Tectonic Constraint: Harvesting Material(s) -- and Building(s) -- to Seed the Creation of Sustainable Architecture

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ABSTRACT: This paper examines the recycling discussion in architecture as being fundamentally about the timeless challenge of exploiting the tectonic constraint of (locally-sourced) material(s). Notable buildings throughout history owe their architectural character to the inherent limitations of the many “found”—read (re)cycled—material(s) used in their construction. The historic traditions of material sourcing, as exemplified by indigenous, classic, and modern buildings, can be correlated to the harvesting practices of the historic preservation, green building, and open building movements. These movements are the true frontiers of sustainable architecture wherein designers intentionally can capture elements of solid waste—and/or whole buildings, as waste in the making of new form.

Exemplary projects from this new practice of material(s) harvest are referenced, including the works of the Rural Studio, and those resulting from application of the U.S. Green Building Council LEED™ Rating System. Works developed for Bachelor of Architecture (BArch) and Master of Architecture (MArch) theses—applied to the design of a new classroom facility and the re-use of an existing high-rise dormitory, respectively—are used also to illustrate this redefinition of the material(s) harvest.

We conclude with the opportunities facing architects as we expand this “recasting” of the materials harvest—both (re)cycled materials and buildings—in seeding the creation of sustainable architecture.

Conference Topic: 10 Reflections on Sustainability
Keywords: materials, building techniques, design strategies, sustainability

INTRODUCTION

As a first gesture of environmental intervention, architecture owes its presence to the choice of construction materials and the related systems of assembly. From the simple gathering of found objects to the use of extensively processed materials, the act of sourcing is, itself, a reading of the discipline of expression embedded in the material—those properties of dimensionality, mechanical joinery, and structural stability that comprise the opportunities for the making of architecture.

The stacking, leaning, or weaving of found objects in the making of the hut reflect first-order examples of this architectural expression; whereas the shaping, honing, and/or fabrication of a material into a more technically precise form as in the Greek column, the Gothic buttress, or the steel girder embody a higher-order system of material reticulation.

But, beyond an assembly, driven by structural stability and gravitational resistance, we must also consider the use of material(s) in response to other force flows of nature—wind, water, sun, and light—and, we must consider the influence of social and cultural practices, especially the import of rituals and ceremonies of human association, in the shaping of the materials palette into built form.

2. MATERIAL DISCIPLINE

2.1 The Codification of Materiality
The immediacy of the “found or worked” resource as a significant influence in the making of architecture is being valued again within the sustainability movement by adoption of the concept of “biological” and “technical” nutrient cycles; these catalyze a re-examination of the codification of the material harvest and the exploitation of the related tectonic constraint.

To gain a foothold in this thinking, it is helpful first, however, to examine works from historic and modern times which illustrate the many forms of codification.

3. HISTORIC PRECEDENTS

3.1 Indigenous Works
Fundamentally, indigenous works are those relying primarily on “found” materials—used in largely unaltered form—as the construction media. The primitive dolmen or the stone-walled shelter would be the most basic examples. [3]

These works also employ construction practices that are transformed over time as they are handed down through generations. The various daub and waddle settlements throughout the African continent provide exemplary models of this form.
Indigenous works also are those shaped by a locational response to environmental force(s). The cliff dwelling settlements in Mesa Verde, Arizona, for example, utilize the exposure to, and shelter from, the respective winter and summer sun by placement of the settlement in the canyon wall.

Or they can be shaped by an expressive response to the force flows of nature. The heat-dissipating sail vaults of Iran, the wind-catcher roofs of Pakistan, or the light filtering Mashrabiyya of Egypt are examples.

3.2 Classic Works

Classic works are those of a more technically exacting material(s) refinement; they can involve the fine-grain working of stones in-situ or the crafting of materials off-site for placement within the principled geometries of architectural expression. Certainly, the columned Greek Temples, the buttressed Gothic Cathedrals as well as the vaulted Roman Baths embody this idea.

These works also typically comprise concepts of symbolic disposition, spatial order, and ceremonial meanings in their configuration. The axiality of spaces in the cathedral, the perspectival positioning of buildings on the acropolis, and the spatial (and thermal) sequencing of ancient baths are examples.

