Eladio Dieste:
A Network of Precise Errors

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Figure 1: Bottom brick courses of Ruled Surface wall with string guides..

In the second half of the 20th century, the late Uruguayan engineer Eladio Dieste developed four structural innovations that emphasized the role of material error and challenged the dominance of graphical representation in architecture. The work presented in this paper considers "the proximate" as the assumption of an error-free architecture. The proximate is the precise execution of drawings and the obsession with infallible material production. In Dieste's work, the combination of double curvature geometries, like Ruled Surfaces, with steel reinforced masonry construction, expanded the modern pursuit of material control. The work discussed in this paper highlights the implications of building a Ruled Surface brick wall in an effort to disassociate precision from complexity. The resulting wall is a network of precise errors.

INTRODUCTION

In his essay, "Architecture and Construction", Eladio Dieste recounts a conversation he had with a colleague about the work of the Catalan architect Antoni Gaudí. Dieste's colleague asserted that Gaudi's work was irrelevant, he added, "I wouldn't know how to draw one of his buildings".[1] This remark highlights the disproportionate importance given to the graphical means used to build structures and the modern idea that the relationship between architecture and construction is primarily manifested through the framework of drawing. Francesca Hughes describes a world in which, "architectural culture's very particular construction precision and fear of error constitute a powerful undertow in all its relations to the process of materialization."[2] The land of error is a remote place that is at odds with the hyper precision of contemporary methods of graphical representation and fabrication. In many architectural practices, to draw or model a brick wall results in its separation from labor. The dimensional tolerance of representation has become an act of absurd precision focused on translating physical matter into error-free form.

Figure 2: DoArch Study Abroad, Montevideo Shopping Center Ruled Surface.

TO ERR IS ARCHITECTURAL

In “Ways About Error”, Sean Keller suggests that architecture is not something that we err from but something that we err into. Keller’s suggestion comes from one of the many definitions of architecture offered by LeCorbusier. Architecture, LeCorbusier remarks, is about a window that is either too large or too small, but never the correct size. If the window is the correct size, the building is just a building.[3] Error as a mode of architectural thinking is evident in this remark. What is not evident are the theories, and more importantly, the practicalities that establish error as a working mechanism for producing architecture.

To examine the theory and practicalities of error, it is important to consider the etymology of the word. A brief examination of the word reveals its meaning, or Latin precursor; to err is to wander or stray. This definition is amplified by the work of J.L. Austin and his distinction between accidents and mistakes. A distinction reinforced by the idea that architecture relies on calculated predictions, which are affected by trail and error. In other words, the architectural effects of error are already implanted into modes of working that analyze accidents and mistakes. The words accident and mistake are often used interchangeability without differentiating their unique effects on architectural processes. There are two scales at which the distinction between accidents and mistakes is relevant. First, an architectural workflow or a designed mode of work. Second, the analysis of an object - a finite building - designed and constructed through a specific workflow. In both cases, architectural accidents point to literal misreading or improper specifications. For example, ordering an incorrect material or following the wrong dimension. Both of these accidents are often mitigated by architectural workflows designed to catch these technical failures. These types of accidents - the failures of execution - fall outside of the architect’s control. Architectural mistakes are more typical and more prone to producing unintentional errors.[4]

When making mistakes, architects execute their intent, but the result is not what they expected. According to Keller, most architectural failures - at many scales - fall into this category. The room should be minimal and sparse; it turns out to be an uninhabitable space. The glass curtain wall should be taut, modern, with seamless concave curvature; it produces a blinding magnifying glass effect that melts people and cars. These are architectural mistakes.

The distinction between accidents and mistakes points to the contradiction of planning error. Despite a legacy of mitigating and managing error, architects are still reluctant to find value in error. In contemporary terms, speculative representation and digital fabrication are venues that explore architectural mistakes. These modes of work rarely embrace the contradiction of planning error.

