Structure and Ambiguity

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> *The Architect is not bound to exhibit structure; nor are we to complain of him for concealing it, any more than we should regret that the outer surfaces of the human frame conceal much of its anatomy; nevertheless, that building will generally be noblest, which to an intelligent eye discovers the great secrets of its structure.*[1] -John Ruskin

This paper analyzes the connotations produced by buildings that require significant structural resolution but nonetheless intentionally confound their structural expression. When we consider the term "structural expression," we typically think of architecture that visually makes evident the forces in its structural form. In this type of *explicit expression*, a building's image and structural form are closely aligned. This includes a broad range of architectural expression from a soaring arch in a Gothic cathedral to the diagonal bracing in a structural steel frame. Another type of structural expression is a more *ambivalent expression* of forces, where the structure of a building has no consequence relative to the image of a building. Here, structure is an unarticulated necessity with no influence on a larger tectonic expression. Many tall buildings, for example, hide their rigorous structural engineering behind a curtain wall of glass and mullions. The building's structure and statical performance remain anonymous relative to the building's image.

A third type of structural expression, which will be the focus of this paper, is an *ambiguous expression* where buildings suppress structural explication to subvert our visual understanding of a building's form relative to forces acting upon it. Ambiguity implies that something can be understood in multiple ways without an apparent hierarchy. An ambiguous expression in architecture would, therefore, produce multiple and conflicting interpretive and tectonic possibilities in the same building.

The impact of a perceptual ambiguity in buildings can be profound: it can create a visual conundrum due to a misleading structural logic; it can induce a psychological tension due to a structural uncertainty; it can produce an aura of mystery due to an inexplicable organization of forces. Although the engineering of ambiguous structures is no less demanding than in an explicit structure, the architectural expression moves from rational denotation to an uncertain connotation, and from physical certainty to metaphysical curiosity. To demonstrate this, I will use three case studies of contemporary architecture and engineering that have effectively manipulated structural form to achieve ambiguity. I will focus on buildings that are visually unstable, visually reductive, and visually mysterious. By virtue of their ambiguity, these buildings draw us into their eccentricities by inducing a perceptual dissonance with the architecture.

STRUCTURE AND EXPRESSION

Edward Ford, in his book, "Detail in Modern Architecture," identifies divergent attitudes to the expression of structure in architecture.[2] He draws the distinction between two modes of structural expression: monolithic construction and layered construction. Monolithic construction derives its architectural expression through the material of the structure itself, such as a steel frame that is both structure and the primary image of a building as in Mies van der Rohe's *Farnsworth House*. Layered construction produces its architectural expression by cladding over the actual structural material but still following its contour such as a marble revetment over a frame as in Terragni's *Casa del Fascio*. Ford explains that both of these strategies are deployed to tell a truth about the architecture, whether it be "literal," in the case of a monolithic architecture, or "analogous," in a layered architecture. But not all architectural expression is about telling the truth: some buildings are intentionally "deceptive" in their structural explication. Buildings that purposefully make the internal forces illegible or confused separate the architecture of support from the image of the architecture. Rietveld's *Schröder House*, for example, is an architecture that appears to consist of planes floating in space unencumbered by the effects of gravity (Figure 1). Such an ambiguous structural expression displaces an explicit reading of a building's forces with a visual conundrum.

Figure 1. Schröder House, Utrecht, Netherlands.

Eduard Sekler carefully parses the terms structure, construction, and tectonics in his article of the same name to distinguish the interrelated semantic differences between architectonic order, architectural matter, and the expression of architecture. He writes, "When a structural concept has found its implementation through construction, the visual result will affect us through certain expressive qualities which clearly have something to do with the play of forces and corresponding arrangement of parts in the building, yet cannot be described in terms of construction and structure alone. For these qualities, which are expressive of a relation of form to force, the term tectonic should be reserved."[3] Here, Sekler connects architectural expression, or tectonics, to phenomenological experience.

Sekler expands his use of the term tectonic to include an ambiguous structural expression in a subsequent article where he analyzes the architecture of Josef Hoffmann. Of the *Stoclet House*, he writes, "The visual result is very striking and atectonic in the extreme. 'Atectonic' is used here to describe a manner in which the expressive interaction of load and support in architecture is visually neglected or obscured."[4] By using the root "tectonic" to create its antithesis "atectonic," Sekler demonstrates the affiliation between an explicit and ambiguous structural expression. Both are perceptions generated by an architectural organization of structure and construction, but the former affirms a structural logic while the latter distorts structural legibility.

