Beam-branes, Surface-to-strand Hybrids, and Hydronic Armatures

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A menagerie of geometries has been developed in the office over the past few years which we use for various projects. They are really prototypes, neither a chunk of building nor a detail. These prototypes are studies of structural, mechanical, and circulatory behavior, particularly in terms of their feedback, collapse, or hybridization as systems. All projects are driven by one or more prototypes, in combination with more prosaic issues of building massing and program. Prototypes are sometimes digitally animated to reveal their range of behavior, in terms of geometric syntax, growth patterns, depth variability, and transformative capabilities such as delaminating, branching, cellularizing, lightening, or thickening. Beam-branes, surface-to-strand hybrids, and hydronic armatures constitute geometric/performative species that link recent projects within a kind of taxonomy.

Beam-branes were invented in 2006 following our investigation into the structural morphology of dragonfly wings. Dragonfly wings are characterized by two distinct but interwoven pattern logics that perform different kinds of work. Ladder-type patterns with quad cells behave like beams and resist bending, while honeycomb patterns with five-, six, or seven-sided cells behave like membranes and are flexible. We recognized the advantage to this kind of hybrid structure, which can transform fluidly from a tension or shell to a bending structure, depending on surface shape and force patterns. This releases architecture from problems associated with shell and membrane structures of the 1960s by Frei Otto, notably the limited shape vocabulary and the inevitable structural degradation caused by apertures. Beam-branes can adapt to any number of extreme conditions without losing overall coherency in the system. Adaptations take the form of depth variability, cell shape and density adjustment, and, like the dragonfly wing, localized material build-up in response to stress conditions. A complex surface can be broken down into local shell behaviors rather than global shell behavior, as is the case in Dragonfly (2007). Most importantly, beam-branes allow for structural phase change from beam to membrane, or difference in kind rather than simply difference in degree.

Surface-to-strand Hybrids offer a different approach to the adaptable shell. Here, there is variability in terms of pattern and depth in response to a shaping environment, but with an additional special feature. When shell behavior is no longer present, and bending behavior takes over, depth is increase is limited based on the maximum economical depth for a welded plate girder. At that moment, the structure transforms from a surface structure into a frame or vector structure. Surface-to-strand hybrids are therefore patchy rather than universal, sometimes very thin, sometimes ornamented with deep relief, and sometimes delaminated and three-dimensional. This structural behavior can be seen in the Sundsvall Performing Arts Theater (2008), where a surface-to-strand transformation is intensified by a variegated color gradient. Another version of surface-to-strand hybrid, found in the Cheongna City Tower (2008), is a monocoque (surface) structure that transforms locally into structural spines. The stable, dogmatic relation of frame to skin in architecture dissolves into a complex dynamic in which skins sometimes become structural and frames sometimes delaminate from skins.

Hydronic Armatures have been a subject of experimentation for the office since the Radiant Hydronic House (2004), in which a hydronic armature organized and structured the entire building. More recently, in Batwing (2008), we sought to establish a relation between infrastructural performance and the realm of sensation. In this case, a network of ducts, structural pleats, and micro-capillary hydronic meshes were collapsed into a single, coherent interior prototype with ambient lighting effects. The micro-capillary meshes cool the air flowing over them, while the structural pleats direct the air in a targeted fashion into the room.

Mechanical systems, especially radiant hydronic systems, are all too often separated from structural systems due to the balkanization of building trades and engineering disciplines since the mid-20th century. The collaging of beams and ducts in architecture is a mess both conceptually and in terms of efficiency. A new sensibility is on the horizon that re-imagines building infrastructure as a network rather than a collage, in which beam and duct behaviors can appear and disappear opportunistically along an armature or branching system. A hydronic armature contains any number of flows—structural forces, liquids, air, heat, electricity, data, and light—in a multiplicitous, robust formation. Armatures, of course, can emerge from surfaces or dive into them; or they can interconnect with other armatures; or they can spread out as networks of pleats in order to increase surface stiffness, while creating a continuous mechanical cavity. This is where regimes of HVAC, structure, and ornament come into dynamic relation, and the efficiency versus excess dialectic begins to collapse.

