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# XX-LAM: The Architecture of Curved Cross-Laminated Timber

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**ABSTRACT:** *Since its inception in the early 90s, cross-laminated timber has surged in popularity as a credible alternative to concrete and steel. Its myriad uses, based on advancing the materials science of timber composites have culminated in new methods of prefabrication, mass production and fast-track assembly. However, perhaps its most significant benefit is its proven capacity to sequester carbon. This paper suggests that to maintain the upward trajectory of mass timber, it should also subject itself to an ongoing process of formal and material experiments that are then evaluated as an architectural language. It presents a research project (XX-LAM) that explores these possibilities through an experimental approach to the act of making. In this case, the term “cross lamination” (or X-LAM) is adopted as a conceptual strategy wherein the material science of wood lamination is combined (or “crossed”) with the discipline of late modernist formal exercises like the New York Five’s “kit-of-parts problem” with particular reference to the work of John Hejduk. The research concludes by applying these forms to speculation on the architectural language of typical building typologies. It presents a series of iterations that combine vaulted ceilings, circular openings and curved vertical extrusions. These iterations produce new materiality, form and architectural language that are interpretations of “free plan”, “cycloid barrel vaults”, and groin vault architecture.*

**KEYWORDS:** cross-laminated timber, formalism, “kit-of-parts problem”

“If the 19th century was the century of steel and the 20th century the century of concrete, then the 21st century is about engineered timber.”

Prof. Alex de Rilke

## 1. FORMALISM & ENGINEERED LUMBER - TWO CONCEPTUAL POSITIONS

Since its inception in the early 90s, cross-laminated timber has surged in popularity as a credible alternative to concrete and steel. Its myriad uses, based on the advanced material science of timber composites, have culminated in new methods of prefabrication, mass production and fast-track assembly and, above all, its proven capacity to sequester carbon. However, in recognising the undeniable benefits of mass timber, the architectural profession, at times, appears to acquiesce to an architectural syntax defined purely by its means of production. This paper suggests that to maintain the upward trajectory of mass timber, it should also subject itself to an ongoing process of formal and material experimentation to be evaluated as an architectural language. It presents a research project, XX-LAM that combines fabrication studies of curved cross-laminated timber with a “formalist” approach to architectural synthesis. In this case, the term “cross lamination” (or X-LAM) is adopted as a conceptual strategy wherein the material science of wood lamination is combined (or “crossed”) with the discipline of late modernist formal exercises that include John Hejduk’s *Nine Square Grid / Kit-Of-Parts Problem*, New York Five and the influence of Historian Vincent Scully.

## 2. X-LAM – A “MASSIVE SYSTEM”<sup>1</sup>

In many senses, CLT today can be seen as the next phase of the postwar expansion of forestry production. In the US, it is directly connected to the de-skilled construction industry and the postwar expansion of stud construction. Globally, this production scale has many big ag similarities, particularly adaptations of post-soviet military infrastructure to forestry in Eastern Europe. In the US, it is not surprising that certification construction grade CLT (ANSI APA PRG 320)<sup>2</sup> is based largely upon existing dimensional lumber strength grading or plywood certification. In this way, these emergent forms of timber lamination have segued neatly into large-scale forestry production where new facilities are, in many cases, extensions of existing mills, especially those with glulam capabilities. With few exceptions, these facilities deal exclusively with spruce, pine and fir (SPF) softwood lamstock and produce large billet (40’x10’) using planar hydraulic press beds. There is a similar homogeneity to the application of lamination adhesives. The majority of panels produced both in the US and Europe are bonded with polyurethane and melamine glue and are CNC cut to produce a prefabricated, dry assembly system that can outperform concrete (and often steel) for onsite construction. Under favorable circumstances, CLT can be exported for a global market, and both remain cost-effective while still achieving net carbon sequestration.<sup>3</sup>

The refinements of these bonding techniques go hand in hand with specific structural and formal constraints that vary according to program. These can roughly be categorized as cellular, planar tectonic systems for compartmentalized arrangements like housing on the one hand to a point-loaded trabeated language for open plan programs on the other. These systems then translate to CLT walls and slabs for the former and glulam

post and beam with mass timber slabs for the latter. These structural patterns, along with the increasing inclusion of CLT in the IBC have allowed many architects to use a basic construction technique to replace concrete and steel.