STRUCTURE AND DECEIT

The *Maison à Bordeaux*, designed by the Rem Koolhaas/Office of Metropolitan Architecture, consists of three distinct architectural types stacked vertically (Figure 2). The lowest level is a series of stone walls that are burrowed into the earth, thereby creating a contained open courtyard with some enclosed spaces at its periphery. The middle level is a free plan with a set of architectonic objects, such as a mirror-wrapped cylinder, an open-riser stair, and an over-scaled bent frame, contained within its glazed enclosure. Dominating the composition is the upper level, a massive concrete box that has no identifiable means of support except the bent frame at one end. To reinforce the sense of the box's mass, the sides are punctured in a random pattern with diminutive porthole-openings. Finally, sitting atop the roof of the upper level is a deep steel I-beam. This beam overhangs one edge of the concrete box from which a conspicuously thin steel rod extends from the bottom of the beam down to the grassy courtyard below. This rod, plus an internal room-sized elevator-platform, are the only elements that are common to all three levels. Otherwise, the building appears to be an improbable assemblage of construction types that are not integrated into a coherent tectonic whole. At the *Maison à Bordeaux*, it appears that the sum of the parts is greater than the whole.

Koolhaas ensures that the elements of this architecture do not cohere visually by carefully detailing them so there is no evident structural interaction between them. For example, the I-beam on the roof has no detail that demonstrates its connection to the concrete mass on which its sits. Instead, the unarticulated I-beam looks like a pop-art caricature of a beam resting on top of the concrete like a still life on a table. Similarly, the cylinder that sits asymmetrically under the concrete box is visually dematerialized by its highly reflective surface, so it is not read as supporting the mass above. Instead, the cylinder appears to be just distorted reflected images of the surrounding landscape. Since the I-beam on the roof sits on the concrete mass that itself appears to be unsupported, the elements of this architectural composition seem to have been thrust into mid-air like Salvador Dali and his flying cats in Philippe Halsman's photograph "Dali Atomicus." In a perverse juxtaposition, the only element of vertical continuity is the steel rod that is far too thin to inspire confidence that it is a structurally supportive element.

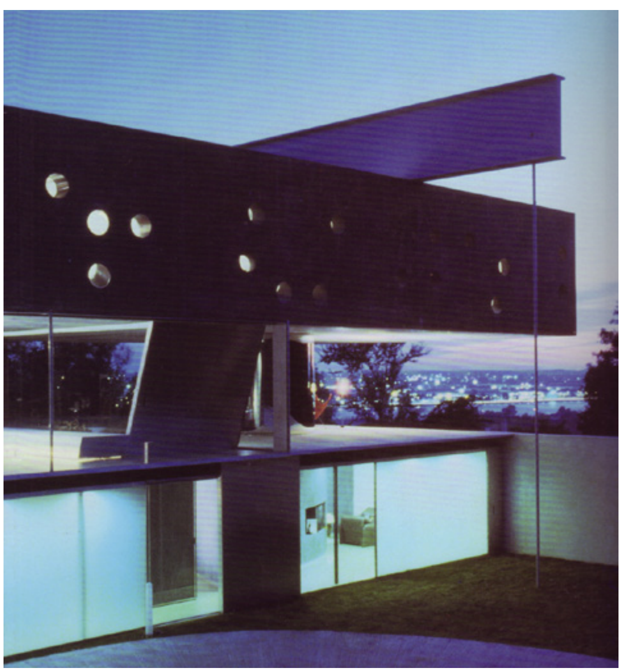

Figure 2. Maison à Bordeaux, Bordeaux, France.

The actual structural scheme, conceived by the engineer Cecil Balmond of Arup Associates, is the antithesis of Koolhaas' architectural expression. The structure is a highly integrated system that is quite dependent on all of the elements that appear to be architecturally unrelated. Structurally, the cylinder is a large supporting column, even though its center is occupied by a spiral stair. This extends through the concrete box of the upper level and supports the I-beam that looks as if it is passively sitting on top of the roof. Although the beam is asymmetrical to the box, it is on center with the cylinder. The vertical concrete walls of the box are, in fact, one-story-tall structural beams that are being hung from the I-beam. As deep beams, these concrete walls allow the box to cantilever well beyond the few points of support.

