The Phototropic Fiber Composite Structure

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THE RESEARCH QUESTION

Can one make a responsive fiber composite where electronics are embedded into the fabric?

A team of landscape architects and architects developed a responsive fiber composite folding structure by embedding conductive yarns into a fiberglass knit fabric. The innovation of this project resides in the introduction of simple electronic components into the fabric itself to make a smart or computational textile. This team presents the materials and design fabrication processes for the construction of a structure that acknowledges the presence and absence of light. Origami folding was used as a method allowing the structure to collapse flat. This folding was inspired by Davis' work titled ***(Un) Covering/ (re) Covering: The African Burial Ground Memorial*** *and Museum* and the project *Chakrasana* fabricated by students and faculty at Clemson University. (Davis, 2000, and Testado, 2017) Communication to people via the skin of the project was inspired by Davis' use of surface pattern on the African Burial Ground. (Davis, 2000) Other research for our work includes work on curved crease origami. (Koschitz et. al, 2008) The purpose of the project was to make a responsive, lightweight, foldable and portable structure that could be different shapes when clipped into place. The team tried a smaller version and added some light sensing capacity to understand how the structure could be potentially intelligent. [Figures 1 &2]

The team embedded conductive thread to carry current up a length of fiberglass knit that could then carry an electronic

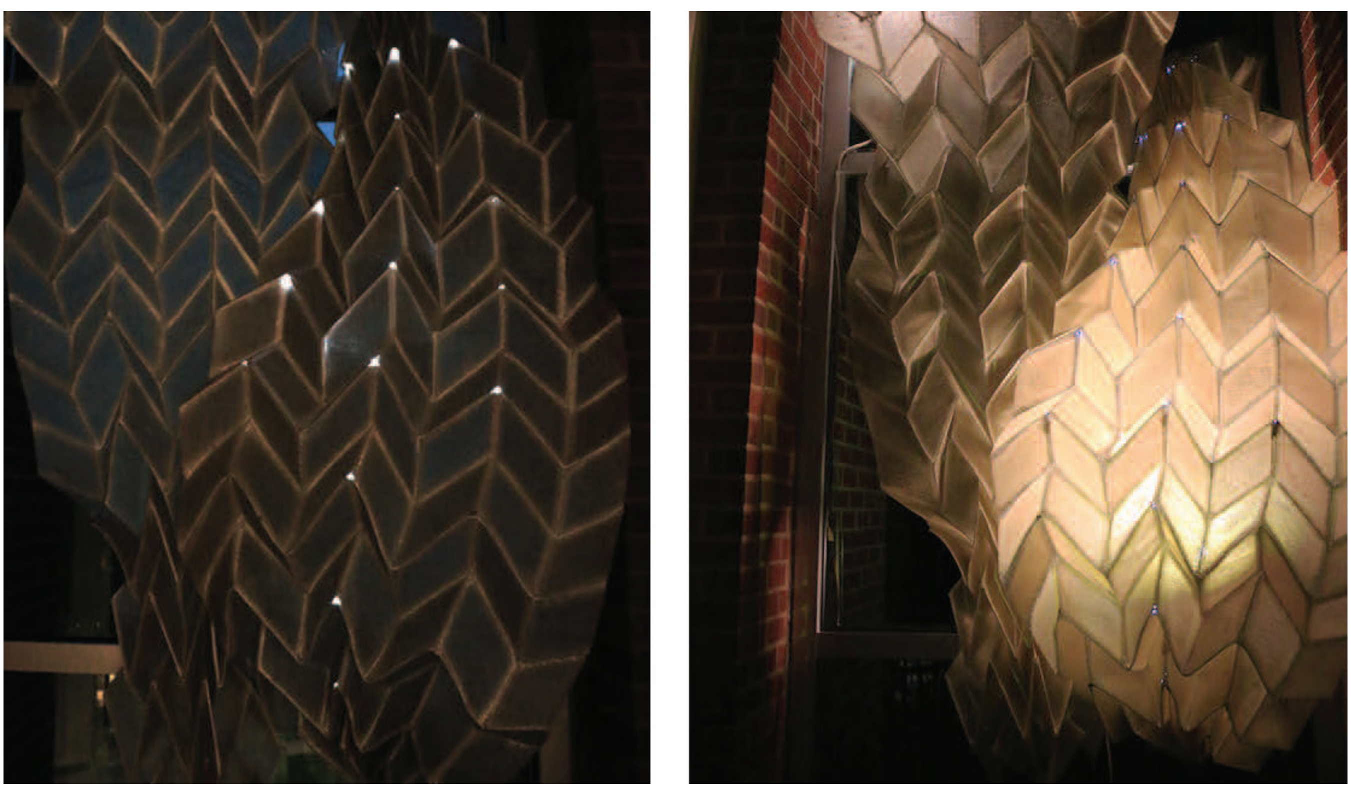


Figure 1. Phototropic Structure at Night. Davis et. al.

