

DESIGNING ZERO-ENERGY BUILDING COMPONENTS WITH SMART THERMOBIMETALS

**A Proposal for the
[Next Idea] Voestalpine Art and Technology Grant
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Project Description

The correlation between the performance of the building envelope and the consumption of artificial energy for heating and cooling in buildings is a direct relationship. Comfortable internal temperatures can be maintained with less energy when the temperature differential is passively controlled before heat and sunlight enters the building. In the case of high-rise structures, the curtain wall system can be more than just a lightweight, highly-glazed, hermetically sealed building envelope. Taking cues from other integrumary systems found in nature where skins breathe, protect and regulate, the curtain wall system can be designed to mediate between man and his environment in a much more dynamic and responsive manner. Universal designs of mass produced, uniform parts can no longer suffice in an era where zero-energy is being sought, smarter materials are being developed and digital fabrication technologies lead the way in design.

When distributed in a tessellated surface, those new materials can respond independently to a variety of factors. In the case of shape changing alloys, such as thermobimetal and Nitinol, where both materials respond to changes in temperature, smart materials can play a pivotal role in the way curtain wall systems are designed, the former as a passive system and the latter as an active one. When the sun penetrates the surface of the building, the strategically designed bimetal can change shape and curl, automatically shading areas on the surface of the building to prevent heat gain, while the wire-like Nitinol can be control manually the self-ventilate mechanism when indoor temperature gets too high. In effect, the use of these



Fig. 1: Thermobimetal automatically curls when hot (left) and flattens when cold (right).

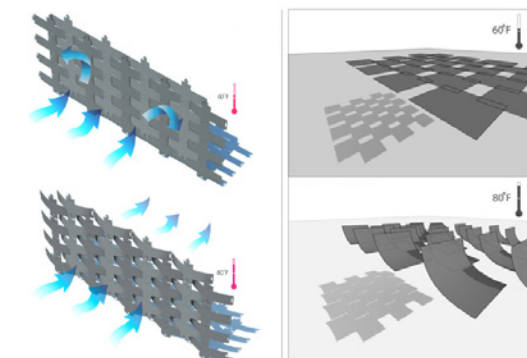


Fig. 2: Thermobimetal can be used for either self-ventilating (left) or sun-shading (right).

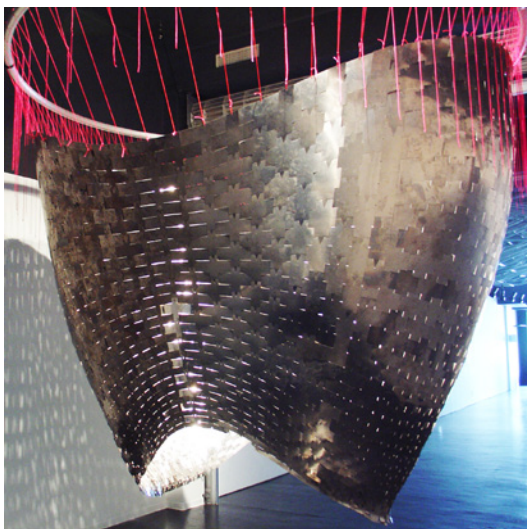


Fig. 3: The first prototype was intended for self-ventilating (completed in 2010).



Fig. 4, 5: The third prototype called, BLOOM, was completed in 2011. It is responsive to heat and the warmth of the sun.

combined materials can produce an automatic system of blinds closing only in areas that get high solar penetration and manually released when shading is not preferred. The result is a curtain wall system that will reduce the need for artificial heating and cooling, maintain panoramic vistas in high-rise commercial building applications, and, inadvertently, determine the dynamic aesthetic of the building facade.

Funding from this grant will be used to develop two code-dependent systems in effort to heightened performance of thermobimetal and Nitinol combinations: an interactive, hybrid system of the two dynamic materials operating simultaneously and a compatible system of oscillating performance where one material performs while the other remains static. The results of these two systems will be applied to a curtain wall panel system and to a bris-soleil surface intended for easy installation in commercial applications.

