A Model of Models of Complexity Preservation in Rammed-Earth System Design: Convergence, Constructal Design, Open-Source Architecture

bLp

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Contents

1 INTRODUCTION

"The history of building construction can be construed as a narrative of the inertia and momentum of two divergent construction logistics. One mode[, discussed above,] has very minimal historical inertia coupled with great current industrial momentum (the muli-layered assemblies of modernity.) The other has great historical, physical, and thermodynamic inertia that is coupled with minimal industrial momentum in the contemporary building industry/building science industry (more monolithic assemblies and masses). The former follows the short history of the twentieth century "rationalization" of construction, air-conditioning, factory production, lightweight envelopes, and, more recently, mass customization. The latter is a several-thousand-year history of accumulative knowledge and performance all but forgotten in the interesting yet hubristically selective amnesia of twentieth century architecture."

— Kiel Moe.
Convergence. 2013.

"Rammed-earth" refers to an earthen building material formed by a particular mechanical process. Rammed-earth architecture has ancient archaeological, anonymous, and autochthonous roots in China, Africa, Europe, India, the Middle East, and other regions globally [1]. Observably, rammed-earth forms have been (re)appearing in the U.S. over the past half-century with a frequency and technical gain atypical of earthen construction, especially in the West. Contemporary rammed-earth forms are predominantly connected to academia, professional architectural design, and building science/industry.

Rammed-earth structures have appeared relatively recently on the campuses of M.I.T. (2005), Stanford (2015), and Princeton (2016)[1]. Rammed Earth Works (the designers of Stanford's Windhover Contemplative Center) is one of multiple professional architectural firms to be designing modernized rammed-earth buildings and installations valued in the multimillion-dollar range[2]. David Easton, the founder of Rammed Earth Works (1976), also invented PISE (Pneumatically Impacted Rammed Earth) and Watershed Blocks (under a $750k grant from the N.S.F.); a sprayed application of wet soil-cement and a mechanical system for mass-producing modular soil-cement blocks, respectively. SIREWALL (Structural Insulated Rammed-Earth, B.C., Canada) is a rammed-earth-based building product incorporating an intermediary layer of patented insulation[3]. Numerous technical papers concerning rammed-earth's structural and thermal properties have been published globally. A select few include: *Analysis of the hygrothermal functional properties of stabilised rammed-earth materials* by Hall and Allinson. (2009), *Modeling rammed earth wall using discrete element method* by Bui et al. (2015), and *Measured and simulated thermal behaviour in rammed earth houses in a hot-arid climate. Part B: Comfort* by Beckett et al. (2017).

Hypothesis: Along the decades of rammed-earth's previous resurgence in the U.S., at the eco-movements of the 60s and 70s, rammed-earth took on a greater socio-technical momentum while standards, practices, and policies of the building culture remained inert. The result was a form-based function of modern construction—a virtual image of sustainability—reducing, reusing, and recycling a historically function-based form of complexity, persistence, and adaptability. The rammed-earth material and method morphed more significantly in forty years than it had in four thousand.

If Doctor E. is right, and we truly can not solve problems by using the same kind of thinking we used when we created them, then it stands to reason that continued control of rammed-earth technology is not as much a determinant of sustainability as the model by which rammed-earth building is conceptualized, codified, communicated, designed, logisticized, and constructed.

Archaeological building principles and heuristics characterize sustainability as a pulsing journey, not an arrival at absolute steady-state.

