

Ubiquity and Autonomy

PROJECTS CATALOG OF THE 39th ANNUAL CONFERENCE OF
THE ASSOCIATION FOR COMPUTER AIDED DESIGN IN ARCHITECTURE

ACADIA 2019

OCTOBER 24 - 26, 2019

THE UNIVERSITY OF TEXAS AT AUSTIN
SCHOOL OF ARCHITECTURE

EDITORS: Kory Bieg, Danelle Briscoe, and Clay Odom

Walking Assembly Craneless Tilt-Up Construction

Brandon Clifford
MIT/Matter Design

Jo Lobdell
Matter Design

Tyler Swingle
Matter Design

Davide Zampini
CEMEX Global R&D



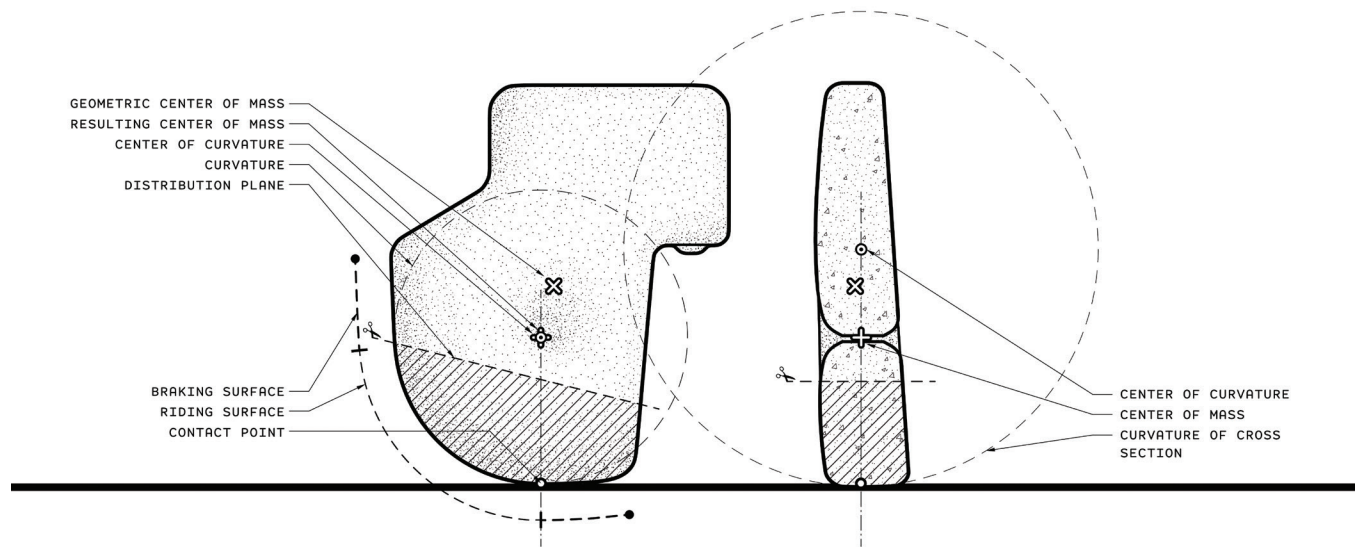
1 Walking Assembly prototype elements

The mysterious knowledge surrounding the transportation and placement of megaliths used by ancient societies eludes contemporary building practices. The construction of massive elements in architecture, particularly tilt-up construction, is largely dominated by reliance on external structures and mechanisms such as cranes and tilting tables (Brown 2014). This reliance has irreducible implications on costs and access to the potentials of massive construction.

Since its invention, concrete is the most used manufactured material in the world with “three tonnes of concrete (...) used annually per person” (Brito 2013). Inherent to concrete is mass, and much of the work surrounding intelligent futures for concrete has focused on reducing mass and deploying the material where needed. These examples include work by Abd Elrehim (2019), Jewett (2018), and Liew (2017). As beneficial as these efforts are, mass is not the only parameter, and it can even be advantageous to have when improving the thermodynamic performance as shown in the Hsu House (Cupkova and Azel 2015). The challenge of today is identical to moments of the past when ancient civilizations such as the Romans or Egyptians erected incredibly massive megalithic assemblies without the energy consumption of mechanical cranes (Diebner 1991). While much is still uncertain about the ancient Egyptian and Roman methods, archaeologists have proven that the colossal statues of the Moai Rapanui were carved using a highly calibrated relationship between the curvature of the form and the center of mass (COM) of the object, enabling the Moai to march forward when tugged side to side (Hunt 2012).

PRODUCTION NOTES

Designer: Matter Design
Industry: CEMEX Global R&D
Size: 6.3m x 3m
Mass: 5,970kg
Material: Concrete
Date: 2019



2 Key of the various geometries that compose an element

Walking Assembly taps into the potentials of innovative concrete technologies and ancient methods of transportation and assembly of megalithic architecture to inform contemporary practice by embedding intelligence into building elements to assemble without the aid of external lifting. The project employs recursive solver computation to locate two densities of concrete in the design process to ensure the safe and stable movement of the massive elements. The computation surrounds two key geometries—the form of the element and the COM. The forms of the elements are constrained by the need to rotate for transportation, to rest for stabilization, and to interlock for assembly. The solver leverages the potentials of varying densities of concrete to drive the geometric COM to a new target position, thus ensuring the calculated movements. This multi-variable calculation is verified with built prototypes that test the assembly approach.

