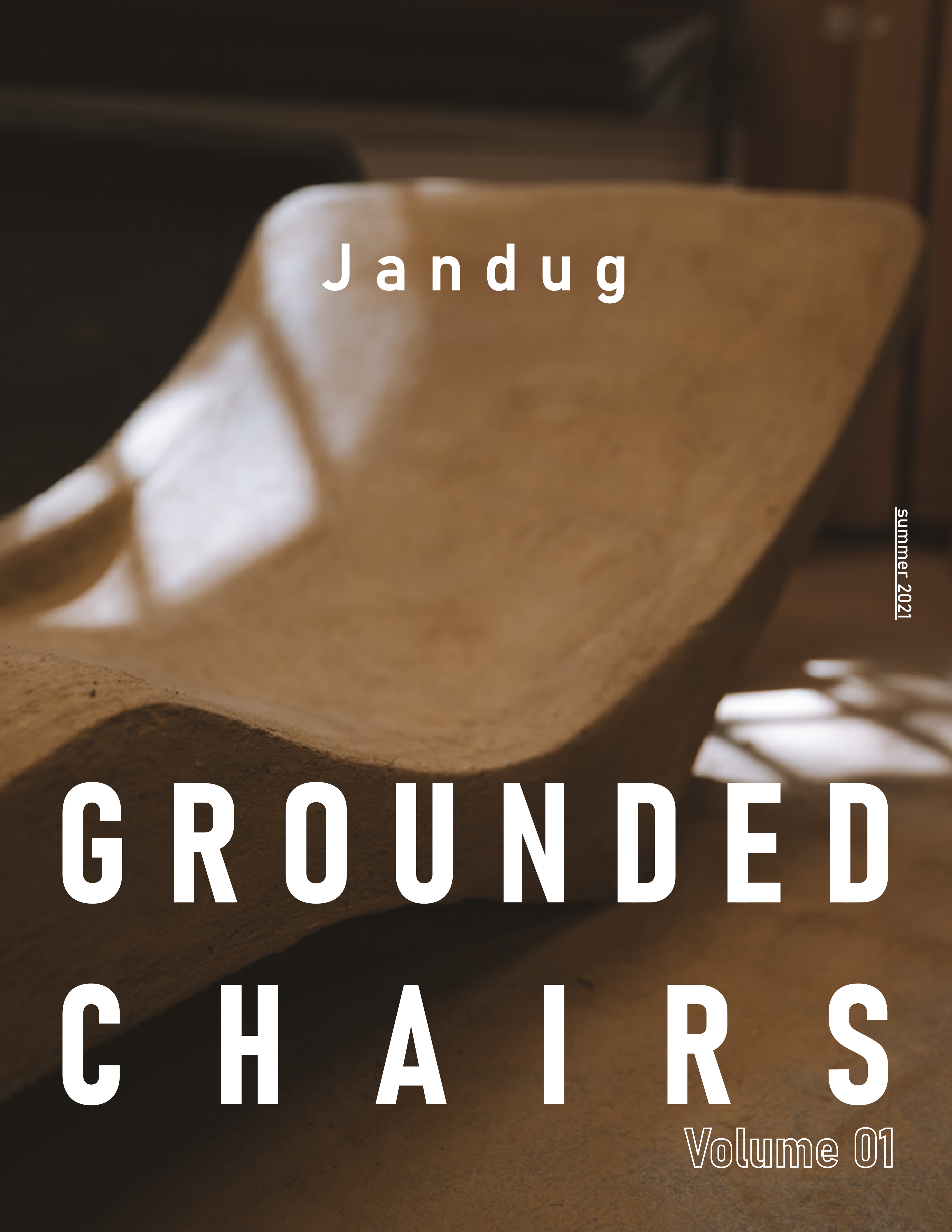


Jandug

summer 2021

GROUNDED CHAIRS

Volume 01

Abstract

Earth has been a generous source of building materials. Earthen materials have been used for over a millenia and are still sheltering approximately a third of the world population, providing thermal delight, availability and affordability benefits. These materials are currently experiencing a new renaissance with upscaled visions and construction technologies introduced to building methods such as rammed earth, compressed earth blocks (CEB), and cob, each includes different proportions of clay-rich soil and fibers and provides different features of sculptability and plasticity.[1]