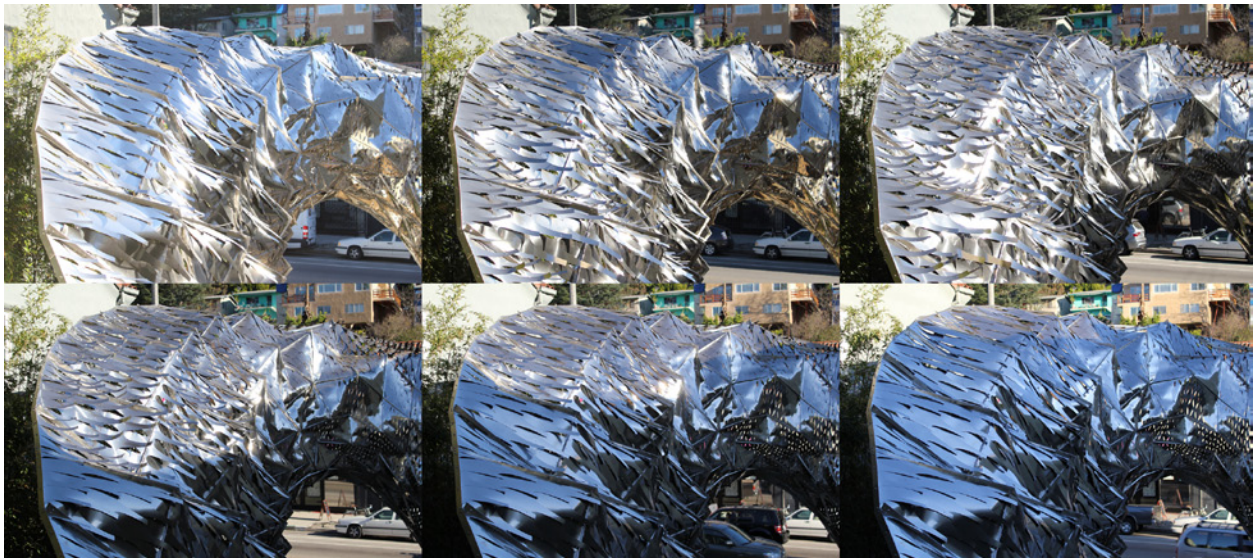


Fig. 6: These time-lapse sequence of images is taken over the course of one day. As the sun heats the surface, the individual tiles curl allowing hot air to escape from the area below.

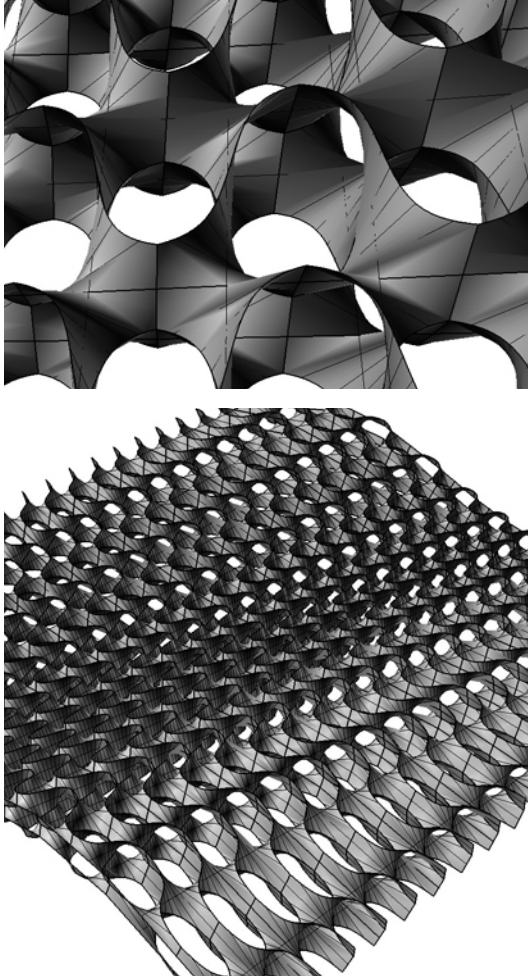


Fig. 7: New complex patterns developed through digital software and programming can allow the thermobimetal and Nitinol to perform in more optimal ways relative to the movement of the sun and the changing needs of users.

1. DOUBLE-GLAZED WINDOW PANEL: With a team of students from USC and SCI-Arc, two operable 4'x8' prototypical panels will be built to test the responsive systems. The first one will sandwich an air gap with the responsive materials between the two layers of glass. A patterned system of thermobimetal tiles will be arranged to allow light to pass through the glazed panel during the cooler times of day. When the outdoor temperature rises and the cavity is heated, the individual tiles will curl to block the sunlight, preventing direct sunlight from entering the building. To cool the cavity and return the bimetal to its original configuration, simple manual controls, requiring a small spurt of energy, can trigger the Nitinol to open small valves in the cavity, allowing air to naturally ventilate. Additional films and materials will be incorporated to maintain insulating qualities of the glazed panels.