Joseph Clarke and Emma Jane Bloomfield describe three architectural responses to this contradiction. First, the role of error must be examined in architectural workflows or the design process itself. These workflows are increasingly defined by automation. Second, some architects respond to this condition by intentionally misusing tools, while other architects invent new tools that expand the role of error. The last strategy is to embrace architectural conventions and mine the core of the discipline for new modes of work. [5]

To err architecturally means to deviate from normative practices and intentionally challenge historical modalities. Based on Clarke and Bloomfield’s responses to error, it is important to consider two questions that make the aforementioned historical challenge evident. What architectural practices have addressed the role of error by focusing on the link between labor and physical matter? How have these practices developed error-prone architectural workflows without resorting to modes of speculative representation? With these two questions in mind, this paper overlays the role of error onto the work of Eladio Dieste, asking the question, how is Dieste’s work defined by error?

ELADIO DIESTE: MODERN ENGINEERING OF ERROR

If error is based on deviating from the norm, straying or wondering from predetermined paths or modes of work, then the work of Eladio Dieste is based in error in two ways:

1. Resisting gravity through form and expanding modernist material vocabulary through structural ceramics and reinforced masonry construction.

2. Developing geometric strategies for designing and constructing literal wall failures through numerical calculations, without making drawings, images, or models.

First, by its own definition, modern architecture was a reaction to all preceding forms of architecture. This historical challenge is one of the constants in every architectural epoch — "modern art and architecture are established by the rejection of the historical tradition; and in regarding error as deviation from this tradition." [6] The rejection of historical tradition is quickly absorbed by culture, transformed into the status quo, and adopted by contemporary modes of architectural production. In modern terms, standard industrialized steel and glass production combined with the advent of reinforced concrete, homogenized a radical field of architects into a predictable set of formal and material practices. The potentiality of error was largely erased from modern architecture by exalting the need for material control and its desired social effects.

Within this field there were architects, like Eero Saarinen and Oscar Niemeyer, who expanded the formal vocabulary of modernism. Broadly speaking, and perhaps unfairly, in the case of Saarinen this expansion was largely the result of reinforced concrete and favorable economic circumstances. During this time there were also architectural and engineering practices that expanded the material and structural vocabulary of modernism through form-finding methods, such as descriptive geometry drawings, or physical modeling simulations. Some of these practices included, Felix Candela and Pier Luigi Nervi. These architects and engineers tied architecture and construction together by creating practices that inextricably linked form and physical matter. They were in charge of the means and methods of construction — controlling the production of error.

The apparent rejection of history is the first condition through which the work of Eladio Dieste addresses the role of error. In fact, Dieste's work did not reject history, it maximized its effects by combining a traditional material like ceramic brick with the technological advantages of steel. His work strayed from the norm and expanded modernism's material and geometric language by developing four structural ceramic innovations: Gaussian Vaults, Self-Supporting Vaults, Folded Plates and Ruled Surfaces. Each of these innovations were focused on resisting gravity through form by using reinforced masonry construction.

The work presented in this paper focuses on Ruled Surfaces. Ruled Surfaces are doubly curved forms defined by a series of straight continuous vertical lines. The geometry of these surfaces is the definition of failure or an architectural mistake. In Dieste's work, the geometry of these surfaces is based on the actual deformation through which gravity affects physical matter. Dieste first used Ruled Surfaces in the construction of the Church of Christ the Worker in Atlantida, Uruguay. In this single room church, he designed two parallel Ruled Surface walls; straight line at the base and sinusoidal curve at the top. The double curvature of these two steel-reinforced, 27 meter tall, 30 centimeter thick walls could easily withstand their own material weight. Additionally, the walls provided the lateral stability and spring line for ten Gaussian vaults spanning 20 meters each.[7] After completing the Church, Dieste constructed many other Ruled Surfaces in projects such as the Church of San Juan de Avila in Madrid and the Montevideo Shopping Center. (Figure 2.)

In modern terms, the resistance of gravity through form was a radical proposition. Dieste's engineering background trained him to think about architecture and construction like the Catalan architect Antoni Gaudi, and his funicular form-finding methods. Additionally, Dieste's work was shaped by the Spanish engineer Eduardo Torroja and his extensive writing about the philosophy of structures. Unlike Antoni Gaudi and other architects previously mentioned in this paper, Dieste did not build many physical models. He did not develop his double curvature forms through descriptive geometry or other graphical means of describing the resistance of gravity. The majority of his work was developed before computer aided design or other automated forms of production. Dieste's double curvature forms were the product of numerical calculations.