[1] `https://archive.is/5gPbZ` (M.I.T.); `https://archive.is/VhpW2` (Stanford); `https://archive.is/9SF6K` (Princeton)

[2] `https://archive.is/K853p`

[3] `https://archive.is/Sf9fu` (PISE); `https://archive.is/x3iwg` (Watershed Materials); `https://archive.is/s0cHI` (SIREWALL)

"Sustainability is never a static goal. It can only be a process. Previous ideas about "sustainability" are not and will never be tenable. A small, beautiful, modest, hand-crafted society, living in harmony with its eco-region, relentlessly parsimonious in its use of energy and resources, can't learn enough about itself to survive. In its bucolic quietude, it may appear timeless, but the clock is ticking for it as it does for all societies. It can avoid many conventional threats by abjuring large-scale, clumsy technologies, but modesty does not make one invisible. That society isnt keeping track—in its loathing for industrialism, it forfeits far too much command-and-control over its physical circumstances. Its bliss is ignorance.
A truly sustainable society has to be sustainable enough to prevail against the unforeseen. The unforeseen, by definition, cant be outplanned. This implies that serendipity is necessary. We cant know what we need to know; so there need to be large stores of unplanned knowledge. . . The ability to make many small mistakes in a hurry is a vital accomplishment for any society that intends to be sustainable."

— Bruce Sterling.
Shaping Things. 2005.

Objective: **Design a system** of design (a coalescing model of models) drawing from contemporary building theory and technology, reaching towards the principles and heuristics of the traditional rammed-earth material and method. As rammed-earth has sustained itself, its settlers, its ecology, and the biosphere at large without mechanisms complicated beyond shovels, buckets, formworks, and tampers, the model becomes a conceptual one that employs computer processing and networks as a low-entropy means for organizing high-entropy processes. The model is ultimately concerned with two flows:

1. The flow of soil from deposit to building site.
2. The flow of knowledge between builders.

"[T]he culture that once was slow-moving, and allowed ample time for adaptation, now changes so rapidly that adaptation cannot keep up with it. No sooner is adjustment of one kind begun than the culture takes a further turn and forces the adjustment in a new direction. No adjustment is ever finished. And the essential condition on the process — that it should in fact have time to reach its equilibrium — is violated. This has all actually happened. In our own civilization, the process of adaptation and selection which we have seen at work in the unselfconscious cultures has plainly disappeared."

— Christopher Alexander.
Notes on the Synthesis of Form. 1964.

1.1 The Model is the Message

Marshall McLuhan noted (*Understanding Media*, 1964) that, with respect to media/technology, the medium is the message. The rammed-earth building medium *qua* pre-modern rammed-earth conveys a perennial socio-technical desire for a functional, durable, and economical form of building. Without any positive rammed-earth heritage, the U.S. has nonetheless considered or adopted rammed-earth construction during energy-sensitive phrases of its history. For instance, in the late-eighteenth century, French architect/builder François Cointereaux presented Thomas Jefferson and America's burgeoning rural economy with a model of rammed-earth architecture. Encoded in a copy of *Ecole d'architecture rurale* (Paris, 1790-91); Cointereaux believed that if America adopted "the economical building art of the ancients, perfected and made more universal," She would incur a great physiocratic power. Jefferson reacted indifferently, in a letter to William Short, "how far it may offer benefit here superior to the methods of the country, founded in the actual circumstances of the country as to the combined costs of labour & materials, and the circumstances of durability comfort & appearance, must be the result of calculation."[4] Ostensibly, it would not be too long before industrialism captivated American hearts and minds and rammed-earth fell by the wayside.

Rammed-earth later appeared in *Popular Mechanics (Vol. 41, No. 2, 1924)* and *The Farmers Bulletin (No. 1500, 1926)*, endorsed as a frugal, do-it-yourself building method. During the Great Depression, rammed-earth briefly held the attention of the New Deal-era Resettlement Administration as an economical building alternative fit for an over-abundance of available labor. During the 1960s and 1970s, rammed-earth attracted marginal interest from the environmental movements following the global recognition of troubling anthropogenic effects on the biosphere [2]. Hassan Fathy wrote *Architecture for the Poor* in 1973; painting earthen architecture as a bottom-up, practical way of rebuilding the Egyptian countryside. [Fathy spoke to a building culture that does possess a positive heritage in earthen architecture, opposed to the U.S. which possesses no such positive heritage.] Through these last resurgences of rammed-earth, the murmur of the D.I.Y. spirit dwindled and dissipated. *Although the material would continue, the "open" method was lost to a certain propriety of building practice.*