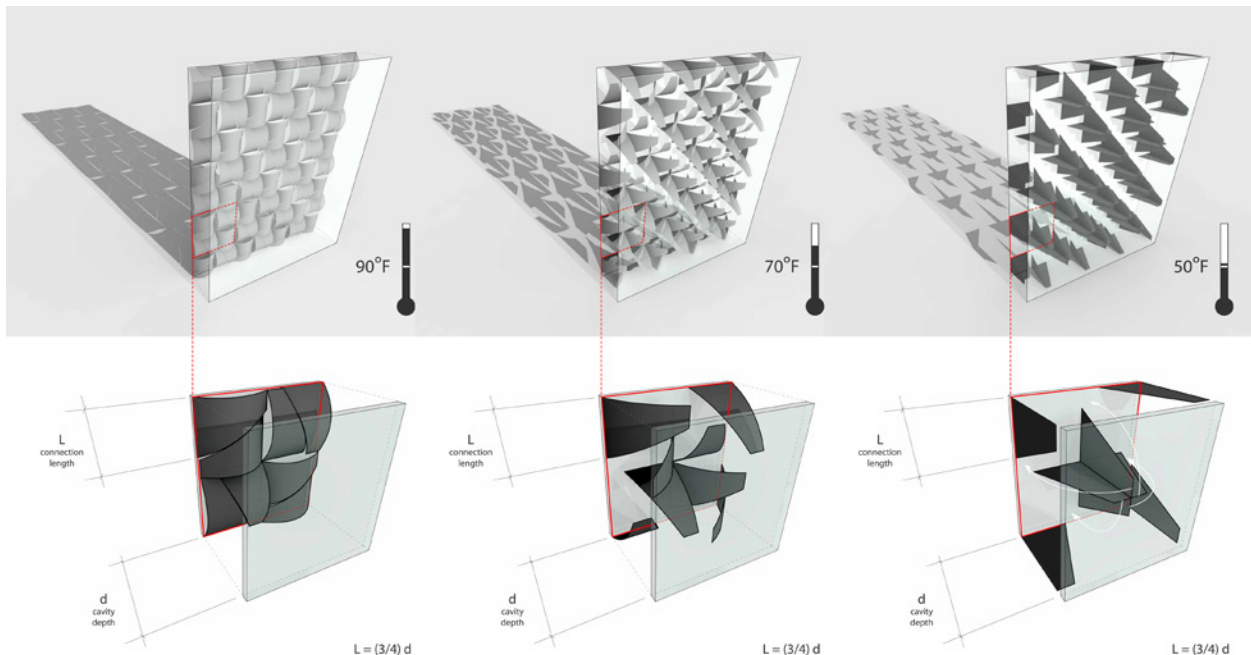


Fig. 8: This proposal utilizes the materials and technologies developed in the previous prototypes to make double-glazed window building components. The intent is to design/build a 3-d pattern, such as the one in fig. 7, into a working prototype, and closing the gap between digital and analogue worlds.

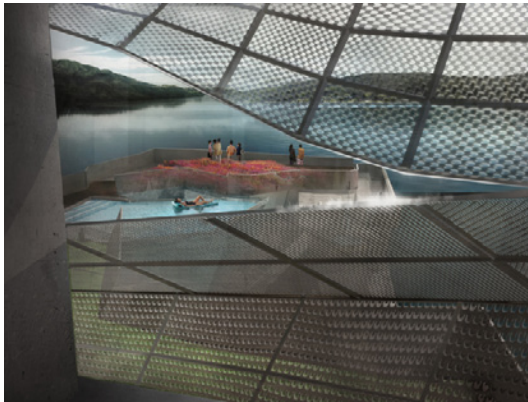


Fig. 9-12: This bris-soleil proposes the possibility of using complex softwares in architectural elements to bring buildings closer to zero-energy. Overall shapes and geometries can be structurally and materially optimized. Additionally, the surface tiles of thermo-bimetal can be parameterized to make the flow of patterns systematized and assembly reasonable.