While earth-based materials are mostly used for building construction, new experiments show premises for smaller scale artifacts used in landscape design, interior design, and most recently - furniture design. While earth-based materials are mostly used for building construction, new experiments show premises for smaller scale artifacts used in landscape design, interior design, and most recently - furniture design. While some designers, like Earth Wall Builders have developed outdoor landscape sculptures that withstand weathering and erosion using rammed earth construction techniques[2] others like Frida Escobedo used rosy rammed earth brick walls to segment the interior of an Aesop store in Brooklyn.[3] As for furniture design, cob tiles and stools were previously developed by Adital Ela, proving that thinly-compressed cob shells can withstand the forces applied on them when pushed to their optimum potential.[4]

Indeed, as an architectural case study, the chair has been an element often used for architect's to experiment with. From Frank Lloyd Wright's infamous Robie to Pierre Jeanneret's Rattan Chair, the chair has been designed by legendary architects as an effort to reinterpret a traditional artifact in a novel way. Indeed, as an architectural case study, the chair has been an element often used for architect's to experiment with. From Frank Lloyd Wright's infamous Robie to Pierre Jeanneret's Rattan Chair, the chair has been designed by legendary architects as an effort to reinterpret a traditional artifact in a novel way.

As part of this trajectory, the Natural Materials Lab at Columbia GSAPP developed Grounded Chairs, a 100% organic biodegradable low-carbon seating system. The Grounded Chairs series aims to use natural building materials such as clay, sand, fibers, and bamboo, to provide a new interpretation of seating sculptures. By using the thermal advantages of naturally driven mass materials and experimenting with electric heating wires, Grounded Chairs provide sculptural comfort seating that can store heat and absorb moisture to provide optimal thermal comfort, while having sustainability at its core.

1. Niroumand, H., Zain, M. F. M., & Jamil, M. (2013). Various types of earth buildings. Procedia-Social and Behavioral Sciences, 89, 226-230.

2. Projects. (2015). EarthWall Builders, Inc. http://www.earthwallbuilders.com/projects.html

3. Frida Escobedo segments Aesop Park Slope with rammed-earth brickwork. (2019). Dezeen. https://www.dezeen.com/2019/04/07/aesop-park-slope-frida-escobedo/

4. Terra Stools | Adital Ela. (2012). Adital Ela. http://www.aditalela.com/terra-stools-2/

As architects and artists declare a climate and biodiversity emergency, and commit to adopting new approaches and technologies, this project reshifts the architectural lens on raw earth as a potential for action. As such, this work aims to reintroduce earthen materials as a readily available and minimally processed source for everyday industrial design.

Our first iteration of Grounded Chairs is ‘Jandug’; a structurally sound cob chaise with an internal bamboo skeleton and a radiant heating system to further enhance the user’s thermal experience. Throughout its construction process and phases, Jandug has posed intriguing challenges to the structural and durability limits of the materials used.

Background on Earth-Based Materials in Design

The use of earthen materials has a long and prehistoric background. An iconic example of earth construction is the city of Shibam in Yemen, whose walls are higher than 8 stories and built solely with earthen materials.[5]

These days, there have been emerging efforts to reintroduce these materials for construction, as the building sector is responsible for about 40% of global greenhouse gas generation. Earthen construction can have a dramatically smaller carbon footprint when accounting for both embodied and operational values. The embodied footprint of earthen wall assemblies is dramatically lower because of their shorter supply chain and minimal processing, and the operational space heating, cooling, and humidification of insulated earthen materials can be lower than other assemblies. Overall, when coupling the embodied and operational environmental impacts, earthen assemblies have been shown to reduce energy demand by approximately 40-60% as compared to conventional building assemblies.[6]

When working with earthen materials, one must learn to develop optimal designs considering the slow speed of construction compared with cementitious materials. And while the extra care in construction and material mixing is required, earthen materials can provide adequate performance to the industrial artifact requirements while not imposing a non-reversible outcome. Through material exploration and form experimentation, earthen materials can be optimized for suitable behavior after drying (mitigation of cracks and mechanical strength).

