Re-envisioning the Knot

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RE-ENVISIONING THE KNOT: LESSONS FROM THE WORK OF NEIL ASTLE

In *The Four Elements of Architecture*, Gottfried Semper explored the material and craft significance of the hearth (ceramics), mound (stone masonry), enclosure (textiles/weaving), and roof (tectonic/carpentry). Each element was a synthesis of the expression of craft, progression of skills and knowledge of production. Semper's analysis differentiated light versus heavy material assemblies, and assigned a particular tectonic craft to each element, such as weaving belonged to wall/roof enclosure and carpentry was essential to the basic structural frame.[1] It was however the textile knot or joint that Semper asserted was the earliest and most significant tectonic element.[2]

The physical act of joining is evidence in the woven textile skin of early nomadic tents (the knotting of fibers) as well as modern wood framed construction systems (the lapping and nailing framing members). The interpretation and understanding of the joint remains essential to architecture; i.e. how structural members are attached to one another to act as a composite system addressing forces and loads. In vernacular building tradition, the textile as a woven system has traditionally been expressed in a purely surface application or *bekleidungkunst* (art of dressing)[3], where the skin represents the composite character of the construction but the core of the building is its structure and substance. In the Neil Astle house built in Omaha, Nebraska, the concept of weaving transformed the traditional wood framing of separate bearing and spanning components into a more holistically woven structural system. The house is based on a logic of interlocking 2x2 wood members nailed together to generate walls, floor and roof components which join together to form an expressive rigid knot like connection, to be described in further detail within "interconnected rational."

ENVIRONMENTAL IMPACT OF THE DESIGN PROCESS

Wood framed housing has been a mainstay of the building industry and dominant force in the American cultural and economic landscape. It has fulfilled the needs of its users through a construction methodology utilizing low-cost, easily-produced, dimensional lumber and assembled via local low-skill labor. With rare exceptions, the effectiveness of normative wood framing has seldom led to serious questioning and challenges in defining what it means 'to build'. It is an important question to interrogate as the built environment impacts the natural through material selection, transport and assembly of material and design intent. These early design and material decisions can lead to unintended consequences of resource waste and local environmental degradation if not rigorous examined. As an architect, the act of building should be a reflective act, one that recognizes it repercussions and limitations. These consequences should emphasize the need for innovative building strategies, which challenge traditional paradigms and discover inventive solutions, which tread more lightly on the landscape.

One architect whose methodology epitomizes this critical exploration of forces on the design process is Neil Astle. He opened his first practice, Astle/

Ericson, in Omaha, Nebraska in 1965, and initially began exploring wood as a building material, testing its structural limits and potential as a craft. During his career, which spanned over thirty years, he incorporated multiple iterations of wood assemblies into his practice.

It is important to understand Astle's underlying philosophical approach to the design process as it informs and directs his investigations of the wood lap joint. Neil Astle was a proponent of modern systems theory, which consists of a set of elements intrinsically linked together. The relationship between elements is such that all actions and activities are interrelated and a change in one part will cause an integral change in all of them as well as the system as a whole. In systems design, the designer is guided by the understanding of contextual systems where a design response emerges from the relationships between multiple contexts. For Astle, a design project was organized into three systems categories: 1) environmental systems (context), 2) social systems (context) and 3) building systems (support). His approach is primarily based on understanding contextual limitations of a design. Throughout the design of his own house, he was presented with numerous limitations that would

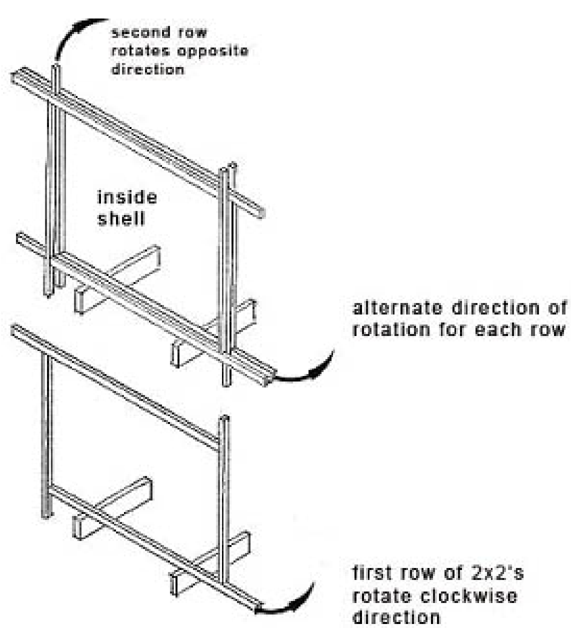

Image 1 - Top: three consecutive layers of 2x2's placed in alternating rotational relationship. First layer rotates counter-clockwise, the second layer rotates clockwise.
Bottom: One Layer of 2x2's showing rotational placement.

ultimately direct his new innovative approach to structure, material and space.