The eccentrically positioned dead load of the concrete box creates a potential over-turning force around the supporting cylinder. This force is counteracted by the thin steel rod attached to the overhanging end of the I-beam. The other end of the rod is affixed to a large counterweight buried under the grassy plane in the courtyard below so that the rod acts in tension holding the I-beam down. Because the counterweight is not visible, one cannot see all of the necessary evidence to understand fully how the building remains standing. This structural balancing act diverts one's attention away from the actual statical equilibrium and creates a visually precarious relationship between the box and the forces of gravity. To further confound the viewer, the bent frame supporting the concrete box at the end opposite the cylinder is slid out from under the box, so the frame's vertical supports do not align with the concrete walls above. This further induces a sense of instability of the large looming volume. Of the supports at either end of the concrete box, Balmond says, "It was so simple and informal or nontraditional a move, like a Karate move with the arm going in and out; here the legs slipped both ways and one jumped up to the top. I broke with symmetries."[5]

The success of the architectural deceit in the *Maison à Bordeaux* required close cooperation between the architectural detailing and the structural engineering. The engineering allows the concrete box to cantilever and the detailing disguises how. This strategy of an architectural slight-of-hand distracts the viewer from the structural reality, similar to a magician's performing tricks of subterfuge on the audience. Here, the coordinated efforts of the architect and the engineer produce an architecture that inexplicably appears to be levitating --- drawing the viewer into its paradoxical structural spectacle.

STRUCTURE AND ABSENCE

There are two qualities that strike one immediately when seeing the *T-House*, by Simon Ungers and Thomas Kinslow: its looming abstract volume and weathered-steel exterior (Figure 3). The house is two sixteen-foot wide bars set perpendicular to each other. The lower bar is embedded into the sloping earth, and the upper bar overhangs the lower bar equally on both sides. The two bars are held apart by a sixteen-foot square volume creating a tee-form with the upper bar. The width of the repetitive windows and the surfaces between the windows are the same, creating a drum-beat rhythm of void, solid, void, solid, etc. . . The absolute symmetry and repeated dimensions create an uncanny regularity. The *T-House* emerges out of the landscape like a symmetrical vessel surfacing from the depths of the earth's core.

Figure 3. T-House, Wilton, NY.

Upon closer inspection, one realizes that the only detail on the exterior is the irregular patina that nature has wrought on the steel. Otherwise, the steel carapace has no details generated from its assembly: no seams, no joints, no reveals. Nor does the exterior demonstrate any control of the natural activities endemic to its upstate New York site like rain and snow: no gutters, no scuppers, no drip edges. Similarly, the seamless exterior surface withholds any clue to an internal supporting structure. Although the upper bar is clearly cantilevering a great distance over the landscape on both sides, there is no tectonic reference to the gravitational forces. As a result, the viewer perceives the large upper volume to stand effortlessly in the sky. The absence of detail renders the building as a mute giant.

The architects eliminate any detail on the exterior steel by having the quarter-inch thick steel plate seam-welded and ground, so it appears as if it were a solid mass of steel.□ The steel exoskeleton was fabricated off-site in six parts, trucked to the site, lifted into place with a crane, and seam-welded on site. The seam-welding of the exterior creates the perfect moisture barrier: there is no opportunity for water to penetrate this enclosing layer of steel. The continuity of the exterior steel also creates a continuous structural membrane that can distribute gravitational and lateral forces throughout the exoskeleton.□ Ironically, the structure becomes surface and, therefore, becomes invisible.

The engineers for the project, Ryan-Biggs Associates, were also cognizant of the expansion and contraction of the steel in the extreme seasonal temperature differentials. As the sun hits some surfaces and not others, different parts of the building will expand while others remain cool. The welded joints will not allow the different surfaces to distort separately: the stresses are shared throughout the steel exterior.

Figure 4. T-House, Wilton, NY.

The *T-House* is actually two skins: the exterior steel and the interior veneered-plywood panels. These systems are allowed to move independently due to their different coefficients of expansion. The repetitive interior panels replicate the regular and equal dimensions of the windows like the modularity of tatami mats in traditional Japanese architecture (Figure 4). Each window can be covered by a hinging plywood panel to control the natural light entering the house. The ubiquity of the interior wood surface creates an enveloping blanket of warm hues, augmented by the regularly spaced sources of natural light. The womb-like architecture of the interior is a refuge from the rigorous abstraction at the exterior.

The *T-House* is an anomalous building. Although it is a house, it does not outwardly connote domesticity. Although embedded into the earth, it does not project permanence in the landscape. The detailing of the exterior is unyielding in its consistency, never acknowledging the specifics of its making. The detailing of the interior is just the opposite: a constructed skin with exposed fasteners attaching the panels to the frame behind. Additionally, the *T-House* appears to have a conflicting temporality: it is at once contemporary, by virtue of its structural bravado, and archaic, due to its reductive form and rusting surface. Its relationship with nature is similarly aloof: natural forces clearly inscribe themselves onto the exterior surface, but no standard features are evident to control them otherwise. The *T-House* is an architectural enigma, causing the viewer's interpretations to fluctuate between contradictory realities.