Generally speaking, a standard modern wall is upright, vertical, continuous, transparent, and more importantly, unaffected by curves. If there are any curved forms these are the product of desired spatial effects or the formal logic of material assembly. For Dieste, building flat, straight walls was irrational — physical matter does not behave in that way. According to Francesca Hughes, the mishandling of material or as Dieste referred to it, "the awkward accumulation of matter", is born from the "strange artifice that mediates all of the architect's relations to material: materiality." [8] This artifice is largely the product of hyper-precise methods of geometric description that are not compatible with the physical realities of matter. Precise methods of graphical representation are the means that remove architects from the eventual and inevitable errors of material production.

ELADIO DIESTE: UNMEDIATED MATTER

The anecdote about Dieste's colleague discussed in the paper's introduction, and his lack of confidence in Gaudi's work, reinforces the ideas of materiality unfolded in Francesca Hughes' "The Architecture of Error". Hughes' argument centers around the conceptual and physical distance between material representation an the actual organization of matter.

The "tyranny of the drawing board", one of Josep Luis Sert's remarks about modern architecture was a critique about imagination being limited by what we can draw. This was a recognition of the conceptual distance between materiality, or mediated matter, and actual matter. Dieste referred to Sert when expressing his concern about architects and engineers who only think of structure through the framework of plans. Instead, Dieste posited that the most simple and economical of structures may be resistant to simple analysis or straight forward drawing. Because a structure can be drawn simply or simply drawn, does not mean it is worth building.

In his practice, Dieste did not use drawings or models as primary means of representing buildings. Drawings were used to design the adjustable formwork and mechanisms used to construct double curvature structures, like Gaussian Vaults and Ruled Surfaces. The precision of these forms was driven by numerical calculations, not precise graphical representation. This magnifies the difference between the quantitative and qualitative aspects of precision and their relationship to error. The quantitative aspects of precision have been critical to the production of architecture since the start of the twentieth century, and certainly long before that period. In quantitative terms, precision is tied to exactitude or what is referred to in this paper as "the proximate". Exactitude is tied to decimal places, through which "a more precise instrument, or method, delivers results to a greater number of significant figures, and is therefore deemed more accurate."[9] The qualitative aspects of precision are visible in the modern culture of standardization discussed in the previous section of this paper. In an industrial manufacturing sense, standardization increases the perception of precision and erases the likelihood of errors. As a result, standardization provides the security of a method or instrument that produces little variation in its outcomes.

Limited variation was at the core of Dieste's practice. The traces of light and shadow that drape over curved brick forms are limitless in their variation. However, the structural conditions and the consistency of double curvature forms are staunch in their formal limitations. To produce such consistency, or more precisely, accuracy, Dieste focused his efforts on the design and construction of formwork and construction patents used to build his structural innovations. Instead of fetishizing the precision of material relationships through detailed drawings of mediated matter, Dieste prioritized the construction of the physical mechanisms used to organize matter. The instruments and methods he devised gave physical form to his numerical calculations. More importantly, these forms were repeatable and accurate. In the construction of vaults and ruled surfaces, the notion of accuracy became a more important vehicle to plan error than the execution of precision. Higher levels of quantitative precision, or increased decimal places, would mean a high degree of scrutiny on site, and insignificant as it may seem, this difference is critical to the idea of error in Dieste's work.

RULED SURFACE WALL: FORENSIC DEMOLITION

The work discussed in the second half of this paper is part of a building shop course at South Dakota State University. The course is titled Dieste Walls. Building Shops are part of a four-course sequence designed to place undergraduate and graduate students in direct contact with faculty scholarship and research. These courses focus on the historic intersection of construction and representational technology. This is based on the haptic study of the implications of designing collaborative workflows. The aim of this study is to build.

The goal of Dieste Walls was to build a full-scale prototype of a Ruled Surface brick wall based on the work of Eladio Dieste. The walls are part of ongoing research in preparation for a permanent installation at the University arboretum. Most courses like Dieste Walls, which follow or draw from Design Build pedagogy, begin and end with methods of making. Making, both in graphical and material terms is the predominant mode of work in this type of course. In Dieste Walls, the semester began with the forensic deconstruction and careful demolition of the previous year's work. Making is at the center of this course but the semester starts with unmaking fellow students' work.