2. BRIS-SOLEIL PROTOTYPE: The second prototype will explore the potential development of the dynamic hybrid system in a brise soleil application, a system that can operate on the outside of the curtain wall panel to passively and actively control direct sunlight from entering the building envelope. Manufacturers will aid in the development of newer material laminations and combinations in preparation for building construction application.

The result of both prototypes will be a facade articulation that will be different at any point in time and constantly change throughout the day. Its innate performative nature will ultimately define the overall aesthetic of the building envelope.

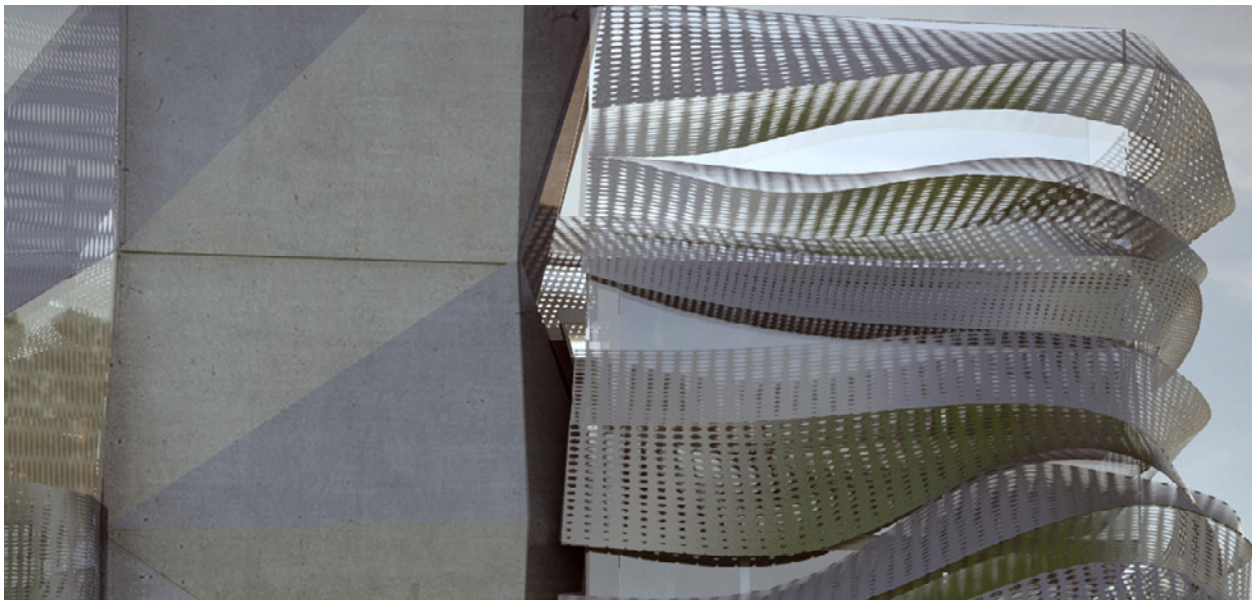




Fig. 13: All digital models will have to be tested physically in preparation for final assembly.

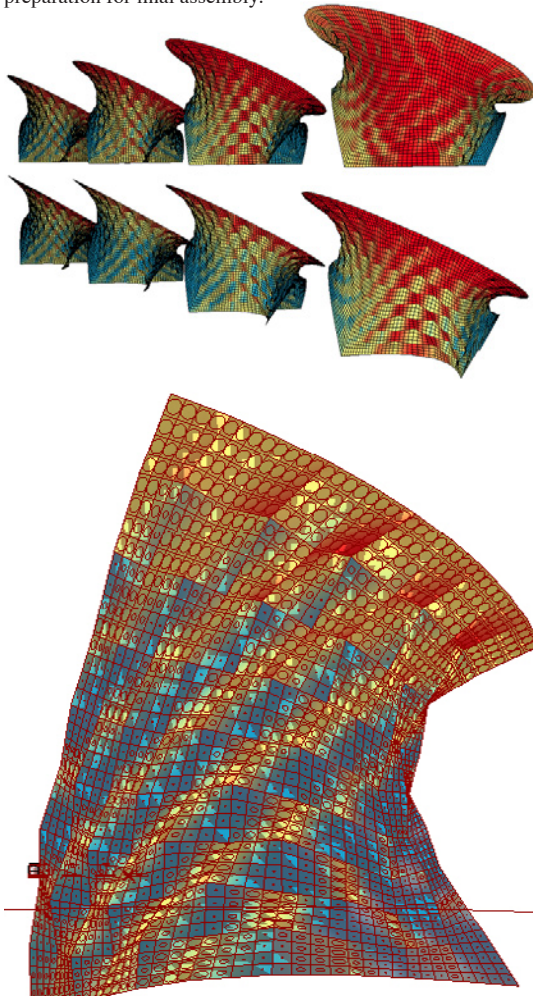


Fig. 14: Surface models will be connected to digital analysis tools to inform the actual parameters of the surface.