4. MODERN MOORINGS

4.1 Architectural Practice

In contrast to the codifications embedded in these historical examples, modern works can be classified by the interests codified in contemporary architectural practice. This would include the historic preservation, green building, and open building movements.

4.2 Re-cycled Building(s)

Historic preservation, conservation and adaptive re-use is the more established of these movements. Though driven by concern for maintaining cultural values, environmental factors are playing more of a role in this work. One of the more famous American examples, in an urban context, is the Audubon House designed by Croxton Collaborative Architects. While bringing new life to this building [2], the architects successfully exploited the floor plate dimensionality and the façade configuration of the existing building in a way which effectively managed the depth of the daylight penetration, the maintenance of air quality, and use of environmentally-friendly building finishes, furnishings, and equipment—including a system for materials recycling for use by the occupants.

“Re-cycling” of the building captured the embodied energy and thus reduced the environmental impact form the manufacture of otherwise needed materials.

4.3 Green Building(s)

Green buildings [5] are typically new constructions made intentionally from a palette of materials which minimize negative environmental impact; they derive their form by seeking a good site and climatic fit.

Convincingly, this is evidenced by Frank Lloyd Wright who had great reverence for response to site and climate, and in a number of instances harvested material locally for the construction of his buildings (e.g. Falling Water). In other contexts, he fabricated construction elements which were inspired by aspects of plant life found on the site or in the region (e.g., the textile block houses).

In fact, we contend that his residence in Scottsdale, Arizona constitutes one of the first green buildings in the western world. Its character came from the use of existing stones from the site as the “aggregate” of the cast-in-place wall system which functioned as the foundational structure of the building. Certainly, the detailing of the wall itself, with the use of concrete as a slurry/mortar infill, with a recessed reveal marking the staged “lifts” of the casting, reflects the surface expression of rubble-wall construction used throughout history—whether in the ancient Opus Reticulatum or the medieval city wall.

The real import in Wright’s home, however, is in how the local harvest inspired the articulation of the remaining elements of the building; the wood trussing to support the canvas-covered roof shingling, which itself served as light filter, ventilation baffle and rain shield. All was disciplined by, if not derived from, the cast-in-place foundational walls of the compound.

4.4 Open Building(s)

The open building movement [4] as promulgated by the SAR Group under the leadership of N. John Habraken has introduced the layering of construction systems as a means to manage the scaling in time and space of the material use and related design-decision making by the many parties involved in the procurement, construction and end-use of a building.

This approach differentiates primary, secondary, and tertiary systems—the base building, fit-out, and furnishing levels—of design decision-making. This categorization provides opportunities for organizing a hierarchical approach to sustainability; it is possible, for example, to physically align the more timeless geographically-rooted (primary) factors of orientation, solar exposure and climatic fit with the making of the base building; the less determinant (secondary) occupancy density, usage schedules and functional needs with the fit-out; and the (tertiary) occupant control of comfort with equipment and furnishings.

5. SUSTAINABILITY FACTORS

5.1 A Systems Approach

All three movements, as described above, involve a systemic view of tectonic constraint and provide a context within which to frame issues of sustainability.

And, they bear relation to other categorizations of material use within the sustainability movement, itself. Examples of such precedent are described below.

5.2 Material Disassembly

Design for disassembly has a long tradition of use. Nomadic tent structures worldwide are perhaps the most universal example. Industrial era fascinations yielded both the Crystal Palace in London and the more recent Museum House in Zurich. The Laredo Demonstration Blue Print Farm in Texas explores this principle in its Evaporative Cooling Tower roofs [9].
5.3 Material Re-Use
Design based on material re-use is exemplified best by a contemporary practitioner group, the Rural Studio founded by Samuel Mockbee. Students and faculty working hand-in-hand with client groups and community members, aggressively seek to identify locally available waste products as a construction material inventory and correspondingly invent means of assembly and fabrication, which are directly expressive of that resource. Examples abound in their work—ranging from the use of discarded street signs as a roof shingling, to abandoned tires as a wall substrate, to automotive windshields as a ventilated glazing system in an open-air building shell [10].