The role of unmaking is key in temporary installations, or work designed to be disassembled. Designing methods of assembly and disassembly connects students with materiality, while eliminating the risk or potential of error inflicted by matter. On some level, this is a good outcome. In terms of error, methods of assembly further reinforce the difference between matter and materiality; widening the gap between architecture and labor. Or, in Dieste's terms, recognizing that most modern and contemporary buildings are assembled, not constructed. This remark points to the separation between physical matter and construction. In large part, contemporary buildings are assembled from discrete pieces, which favor the unreachable demands of quantitative precision.

Beginning with demolition demands a close inspection of the organization of matter. During the demolition of the wall, the bricks were cleaned, catalogued and used the build the most current prototype of the wall. Upon close inspection, students evaluated the work of their peers and documented the existing wall as a network of errors. The forensic analysis and subsequent construction, asked how and if, this network of errors undermined the structural and material integrity of the wall. This was an evaluation of qualitative precision.

APPROXIMATE STACKING AND AUTOMATED REPRESENTATION

Forensic demolition showed errors in construction - architectural mistakes - demonstrating an understanding of the difference between materiality and matter. Inconsistencies were magnified by the fact that this double curvature, Ruled Surface form was made with no construction drawings (Figure 5).

Architects produce drawings to a level of quantitative precision that cannot be translated into materialization. Eliminating drawings from the construction of complex forms subverted architecture's primary method of material mediation. How can qualitatively precise forms be built without quantitatively precise drawings or models? How can familiarity with complex forms be a product of understanding matter over materiality? These questions were addressed in two ways that engaged the nuanced relationship between error and matter:

1. Automated representation and familiarity with complex forms using 3D printing and other ways of translating quantitative precision into exact matter.

2. Approximate brick stacking and familiarity with complex forms through qualitative, improvisational organization of matter.

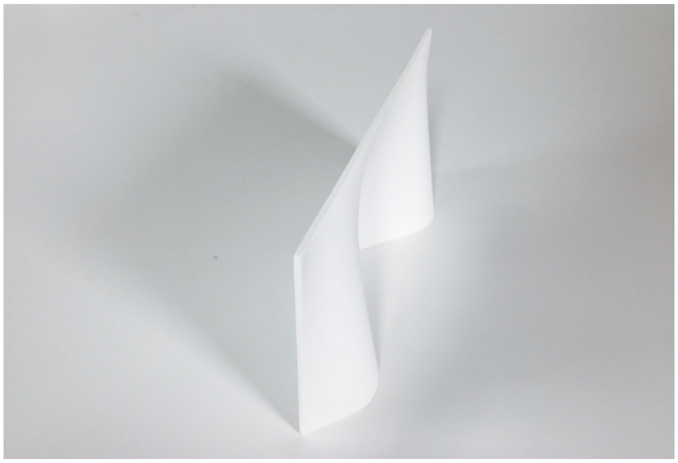

Figure 3: 3D Gypsum Powder Print, 8”x12”x1/4”.

Figure 4: Improvisational Dry Stack Ruled Surface Brick Wall, 4’x12’x4”..

First, small-scale representational 3D printing and rapid prototyping replaced the part to whole relationship with a single continuous surface. (Figure 3) In a contemporary sense, this refers to continuously differentiated surfaces made by digital fabrication and parametric processes. These surfaces appear smooth and continuous. Paradoxically, these surfaces can only be constructed by designing custom components, which are dependent on a part to whole relationship that is rendered invisible. Additionally, these forms seldom respond to the laws of physical matter. In other words, the rationality of Dieste’s Ruled Surfaces highlight the irrational structural and material product of many examples of contemporary differentiated surfaces. In Dieste Walls, 3D gypsum powder printing translated quantitative precise representations of Ruled Surfaces into continuous single material models. These models showed that 3D prints have materiality but no articulated matter.