5. Mileto, C., & Vegas, F. (2018). Earthen architecture: sustainability and heritage. Compasses, 29, 36-42.

6. Ben-Alon, L., Loftness, V., Harries, K. A., & Hameen, E. C. (2021). Life cycle assessment (LCA) of natural vs conventional building assemblies. Renewable and Sustainable Energy Reviews, 144, 110951.

7. Trujillo, D., & Lopez, L. F. (2016). Bamboo material characterisation. Nonconventional and Vernacular Construction Materials, 365–392.

8. Miccoli, L., Müller, U., & Fontana, P. (2014). Mechanical behaviour of earthen materials: A comparison between earth block masonry, rammed earth and cob. Construction and Building Materials, 61, 327–339.

Mixture designs can be accompanied with a range of fiber reinforcement (such as reed and straw), as well as binding sealers (such as flaxseed oil). Additional reinforcement can be introduced by using bamboo. Providing resistance to tensile, bending, and compressive forces, bamboo seems to correlate with its density due to its high content of cellulose making it a great reinforcing element and a sustainable alternative to steel.[7] As an internal skeleton, bamboo pairs with earth-based materials much better than steel, which is prone to oxidification within the highly hygrothermal earthen mass.

Cob, on the other hand, exhibits lower compressive resistance and shows relatively ductile post peak behaviour. It can deform beyond the elastic range with a gradual drop in capacity which is strongly influenced by the presence of fibres. In terms of shear behaviour, cob presents relatively good performance within the earthen material range.[8]

The Importance of Material Testing

Sourcing the right type of soil is integral to the workability, durability, and structural integrity of any design that utilizes earth construction, especially when the form of the design is load bearing.

Our search for optimal local soils for construction was a journey; We have traveled around New York City seeking for clay-rich soil that passes a range of tests for clay content, texture, shrinkage, and strength. We have initially found clay-rich soil (25% clay) in a quarry an hour north of New York City. However, that soil proved to make rough textures that can be eroded quickly, indicating its high silt content, which is not suitable for construction due to its weak connection within the mixture matrix and tendency to erode.

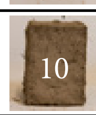
Our further search yielded a better source of soil, sourced an hour north-west of NYC. This preferable soil had 40-45% clay, which is higher than needed for cob construction, since a mixture of high clay content is more susceptible for cracking. This challenge was mitigated by adding finely sieved sand which enhanced cracking control.

After finding local suitable soil for construction, we continue the material testing by mixing the soil with different reinforcing agents. These tests allowed us to decide on the different mixtures that would be needed on the different layers of the chair. Our design decisions were based on both visual and qualitative measures, looking at the testure, erosion, and density of each specimen.

Table 01 - Different ratio categorization of different specimens (Mixtures 01-05)

	Medium Soil	Concrete Sand	Fine Straw 0.5"-1"	Long Straw 4"-6"	Density (g/cm³)
 01	1	0.75	0.5	0.5	1.53
 02	1	0.5	0.25	0.25	1.76
 03	1		0.25	0.25	1.91
 04	1	0.5		0.5	1.56
 05	0.5	0.25		1	0.98

Table 02 - Different ratio categorization of different specimens (Mixtures 06-16)

	Fine Soil	Newman's Red Clay	Concrete Sand	Fine Straw 0.5"-1"	Reed Inflorescence	Density (g/cm³)
 06	1				1	1.86
 07		1		1		1.24
 08	1			1		1.30
 09		1		1		1.05
 10	1				1	1.53
 11		1				1.25
 12	1		0.5			1.32
 13	1	0.5	1	1		1.58
 15	1	0.5	1		1	1.61
 16	1	0.5	1	0.5	0.5	1.50

The final mixtures we used were the following:

- Mixture 05 for the infill straw between bamboo elements.
- Mixture 04 for the interior layer.
- Mixture 02 for the exterior layer.
- Mixture 16 for the finish layer.

