

# Questioning the Finite: Lessons in Structural Design and Adaptability for Beginning Design Students

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## Introduction

Beginning design students frequently view architectural design as a process that culminates with a built structure, which is often regarded as transient and ultimately disposable after serving its original intentions. As educators, how might we effectively alter student perceptions and propose new attitudes towards the built environment, with specific attention given to structural principles and their relationship to architectural design, that question the concept of finite and encourage a thought process that is fluid, organic, and adaptable? This paper examines the work of second-year architecture students who were presented with an opportunity to think and adaptively respond to learned lessons from failure throughout the design process as part of their initial studies into structural principles and concepts.

## Finite vs. Continuity, Variation

The term finite suggests a limitation, culmination, or end state of a body's ability to change, grow, or exist. Often the capacity of something labelled finite is known, or agreed upon, before its origination among a predicated process of its existence. With respect to architecture, the finite state of an edifice suggests that an act of architecture has achieved its realized state of construction and has potentially begun to undergo a process of acclimation towards ultimate decay, with respect to its situated environmental conditions or predetermined programmatic demands, as established prior to its finished construction. The ability to respond and adapt to these criteria speaks directly to the building's capability to achieve a state of continuity. Along this line of thinking, architecture has increasingly become concerned with its ability to resist deterioration or becoming obsolete towards extending its lifespan by way of continuity, as well as potentially altering its programmatic capabilities through variation and adaptive strategies in an effort to remain relevant to changing functional demands.

The terms "continuity" and "variation" suggest both a prolonging and, at times, a refutation of the concept of finite with respect to architecture. Lars Spuybroek has written extensively on the concept of continuity and its role in architectural theory. For Spuybroek, 'continuity, as a modality of architectural form, is the last mode of existence before defaulting to generality.' (Spuybroek, 2008: p. 25). Continuity is a condition denying ambiguity, or the dual state of being among two determined entities with little information portrayed about the relationships between the identifiable entities within a body's compositional makeup. Therefore, continuity is a process towards a resolution of the relationships between the constituent parts, a state of flux among these determinate forms, where 'all is materialized, the objects as much as the relations between them.' (Spuybroek, 2008: p. 25). As such, the condition of continuity evokes transition, or the evolution of the parts within the composite body, where objects and their structural formation begin to respond to one another and offer an exchange

among their functional responsibilities between these adjoining counterparts. Ultimately, for a composite body to undergo the process of continuity means that it will not succumb to the condition of the finite, but instead will intelligently translate the needs and desires of each comprising entity through an acceptance of the necessitated demands required for the advancement, and perhaps survival, of the composite body.

The writings of philosopher, Manuel DeLanda address the term variability in relation to linear and nonlinear “processes of becoming” within pattern formations (DeLanda, 2009). For DeLanda, to understand the concept of variability requires us to consider the capacities of all members involved within a meeting of elements in relation to their cause-and-effect process within a given interaction. DeLanda describes a typical approach to structural design where an architect or engineer designs a load-bearing structure by employing compressive and/or tensile members to accept and transfer loads through a linear process of events: the first event being that by which the load is applied, and the second event entails the change in form of the structure to deform, resist, and transfer these loads to adjacent members. Within this linear procedural way of thinking, one event triggers a subsequent event, that which is ‘the becoming of form, shrinkage, or enlarging.’ (DeLanda, 2009: p. 14). Therefore, a linear process implies the same cause resulting in the same predictable effect. To think nonlinearly means that we must consider not only the capacity of the affected medium (the structural assembly in the previous example), but also the capacity of the instigating agent (the load in the same example). Consideration of the capacities of both the cause and effect factors within an interaction suggest ‘nonlinear patterns of becoming, nonlinear patterns of change, and nonlinear casualty.’ (DeLanda, 2009: p. 14). Thus, variability is an ever-present trait within a nonlinear process of becoming.