5.4 Material Substitution
At a more fundamental level, materials extracted from the waste stream are re-constituted as "new" raw product for use in conventional manufacturing processes. Strawboard, for example, is manufactured as a substitute for plywood—the core substrate for many contemporary furnishings.

Material substitution in this manner has become institutionalized in construction practice. Under the Materials and Resources guidelines of the USGBC LEED™ Rating System, points are awarded for use of recycled content products (ranging from 5% post-consumer and 50% post-industrial, to 10% post-consumer and 50% post-industrial) [13].

And, beyond such crediting for waste stream extraction, the LEED™ Rating System establishes a "prerequisite" for the storage and collection of recyclables on site—during construction.

Moreover, "points" can be accumulated for varying degrees of other forms of material substitution, ranging from building reuse, to resource reuse, to selection of reusable or rapidly renewable materials, to considerations of the use of certified wood.

In addition, credits are extended for the sourcing of manufactured products within a several hundred mile radius of the site, including raw materials which are sourced within the radial boundary and material systems which are assembled within that boundary.

Within this market-place-driven methodology the many tectonics of materiality are broadly embraced.

6. EXPLORATIONS

6.1 Student Work
Students at our institution have been encouraged to build their Design Studio work around the structural view presented in the topical sections of this paper.

To illustrate the import of this approach, the work of two students—one pursuing a Bachelor of Architecture degree and the other a Master of Architecture degree—are presented. Their studies engage specific exploitation of the concepts presented in the many paragraphs above, wherein they strategically frame the sourcing and use of materials to address demountability, re-use, and substitution as the foundations for insightful designs.

Each student exploits the tectonic issues of mechanical joinery and structural response to engage factors of environmental response and climatic fit.

Moreover, each presents her respective design studies as the bases for new curricular initiatives within the institution. One approach is to treat the immediacy of interaction and the encounter of the building design as itself a form of student education; another approach is to broaden the arguments to include institutionalized course offering integration. In both cases, the projects exemplify the theme of our presentation: a conscientious harvesting of materials and buildings can be used to seed the creation of a more sustainable architecture.

What follows are detailed descriptions of each thesis project, the initial research that fed into the proposals, and the closing arguments for integration with the educational mission of the university.

6.2 BARCH Thesis by Elizabeth Riegle
Our dominant modern practice is to treat material sourcing as a linear flow; a material is used once, and then discarded as "TRASH". But, McDonough and Braungart [8] tell us that material use must be a cyclical process; materials should be used over and over in a variety of ways; we must see them as a source for harvest.

How does one communicate such an idea to the general public through the design of a structure? The designs described below represent an attempt to do just that: promote the realization that the popular conception of waste needs to change, emphasize this point on a continual basis, and present a means for the public to become actively involved in the process of changing this idea.

These studies were designed for the campus of Ball State University, a so-called typical, mid-sized American university and an ideal atmosphere in which to propagate new ideas for future generations. Three designs were conceived in order to focus attention on this issue at three different levels.

6.3 Recyclables Collection stations
Combining the functions of a recycling drop-off station with that of a bus stop (Fig. 1) creates small focal points throughout campus so that the public is constantly confronted with the idea of reuse instead of waste.

Figure 1: Paper/Cardboard Recyclables Collection
6.4 Recycled Materials Drop-off Pods

The sustainable themes of material reuse and design for disassembly are also the basis for the design of three pods containing drop-off bins for materials collection and seating for waiting passengers (Fig. 2).

Each pod is built of those same materials collected within—metal, paper (cardboard) and glass—as a way to demonstrate the idea of material reuse. The materials are mechanically bolted/easily unfastened so that the structure may be assembled and/or disassembled easily and if necessary, moved to a better location or even recycled as a whole, if no longer needed. The pods share a single roof but are separated spatially to provide passage through the space to encourage public interaction.