AN INTERCONNECTED RATIONAL

A range of factors influenced Astle to abandon traditional stick frame construction and find new construction logic from which to build. Traditional wood framing is based on dimensional members nailed together and given rigidity through the application of interior and exterior sheathing that resist lateral forces. These assemblies form walls, floors and roofs that are then conventionally nailed together through simple plate surfaces. These connections are not considered rigid and thus are typically supplemented with specialized connection components. In contrast, the Astle interconnected wood system is based upon the lap joint, which utilizes overlapping 2x2 cedar, nailed to each other from both horizontal and vertical elements of an interlocking bearing wall structure [image 1]. Similar to a weaving process, the alternating layers of 2x2's are rotated in the opposite directions, forming the vertical and horizontal planes, and the lengths of each wood member are left random to allow walls, floors and roofs planes to engage one another. The inner layer of 2x2's are oriented horizontally and become an integral part of the structure when interlocked with the floor and ceiling thus eliminating the need for the normative nailing plates. The lapping members acts like a woven knot creating a rigid connection, which reduces moment forces (the tendency to overturn) within the assembly. It also eliminates the need for normative interior/exterior sheathing required for lateral resistance. The overlapping ends were then trimmed and creatively used in other parts of the construction thereby minimizing material waste.

Astle's rational approach addressed various cost, material and craft limitations and through the integration of small wood members became the material and structural expression of the building. The first limit that Astle addressed was that construction would be completed by the owner/architect. Astle acted as the prime contractor on the project along with a mechanical subcontractor and young carpenter as the only other key participants in construction. It was desired that the lapping structural system have a material and aesthetic consistency, which then must address the most basic skill level of the participants. The lapped joint was chosen because it required a relatively low skill level for the builder and removed the burden of precise joinery and sophisticated construction methods. Despite the lack of sophistication as an assembly, the interlocking and overlapping language of the lapped joint allowed Astle to stitch together elements of material and structure to create architectural space.

Another aspect to the system was that it could be used in both interior and exterior applications. Astle chose small wood members, in this case western-red cedar, because a single person could handle it easily and it fit the naturally wooded context, especially after turning a weathered grey. Upon approaching the Astle house, you immediately notice its strong connection to the site. Cedar was specified for the project because of its excellent resistance to decay yet it also has superior insulation qualities over comparable woods. Its only disadvantage, however, is in its strength because it has an allowable bending stress of only two-thirds that of redwood. This disadvantage became a primary motivation for abandoning a traditional wood framing system and implementing the interconnected wood system in its place.

THINNESS OF SECTION

Semper classified building craft into two fundamental strategies: The first is the heavy mass of the earthwork or grounded elements. The second is the tectonic frame in which linear elements are assembled to form a lightweight spatial matrix. The reliance on redundancy within the spatial matrix gives it a decidedly thin but stable structure. Thinness is a fundamental principle of the Astle house, which is achieved through a similar spatial (textile-like) matrix. Under normal beam loads, a pair of 2x4s nailed together could structurally span about 12'-0" [Fig. 1, Image 2]. However, Astle was able to increase the span capabilities of the 2x4 assembly through fixed connections at the wall and ceiling (same for the floor and wall connection). The interlocking joint created a rigid connection thus reducing the critical moment stresses by allowing some of the bending stress of the floor or ceiling to be taken by the walls [Fig. 2, Image 2]. Staggering alternate members increased the span at the ceiling and floor structure vertically, thus increasing the effective depth and stiffness of the assembly. At the roof, the vertical stagger was increased to work with the slope of the roof, which increased the effective depth allowing 2x4's greater spans of up to 17-0". In contrast, the exterior wall assembly is thin, utilizing a sandwich assembly of 2x2 nailed cedar for the outer layers (running perpendicular to each other) and a 1-1/2 inch rigid insulation core with vapor barrier giving the house a striking lightness revealed through its thin exposed edges [image 4].