From this perspective, it is possible to imagine that architects will soon come to adopt CLT as “system” rather than a discipline or as building rather than architecture. We might argue that the expansion of engineered lumber is in danger of becoming industrialized to the point that we will miss the chance to establish its own architectural language. Furthermore, the “moral imperative”<sup>4</sup> engineered lumber (sustainable, practical, affordable) may justify superseding the kind of disciplinary analysis that every emergent technology undergoes in complex architectural synthesis (space, proportion, promenade, and architectural composition). In recognizing the (undeniable) benefits of mass timber, the architectural profession, at times, appears to acquiesce to an architectural syntax defined purely by its means of production. At times its materiality adopts a similarly passive aesthetic stance, i.e. that the “natural” beauty of wood is enough in itself. The powerful eco-message of a new green architecture often seems to exempt it from disciplinary considerations like tectonic systems, formalism or notions of *Gesamtkunstwerk* – all considerations that might transform it into an architectural language of its own.

### 3. XX-LAM – “CROSSING” NINE-SQUARE-GRID COMBINED WITH CURVED CLT

With this in mind, in the fall of 2022 *PLAIN Design-Build* established the *XX-LAM Design Research Studio* to explore a series of new possibilities for mass timber architecture. The studio sought to challenge the current tectonic system of mass timber by combining ideas about architectural “formalism” with new techniques of bonding single curvature CLT. In this way, the studio was framed by a conceptual point of departure that adopted “cross lamination” as a theoretical strategy as well as a technical one. It proposed that the physical pattern of cross-lamination is also used as a metaphor for analytical, synthetic and creative activities with the aim of creating new hybrid conditions of architecture. From this strategy, we derived the name *XX-LAM* because cross-laminated timber is sometimes abbreviated to cross-lam or X-LAM, and the additional “X” refers to the conceptual strategy of “crossing”.

Having set up *XX-LAM* as a conceptual “lens” for exploring new forms of mass timber architecture, we then analyzed the theoretical precedents that might provide useful parallels to contemporary forms of engineered lumber. From a disciplinary perspective, these “formalist” exercises focused on the late modernist architectural theory of the New York Five as well as the work of historian Vincent Scully. Particular projects from these authors were, respectively *The Nine-Square Grid Kit-Of-Parts Problem* (Hejduk and the New York Five) and Scully’s 1974 publication, *The Shingle Style Today or The Historian’s Revenge*, both of which allowed us to draw parallels between the 60s / early 70s architectural theory and mass timber architecture at a number of levels.

These parallels offer a useful critique of overtly rational architecture. In speculating that mass timber is in danger of becoming overly logical in its repetition of structural formula, it is useful to remind ourselves that NY5 had come to a similar critique in the late 60s, i.e. that European and US modernism had reduced itself to dull, functional repetition<sup>5</sup>. If this is the case, then what might come out of a study of mass timber if we subject it to similar “principles of architecture as an autonomous discipline”? How might these exercises support a purely sculptural, spatial poetic of mass timber? Furthermore, can this supposition be further reinforced by the way the *kit-of-parts* idea appears to have an uncanny precursor in pre-cut flat-pack assembly systems of CLT construction (rough 80% of mass timber buildings are a prefabricated kit)? This parallel aided us in “functionless”, purely formal experiments of those “parts” by translating “point, line and plane” into glulam columns, beams and CLT panels. This offered us a way of seeing beyond the constraints of a purely functional grid i.e

“plan diagram itself could a subject of critical inquiry emerged from post-war architectural theory in Colin Rowe’s essay “Mathematics of the Ideal Villa” (1947). (Timothy Love)

It is difficult to avoid a renewed discussion about the language of wooden buildings in the US without considering the influence of Vincent Scully. While much of Scully’s argument (based on the idea that wood represents the historical narrative of American “identity”) may seem questionable today, his observations about the uniquely wholistic quality of timber seem much more prophetic. If we study parallels between the total wood *Gesamtkunstwerk* of many mass timber buildings and those chosen by Scully, similarities start to appear. In some cases, the buildings of Scully’s “second wave” seem to offer a kind of “proto CLT” language to them. These similarities are most notable in the work of Robert Gwathamy, Edward Barnes and Charles Moore<sup>6</sup>.