6.5 Center for Regenerative Studies

“The Center” (Fig. 3) encompasses a variety of sustainable functions within one central campus location. Environmental education classrooms, a sustainable materials library, a recycling center, eco-kitchen, and a “living system” installation (with wastewater recycling ponds) all are introduced to change students’ conception of waste on a day-to-day basis. The building itself is made of recycled materials (rammed earth walls, glue-lam beams, telephone pole columns) and is designed for disassembly. Its design provides integrated interior and exterior spaces (using day lighting, indoor and outdoor classrooms, and landscaped hallways) in an attempt to emphasize a connection between humans and nature and not a separation, as in typical campus structures.

The intent of this project was not only to awaken students to the idea that materials have value beyond their initial use, but also that those materials can be used to make an architecture, which in its form and presence can convey the lessons of sustainability. Whether walking down a daylighted corridor, passing through a wall of earth, or experiencing a landscaped classroom, the lessons can be ever present.

6.6 MARCH Thesis by Dorothee Dettbarn

The re-use of a high-rise dormitory illustrated in this thesis is part of a larger idea for “Linking Design of Facilities, Recycling and Curriculum”.

Designing the re-use of buildings shows the necessity of planning for disassembly. In works of vernacular architecture the material cycle is closed. Adobe huts in Mexico are only one example: the materials of construction (clay, wood, palm leaves) are frequently harvested and assembled on site. And after the hut’s lifetime can be easily disassembled and most of the materials can then serve as a resource for new construction or firing.

This thesis explored the possibilities of applying the biological and technical nutrient cycle (Fig. 4) developed by McDonough and Braungart [8]. This closed nutrient cycle describes the long term goal for product and waste management: specifically, the total elimination of waste.

6.7 Re-use of a Dorm

The high-rise dormitory in question suffers the typical ‘mass storage architecture’ problem-set: high energy use, low comfort regarding day lighting and fresh air, lack of student interaction and related occupant anonymity. Areas covered in the renovation program (for building re-use) include the potential for re-use of waste materials in processed form, such as: the use of non-insulated windows removed from the exterior of the building and re-used on the interior as part of a reconfigured entry area; the optimization of energy use through reconfiguration of the building skin, day lighting, natural ventilation and passive heat gain/protection through louvers; the creation of communication interfaces and dorm-identity through a new balcony system, floor community areas and the entry area; as well as the communication of personal responsibility for waste-management and energy-use.

Strategies to communicate personal responsibility require the involvement of the more general university students in greening the campus activities, the architecture students in the renovation process of a
dormitory and/or the construction of the ‘Trash-art-frame louver’-module (Fig. 5), discussed below.

The louvers in front of the resident’s bedrooms are designed in such a way that their four removable standardized fillings can be exchanged with trash-art-frames created by the students themselves—using material which otherwise would be wasted. The empty frames which are distributed by the residential hall are filled creatively with trash to produce the sun filtering façade device and at the same time give the residents the opportunity to participate in the creation of their immediate environment.

Figure 5: Trash-Art-Frame Louver

6.8 The course of trash-art-frame louvers

At the beginning of each academic year a louver competition would take place and a jury would award the most creative and felicitous louver-trash-art-frames. At the end of the academic year, when the dwellers vacate the dorm, they would leave their louver-trash-art-frames behind. It would be up to each next dweller to decide which louver-trash-art-frames stay part of the façade, and which ones get modified or totally exchanged by him/her. Demounted frames would be given to the residential hall; those still intact and attractive would be made available to other residents. The outsourced frames would be emptied and if necessary repaired for reuse. The reusable filling material would be stored for the use by new trash-artists and the discarded material would be recycled appropriately. The louver-trash-art-frame material cycle (Fig. 6) illustrates how ‘waste’ can be harvested and upgraded as a sequestered technical nutrient.

Figure 6: Trash-art-frame material/waste cycle

6.9 The environmental mitigation of the louvers

The façade is subject to ongoing change. In this case the architecture, as a stable element of the built environment, manages to embrace and illustrate the nomad-like residential movement of its student dwellers. Additionally, the balcony-facade-system (Fig. 7) would enhance communication between the residents by its layout of balconies using alternating depths. It would have an educational mission, displaying ‘trash’ not as ‘trash’, but as an architectural and even artful façade element. It would indirectly question society’s wasteful behaviour and raise student awareness of over-consumption and resulting over-production of waste.