Figure 2. Photoropic Structure Daylight testing LED’s. Davis et. al.

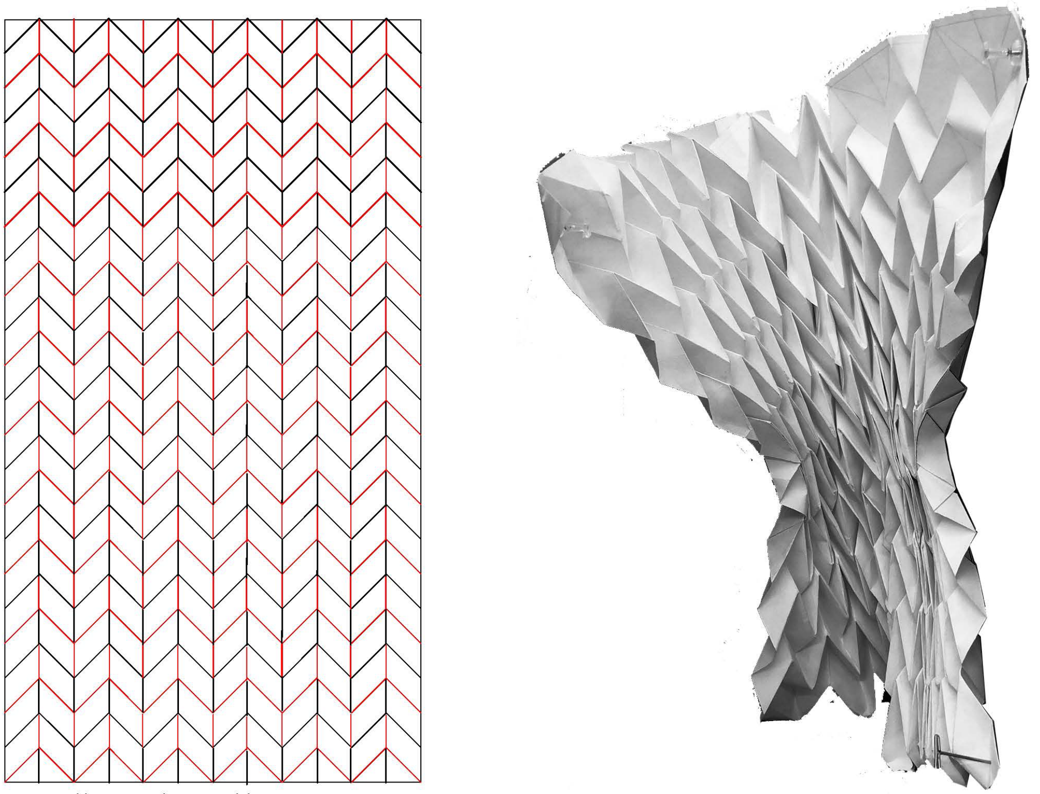


Figure 3. Origami Pattern and Paper Model. Davis et. al.

signal to a series of LEDs sewn onto the front side of our origami project. These LEDs were connected to a photocell that turned the LEDs on and off according to the level of light. In bright daylight the LEDs are off and as evening arrives the LEDs are on. While our proof of concept is basic using LED's, if one can introduce integral conductive yarn to base fiberglass then the fabric itself with integrated electronics can connect to the larger internet of things or sense and communicate other properties to people using the structure such as temperature or CO2 pollution for example. These capacities would permit applications that would allow people to have a wireless connection or other functions for example embedded into fiber composite, lightweight structures. Such integral functions could be useful in emergency shelters or shelters in places that are not connected to a main power grid. In this project the team was able to see how the conductive yarn, resin and fold lines behaved together, and how the large scale of the project would affect the response of the system.