Production Plan

The method of work will be similar for both processes. Lead by Doris Sung, a team of digitally-fluent members will work closely to develop the project from beginning to end. Team-members can be comprised of a combination of students and ARS Electronica Futurelab personnel. Depending on the workforce, various stages can be performed at the ARS site during the 3 month fellowship or at DOSU Studio in Los Angeles. The general stages will be as follows:

- a.) Digital Modeling:
Using Rhinoceros, Grasshopper and CATIA, we will strategically build forms that can shade sunlight when necessary AND retain significant views for the user. Scale, depth and orientation will play large roles in this determination. Combining complex shapes and patterns with common polarizing techniques can result in new possibilities.
- b.) Material Testing:
The author has already developed a relationship with the manufacturers. In-kind material donations will be secured. Preliminary testing of the materials in various configurations will be devised and documented. A catalogue of various forms will be categorized and methodically documented.
- c.) Model Analyses:
The proposed model will be tested for both structural integrity (LS-Dyna) and for responsive performance to solar penetration (Ecotech and Gecko). Adjustments to the model will be made accordingly. Personalization of the tools are required in this area because there is no existing program that can completely suffice.
- d.) Digital Fabrication:
Preparation of the laser-cutting files will be prepared direct digitally fabrication, or CAM (computer-aided manufacturing) through Grasshopper and RhinoNesting.
- e.) Prototype Assembly:
Once all components are ordered and fabricated, they will be assembled by hand.
- f.) Review/Documentation of Results:
Using time-lapse photography/videography, laser thermometer and infrared camera, the performance of the final panels will be tested and documented digitally and physically.

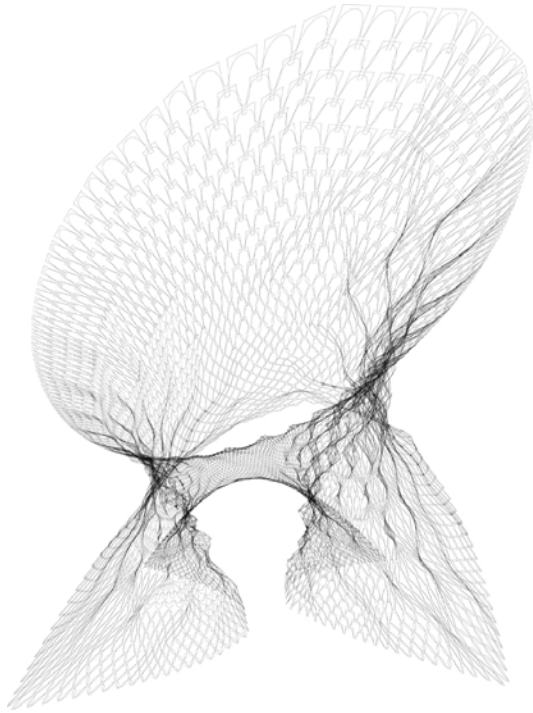


Fig. 15: Early digital models of the BLOOM prototype guided the seamless marriage of the performance with the actual fabrication.

Other Funding Sources

Matching and additional funds are greatly needed. Initial funding has already been secured from the following organizations:

- American Institute of Architects Upjohn Scholars Program
- University of Southern California Graduate Research Student Program
- University of Southern California Undergraduate Research Associates Program

More Information

Video Interview of Author:

<http://www.youtube.com/watch?v=-Ms5qoMO3gQ>

Video of surface change:

<http://vimeo.com/woodd/bloom-surface>

Video of construction of BLOOM:

<http://vimeo.com/woodd/building-bloom>

Photo/Project Credits:

All work (Figs. 1-16) has been completed by the author.



Fig. 16: Thermobimetal is lightweight and easy to assemble. Much of the structural stability comes from the geometries of the surface which can only be determined, developed and completed with the use of current powerful digital softwares.