The term variability therefore suggests a degree of unpredictability between the cause and effect agents within a given interaction, resulting in a process by which the comprising body undergoes an active state to refuse stagnation and instead, searches for an optimal condition among a multiplicity of configurations to best accommodate the interactions among these agents. For a composite body to variate, it must acknowledge a memory of its previous iterations and transformations and adapt accordingly to the discoveries learned from its previous strategic assemblage. Applying the lessons of Spuybroek and DeLanda to structural definition within architectural design and form generation suggests that the phases and processes of continuity and variability embrace a logical advancement of a composite’s origination state, thus rendering the finite as an obsolete status.

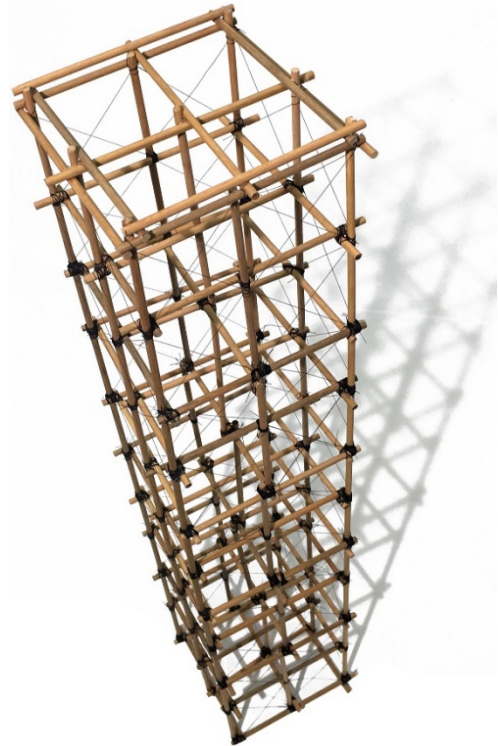
## **Truth and Evidence from Physical Performance**

As part of a foundational course that investigated principles of statics and structural properties, beginning design students were presented with an exercise, consisting of two phases, that was intended to both encourage the students to consider ways in which structural behaviors and architectural design can inform one another and question the concept of finality through a response to the discovered failures and vulnerabilities of their design’s performance for the project. The exercise was a physical exploration into the behavioral performance of structural principles within a designed system and drew inspiration from the writings of several notable authors. Peter Pearce and Susan Pearce have written extensively on the influence of structural performance capabilities towards the realization of architectural form, where they state, ‘...design objectives should be performance orientated. One of the limitations of a visual effects approach to form is that it encourages a direction

that is not particularly sensitive to performance-orientated solutions.’ (Pearce & Pearce, 1980: p. ix). Engineer and mathematician Robert Le Ricolais places value on performance discovery within the design process. According to Le Ricolais, ‘...to discover the nature of things, the secret is to be curious.’ (Le Ricolais, 1997: p. 39). Further, Le Ricolais champions the use of physical models as conceptual tools over the creation of visual imagery along the design and analysis processes by stating, ‘Things themselves are lying and so are their images, therefore experimental evidence is of critical importance.’ (Le Ricolais, 2012: p. 64).

### *Phase 1: Hollow Column/Stick Tower*

The initial phase of the project asked students to fabricate a thirty-inch tall vertical structure using repetitive or modified pattern formations with specific material palette restrictions (Fig. 1). The initial expectation given to the students for the project was that each design would be tested to support a minimum weight of seven pounds. The project was dually entitled “hollow column/stick tower” in an effort to persuade students to consider the project at a multitude of representative scales, instead of designing a structural system that was representative of a specific architecture typology, thus curtailing the students from inheriting and applying potential connotations to their organization and form generation for their structural assembly’s design based on a preconceived notion. Permissible materials for the construction of their hollow tower/stick column included 1/8” diameter wood dowels, thread, and glue. The dowels were chosen due to their circular cross section as the inclusion of these structural elements within the assembly demanded that the students gave thoughtful consideration to how the adjoining members might be detailed as rigid or soft connections to optimally transfer the applied load through tension or compression to adjoining members within their assembly. Thread



emerged as a vital element within the design and fabrication of the structural assembly, both as a member that permitted the transfer of tensile loads between the rigid dowels, and as a component to increase the rigid capacity through lashings at adjoining dowel connections.