The *Walking Assembly* prototype incorporates the COM solver with a fully three-dimensional curvature continuous motion geometry as well as interlocking assembly geometry

(Figure 2). The purpose of this prototype is to embody the intelligence of COM location in relation to the element's COC so it can spin, rotate, and tilt safely, therefore making it transportable and adjustable on site. Further, all elements utilized braking regions and variable curvature in the cross section of the motion geometry for stability. The assembly geometries incorporate dado connections into the element overlap as seen in Figures 3 and 4. The additional interlocking surfaces aid in the final alignment of the elements and account for the element's rotational draft during assembly.

Each of the smaller elements is roughly 1.2 m wide and 1.5m tall, ranging in depth from 0.3 m to 0.5 m. They range in mass from 420 kg to 700 kg and can easily be positioned by a single person. A stair is incorporated into a series of smaller elements (Figures 5-6) so that a person can climb and continue the assembly of a larger element twice the size. This element is 1.75 m by 0.5m by 3.0 m and weighs over 1,770 kg but is just as agile as the smaller elements (Figure 7).



3 Detail view of the top assembly detail that aides in alignment



4 Interior view of the corner assembly detail

The resulting prototypes are incredibly massive solid cast concrete elements that can walk and assemble effortlessly (Figure 8). The introduction of innovative concrete technologies was fundamental to enable versatility in geometrical design and achieve the target performance from the displacement of the COM. The success of these prototypes points to the possibility where computation, coupled with novel concrete technologies, can expand the reach of, for example, tilt-up wall construction and reconsider the potential of mass in rapid and responsive deployable systems.

ACKNOWLEDGEMENTS

This research is produced in collaboration between Matter Design and CEMEX Global R&D. The recursion solver is generated through a custom definition that employs Anemone (theobject.co/anemone). The former, a plugin developed by Object to resolve recursion in Grasshopper (grasshopper3d.com), yet another a plugin developed by David Rutten for the Robert McNeel-developed program, Rhinoceros (rhino3d.com).

IMAGE CREDITS

All drawings and images by the authors.



5 Detail of the assembly geometries



6 Assembled units with an incorporated stair

REFERENCES

- Abd Elrehim, Mostafa Z., Mohamed A. Eid, and Mostafa G. Sayed. 2019. "Civil Engineering: Structural Optimization of Concrete Arch Bridges Using Genetic Algorithms." *Ain Shams Engineering Journal*.
- Brito, Jorge de, and Nabajyoti Saikia. 2013. *Recycled Aggregate in Concrete: Use of Industrial, Construction and Demolition Waste*. Green Energy and Technology Series. London, New York: Springer.
- Brown, Jeffrey Blaine and Sabita Naheswaran. 2014. *Tiltwallism: A Treatise on the Architectural Potential of Tilt Wall Construction*. Mulgrave/Melbourne: The Images Publishing Group Pty Ltd.
- Cupkova, Dana and Nicolas Azel. 2015. "Mass Regimes: Geometric Actuation of Thermal Behavior." *International Journal of Architectural Computing* 13(2): 169-93. doi:10.1260/1478-0771.13.2.169.

- Dibner, Bern. 1991. *Moving the Obelisks: A Chapter in Engineering History in Which the Vatican Obelisk in Rome in 1586 Was Moved by Muscle Power, and a Study of More Recent Similar Moves*. Burndy Library Publication in the History of Science and Technology 7(6). Norwalk, Conn.
- Hunt, Terry and Carl Lipo. 2012. *The Statues That Walked : Unravelling the Mystery of Easter Island*. Berkeley, Calif.: Counter Point Press.
- Jewett, Jackson. 2018. *Design, Fabrication, and Testing of Plain Concrete Beams Using Topology Optimization*. Mech.E dissertation, Massachusetts Institute of Technology.
- Liew, A., D. López López, T. Van Mele, and P. Block. 2017. "Design, Fabrication and Testing of a Prototype, Thin-Vaulted, Unreinforced Concrete Floor." *Engineering Structures* 137(April): 323-35. doi:10.1016/j.engstruct.2017.01.075.



7 Each element is calibrated to be maneuvered by a single person



8 *Walking Assembly* prototype

Brandon Clifford mines knowledge from the past to design new futures. He is best known for bringing megalithic sculptures to life to perform tasks. Clifford is the director of Matter Design and assistant professor at the Massachusetts Institute of Technology. As a designer and researcher, Clifford has received recognition with prizes such as the American Academy in Rome Prize, a TED Fellowship, the SOM Prize, and the Architectural League Prize for Young Architects & Designers. Clifford is dedicated to re-imagining the role of the architect. His speculative work continues to provoke new directions for the digital era.

Jo Lobdell is a partner at Matter Design where she is driven to bring inspiration and joy to the world through the lens of design. As a designer she uses play as a way to tackle how the body and mind can interact with objects and environments. Her focus is on the way in which color, pattern, and form operate together to express a narrative. Examples of this process can be seen in projects like the award winning Five Fields Play Structure, The Cannibal's Bath for MoMA's Young Architects Program, and The Cannibal's Cookbook that received a PRINT design award.

Tyler Swingle is research lead and project manager at Matter Design and holds a lecturer position at McGill University. In his work, he is committed to exploring the reciprocity between materials and computational methods and frameworks. As a part of Matter Design, this includes both ancient building techniques and new material technologies.

Davide Zampini has over 30 years of experience in the construction materials industry and is best known for pushing the limits of innovation in cement-based products and building solutions. Adopting a design- and industrially-driven innovation approach, Davide leads a multi-disciplinary and culturally diverse team at CEMEX's Center for Innovation and Technology. Through adaptive research and development conceived with versatility in mind, Davide's team at CEMEX in Switzerland develops novel functionalities in cement-based materials that incorporate customer-centered strategies and are designed to create solid emotional ties to a material that for ages has been considered "grey."