The project was sponsored by the American Composite Manufacturers Association that provided all fiberglass and fabric materials, resins and accompanying supplies. They also shared industry knowledge with us through a Fiber Composite Workshop. While the team did test the project inside, they are developing this project as small shelter in the landscape outside where people fold different shapes to provide shade or the shelter provides delicate lighting at night.

FABRICATION METHODS AND MATERIALS

The project was done during the semester at Penn State School of Architecture and Landscape Architecture in SOFTLAB@ PSU. The team was a mix of undergraduate students, graduate students and faculty.

FABRICATION PROCESS

There are several steps to fabricate the phototropic structure. The fabrication steps are listed below.

ORIGAMI PATTERN

The origami pattern was tested first as a 1"=1'-0" model a digital model and then at 1:1 using printer paper. [Figure 3&4]

Orienting the triaxial fabric to the pattern made a big difference in how the fabric folded. Folding worked best if the diagonals of the peaks and valleys of the origami pattern followed the directions of the diagonally laid stitched tow. The size of the folds also greatly affected the stiffness and stability of the fabric. The team made a patterning tool that could be used similar to a block print to get the pattern onto the fiberglass. The pattern was taped onto the fiberglass using duct tape. Areas under the tape were kept free of resin. [Figures 5]

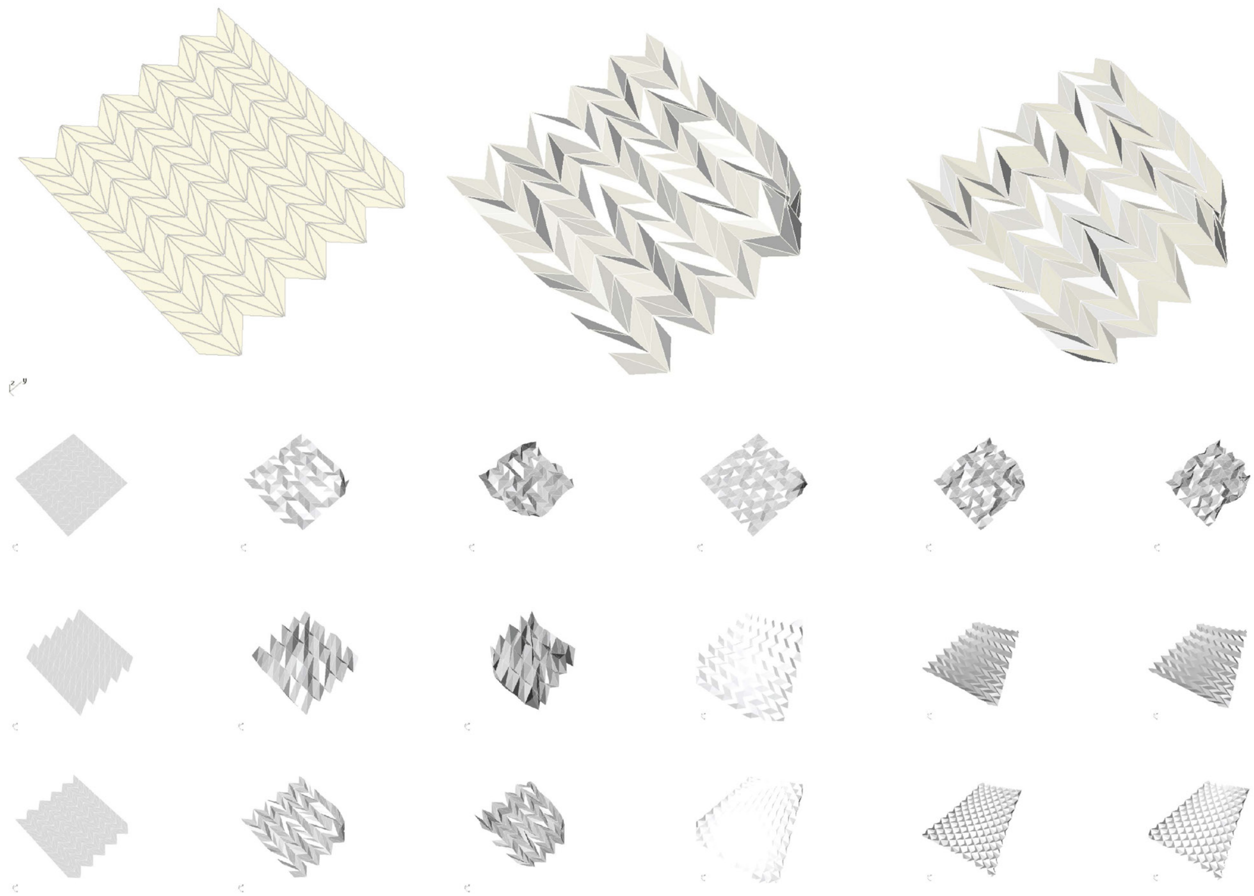


Figure 4. Digital Origami Models. Karen Kuo.