The resulting images and 3D printed models expanded error into two contradicting categories that affect labor: the Ruskian sense of imperfect craft and the contemporary role of precise automation. In these images the dimensional tolerance of architectural representation solidified the unproductive notion that error is any perceived gap between the physical and performative aspects of form.[10]

Second, improvisation is one of the most important strategies for producing intentional error. After building familiarity with Ruled Surfaces through quantitatively precise 3D models, students improvised by stacking ruled surfaces using nominal bricks. In architectural terms, improvisation is an active seizing of opportunities presented by architectural frameworks. What is essential about improvisation is that there are no ways of guaranteeing success. Improvisation breaks and distorts the system in which it exists — it requires the potential for error.[11]

If improvisation is the strategy used to stack bricks into Ruled Surfaces, then approximation is the effect this strategy has on matter. (Figure 4) The role of precision discussed in previous sections of this paper excluded the effect of approximation. Approximation is not discussed in contemporary quantitative or qualitative precision terms because computation prefers exactitude over approximation. Through dry brick stacking exercises students learned that geometric approximation is critical to structural capacity, distribution of weight, and is conditioned by the absence of mortar. Automated forms of production (3D prints and images) detach construction from labor. Pairing improvisation with approximation asked students to design methods of construction or simple stacking that was compatible with or maximized the potential for error in collective labor. Physical labor was designed; drawn or modeled labor was automated. Automated representation and approximate improvisation prepared students for construction without graphically controlling the process of construction.

UNSKILLED LABOR AND TOO MANY HANDS

To build a brick and mortar Ruled Surface wall, students designed a system of vertical string guides that established the geometry of the wall surface and limited improvisation; approximating matter into a complex form. This process was analogous to Dieste’s method of designing formwork to build double curvature forms. (Figure 1)

Unlike Dieste’s practice, students are not skilled laborers and no amount of practice could turn architecture students into master masons in twelve weeks — this was not the intent. Student labor did not have the quantitative precision of automated robotic processes or the qualitative precision of master masons. The role of building the wall centered on issues of labor and its effect on the relationship between precision and complexity. These effects are evident in Joan Ockman’s introduction to “The Architect as Worker”.

> Certainly serious reflection on labor in architecture today must entail a recognition that buildings begin in both embodied and disembodied — material and immaterial — production, not just architects’ designs but also in raw materials from the ground and bodies on the construction site; and they also end there, in physical objects located in actual places as well as in images or “effects” that enter into a cycle of future reproduction and commodification. [12]

The role of labor in architecture is tied to how architects materialize the social and political effects of producing architecture. Ideas about labor exist in the gap between materiality and organizing physical matter. The question asked through the work in *Dieste Walls* is how to consider labor and its association with error as an intellectual endeavour. This question points to the distinction between mental and manual labor, or "concrete labor" and "mental production" expressed in Karl Marx's "Capital".[13] Offering a critique of Marx, Hannah Arendt popularized the academic distinction between labor and work. According to Arendt, the former leaves no trace of effort, while the latter results in an object or a demonstration of effort. Additionally, labor is considered a biological process that "assures not only individual survival, but the life of the species. Work and its product, the human artifact, bestow a measurement of permanence and durability upon the futility of mortal life and the fleeting character of human time." [14]

In architectural terms these definitions are problematic for two reasons. These reasons are manifested through two primary tendencies in contemporary architectural discourse about labor.

First, a resurgence of the notion of craft as a link between the object and its maker. This way of thinking about producing architecture preferences work over labor. Craft, as a method for making is not seen as a measure of precision in this case, but rather a direct relationship with the object and its resulting effects. Digital production and CAD technology supports this notion of contemporary craft. Digital craft increases the number of participants in the making of an object and subverts the sole authorship of traditional craft. This reconfiguration of authorship does not affect labor, it simply displaces intent as a major factor in the process of making. Digital authorship, "style of many hands", also means relinquishing control of design decisions over to computational algorithmic processes.[15] These generative parametric processes are an effective way of exploring error. However, these processes are mostly indifferent about issues of labor or questions of material production that affect labor.

Second, robotic processes and automated production assert that the way to think about labor intellectually is to reconfigure, or eliminate "concrete labor". Thinking and acting on the production of architecture as a programmable process is not new. Since the digital turn, over twenty years ago, architects have been mitigating the automation of work. In the last ten years, automation has been focused on construction work. The means of producing architecture are still focused on "systems of labor" and the choreography of bodies on site. These systems connect architects and technology to people and place. In "More for Less: Architectural Labor and Productivity" Paolo Tombesi describes the ideas of work and labor established by Ardent: "work does indeed define architecture's intellectual objectives while labor reminds us of the salaried workforce necessary to articulate them."[16] With this distinction in mind, it is relevant to ask two questions about robotic automation. Do robotic construction processes perform work or labor, are they programed to do both? If so, what type of system of labor are they producing?

