EXECUTIVE SUMMARY for AIA Upjohn Grant

Smart Sun-Shading: A Demonstration of Smart Thermobimetals as a Building Skin

Submitted by Doris K. Sung

OBJECTIVES

Once merely an element to build basic shelter, materials have now become instrumental in the design of innovative building skins. Many newly developed materials are capable of adapting physically to external conditions, allowing the building surface to respond automatically to changes without the need for external energy input. Thermobimetals, one of these smart materials, are comprised of two metals with different thermal expansion coefficients that are laminated together. By nature, bimetals will curl when heated and return to their original shape when cooled. Surprisingly, although they are commonly used today in the control system of thermostats, there have been no architectural applications of bimetals to the design of building skins or surfaces.

<u>Material Demonstration</u>

The completed project, funded partially by the Arnold W. Brunner Grant, demonstrates the application of this material at the outdoor gallery space of Materials&Applications (M&A) in Los Angeles, an organization supporting experimental reconfigurations of public space. Beyond the structural integrity necessary to create the successful surface installation, two important performance matrices are produced with this research. The first involves the TBM's efficacy as a sun-shading device that dynamically increases the amount of shading as the outdoor temperature rises. The size, shape and orientation of the tiles of the tiles are positioned strategically to perform optimally relative to the angle of the sun. About 14,000 parametrically-designed, laser-cut TBM tiles curl when the sun penetrates their surfaces. Using advanced modeling software, the final pattern optimizes the curling performance of the individual tiles and panels relative to the direction of solar penetration. Reliance on digital modeling and physical panel testing prior to final installation is necessary to ensure top performance. The second opens up the ability of the TBM to ventilate unwanted hot air. By optimizing the contortion of individual TBM tiles, any captured heat would automatically ventilate, retaining cooler temperatures below the surface of the canopy. The 414 saddle-shaped panels together form a structural shell-like network that, when assembled properly, amounts geometrically to a large hyperbolic paraboloid (or hypar) form.

<u>Structural Testing</u>

The hypar shape is a common form used in thin shell structures. A double-ruled surface, it gains its strength by its curvature in two directions. This principal is applied to the panel shapes in 'Bloom' as a device to implement a monocoque system. This strategy would keep the overall structure lightweight and flexible, where the structural integrity of the surface is reliant on the integral composition of the frame and skin together. Without the other, the structure will collapse. This same monocoque principal makes sense in the sequencing of assembly. Without expensive or fancy equipment, each frame is added one-by-one. Once the entire structure is assembled, the actual geometry is automatically set and the structure stiffened. Surprisingly, the entire piece is lightweight only amounting to about 600 lbs.

Digital Trials

Finally, the use of complex digital tools continues to challenge the process of design and bring it to new levels. Original intentions of using CATIA (Computer Aided Three-dimensional Interactive Application) are set aside early because the digital models are too heavy. The software is overly complex for the application. Instead, the choice of digital software is Grasshopper, which after hundreds of hours of manipulation pays off. Its ability to interface with other softwares like ecotect and other structural analysis tools are hugely helpful. With very few mistakes in the final fabrication files, the digital software proves to be an amazingly useful tool in computer aided manufacturing (CAM). With my past experiences in working with CATIA and now with Grasshopper, it is difficult to say which works better. In either case, the fact that there is a choice of tools is a positive result for our field.

CONCLUSION

The installation has a huge success. The buzz at opening day was palpable and measurable through Twitter activity and Facebook hits. Currently, the project is gaining broad exposure in the architectural, engineering and art industries. The research is being published in books such as *Sculptural Architecture* (Gestalten Press, Germany) and *Active Envelopes* (Images Press, Australia), in magazines such as *Maru* (South Korea) and *Vision* (China), and in *National Science Foundation (NSF)* websites such as the *Science 360 News Service* at http://news.science360.gov/files/ and *The Knowledge Network* at http://science360.gov/files/, to name of few. The list continues to grow.

The impact on the design profession, construction industry, and academia are tremendous: It is an early step to the reduction of artificial climate control systems and other infrastructural elements and, ultimately, the reduction of the usage of energy; It exposes, the integration of a comprehensive and materially efficient structural strategy that takes advantage of reduced infrastructural needs; And, it demonstrates successful utilization of complex digital technologies in the design and realization of architectural applications;

Research of the thermobimetal in architecture continues on many levels. New laminations are being tested with the manufacturer for use in permanent applications and in different forms with various other deformation characteristics. At the same time, various applications are being developed. Use in simple bris-soleil applications has the most immediate impact. Several different patterns are being developed, tested and built. Application at the building component scale are also promising. A prototype of the development of a double-glazed panel system where the smart thermobimetal is configured between the two panes of glass will be completed by the end of summer 2012. In these panels, when the cavity is heated the bimetal curls and blocks light and heat from entering the building. It is an automatic shutter system that opens and closes automatically. And, finally, breezing blocks controlled by bimetal valves on the surface can control the amount of air passing through a CMU-like block wall. Using larger air cavities and complex molding methods, these readily available blocks can now be reconsidered as a performative building component. The various continued research is testament to the potential of this smart material in performative building skins.

For video footage of project, please see:
1. INTERVIEW: Doris Sung http://www.youtube.com/watch?v=-Ms5qoMO3gQ
1. BLOOM: Thermally Responsive Surface in Action http://vimeo.com/woodd/bloom-surface
2. BLOOM: Construction Timelapse Video http http://www.vimeo.com/woodd/building-bloom
3. BLOOM: Opening Day http://vimeo.com/woodd/opening-bloom

CREDITS

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Site: Materials&Application Gallery, 1619 Silver Lake Blvd, Los Angeles, CA, tel 323.739.4MN8 (emanate.org)

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