Figure 1: Charles Moore The Sea Ranch and Susan Jones' CLT House

By aligning contemporary mass timber buildings to those depicted in the *Shingle Style*, we can establish a path back to earlier theory and provide added influence to emerging forms of mass timber architecture. XX-LAM suggests that Scully provides a model to explore a possible third phase of his narrative, this time based on engineered lumber.

Finally, we felt that it was worth exploring another parallel in the aesthetic similarities of material homogeneity.

“While the kit-of-parts problem refocused design education on the definition and articulation of space, and on the enrichment of the “architectural promenade” (achieved with spatial elaboration), the exercises most decidedly de-emphasized the material aspects of architecture” (Timothy Love).

While it is true that the NY5 considered materiality a non-issue in the experimental phase of the nine-square grid, this sense of non-materiality went on to characterize many of the buildings that were eventually built. Many of these architects felt that by separating architecture from any distinct material associations, they would allow a rich variety of spatial relations to emerge more easily. Initially, this dematerialized architecture was seen as a way of stripping it from any cultural bias that comes with material choices<sup>7</sup>. Although this varied in the outcome, there was certainly an attempt to celebrate a kind of synthetic material indifference or anonymity. In the case of John Hejduk this led to an all-stucco rendered architecture, with Peter Eisenman, buildings appear to be made as if they are large architectural models, and with Richard Meier, the homogenizing, Purists associations of white modernism. These influences can also be applied to Brutalism and the celebration of the totalizing materiality of cast-in-place concrete. However, the parallel between these forms of architecture and new forms of mass timber architecture only lies in a shared sense of homogeneity. Frequently when you look at CLT buildings, particularly in the interior, they celebrate a total wood aesthetic and often use different types of engineered lumber to resolve all elements of that building (often to reduce the number of trades). While this produces the effect of giving them a similar homogeneity to New York Five architecture, this homogeneity has a radically different materiality. Mass timber buildings' advantages are that are homogenized through the natural texture of wood and are in stark contrast to the deliberately synthetic appeal of late modernist architecture in the USA.

#### **4. DESIGN EXPLORATIONS- CURVED ENGINEERED LUMBER AND THE “KIT-OF-PARTS”**

XX-LAM explores the potential of the homogeneous materiality of CLT to create beautiful, sculptural spatial conditions. Proposals adopt the plan as a spatial generator, with an emphasis on a free arrangement of basic elements of planar and cylindrical walls. All compositions modulated a sense of enclosure, and circulation within the nine-square structural frame. The iteration shown in Figure 2 was focused on movement through the space while arranging the elements along the grid in an absolute manner. The location of elements relates directly to either the intersections or midpoints of the grid.

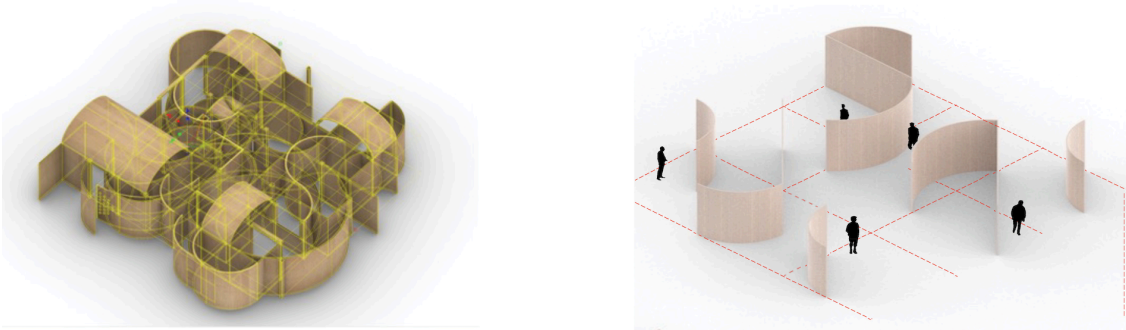


Figure 2: Jacob Urban - XX-LAM Studio Masters Student & Figure & Composite of all iterations - Jason Griffiths

"Use of planes and pure geometric volumes -- cubic and sometimes cylindrical; manipulation of two- and three-dimensional compositional systems -- such as grid patterns -- to modulate space, structure and surface.