When designing their structural assemblies, students were asked to consider what criteria they held in value for their approach to design of the project and then express that desired assessment criteria throughout the process as it related to form generation, while simultaneously meeting the given structural performance requirements. Responses to this request varied from an emphasis on efficiency in use of material and weight of the assembly to conforming the structural design to accommodate a desired form. Ultimately, all considerations directly led to the students exploring repeating, or modified sections within their strategic approach to the design of the hollow column/stick tower.

The students were also asked to predict the path of load transfer within their structural assembly and indicate whether the designed members within the assembly would internally transfer the applied load via tension or compression through the created joints and subsequently to the adjacent members within the assembly (Fig. 2). Before testing

*Figure 2: Initial analysis of suggestive internal member behavior relative to transfer of loads in compression or tension assuming applied loading by students Akhtar Karkia, Maddie Dewitt, and Zachary*

the strength capacity of the students' hollow column/stick tower designs, the models were weighed to allow the students to consider the efficient use of the prescribed materials and compare that value to its capacity to support the required seven pounds. Each model was then loaded with the minimum required weight, (Fig. 3) as the students were asked to consider and inscribe the point of greatest concern for ultimate failure on their diagrammatic drawings of their design.

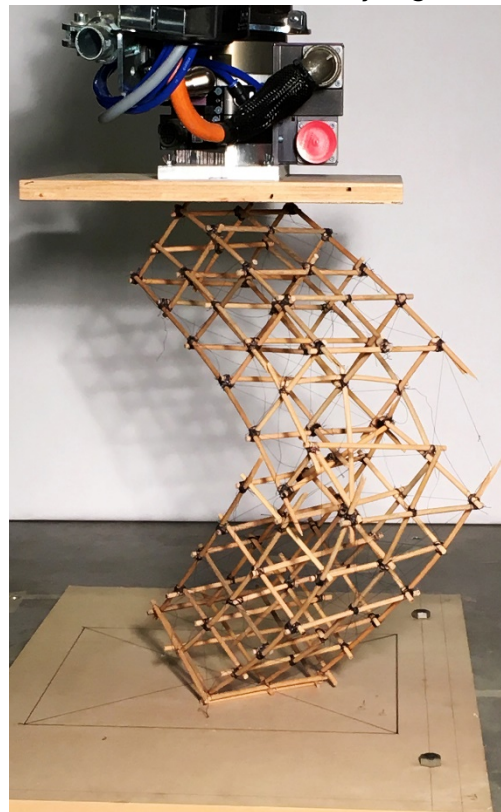
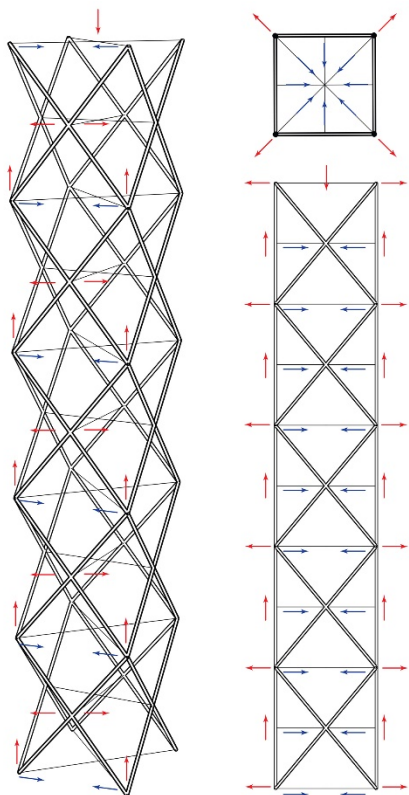




Figure 3: Testing of hollow column/stick tower to meet minimum required loading and consideration of transfer of loads between members and behavior of assembly. Student design by Jake Kriech, Adam Freeby, and Nicholas Bloom. Photo by author.

Figure 4: Application of compressive force using Kuka robotic arm towards damaged state and generative formal configuration of original design for structural assembly. Student project by Antonio Medina, Brooke Selzer, and Roberto Fayed. Photo by author.