STRUCTURE AND MYSTERY

The experience of approaching and entering the *Glass Pavilion at the Toledo Museum of Art*, designed by Kayzuyo Sejima and Ryue Nishizawa/ SAANA, is visually and psychically confounding. The reflections emanating from the myriad floor-to-roof glass surfaces constantly fluctuate as you move to and through the space captured under the hovering roof form. The reflections are doubly confused given that a large percentage of the glass is curved so the reflected images seen in the glass move in retrograde (Figure 5). Similarly, the many layers of glass visible from almost every vantage will repeat each reflection, but with variation: this produces a cacophony of visual stimuli. This kinetic visual phenomenon generated by one's own movement produces a thickness to the interior spaces that is completely unexpected, given that the vertical surfaces are transparent glass. The substance of this space is immaterial: reflected light and non-specific reflected images define the boundaries of the interior spaces.

Figure 5. Glass Pavilion, Toledo, OH.

Once one has had a chance to acclimatize to this agitated visual display and look beyond the reflections to the spatial and tectonic organization, more mysteries emerge. For example, one can't help but notice that the first layer of glass at the exterior is a single pane thick. This is almost unfathomable for a building of the twenty-first century given the current focus on the energy consumption of buildings. Additionally, the roof itself is a highly abstracted floating form that is uncanny in its thinness and lack of articulated detail. The exterior edge of the roof is a flat featureless metal fascia without a coping or drip edge. The fascia is flush with the exterior glass and it does not visually explain how it is attached to the building. Furthermore, there is no apparent structure behind the glass enclosure to suggest structural support for the roof. Instead, there is only an inaccessible void between the exterior enclosing glass and the series of figural glazed spaces throughout the plan of the interior.

This void space, which varies from a few inches to a few feet thick, acts like *poché* in a traditional neoclassical plan: it is an amorphous zone that defers to the geometrically regular but differently shaped interior figural spaces. Traditionally, poché is made of solid material and therefore encompasses the load bearing structure for the building. What is radically different in the *Glass Pavilion* is that its poché is not produced with a binary void-and-solid, or figure-and-ground, relationship. It is all void and all visible: this is a *transparent poché* that strangely reveals both the figure and the ground simultaneously. In this case, complete visibility of what is conventionally divided into the seen and the unseen produces an x-ray-like view into its transparent thickness. The realization of this cunning commentary on traditional plan-forms in contemporary architecture comes as an epiphany, an intellectual gift, revealed by gazing through all the layers of glass and space.

This poché space is not just a quiescent void: it is integral to the thermal performance of the building. Cosentini Associates produced the mechanical engineering with thermal modeling by Transsolar. The interstitial space is conditioned with a hydronic radiant heating and cooling system to mediate the temperature differential between the exterior environment and the interior of the figural spaces. The void space, therefore, architecturalizes the quarter-inch gap typically found between sheets of double-pane glazing, that is, the detail becomes large enough to conceivably inhabit. The hydronic system is imbedded in the concrete floor and plaster ceiling so it remains unseen. Since there are no ducts or grills within the void space to denote the presence of mechanical systems, the transparent poché plays a cryptic performative role.

Since the transparent poché cannot serve a structural role, the viewer is struck by the lack of vertical structure to support the roof above. Due to the slenderness and paucity of the vertical pipe-columns that one can apprehend in the layered glassy spaces, and the lack of confidence that one has in the ability of transparent sheets to support the load of a roof, it appears that the pipe-columns are less holding the roof up (i.e., acting in compression) as they are holding it down (i.e., acting in tension). Perceptually, therefore, one discounts the ability of the pipe-columns to support the roof. Instead, the mind's-eye relies on the ubiquitous shimmering glass surfaces to ambiguously tether the roof to the ground. Naturally, the inability to justify visually how the roof is supported causes a perceptual tension.

The structural engineering team of SAPS/Sasaki and Partners, and Guy Nordenson and Associates, generated unique solutions to satisfy the architectural criteria, that is, to minimize the presence of vertical and lateral structure and maintain a thin roof profile. For example, the few vertical pipe-columns that do exist are solid steel to support the exceptional loads generated by the dearth of vertical support opportunities. The lateral forces are resisted by constructing one of the few opaque, interior, figural spaces with three-quarter-inch-thick plate steel that is curved, seam-welded, and welded directly to the steel roof structure. Also, precise coordination was required among a plethora of sub-disciplines to integrate the roof girders and beams with the lighting, sprinkler, insulation, roof membrane, and roof drain systems, all within a depth of twenty-four inches.[8] In the *Glass Pavilion*, these extraordinary structural solutions are a creative response by the engineers to an architectural vision that intentionally obfuscates a perceptible structural resolution.