The way to see plan as a spatial generator is by simplifying the plan as an arrangement of four basic architectural elements, columns, slanted walls, cross columns, and rooms, and each element forms a type of field that contains a gradient of enclosure, ways of circulation, and structural stability." (Roger K. Lewis)

XX - LAM then develops its conceptual position by simultaneously exploring abstract compositions while learning to fabricate construction-grade CLT in curvilinear forms. The initial explorations of Nine-Square-Grid arrangements were, at the same time, tested against our ability to resolve the technical challenges of full-scale fabrication.

After proposing initial grid layouts, the studio focused on vac-formed bending methods, lumber types, glue varieties, bending radii, connection conditions, and layer depths. This process allowed the studio to refine the parts for a full-scale installation.



Figure 3: Timber types and lay-up studies XX-LAM Studio

Testing a different number of layers included concentric arrangement in odd numbers (Figure 4 shows three, five, and seven) This uneven number of layers is used for strength to combat the internal compression and tension forces placed on the centre layer instead of allowing that force to act on the bonding surface if it were an even number of layers. Further consideration was given to the thickness of each layer until we settled on five layers of 3/8" that were efficient and thick enough to be considered for building. Testing thicker layers than 3/8" produced cracks along the length while thinner layers would begin to split across the width of the boards used in the longitudinal orientation.

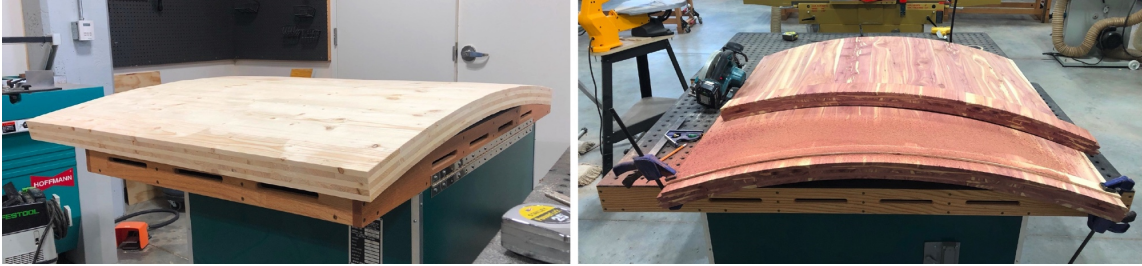


Figure 4: Post vac-formed lay-ups - XX-LAM Studio

After exploring a range of possible different timber species, we settled on local pine and eastern redcedar. Both varieties of softwood were proved flexible and durable enough to withstand the forces of bending in a vacuum former and maintain shape when glue bonded with minimal spring back after drying. These varieties could be sourced with minimal moisture, which was important in allowing us to process the raw boards into the desired dimensions. Once bonded, this solid mass of wood and glue made these panels extremely flexible for structures and could accommodate perforations for mechanical fixing. This allowed us to connect panels with one-foot threaded rods that were fastened between hole perforations to complete multiple panel assemblies.

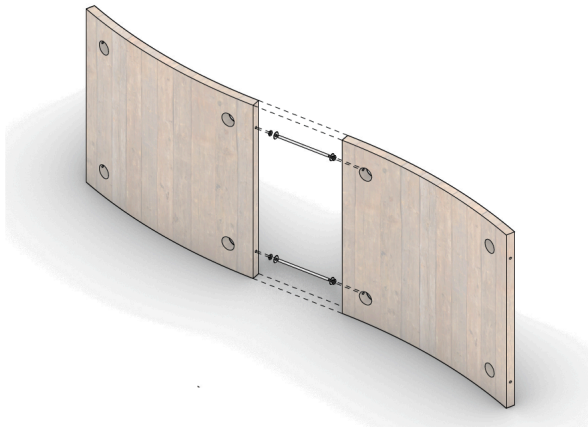


Figure 5: Jacob Urban - Panel-to-panel connection

The learning process directly shaped the final arrangements of *XX-LAM*. The homogeneity of the composition and its inherent strength as a construction material, proved incredibly durable when tested in full-scale arrangements. In the first assembly *XX-LAM Exhibition* at Omaha by Design in the fall of 2021, a combination of 5' and 10' radius panels were assembled in an interior configuration around an existing grid of wooded columns. These panel modules and mechanical fixing allowed us to quickly test different spatial arrangements at full scale. In the next iteration at Wesleyan's Elder Gallery<sup>8</sup> we added more modules and reconfigured the arrangement as a vertical enclosure. This arrangement explored the implications of interior architectural moments within the field condition that refer to details of Hejduk's Project A - Diamond House configuration<sup>9</sup>. This arrangement was restricted to a concatenation of curved panels arranged with tangential continuity between panels to form a simple curved enclosure. While this arrangement suggested a complex curve, it could be simply formed by two radii and flat panels.