The Astle house sits on a severely sloping site with a basement in the middle section of the house and the outside walls overhanging the basement walls and supported by concrete piers. By pushing the

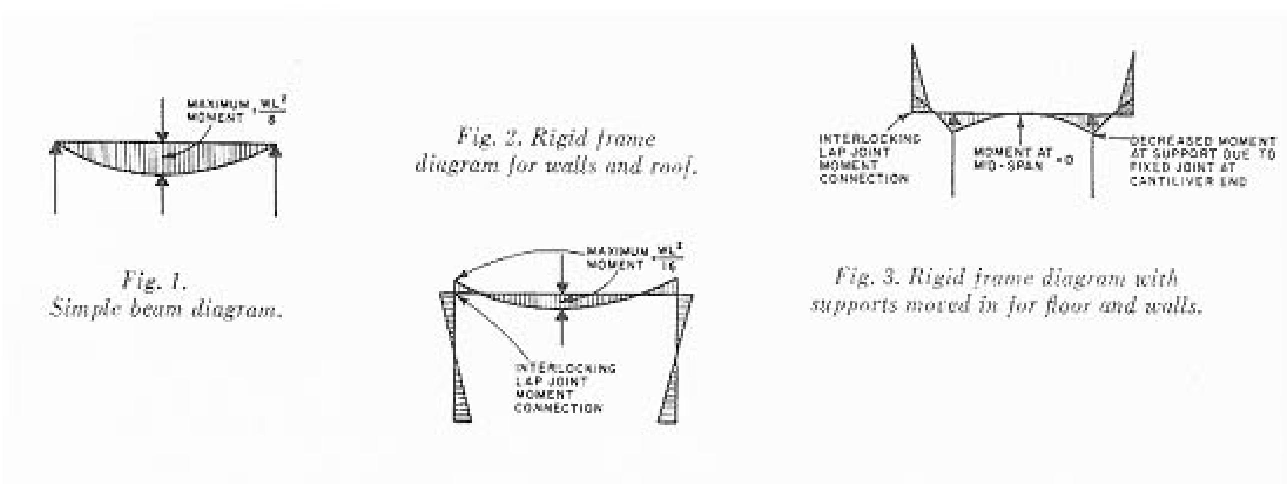

Image 2

supports (piers) inward from the outside wall bearing line and allowing the main floor to overhang, effectively weaves together the external forces within the floor and wall connection reducing the moment at the center of the floor span (where traditionally the moment forces would be the greatest) to almost zero. [Fig. 3, Image 2] This allowed the floor assembly to use smaller 2x4's and retain a thinner sectional depth from that of a standard framed house. The interconnected methodology also generated significant increases in spanning ability allowing greater volumetric space through shallow floor depths, making the house feel much larger.

CONSTRUCTION PROCESS

The simple nature of the interconnected wood system required only a small construction crew. Astle and one carpenter framed the entire structure themselves, with a minimum number of tools and without the need for scaffolding. The interlocking system of floor, walls and ceilings precluded independently constructed assemblies: one row of random length 2x2 cedar were placed in a rotational manner with the length left to run long. The next layer of cedar 2x2's were rotated in the opposite direction locking the walls, roof and ceilings in place leaving an open end, essentially creating a thin single board width rigid shell. [Image 1]. This allowed one person to construct the roof and upper sections of the walls while another person working simultaneously on the floor and lower sections of the walls. The construction began in the center and worked outward longitudinally in both directions. This required both individuals to build the platform section (roof or floor) they were standing on, requiring only a small number of wood working tools, such as hand held circular saw, hand saw, hammer, level, string line and carpenter square, etc. that could be easily transported and handled at their area of construction. Although low-tech in skill and limited in number of workers, the construction of the house took just a little more than a year to complete.

