CUSTOMER STORY

Studio-X

Soft-Kill Pavilion-X: Structural Stability and Design for an Unstable System

INSPIRE
solidThinking

Images courtesy of DIGITAL STUDIO, Inc.

"Adopting Inspire for structural optimization in the first stage allowed us to fabricate a better model that simultaneously addressed strength and stability."

Daisuke Hirose Manager of Studio X, Director of Archicomplex Inc.
Professor at DIGITAL STUDIO, Tokyo

A SURPRISING pavilion caught the attention of many visitors during the Tokyo Designers Week 2013 (TDW 2013). The application of Altair's structural optimization software, Inspire, generated a buildable complex shape increasing the stability performance of the pavilion. The project was a collaboration between Columbia University's Studio-X and Tokyo DIGITAL STUDIO. The concept of the pavilion was defined with an investigation on material waste reduction focusing on the evaluation of structural aspects like stability and instability. Among the general appreciation for the project by the design community at the TDW 2013, the Soft-Kill Pavilion-X has been the recipient of three corporate awards and the semi-Grand Prix at the school exhibition.

THE CHALLENGE

It's like capturing the dancer's movements; being unstable at a glance, yet stable the next move. A kind of "stable object's instability" concept. Thanks to Inspire, DIGITAL STUDIO simultaneously addressed the stability of the pavilion and also provided further optimization of the shape's components. The design gradually evolved into a material waste reduction, minimizing the use of structural components.

After the initial configuration using 3D modeling tools, Inspire was used to perform structural optimization. The result of the optimized model was then refined using 3D modeling tools to define the optimal structure of the pavilion adopting pipes. The pipes were cut out using a multi-axis laser cutter and then assembled.

In the 2012 edition of the Tokyo Designers Week, DIGITAL STUDIO's team fabricated Inspire's structural optimization model by using 2D plastic panels. For the 2013 edition of the TDW, DIGITAL STUDIO used steel pipes to quickly assemble the pavilion on site, thanks to an improved digital fabrication approach.

We assumed that a small portion of the material would be carved off by the soft-kill option when performing structural optimization, which is why the initial form was rough and simple. Subsequently, a semi-circular shape was drilled at the bottom of the cube, creating a shape with four legs; then twisting the whole cube generated the final form, ready for the optimization. The dynamics within the optimal model configuration, in which the four delicate legs and roof were fused, is exactly like a dancer's pose. It gives the viewer a momentary sense of anxiety, and it becomes a dynamic space.

STUDIO X
GSAPP COLUMBIA UNIVERSITY GRADUATE SCHOOL OF ARCHITECTURE, PLANNING AND PRESERVATION
Digital Studio

INDUSTRY

Architecture Engineering Construction

CHALLENGE

Combine advanced structural optimization with the fabrication of a complex space

SOLUTION

Inspire helps architects to create an innovative pavilion for the Tokyo Designers Week 2013

RESULTS

- Define innovative architectural forms with design optimization
- Structural design investigation to improve building performances
- Reduce assembly time and material waste with lightweight design

THE SOLUTION

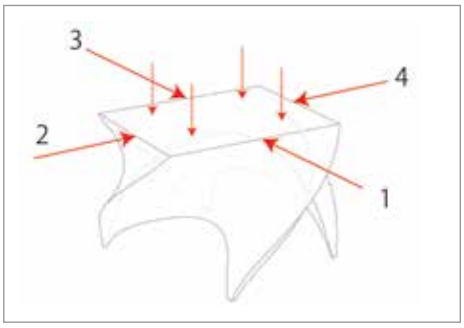
In Inspire, the setup of the optimization for the initial shape was based on the following conditions, first, the stress result was determined by applying the self-weight of the entire volume as a fixed load. Next, DIGITAL STUDIO made simple assumptions to simulate wind pressure and seismic study to evaluate the structure in-depth. Four lateral loads, from main directions, were applied to the model to simulate wind and seismic actions and obtain the final stress results. Four different analyses were carried out combining self-weight with a lateral load each time. Although different from a dynamic analysis, our assumption, a sort of multidirectional analyses, generated stresses that can occur in a building in similar conditions. Finally, the results of the four analyses were combined together, with a Boolean sum, to generate the final optimal model.