Frichot, H. (2019). Dirty theory: troubling architecture

"to work with dirt is to work against the flow, to "cross boundaries, challenge decorum, contravene norms"; to work with dirt is to touch on the entanglements of humans and non-humans and rethink collective bodies; to work with dirt is to tap into a rich lineage of thinkers both historic and contemporary" - Hélène Frichot

Design and Build

Step 01: The Skeleton

We approached the design in an attitude that allowed us to use the potential of the materials to guide us through the process. Limiting ourselves to the amount of bamboo that we would need, we created a structural truss skeleton containing 3 triangles with diagrids that would respond to the ergonomics of the human body, a section for each; the shank, the thighs, and the torso. The thin bamboo structure was then joined by lashing biodegradable jute rope to provide the necessary strength to sustain the tension within the earthen mass material.

Figure (1) - Bamboo Skeleton

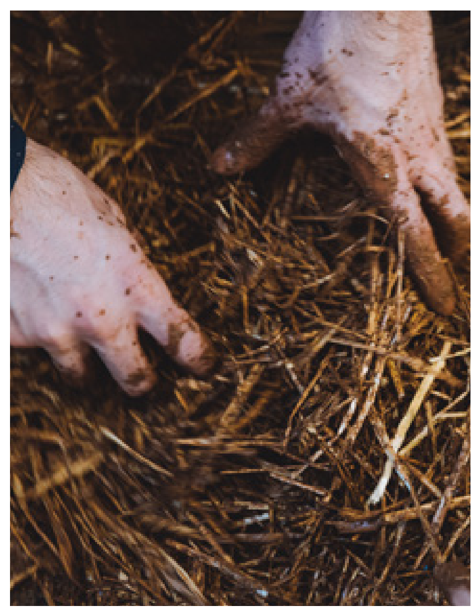
The 3 rectangles had their angles determined based on the length of the supporting truss bamboo structure. These diagonal pieces employed a traditional technique of hand-sawing a fisheye joint with a japanese saw. This particular joint allowed us to join the diagonal pieces of bamboo where the angle of incident is not 90 degrees.

Figure (2) + (3): Lashing the fisheye joint

Step 02: Infill Straw

After having built the bamboo structure, we created a jute rope “net”between the diagonal bamboo members to act as a surface for the infill mixture. Once the weaving was done, the infill layer was placed in between the bamboo members and on the joints to give the skeleton more rigidity and strength. The density of this layer is very low and therefore would make the chair less heavy.

Figure (4) + (5): Infill Layer - Mixture 05



Step 03: Interior Layer

After the infill layer was dry, we started adding the first layer of earth using mixture 15 (medium sieved soil, sand and long straw) onto the weaved jute between the bamboo members. While long straw gives the mixture a great tensile strength, the sand gives it a compressive strength which both are needed in our design.

Figure (6): Mixture 04 is added (Medium sieved soil, sand and long straw)

Step 04: Electric Heating Cables

After finishing the first layer, electric heating wires were embedded to allow the user to control the thermal properties of the chair.

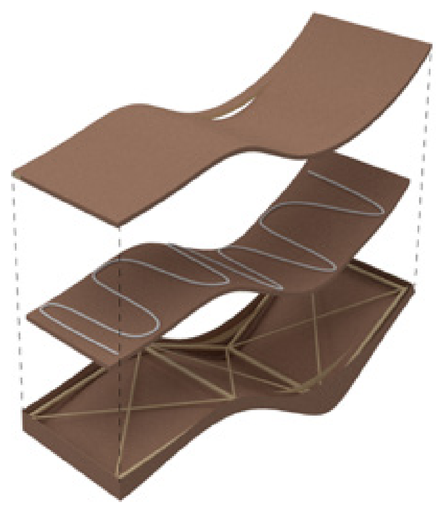


Figure (7): Axonometric diagram showing skeleton, first layer, heating wires, and exterior layer

Step 05: Exterior Layer

In order to keep the heat of the wires trapped inside, an exterior layer was added using mixture 13 (medium sieved soil, sand, short straw and long straw). As this layer was added, it was important to start sculpting the chair. The final shape of the chair was dictated by the workability and fluidity of the mixture during this sculptural phase.