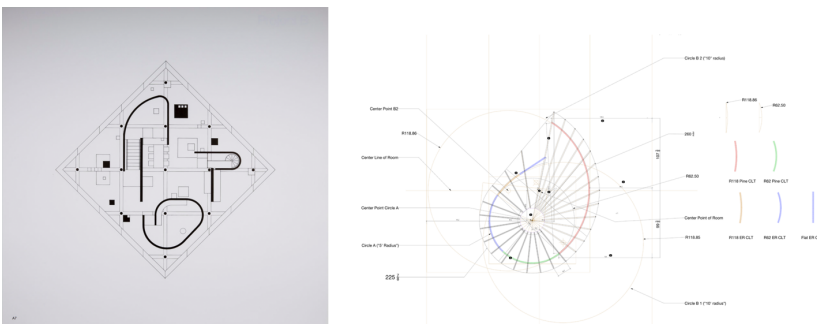


Figure 6: John Hejduk (1929–2000), Project A, Diamond House, 1969 and XX-LAM Installation at Wesleyan Elder Gallery



Figure 7: XX-LAM: OBD Exhibition fall 2021 and Wesleyan Elder Gallery summer 2022

These full-scale configurations led to a series of speculative multistorey typologies that propose three outcomes for an iterative syntax for mass timber buildings.

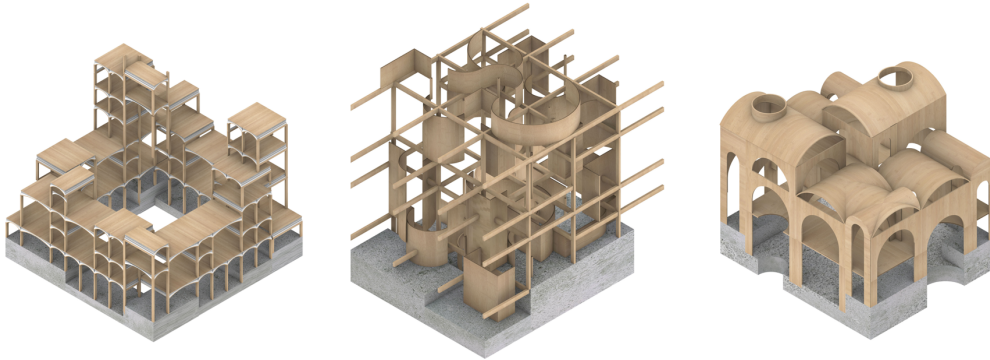


Figure 8: 3 Multistorey Speculative configurations - Jason Griffiths

Version I consists of point loaded glulam column structure with glulam beams and single-direction vaults of curved cross-laminated timber floors. This system is an extension of the Nine Square Grid in 1:2:1 proportional relationship. Grid spacing is on 10 and 20-foot centers and vault radii 10 or 20 feet. Vaulted slabs are composed of a permanent formwork comprised of a five-layer CLT vault, a layer of foam insulation, a poured concrete slab topped with a timber floor.

Version II consists of a point-loaded glulam column and beam structure with curved and planar CLT walls. This system is comprised of single curvature CLT walls that divide spaces between columns and are independent of structure. Formal studies demonstrate free-floating or intersecting column and wall proportional relationships. Grid spacing is on 20-foot centers with curved walls in 10 and 20-foot radii. Curved wall spaces are created through concatenation of curved wall radii joining with tangential continuity or at 90 degrees with planar CLT walls. The floor system (not shown) consists of CLT slabs in composite concrete and foam insulation or suspended floor arrangements.

Version III consists of planar CLT wall and floor structure with single curved vaulted elements. This system is arranged on a 1:2:1 proportion with single, double and triple height volumes. Curved CLT elements comprise mostly of vaulted roof structures in 10 and 20-foot radii with one-directional spans of 10 and 20 feet. These vaulted structures are arranged as barrel vaults and groin vaults with spans intersecting at 90 degrees. Planar, curved CLT elements also include cylindrical light wells. Planar CLT elements include semicircular arches and circular/ semicircular CLT floor penetrations.