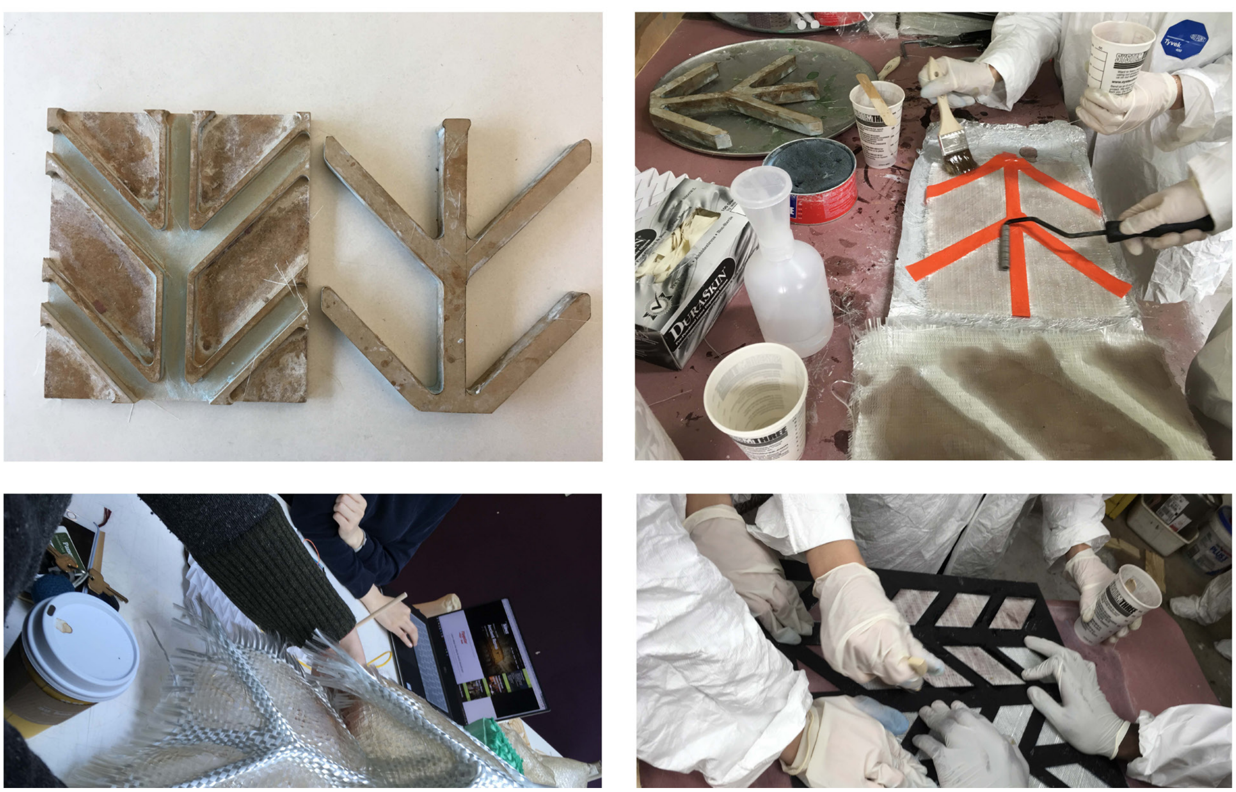