In a gross linearization of history, it would appear that a growing field around "ecodevelopment" in the 1960s/1970s reintroduced rammed-earth building into a technologically dependent world caught between (in binary terms) developmentalist and zero-growth strategies[5] to face the pertinent biospheric uncertainties. Hypothetically, at this shearing of [simply] technological optimism and technological pessimism, building societies retrofit rammed-earth into a hybrid model where cake could be had and also eaten. On one hand, the tried method would remain a virtual image of sustainability. On the other, seemingly innocuous technical changes to rammed-earth's composition and construction would modernize the material-method, ensuring scalability, standardization, and security.

Rammed-earth v2.0 manifested as "soil-cement", also known as "cement stabilized rammed-earth." Over time, it was layered with modernizing assemblages of mechanization, pre-fabrication, insulation, transportation, seal-ification, svelte-ification and modularization. An early code of practice was *Soil-Cement: Its Use in Building*, distributed by the U.N. Department of Economic and Social Affairs in 1964.

> *"The use of simple compacted soil (natural earth) as a building material dates from time immemorial, and it can be said that ever since, and down to the present day, the method of building houses with earth has been used, because of its constructive qualities. Yet, despite its good insulating and resistant properties, there are limitations to the use of earth owing to its lack of strength and its vulnerability to moisture and the erosive effects of external agents. Provided that natural soil possesses a combination of certain characteristics, however, it can be subjected to the process known as 'stabilization'. The effect of adding a*

[4] `http://archive.is/yWexi` (Cointereaux to Jefferson); `http://archive.is/ozqQv` (Jefferson to Short)
[5] `http://archive.is/sOf7w`

stabilizing agent like Portland cement, for instance, is not only to enhance its best qualities but to impart to it other properties which soil alone does not possess."
— Augusto A. Enteiche
Soil-Cement: Its Use in Building. 1964.

"Contemporary stabilized rammed earth (SRE) draws upon traditional rammed earth (RE) methods and materials, often incorporating reinforcing steel and rigid insulation, enhancing the structural and energy performance of the walls while satisfying building codes. SRE structures are typically engineered by licensed Structural Engineers using the Concrete Building Code or the Masonry Building Code."
— Bly Windstorm and Arno Schmidt.
A Report of Contemporary Rammed-Earth Construction and Research in North America. 2013.

Generally, the above quotes represent modern/contemporary models concerning rammed-earth's function as a building material, physically, and with regards to its respective building culture. Endemic to both rationalizations is [what is seen to be] a destructive reduction of vital qualities (or non-qualities) of rammed-earth building, e.g. "resistant properties" and "energy performance [3]." McLuhan's wisdom still applies, the rammed-earth v2.0-medium conveys the message that, as Bruce Sterling noted (*Shaping Things*, 2005), the model is the message. This is to say that rammed-earth *in rem* does not necessarily possess the property of sustainability, instead, the veritable sustainability of rammed-earth is a phenomenon emerging from the inanimate and animal collectives involved in rammed-earth building, i.e. the model.

1.2 How Much Does Your Building Weigh?

massiveness: opportunity and challenge: transportation and stabilization

emergy and intelligent standardization

2 CONVERGENCE

Architect/builder/author/professor Kiel Moe has authored a number of texts and a number of buildings in and around the past decade that cogently embody a novel theory about building(s) and energy. "An Architectural Agenda for Energy", the subtitle of *Convergence*, describes a "more totalizing" conjunction of building systems with the subtle yet opportunistic complexities of energy typically siloed off to engineering and applied science. In this way, the Agenda predicates healthier building dynamics (more durable and effective flows of matter/energy), in turn, predicating healthier inhabitants (re: Sick Building Syndrome, Building Related Illness) and healthier ecosystems (holistic environmental accounting) [3]. The Agenda and its network of references form an ideal system with which rammed-earth's contemporary presence may be bridged to its sustainable history. This section is dedicated to fitting rammed-earth design and building further into the Agenda, hopefully with minimal gain in conceptual entropy from Professor Moe's work. At once, the Agenda reflects latent, useful properties of the rammed-earth material and method as well as the terrifically complicated, complicating mega-structure of building rammed-earth currently finds itself in.