Figure (8) + (9): Dry Exterior Layer - Mixture 02

Step 06: Finish Layer

For the finish layer, a very fine mixture was needed to achieve a smooth surface. Mixture 10, which uses finely sieved soil, red clay, sand, reed and fine straw, was implemented to achieve a plaster-like texture that is soft, smooth and sticky. In order to achieve a smooth paste as possible, this mixture was feet-stumped, as practiced in traditional Devon cob. This final layer required a high level of craft, given it was used to make the sculptural details of the chaise. After being dry, the finish layer was sanded to achieve the smoothness required.

Figure (10) + (11): Finish Layer - Mixture 16

Step 07: Natural Sealant Layer

As a final layer, a natural flaxseed oil sealant was used to coat the chaise. The flaxseed oil, used traditionally in earth building and especially in earth floors, provides a waterproof protection to the earthen surface, and increases durability against mechanical abrasion and encounter with moisture and fluids. For this final coat, multiple layers of flaxseed oil were applied and let dry.

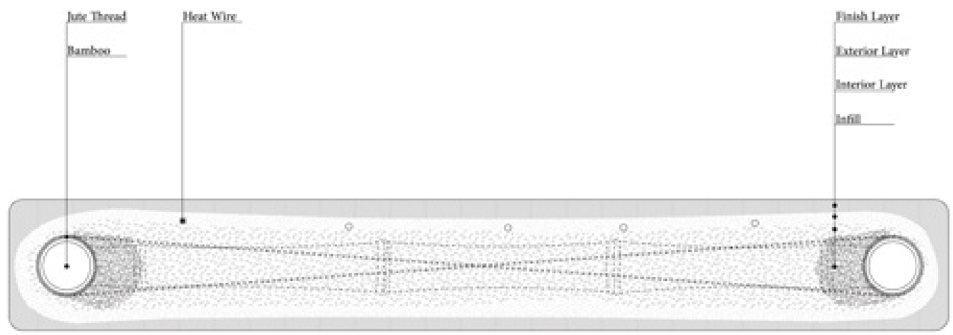


Figure (17) - cross section in Jandug

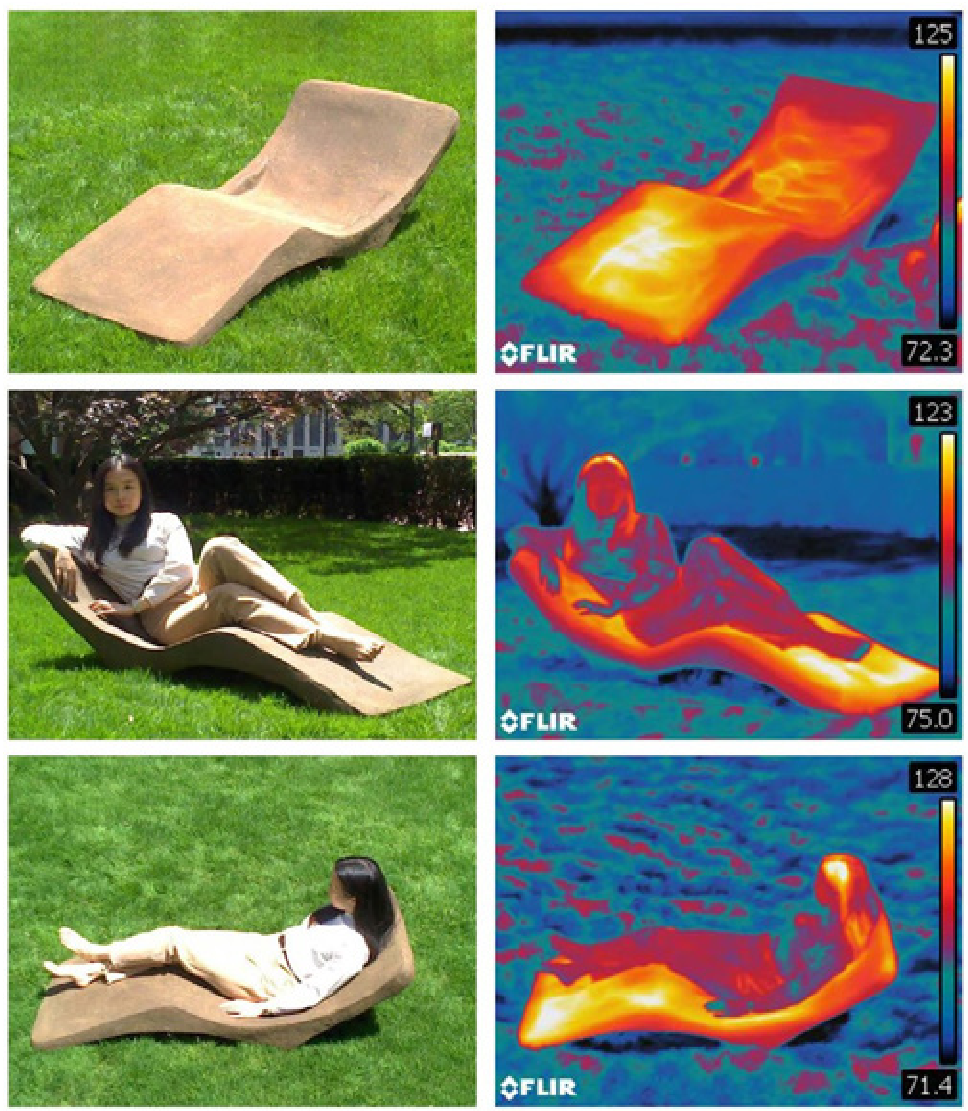


Figure (14): Thermal Wires embedded in the chaise warms it up to 125 °F, in comparison to the surrounding lawn which is around 85-90 °F

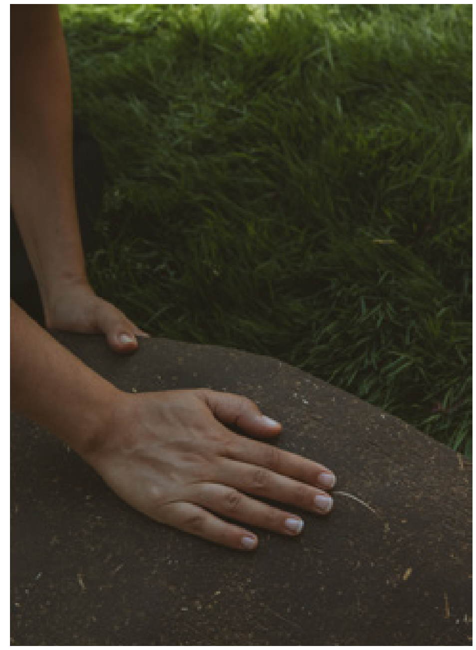


Figure (15) + (16) Jandug outdoor

Lessons Learnt and Future Avenues

Jundag, the first iteration of Grounded Chairs, provided important takeaways that should be implemented in future earthen materials experiments..

First, the form of the chaise was shown to be challenging due to the bending moment occuring between the back and sit of the chaise. Ergonomically, the structure should be designed to provide a long enough back to support the user's head, thus increasing the bending forces enacting on the structure. While the bamboo skeleton provided initial tensile strength, after the cob let dry, it was shown to contribute weakness points at the joints. Thus, further experiments should be conducted without the skeleton, asking whether cob would be able to withhold the tension with no added reinforcement. Throughout the iterative process, it became evident that the base layers of the cob, which had 3"-6" straw, could withstand more tension than we had hypothesized.

This realization could lead to more experiments that utilizes the tensile quality of the weaved straw reinforcement to create structurally innovative forms without the need for a skeleton. While this first demonstration used cob in a structural manner, additional experiments should test cob in compression, which could add to its structural performance.

Another takeaway is the ability of cob to act as a thermal mass. With every layer added on top of the electric wires, the heat trapped inside the thermal mass of the chaise was felt more intensely. Critical investigation into the thermal properties of cob construction should determine optimal layer thickness, mixture ratio and shape of the chair that would provide enhanced thermal experience and control.

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