## CONCLUSION

In the last 20 years, we have seen a remarkable proliferation of mass timber buildings, beginning first in Central Europe and then subsequently in numerous locations around the globe. In North America, this began first in Canada and the Pacific Northwest and then subsequently within the southeastern states, along with a considerable scattering within most US cities. The bulk of these buildings refines a five to six-story mid-rise typology that results in a simple trabeated architectural syntax of a point-loaded column and beam structure with planar floor slabs. While this arrangement offers clear benefits over concrete and steel from both fabrication and sustainability perspectives, these attributes alone may mean that mass timber may circumvent a conscious discourse on their architectural syntax. Without this input, the future of mass timber buildings as an architectural language may stall as they are fast-tracked into a standardized system of construction.

Project XX-LAM is a research project that speculates on potentially diverse forms of timber architecture by adding single-curvature planes to the current palette of available mass timber elements. This research combines the technical challenges of fabrication with experiments into autonomous, spatial and compositional possibilities. Adding this element of curvature allowed us to reconsider the current point-loaded grid arrangement as the “frame” element within the “kit-of-part nine-square grid” exercise. This parallel, along with a homogeneous timber, materially draws many parallels with the disciplinary discourse of late 60’s architectural theory in the US. By combining these technical and cultural factors, XX-LAM speculates on a potential syntactical procedure to define a new architectural language for mass timber buildings.

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John Hejduk, *Plan for Texas House (1953-1963)*. John Hejduk, Collection Centre Canadien d’Architecture/Canadian Centre for Architecture, Montréal © CCA

## ENDNOTES

- <sup>1</sup>Ted Cavanagh refers to Thomas Hughes’s use of the term " Massive System" to describe the scale of stud production and industrialization of forestry in the US.
- <sup>2</sup>ANSI/APA PRG 320: Standard for Performance-Rated Cross-Laminated Timber covers the manufacturing, qualification, and quality assurance requirements for cross-laminated timber (CLT). This certification has been adopted for most CLT buildings in the US and is included in the International Building Code IBC
- <sup>3</sup>The most recent example of this is White Architecture’s Sara Kulturhus in Skellefteå - one of the world’s tallest wooden buildings. Therese Kreisel, Skellefteå’s head of urban planning, says that Sara kulturhus has been constructed from 12,200 cubic meters of wood from trees harvested from within a 60km radius of Skellefteå. The amount of carbon dioxide stored is equal to approximately 13,500 flights from Stockholm to New York
- <sup>4</sup>The 1982 debate between Christopher Alexander and Peter Eisenman. Eisenman argues against a “moral imperative” within architecture that ignores the significance of disorder and disharmony. This term might be applied to mass timber architecture if it is solely predicated on sustainable principles. [http://www.katarxis3.com/Alexander\\_Eisenman\\_Debate.htm](http://www.katarxis3.com/Alexander_Eisenman_Debate.htm) contrasting Concepts of Harmony in Architecture
- <sup>5</sup>Timothy Love’s *Kit-of-Parts Conceptualism* describes the deliberate manner in which formalism of the nine-square grid problem deliberately deflected from functional considerations and focus upon architectural form as an autonomous exercise.
- <sup>6</sup>Each of these examples are drawn from Scully to illustrate the similarities between contemporary CLT buildings and what Scully advocates for in *The Shingle Style Today*. These similarities are most apparent in the interiors with boarded walls and solid timber for load bearing structure especially at Sea Ranch.
- <sup>7</sup>In many ways, this process of stripping back architecture to fundamental principles can be traced back to similar exercises like the early Bauhaus Vorkurs program. Johannes Itten’s preliminary courses for students entering the program brought all students to a similar starting point to disinvest them of any precognition of architecture in much the same way as *The Nine-Square Grid*
- <sup>8</sup>The aim of each exhibition was to keep adding to the installation until it could become a complete building. The first two installations have led to a third phase currently under construction as a “blind” for viewing prairie Dogs at UNL’s Cedar Point Bio Station
- <sup>9</sup>This arrangement was also informed by enclosures within Corbusier’s *Mill Owners’ Association Building*, in Ahmedabad especially the curved panelized auditorium on the third floor.