There are two primary claims that support the emergence of robotic construction. Both claims are based on current methods of production that are unsustainable in two ways: environmentally unsustainable in material production and socially unsustainable in terms of labor. These are important concerns, however, it is difficult to believe that either one of these concerns are eminent if we consider that, "in architecture today, despite the proclaimed integration of all phases of the building process through high-tech management techniques, the rhetoric of immaterial production contributes to absolving architects from accountability to material bodies and places, not to mention provides an alibi from legal liability."[17]

Architectural error and its relationship to labor are at the confluence of digital craft and robotic automation. Digital craft seeks to expand the nostalgia of thoughtfully built objects through the manipulation of authorship. Robotic automation looks to replace literal bodies on site with automated programmable technology. These two approaches have conflated into a sense of digital materiality that neither addresses the social implications of labor or architects' diminished knowledge of matter.

The work from Dieste Walls is neither techno-phobic or technologically deterministic; it feeds from digital craft and questions automation. The work from the course resulted in a six-foot-tall Ruled Surface wall, which took 12 students divided into interchangeable teams of four, a total of 6 weeks to construct. The construction of the wall was documented in a shared log. The log is a trace of labor, which binds students, material, and the inevitable errors that will be evaluated when the wall is demolished in the Spring of 2018.

No robots were used — and no students were harmed in the making of Dieste Wall 1.0 or 2.0.

Figure 5: Ruled Surface Brick Wall, 7’x8’x4”, Spring 2017.

ENDNOTES

1. Dieste, Eladio. "Architecture and Construction", in Eladio Dieste: Innovation in Structural Art, ed. by Stanford Anderson (New York: Princeton Architectural Press, 2004), 189.

2. Hughes, Francesca. The Architecture of Error: Matter, Measure, and the Misadventures of Precision (MIT Press: London, England, 2014), 5.

3. Keller, Sean. "Ways About Error", in Perspecta 46: Error, Edited by Joseph Clarke and Emma Jane Bloomfield (Cambridge, MA: MIT Press, 2013), 33.

4. Ibid. 34.

5. Joseph Clarke and Emma Jane Bloomfield, "Introduction", in Perspecta 46: Error, Edited by Joseph Clarke and Emma Jane Bloomfield (Cambridge, MA: MIT Press, 2013), 22.

6. Asli Serbest and Mona Mahall, "Theory of the Impossibility of a Theory Error", in Perspecta 46: Error, Edited by Joseph Clarke and Emma Jane Bloomfield (Cambridge, MA: MIT Press, 2013), 342.

7. Pedreschi, Remo. The Engineer's Contribution to Contemporary Architecture, (London: Thomas Telford Publishing, 2000), 73.

8. Hughes, Francesca. The Architecture of Error, 29.

9. Ibid. 27.

10. Ibid. 28.

11. Keller, Sean. "Ways About Error", in Perspecta 46: Error, 34.

12. Ockman, Joan. "Foreword", in The Architect as Worker: Immaterial Labor, the Creative Class, and the Politics of Design, ed by Peggy Deamer, (New York, Bloomsbury, 2015), xxiv.

13. Marx, Karl. Capital Volume 1, trans. Ben Fowkes, (London: Penguin Books, 1990), 284.

14. Ardent, Hannah. The Human Condition, (Chicago: The University of Chicago Press, 1958), 8.

15. Carpo, Mario. "Digital Darwinism: Mass Collaboration, Form-Finding, and The Dissolution of Authorship" in Log 26, (New York: Anyone Corporation, 2012), 97.

16. Tombesi, Paolo. "More for Less: Architectural Labor and Design Productivity", in The Architect as Worker: Immaterial Labor, the Creative Class, and the Politics of Design, ed by Peggy Deamer, (New York, Bloomsbury, 2015), 83.

17. Ibid. xxiii.