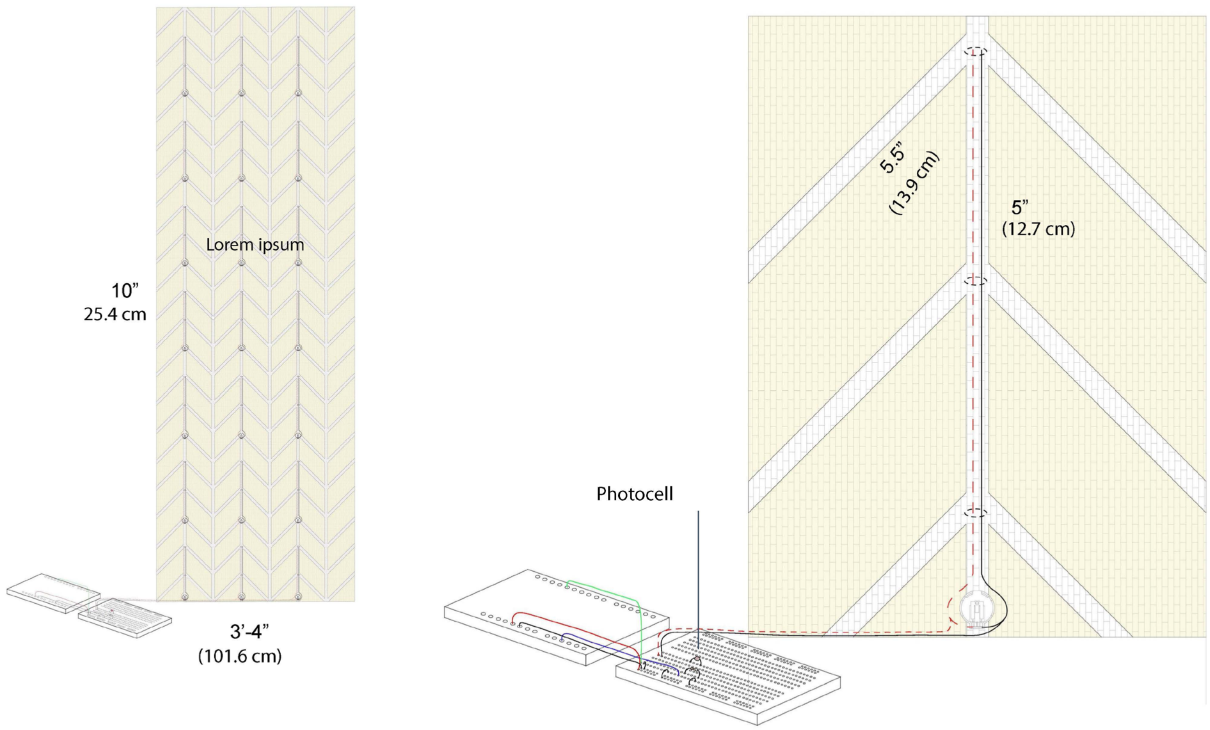