Wild Structures

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> *Design today must find ways to approximate … ecological forces and structures. To tap, approximate, burrow, and transform morphogenetic processes from all aspects of wild nature, to invent artificial means of creating living artificial environments.*
> *-Sanford Kwinter*

The history of architecture reveals a constantly shifting relation of structure to space. Structure is sometimes latent, sometimes expressed, other times dematerialized at great effort. Whatever the case, considerations of efficiency alone are never enough to explain the role of structure in architecture. In the contemporary digital environment, vital, adaptive, formative potentials of structure have begun to emerge. There is a growing acknowledgement that structure, when removed from a state of equilibrium, can become as unpredictable and varied as natural phenomena. When released from critical states of suppression and representation, structure can become fluid, color-variegated, cross-pollinated, and hybridized, in a jungle-like ecology. Such wildness has been theorized by Sanford Kwinter, who is a tireless promoter of the dynamics of animal packs, storms, and guerilla tactics—all that is untame—as a way out of the mechanistic dilemmas of architecture.

One way to frame a discussion of wildness is through Mies van der Rohe and Pier Luigi Nervi, who offer two divergent approaches to structuration. Mies's canonical National Gallery in Berlin (1968) appears to be about structure, with its exposed beams and fetishistic steel detailing, but it doesn't exhibit any intensive material or structural logic per se. The project is about the universality of flat planes, and the purity of endless metric space. In this sense, it is a conceptual project. Columns are removed from the interior and dissolved with his trademark cross-section; there is no response at the location of maximum shear where column meets roof, and the roof structure is equally deep, independent of the variable bending forces at work within it. Nervi's Giatti Wool Mill (1951), in comparison, begins to exhibit a materialist flow of forces, a proto-wildness. In this project, the structural ceiling morphology begins to organize in response to force flows along its surface. The vertical is not suppressed, but rather begins to effect transformation in the horizontal. The variability and elegance of the relief can be experienced on a conceptual level, as intensive forces at work, but also on an immediate, sensate level. Jeff Kipnis has referred to this kind of simultaneity as a "dual-ontology."

Wild structures are not simply expressive structures. The drive toward legibility, in the sense of being able to trace a genealogy of forces back to a source, is actually quite tame. Wild structures are instead a seething combination of behaviors that coalesce into an emergent whole with effects that may exceed the structural. Butterfly wing structures are wild in that sense: their porosity is certainly related to structural lightness and aerodynamics, but it is also unpredictably related to the production of visible color effects. It turns out that color-variegated wing patterns are often not based on pigment, but on the micro-patternings of variable-depth pores modulating wavelengths of light. Structural Expressionism, as a movement in architecture, has been more about zero-sum, one-to-one legibility—no doubt a late permutation of the modernist instinct toward transparency. But it also must be noted that its practitioners have often gone to great lengths to produce legible images of efficiency at the expense of actual efficiency. This drive toward excess for the sake of producing affect in terms of structure is quite interesting, and re-examined in the contemporary environment, opens up ways of thinking about legibility versus obfuscation in structural design. I would argue that engineering efficiencies do not have to exclude excesses, that these territories can cross over, creating complex formations that might do unexpected work, and might be felt as well as read.

While the term “wild” is easily associated with the biological, it is important to remember that in architecture, we are talking about artificial, inorganic constructions that don’t literally grow. Wild behavior can be synthesized through any number of opportunistic processes, however, wherever material logics operate within shaping environments. In a military-industrial setting, exactly where we would expect not to observe wildness, we find salient examples. The F-22A Raptor is a radically heterogeneous construction that reflects local, opportunistic thinking in terms of materials, engineering, and manufacture. Instead of one continuous material system, this aircraft was designed using several interwoven materials and structural morphologies. Boeing made the fuselage from a deep-celled aluminum and steel egg-crate system and the wing spars from cast titanium, while Lockheed Martin made the wings, fins, and duct manifolds from formed thermoplastics and carbon-fiber composites. The structural patterning that results is patchy but nonetheless coherent. This is not an ‘exquisite corpse’ or collage of parts, but a radically responsive model for structuration that injects variable materiality into a system of variable patterning. The result is technically intelligent, but also beautiful, articulated, exotic.

In our office, the design and evaluation of structures always occurs on a qualitative level as much as a quantitative one. This produces formal and operational elegance, but also the messy redundancies and heterogeneities we see in the wilderness. The development of projects usually occurs in leaps rather than small increments because of the conscious lack of consistency in the techniques and sensibilities of the working process. Structural wildness—as much as we can identify it from inside the jungle—occurs at moments where systems exceed type and mutate, where tension forces suddenly switch to compression forces, and where legibility melts into unpredictable formal and atmospheric effects.