this research is to achieve and control structural integrity over material. In order to understand this state of materiality a few observations were done with a use of plywood, aluminum and Foamcore (Figure 50). A sheet of Foamcore “sandwiched” between two sheets of aluminum results in a composite material that is light and strong. This could be explained by observing the section of a simple beam.

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under load. The very top and very bottom get the maximum pressure, while the middle line is in neutral load (the “neutral axis”). Aluminum plate takes both tension and compression loads, while Foamcore is in neutral. Both aluminum and Foamcore depend on binding adhesive, the same as Chipperfiled’s composite material. In cases where wood is used, the grain gets both compression and tension along the entire section except for the neutral axis. A heavy middle section of wood adds to the weight when compared to a composite board. The traditional approach of cabinetry comes from the use of traditional wood planks. Composite materials allow us to have better strength to weight ratio. However, composite materials cannot avoid problems such as: maximum moment at corners, bending and torsion (Figure 45, 51, 52, 53, 54).

A sideboard is an item of furniture traditionally used for both storage and display. It usually consists of a set of cupboards with a flat display surface on top approximately at waist height. Originally, as indicated by its name, a sideboard would have been used for serving food, but it came to be a household object found in a living room, where items such as books or ornaments might be found. It is now almost obsolete.15

The term credenza desk is also used for a piece of domestic furniture such as a sideboard buffet where food is placed before serving (Figure 45, 46, 47). The function of such shelving units changes due to the differences in the culture of eating, or it gets fused with similar shelving units that house objects such as books, home electronics, aquarium, pottery, flowerpots etc. Therefore the term sideboard is expanded to a display unit, credenza, bookshelf etc. Its relationship toward the living space is evaluated in order to fulfill different needs. The position of these objects is marked by different heights of the shelving unit. My thesis design project focuses on the design of a cabinet that expresses horizontality on different heights.

A study of shelving systems was done through schemes and precedents of modern and contemporary design. One of the early examples of modern cabinetry that expresses flow of space by freeing the horizontal plane is the 1952 unit by Charlotte Perriand. Horizontal wooden boards are supported by elements made of three separated pieces of bent sheet metal (Figure 55). To prevent the shelving unit from collapsing, a steel rod ties the top and bottom horizontal board together. In his shelving unit Jean Nouvel reversed this structural order, with shelving that hangs from highest horizontal instead of resting on the floor. Nouvel presents a complex system of tie-rods to accomplish this task (Figure 56). The shelf is fixed to the wall at the top with number of metal uprights that have regular notches, which are hooked to this shelf at different heights. This elegant appearance is expressed with the openness of the structure. It was done through a complex technical solution. Here Nouvel uses tie rods to hang horizontal plywood shelving components, and also connects them in a detail that prevents rocking of the shelf, torsion of the horizontal members, and defines the height between them. Similarly Rezno Piano develops a shelving system that features a unique bolting mechanism, where a customized tool was developed for assembly of this shelf (Figure 57).

The work of Chipperfield, Perriand, Nouvel and Piano expresses the openness of the shelving space and the flexibility of its use. They feature different structural solutions for the problem of horizontal-vertical connections.

**Design of the shelving unit**

In terms of structure, the shelving system required vertical support for horizontal members. The solution comes directly from the choice of material and the development of

17 Design Jean Nouvel by Molteny & C, www.molteni.it
joinery for the shelving system.

Vertical components bear the load and distribute it from top to bottom (Figure 58, 59). In order to express the openness of the shelves, as seen in precedent studies, horizontal members had to be long and deep enough to withstand the compression coming from vertical components (Figure 60). A major concern becomes joinery, which had to deal with load transfer. The vertical and horizontal components had to be well integrated.

Refinement of the design schemes was done through models and drawings. Study models of joinery show evolution of the single idea and its relationship to the overall design. The initial scheme was simplified to its essential components (Figure 61, 62). The joinery problem was solved through several revisions with special attention to detail. Horizontal shelf components are stacked on vertical supports with dry structural friction joints. This friction is carefully tested and balanced through use of a CNC (Computer Numerical Control) router on the Foamcore study model. The CNC router was used for final shelf component production as well (Figure 63). For components to “sit” and transfer the load evenly throughout the shelf, great precision is required. The joinery detail is repeated in all connections (Figure 61). If for any reason the joinery fails to maintain its connection, then the neighboring member would take over its role. The CNC router allows precision of 1/100th of an inch. Plywood was the material used for the shelf construction. It turned out to be the most appropriate wood product whose grain orientation and density could withstand shelf production and the load of shelving material plus display or books. The only tool used for the final shelf assembly is a rubber mallet (Figure 64).

Material manipulation is reflected on its surface. The surface of the shelf components, cut from CNC router, were finished by sanding and then coated with Polyethylene. In this process the thickness of the shelf components was adjusted to achieve needed friction.
Sanding was done on the face of the plywood shelf members only, not on the area cut by the CNC router. This decision helped to emphasize the contrast between the two faces of the plywood board, expressing the quality of the wood grain. Leg supports are done in the same fashion as vertical supports.

There are structural similarities found between my shelf and the bench designed by George Nelson (Figure 65). Fundamental differences are that Nelson’s bench was made in solid wood, versus plywood, and that Nelson used wood glue for the joinery of his bench, as oppose to dry joinery. Dimensions of the shelf were in part the result of thorough comparison and analysis of the Nelson bench.
CHAPTER 5

CONCLUSION

Material investigation is integral to my design approach. Through my thesis research I have explored design processes that focus on intricate relationships of materials and craft by observation, experiments and analysis. The relationship between material and craft informs my design process integrally. Research was conducted as an open-ended study and I found that it could be built on. This thesis defines a framework for future material-craft explorations and it leads to a deeper exploration of issues of materiality. My long-term research and career objectives will be based on the relationship between design, craft and technology.

Considering the thesis question “materiality and crafts within design” the problems are to be acknowledged and solved through design projects. The hands-on workshop environment offers many solutions for design problems and I believe this idea is transferable in scale to larger building projects. As seen in the shelving project, elaborative and systematic study is required for understanding design processes. This study is conducted through a scientific approach by material experimentation. This approach provides a strong base for decision-making.

Over the course of this study many important questions, related to design processes, were raised. The thesis also pointed many directions for further research to develop. Answers on many of these questions are still to be found in future studies that will be the continuation of this work. I believe that this thesis presents a strong basis for those future studies and fertile ground for exploration. Rather than consider this the culmination of my academic career, I consider it the beginning of my lifelong study.
BIBLIOGRAPHY

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Figure 2. Left to right: Sketch by Carlo Scarpa; Sculpture support for Ivory Madonna. The steel support holds the sculpture clear of its background. Sketch is taken from the book: *Carlo Scarpa and the Castelvecchio*, (Butterworth Architecture 1990): 24.

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