The power in this architecture resides not only in its spectacle of transparency and reflection, but also in its thwarting of basic expectations of building structure and stability. It draws the viewer into its idiosyncrasies, slowly forcing the viewer to confront the interrelated tectonic mysteries. The architecture asks, "What is surface and what is reflection? What do the inaccessible spaces serve? How is the roof being supported? How can the roof be so thin?" I am not implying that the *Glass Pavilion* is an "architecture parlante:" quite the opposite. This architecture demands one's consideration by what it does not say. Once an architectural structure is not visually explained, then the building projects a provocative ambiguity that draws the beholder into a process of deduction to solve its architectural riddle.

STRUCTURE AND AMBIGUITY

Although these three buildings analyzed here are structurally ambiguous, they have no less an obligation to their structural engineering than conventional buildings: the physics of buildings is constant. As seen in these projects, the constructed ambiguity requires even greater cooperation between architects and engineers since more explicit engineering solutions would foil the spatio-perceptual schemas. Not only does this architecture blur distinctions between architectural expression and structural reality, but also the roles of architects and engineers merge through the design process into less distinct and more affiliative relationships.

We may ask, do these disciplines becoming diluted in the fusion of such close design cooperation? To a degree, and in a most beneficial way, the answer is yes, new fruit is being born of this disciplinary grafting. To further this inquiry, we could question whether the architects are thinking more like engineers, or whether the engineers are thinking more like architects. An answer here would need to be proceeded by more rigorous definitions of both disciplines, but this grounding in the respective fields would likely lead only to a dogmatic classification---one that would not reflect the fluid and diverse activities practiced by design professionals on a daily basis. A more constructive question, therefore, is to ask how architects and engineers distinctly contribute to the design process. What these buildings demonstrate is that the architect establishes the perceptual relationships through architectural details while the engineer determines how to support and reinforce them.

These three buildings exploit the semantic gap between structural expression and structural legibility because their expression is shaped from what they withhold, not what they offer. They are at once inexplicable, due to their subverted structural legibility, and credible, in that they persist in statical equilibrium, i.e., they remain standing. Sekler describes the cognitive dissonance that such architectural ambiguity can induce in the viewer when he writes, "The tectonic expression may be deliberately unclear, leaving a beholder marveling at vast expanses of matter hovering apparently without effort over a void."[9] By thwarting our visual expectations both through artful architectural detailing and structural manipulation, the *Maison à Bordeaux*, the *T-House*, and the *Glass Pavilion* are perceptually demanding: they command an active response by virtue of their mystifying presence. These buildings do not, however, simply overpower the viewer with formal explorations of amorphous shapes or exhibitionistic structural complexity. Instead, with the aid of the engineers' exactitude, the architects of these three buildings engage the viewer in an active intellectual dialogue of perceptual possibilities and impossibilities.

ENDNOTES

1. John Ruskin, "The Seven Lamps of Architecture," *Selected Prose of John Ruskin* (New York: Signet, 1972), p. 66

2. Edward R. Ford, *The Details of Modern Architecture* (Cambridge: The MIT Press, 1990), p. 1-5

3. Eduard Sekler, "Structure, Construction, Tectonics," *Structure in Art and Science*, Gyorgy Kepes, ed. (New York: George Brazilier, Inc., 1965), p. 89

4. Eduard Sekler, "The Stoclet House by Josef Hoffmann," *Essays in the History of Architecture Presented to Rudolf Wittkower* (London: Phaidon Press, 1967), p. 230

5. Nina Rappaport, *Support and Resist: Structural Engineers and Design Innovation* (New York: Montacelli Press, 2008), p. 19

6. Gustavo Gili, *Simon Ungers* (Barcelona: GG Portfolio, 1998) p. 16-23

7. Manuel Gausa and Jamie Salizar, *Single-Family Housing: The Private Domain* (Basel: Birkhäuser-Publishers for Architecture, 1998), p. 136-139

8. Kiel Moe, *Integrated Design in Contemporary Architecture* (New York: Princeton Architectural Press, 2008), p. 104-111

9. Eduard Sekler, "Structure, Construction, Tectonics," *Structure in Art and Science*, Gyorgy Kepes, ed. (New. York: George Brazilier, Inc., 1965), p. 94