The fabrication model was based on the model generated in Inspire. All polygons' center points were extracted onto the surface. More than 3000 points were extracted to create lines along the optimized model then turned into pipes for the final fabrication. The fabrication model was based on the optimized structural model made in Inspire; therefore, it maintains its structural strength. The final model created was evaluated from various angles, and finally the pipes were placed.

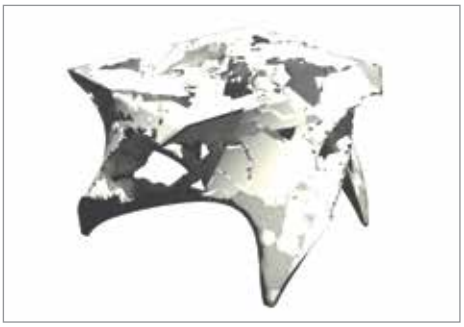
The pipe bonding process involved 3D CAD, but no welding. The bonding method consisted of two types of pipes connected at each joint, which were *male* pipes with pins and *female* pipes with sockets. The *male* pipes were pierced through the sockets matching the corresponding pipe. The assembly task considered the different solicitations in the structure to create the joints. In fact, the *female* pipes had a low tension, which made the fabrication simple, while on the other hand, the *male* type had high tension and compression, which made the construction difficult

The complexity of the joint was resolved by adopting a multi-axis laser cutter, one of the only two machines available in Japan. A total of 36 steel pipes were cut out. Each joint and pipe was numbered to easily assemble the articulated shape of the pavilion.

It was necessary to simulate the assembly and disassembly processes since it was an experimental approach. For example, some pipes in the mock-up could not be softly tightened, and some pipes broke due to deep sockets. In addition, the assembling time took too long due to the small tolerance for the assembly process, which rejects any human error during the assembling. Based on this observation, instead of providing minimal margins, we increased the tolerances for the assembling. The mock-up was fundamental to improve the realization of the final model.



Initial form: design space and application of self-weight and lateral loads


Inspire, final optimization results


Tokyo Designers Week 2013, Award Ceremony

THE RESULTS

DIGITAL STUDIO presented the work to the many visitors during the student presentation event, and the exhibition at the Tokyo Designers Week 2013. In the Asia Awards, out of sixty-seven works in the school exhibition, the project was selected among the top eight for the final presentation. "Soft-Kill Pavilion" received three corporate awards and the semi-Grand Prix at the school exhibition.

According to DIGITAL STUDIO, Inspire's key features are that it is easy to understand, and also very intuitive when dealing with structures, material, loads, and constraints. Moreover, the deadweight for complex models is automatically calculated, which greatly improved the user experience. Inspire is easy to learn and easy to use. During the project, DIGITAL STUDIO discovered that Inspire's optimization technology was actually the result of extensive research about the growth of the human bones. The same principle of optimization can be easily applied to structural design. As a result, not only can the form be obtained without special skills on structural mechanics, but a complex shape can be captured and optimized as a more realistic structure.

ABOUT DIGITAL STUDIO

Studio X is a global network of advanced research organizations founded by Mark Wigley, director and professor of the architectural department at Columbia University's graduate school. Studio-X has research centers in Amman, Beijing, Mumbai,Istanbul and Japan. Thanks to local leaderships, Studio-X's community share projects, professionals, and ideas in real time between cities like New York, Rio de Janeiro, and Moscow. Studio-X performs interactive research activities through workshops and lectures on topics like the city and its architecture.

DIGITAL STUDIO was founded in 2010 as a community of several university students around the world with a common passion in computational design and digital fabrication. DIGITAL STUDIO is located in Japan and focuses on undeveloped architectural education. The studio is led by Professor Daisuke Hirose, architect and a director at Studio-X Tokyo and Archicomplex Inc.

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