## Phase 2: Generative Form and Structural Vulnerabilities - Prosthesis Design

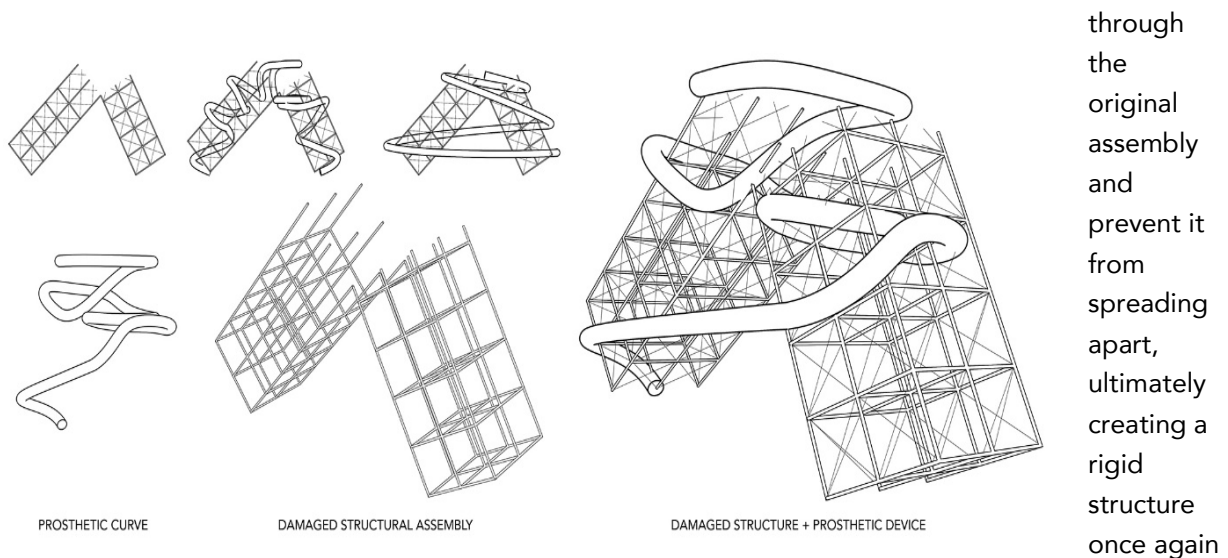
Upon testing the strength of the structural assemblages to successfully meet the minimum loading requirements, the project was continued and the hollow column/stick tower was reconsidered as a new design problem for the students. The second phase of the project offered the students the opportunity to physically test their designs to a state of casualty by realizing the ultimate point of failure within their assembly. Upon this discovery, students were asked to generate a new formal configuration of their design to examine the principles of structural continuity and variability in its ability to exist and be beneficial as a structural assembly in its resulting configuration after failure. To begin this phase of the project, each of the student's designs was placed beneath a Kuka robotic arm, which applied a compressive force to the respective structures in incremental steps towards failure. The ultimate goal of this procedure was to leave the structural body in a damaged state, with care to not catastrophically crush the assembly (Fig. 4). The application of the force through the robotic arm to the structural assembly for this exercise recalled Manuel DeLanda's writings of a "nonlinear process of becoming," where both the capacity of the load and the capacity of the developing structural assembly's configuration to respond to the dynamic load were both in a transitional state throughout the process.

After loading the assemblies to achieve a new realized form, the models were returned to the students. Here, they were asked to address the discovered structural vulnerabilities of the resultant generative

configuration of their assembly through the integration of a complimentary structural system to allow their original structural formwork design to extend its lifespan and thus, achieve a state of continuity. To address this requirement, the students were given the charge to design and fabricate a prosthesis, using different materials, as a device grafted to their generative structural form to once again make their project capable of supporting seven pounds. For this phase, students were required to leave their project in its current damaged state and not repair it back to its original configuration. Instead, each student was asked to address their prosthesis as a complimentary and critical element that responded to the vulnerabilities of their damaged structure, allowing the student's original designs to have a second life as a structural assembly.