Figure 5. Template, Taping, Test Folding Material, Template 2.Davis et. al.



Circuit Drawing for LED’s on One Panel

Figure 6. Circuit Layout and Arduino Board Set Up for Light Response.Davis et. al.

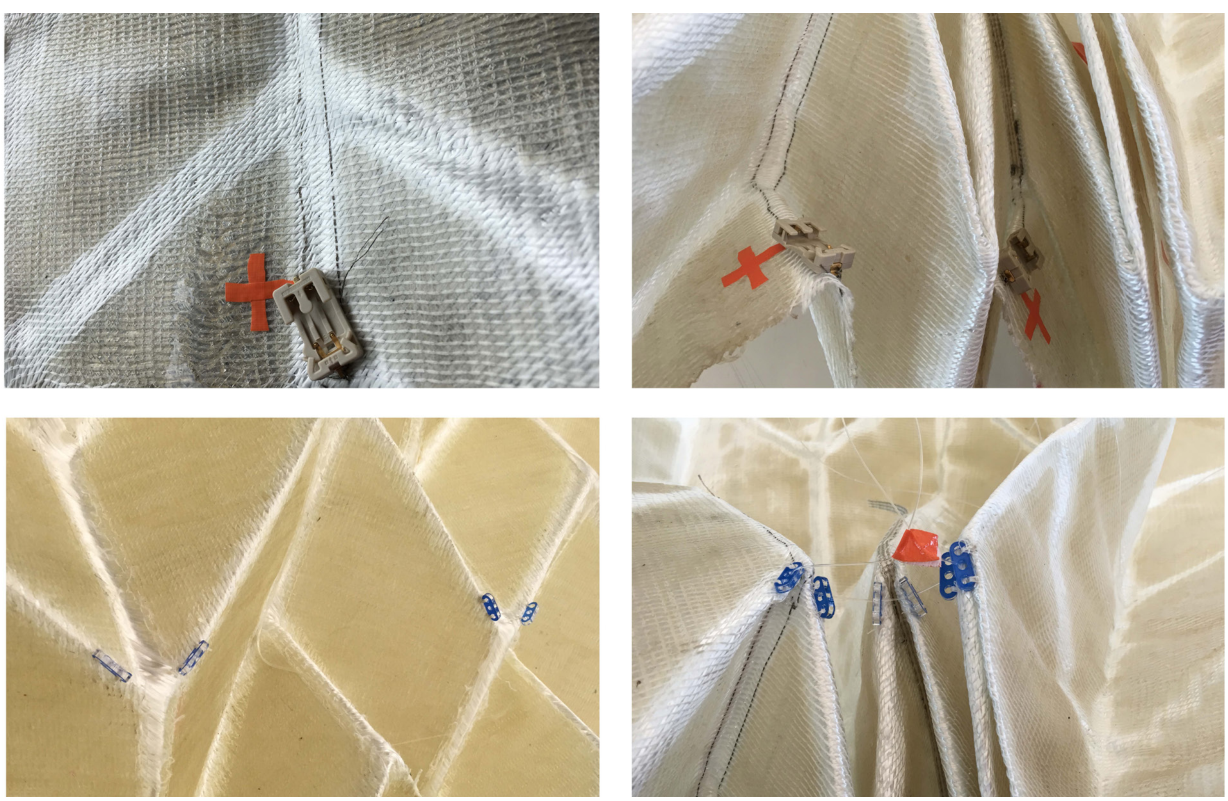


Figure 7. IConductive Thread and Coin Cell Battery Holder, Understanding Circuits and Folds, Button Used for Gathering Folds Together. Davis.

Figure 8. Phototropic Origami Structure Daylight. Davis et. al.

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MATERIALS

The phototropic structure uses triaxial stitched fiber glass at 36 oz./yard that is a high strength fabric. There are two pieces that make up its parts each 3'-4" [101.6cm] wide and 10'-0" [304.8cm] in height. A fast curing polyester resin was used to make the structure. The team also worked with a soybean based resin that worked equally as well for these purposes but did not produce the same translucency in the coated fabric. Duct tape was sturdy enough to withstand curing resin.

RESIN COATING

The fiberglass was placed on non-stick foil coated with wax. The fiberglass was then coated using brushes very rapidly to coat the entire height and width of the fiberglass. The fiberglass and resin cured in a fume hood overnight or for 10 hours. [Figure 5]

CIRCUIT

Once the fabric was cured, duct tape was removed. The fabric was folded. As it was quite stiff, it took at least two from the team to stand on it to get it folded flat. Conductive yarn was used and threaded into the fiberglass using the layer of stitches that held the different layers of tow together. [Figures 6&7]

Conductive yarn was used and threaded into the fiberglass using the layer of stitches that held the different layers of tow together. Circuit materials included 4 ply stainless steel coated conductive thread, coin cell battery holders, 3 volt coin cell batteries, small LED's and an Arduino board, breadboard with photosensor.

Lasercut buttons from plexiglass were used to gather the folds of the material in tension. Monofilament line was used to place the folds under tension.[Figures 6&7]

SAFETY

Working with the fiberglass required wearing Tyvek work-suits, and hands were protected with vinyl gloves. The resin coating was done in a room sized fume hood to ventilate fumes.

CONTRIBUTIONS OF THE PROJECT

A design for an electronically active textile that could react to specific physical conditions such as light. A design, with sewn circuits and programming for a textile that can light up when it is dark. A design for a responsive mobile fiber composite structure that could change its shape in response to changing physical conditions. [Figure 8]

ENDNOTES

1. Justine Testado, "See how Joseph Choma built the 'Chakrasana' arch using his fiberglass folding technique" https://archinect.com/news/article/150026343/see-how-joseph-choma-built-the-chakrasana-arch-using-his-fiberglass-folding-technique Archinect, Sept. 5, 2017.
2. Felecia Davis, "(Un) Covering/ (re)Covering," In White Papers, Black Marks, edited by Lesley Naa Norel Lokko, (London: Routledge, 2000), 348-355.
3. Duks Koschitz, Erik D. Demaine, and Martin L. Demaine, "Curved Crease Origami", in Abstracts from Advances in Architectural Geometry (AAG 2008), Vienna, Austria, September 13-16, 2008, pages 29-32