Figure 7: The Balcony System

The students would be challenged to harvest wasted material and use it to create a part of their built environment. Although tectonic constraint would be given to the students through the stable louver frames, they would need still to choose material which would endure the climatic conditions and provide the function of a sun protection device. The goals of this proposal are awareness of personal responsibility, the creation of personal identity and the use of louvers as a communication interface to the environment.

7. RECOMMENDATIONS FOR TODAY

7.1 Opportunities

These examples of student work, as well as the descriptions of historic precedent, modern moorings and sustainability factors lay the foundations for understanding the timelessness of tectonic constraint. The citations illustrate the opportunities embedded in the harvest of “waste materials” and “waste buildings” when applying the fundamental tenets of architectural design in service to the principles of sustainability.

Making use of the shingling of highway signs, the panelization of cardboard tubing, or the construction of student art frames is no different than the stacking of stones or the weaving of saplings from a building site. The opportunity to engage this material harvest function as a “new” adventure, however, requires that, as designers we remain clear-minded about the many systems of codification—material, environmental, social, and architectural.
7.2 Systems of Material Codification:
It must be said that the categories used in this paper, which distinguish material disassembly, re-use, and substitution are not mutually exclusive [6]. Opportunities may well present themselves for use of recycled steel struts as a modern “saplings” at the same time that they are to be reconstituted as the raw product for extrusion as a new building skin. The challenge is to understand the potential inherent in a given material(s) inventory and envision the options for a respective systematic use in making a built form.

7.3 Systems of Environmental Codification
Environmental forces such as wind, water or solar “flow” can be mapped also as a harvestable resource; the shedding, capturing, or mitigating of each can provide organic influence on physical geometries and can shape the surface form and/or arrangement of a building or building group [1].

But responding to these natural flows requires a prioritized view of the passive/active interpretation of their “throughput”. The degree to which the building can passively “manage” the shape of wind flow and promote cross- or stack-ventilation, the collection of water and its use as an aesthetic presence, and the capturing/shielding of solar energy, each becomes a driving first principle in the design decision-making. The method, by which this is to be supplemented actively, must function as a second-order intervention.

7.5 Systems of Social Codification
The collective pattern of our individual movements in space establishes a fundamental physical structure for socialization. Whether describing our movement as a transitional sequencing through gate, along a path, to a sanctuary, or categorizing our movement as a distinction between unintentional loose association and intentional formal gathering, the structure of ceremony and ritual are there. Architecture stimulates such understanding by its spatial codification [7].

7.6 Systems of Architectural Codification
Material systems can be connected to other systems of architectural codification. Significantly, this can include ideas for systematic formal design, such as the elements, relationships, ordering ideas, and parts of the plan and section cut; or can include the inspirations embedded in the metaphors and analogues of nature described by Von Frisch [14]; or the patterns of proportional transformation as described by Thompson [12], or the evolutionary development of ornamental form as elaborated in the terra cotta design illustrations of Sullivan [11].

7.7 An Integrated Codification
In the end, expressing the inherent architectural potential of a material requires an integration of all these systems of codification. As embodied in F.L. Wright’s Scottsdale house—a material’s physical properties must be used to respond to the factors of climate and site, its use must be disciplined by social purpose, and its assembly must heed those fundamental ordering principles of architecture that provide for human inspiration, interaction and understanding.

CONCLUSION
Design is an intellectual process in which vision is brought to, and/or found within, the problem set; materials and their assembly are always a factor in the framing of that vision. Moreover, the design function thrives on limitation and is highly dependent on insight. Whether valuing indigenous building, the modernist construct, or the paradigms of design for sustainability, the resulting architectural codifications must be seeded by a systematic exploitation of tectonic constraint.

ACKNOWLEDGEMENT
We collectively would like to express our gratitude for the intellectual contributions by the thesis committee members, Dr. Wes Janz and Professor Andrea Swartz. We also want to thank Adjunct Professor Jeff Culp for his technical help in production of this paper.

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