When approaching the design and fabrication of the prosthetic device to address the modes of failure and structural vulnerabilities of their damaged and reconfigured assemblies, students gave consideration to both the discovered behaviors of the assembly under duress during its ultimate loading, as well as potential materials to best address the vulnerabilities of the assembly's reconfigured state in an effort to again accommodate an applied gravitational loading of seven pounds. As described by architecture student Antonio Medina:

'When initially thinking about how to support the collapsed, yet pliable, structure in its new configuration, materiality immediately became a major concern. We thought about how the structural model behaved under pressure, resulting in a distinctive bend through its performance and resistance to the load (Fig. 5). Our team wanted to use this continuous bend, as inspired by the process of failure, for the design of the prosthetic device. We therefore, wanted to choose a material based on its ability to be constructed and realized into the derived form to surgically and subordinately assist the damaged carcass in a manner that best supported its capacity to become a structural device again as one combined unit. Our first idea was to use concrete to create a fluid form in order to support the structure, but after analyzing the heavy weight of concrete and the limitations to shape the material as a sweeping curve for the prosthesis, we decided to use the 3D printer to stitch the rosthetic evice



(Fig. 6). (Medina, 2018).

Figure 5: Design of prosthetic device to accommodate vulnerabilities of structural assembly's generative formation by students Antonio Medina, Brooke Salyer, and Roberto Fayad.

## Conclusion and Findings

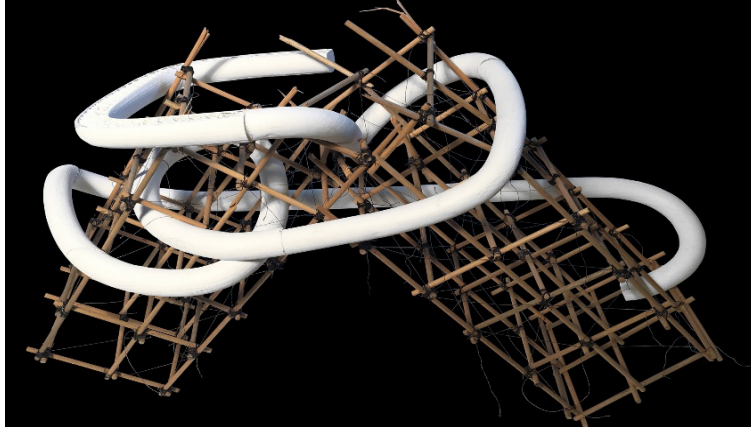


Figure 6: Final realized state of design and fabrication of prosthetic device grafted to damaged structural assembly by students Antonio Medina, Brooke Salyer, and Roberto Favad. Photo by author.

The introduced exercise of this paper explored the lessons and learning outcomes of a design project that examined the relationship between structural performance behaviors and architectural formal expression, while questioning the duration of a structural assembly to remain purposeful throughout its lifecycle. Students were persuaded to reflect upon the concepts of continuity and variability throughout all phases of the project as the allowable capacity of individual members and the complete structural assembly

experienced nonlinear patterns of becoming, change, and casualty, throughout the process. The robotic arm served as a device, specific to phase two of the project, that applied a dynamic load to the structural assembly, allowing it to generate a new formal configuration while exposing the vulnerabilities that led to its demise. The prosthesis design and fabrication asked students to examine ways to extend the life of their designs in an adapted state, thus allowing their assemblies to be structurally capable again. Each student team's response to the design of the prosthetic device was specific and authentic in its ability to engage the original structural assembly and address the vulnerabilities of the modified configuration. In closing, it is the author's belief that asking students to explore and exhaust potential responses to emergent criteria established in the phases after the initial testing can help teach beginning design students to think more adaptively in their approach to the design process, appreciate the lessons learned from failures, and question architecture as a finite entity. As commented by architecture student Evelyn Miller, 'The concept of taking something that has reached critical structural failure and giving it new structural potential was unexplored by our second-year class before this project. The project pushed us to see potential in things that would be otherwise considered useless. I no longer look at materials as something to be recycled into new materials but look at how materials can be used in their current state to still achieve the desired goal.' (Miller, 2018).

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