Professor Moe explicitly references rammed-earth at least twice. Once, in the Building Lecture Series at the University of Virginia[6], in the context of rammed-earth as a thermally massive building material. Capillary to this vein, Professor Moe discusses the material quantities thermal effusivity (e) and thermal diffusivity (α) contributing to a more wholesome understanding of building materials as thermally transient, interactive, qualitative systems rather than scientifically ideal systems forever operating in the steady-state mode. Second, Professor Moe references rammed-earth as a case study in *Convergence*: the Granturismo Earth and Stone project in southern Portugal. Initially a reforestation initiative funded by the European Union, the project entailed ten rammed-earth and stone structures in the inner Algarve region suited for tourism and recreation. In this remote area, the locally-sourced property of rammed-earth proved to be critical for design, construction, economic, and ecological reasons. Furthermore, the Algarve does possess a positive heritage in rammed-earth building and Granturismo was an opportunity to "[make] the history of the Algarve material culture apparent while [the material selection reinvests] in the labor and skill connected to that material." [3]

In the next three subsections, rammed-earth codes, performance, and energetics are drawn around the Architectural Agenda for Energy. The ultimate motivation for doing so is founded in the fact that the Agenda values the historical inertia of rammed-earth with its contemporary potential in a profoundly integrated manner. Ostensibly, no other theory of building draws across disciplinary boundaries (engineering, physics, architecture, ecology, history, economics. . .) nor across scales ("From the Molecular to the Territorial"[7]) so applicably.

At a high level, the socio-technical, building codification is regarded as a great challenge and a great opportunity to preserve traditional rammed-earth. At an intermediate level, material and thermal performances of rammed-earth are considered in light of standard building envelopes. At a third level, the quantum and the global simultaneously, quantities and qualities of energy are considered as they pertain to the design and construction of rammed-earth buildings.

[6] http://archive.is/u9TKf

[7] http://archive.is/7lXIB

2.0.1 Rammed-Earth Codes

2.0.2 Rammed-Earth Performance

2.0.3 Rammed-Earth Energetics

3 CONSTRUCTAL DESIGN

3.1 Constructal Design

“The pyramid and the quarry grow at the same time. If the pyramid is a positive architecture (y ¿ 0), the quarry is its negative. Such positive-negative pairs are everywhere in history and geography, even though modern advances in transportation technology tend to obscure them ”

“Pyramids and ant hills are like the dried beds of rivers, cracked mud, and dendritic crystals (snowflakes): They are traces (fossils) of the optimized flow configurations that once existed. The universal phenomenon is the generation of flow architecture, and the principle is the constructal law: **For a flow system to persist in time (to survive), its configuration must change such that it provides eas** [author’s emphasis] In a flow system, easier access means less thermodynamic imperfection (friction, flow resistances, drops, shocks) for what flows through the river basin or the animal. The optimal distribution of these numerous and highly diverse imperfections is the flow architecture itself (lung, river basin, blood vascularization, atmospheric circulation, etc.). . . In the making of a pyramid, the constructal law calls for the expenditure of minimum work. This principle delivers the *location* and *shape* of the edifice.”

In the same way, rammed-earth structures are traces of animal collectives that have known to expend work to converge a particular soil gradation from local soilscape to site (area to point), compose a workable mixture

4 Open-Source Architecture

4.1 Open-Source Architecture

References

[1] Charles Augarde. “A chronological description of the spatial development of rammed earth techniques”. In: *International Jounral of Architectural Heritage* (2008).

[2] Jennifer Lynn Carpenter. *Dirt Cheap: The Gardendale Experiment and Rammed Earth Home Construction in the United States*. 2010.

[3] Kiel Moe. *Convergence. An Architectural Agenda for Energy*. Routledge, 2013.