JUSTIFY EVERY STICK

Astle's mantra was "Justify every stick!" The overall strategy of the Astle house was influenced by textile fabrication; where in lieu of threading, small wood members are used in a wide range of applications. Working at multiple scales, the same holds true for the detail strategy used in the house where one basic member is optimized for the maximum number of construction conditions. Astle wanted a detail to be appropriate to the skill level of the builder as well as repetitive in the material being joined and the tools employed. It allowed flexibility in dimensioning and adapting to varying situations, which eliminated the need for pre-measuring, pre-cutting and pre-fitting. Any length member could be used at any time and placed within the assembly resulting in 2% material waste during the construction in comparison to more than 20% waste produced found within traditional wood frame construction practices.[4]

INTEGRATIVE SYSTEM

Astle's rational method, employed in his house, was a closed system where universal strategies to problems are secondary to issue specific or contextual approaches. In all of Astle's work, programming is an essential part of the design process. He believed in developing usable space centered on human activity and facilitating human choice by allowing the user to find their own unique fit. Astle's new system was oriented towards his family's living needs and the limitations of construction knowledge and experience of his crew.

This rational approach can be clearly seen in the open spatial layout of the Astle residence. The living room, family room and three bedrooms are organized around a sunken central kiva and fireplace. All the bedrooms have sliding wood doors made from scrap sections of cedar. Using the scrap material from the random length scantling, Astle created abstract textile-like patterns and burned the wood black to read as a three-dimensional painting. The intent of the sliding doors was to open the bedroom up to the central core of the house and allow heat from the fireplace to radiate through to the bedrooms. Another distinct feature of the house on the exterior is a series of ventilation strips between the layers of the cedar. This detail accentuates the thinness of section and lightness of structure and space [Images 4&5]. The windows in the house are fixed so natural ventilation is achieved through the wall membrane by opening narrow doors on the inside of the wall that draw air through the house.

Despite its development as a closed system, the interlocking wood system uses repetitive pieces of wood and gives future adaptability to the house, which is uncommon in traditional stick frame construction. When the house was built in 1968, the 3-bedroom house was approximately (2,140sf). It was later sold in 1978, and easily expanded at both ends of the house by adding additional bedrooms and family space. The current owners explained that the open ends created by the interlocking wood system allowed the end walls to be removed so that the rigid frame could be continued, creating additional bays. Astle's system also allowed areas of the front and rear façade to be removed and larger windows installed without the need of headers and additional framing.

LESSONS FROM THE WORK OF NEIL ASTLE

Semper emphasized textiles as primarily sheathing or covering: a thin membrane-like material that is highly malleable but must rely principally on the stability and rigidity of the wood frame to achieve its resultant form. His insight into the textile as a woven system or matrix provides opportunities for more innovative architectural solutions. Creating lighter and more efficient buildings is not just a matter of using lighter materials but understanding a material's inherent property in terms of shape, and (fabrication) technique.

The lessons in Neil Astle's work come from the rigor of his design approach and his ability to creatively analyze the needs and limits within a project. The design of the Astle house was driven by economy and efficiency constructed around the project limits. That ultimately led to a rational material system such as the interlocking joint technique demonstrating the beauty of wood as a woven/lapping detail. The essence of this connection also brought flexibility to the larger structural and enclosure system. The result is a modern house rooted in history by a quest to design efficient structures and systems.

The system's sophistication is measured by the precision of material and consistency of labor. *Would material and labor efficiency of the inter-*

Figure 3: *Ferraria*, Prototype, cast urethane rubber, 2010.

Image 4 – Ventilation strips at wall

Image 5 – Floor to wall (knot) connection

locking wood system be meaningful for mass- produced and repetitious housing, which encompasses a significant portion of the cost-sensitive housing market? Not-likely, but the systems approach Astle utilized provides a framework that can be applied to projects with similar conditions to be developed differently. It would need to grow from a similar attitude of defining limits linked to direct applications. The textile influenced strategy for the Astle residence evolved beyond the initial house; linking together a wide range of structural and non-structural applications in many projects throughout his career. Yet in all his work there is a high sophistication of craft and synthesis in weaving elements of material, structure and space together with aesthetic and tectonic assemblage.

ENDNOTES

1 Kenneth Frampton, *Studies in Tectonic Culture*, (Cambridge, Mass.: The MIT Press, 1995), 87.
2 Ibid., 86
3 Ibid., 18
4 Caolos, T. Formosos, Luico Soilbelman, Claudia DeCesare, Eduardo L. Iassato, *Journal of Construction and Engineering Management*, (July / August 2002).

Image credit: All Images courtesy of Kari Astle