Landscape Evolution Observatory at Biosphere 2

Building Three Ships inside of a Bottle

By Allan Ortega-Gutierrez, P.E.

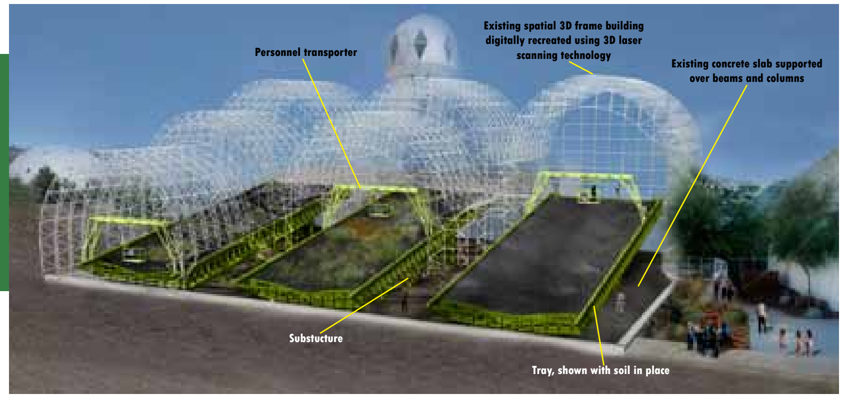

Figure 1: Rendering of the LEO system showing its parts and the existing building partially opened to show the structures inside. Courtesy of University of Arizona School of Architecture/M3 Engineering and Technology.

Biosphere 2, just North of Tucson, Arizona, has a new project in progress: Landscape Evolution Observatory (LEO), a science project from the University of Arizona that is changing the way nature is studied, while at the same time raising the bar for structural engineering challenges.

Description

The project consists of three identical large steel planting tray structures built inside an existing glazed space frame building, a large greenhouse previously used for intensive agriculture, and supported over an existing concrete floor structure. These steel structures have three main parts (*Figure 1*):

1) The *tray* is a 38-foot wide by 100-foot long (11.6 m x 30.5 m) steel box open on the top, sloping 10% in the longitudinal direction and changing the transverse slope along the tray's length to form the ridges and valley channels that simulates a hill slope. To form this compound slope, the tray is structured with transverse U-shaped frame beams spaced at 1 meter on center, to match the sensor grid spacing resembling the ribs of a ship's hull structure. All the transverse beams are attached to two deep longitudinal girders that connect to the substructure. The tray is clad on the bottom and all four sides with 3-inch deep steel N-deck, fiber reinforced cement board and a special waterproofing membrane to contain a one-meter thick layer of a special soil made of crushed basalt, irrigation water and a complex array of 2,847 different sensors.
2) The *substructure* is a system of steel columns, beams and steel braces that support the tray through ten load cells centered on the top of each column,
3) The *personnel transporter* is a mobile steel structure similar to a gantry crane that travels over the tray, covering the full width and length of it, and allows scientists to monitor and take samples of the experiment without disturbing the soil.

These three steel structures are unique in the world, in size and purpose, as they will simulate the interaction of the elements, especially water, with soil and vegetation on a hill slope. A special irrigation system and its supporting structure runs parallel to both sides of the tray, rising over 10 feet (3 m) above the top of the tray to support sprinkler heads that will simulate the effect of rain in various patterns.

Challenges

Each planting structure of LEO mimics a hill slope; several concepts were explored during the early design phases to achieve the desired surface slope. A steel structure with 16-gage N-deck was defined as the most cost effective based on the design loads and the different slopes that define the "hill".

The existing building introduced challenges with regard to space and the limited weight that could be carried by the current concrete structure, making the steel structure layout and optimization a priority. The layout of the structure using a steel tray and a braced substructure, is in response to these characteristics as well as a product of the selection of the load cells. The 10 steel columns of the tray frame were aligned directly over 10 concrete columns of the basement structure, thus eliminating bending loads on the concrete floor beams.

Subsequent to the design phase, one more challenge presented itself: the access to the building. There is only one direct entrance from the outside that measures 10 feet wide by 12 feet high. This demanded the design of several connections to be bolted for ease of field construction, as well as set a limit on the size and weight of pieces that were transported to the construction site.

The selection of load cells presented challenges, as the connection of the load cells needed to support the tray at an angle. The high axial loads in combination with the lateral load from the sloped tray reduced the options available in the market. Furthermore, one of the performance requirements set by the scientific group for the load cells was the ability to detect a change in weight equivalent to a layer of 1 cm of water (about 2 lbs/ft^2) over the tray. All of these conditions required consultation with the load cell manufacturer, Honeywell, who provided a semi-customized set of load cells. The load cells are rigidly attached on the lower end to the column cap plates and have a self-centering pinned connection at the top, thus reducing the overall moment transferred to the load cell. The use of these load cells required tighter construction tolerances than standard steel construction, making the construction dimensional control more stringent.

Working as the world's largest weighing lysimeters (measuring devices that are used to measure the amount of water released through evapotranspiration) in addition to monitoring other parameters in the soil, these structures are subject to conditions that restricted the use of certain materials and required tighter tolerances during construction. For instance, any material in contact with soil or water inside the tray had to be tested by the scientist group in order to determine its effects on the experiment, leading the team to use materials such as fiberglass, polypropylene and special waterproofing membranes that could satisfy the complex conditions of loading and performance for such an experiment. Materials such as galvanized and stainless steels were prohibited from contacting soil or irrigation water, as they could affect the experiment. Nonetheless, the solutions were developed satisfactorily and construction started on time.

Steel shop drawings were developed using Tekla® Structures as part of the design documents. This saved money and time during the construction phase, as the detailing complexity and any clashes were solved during the design phase. In addition, the model used to generate the detailed shop drawings was used to quantify materials and helped the steel fabricator to understand the complex structures in a more efficient way before starting fabrication. The advantage of using BIM technology was reflected also in the reduced amount of RFI's and field changes, given the complexity of the project.

During the final phases of design, an additional concern was raised: can we fit LEO within the complex spatial configuration of the building? Laser scanning technology was used to recreate a model of the existing building and determine more accurately the available space, which helped enormously in finding possible clashes and redesigning areas such as the personnel transporter. Such technology allows the designer to improve the use of space, and reduce or eliminate costly modifications during construction.

The personnel transporter idea started with a need to mobilize scientific staff over the experiment without affecting the soil or its content; however, no similar system had been previously used in such conditions. Many ideas were explored during this process and, finally, the use of window washing technology combined with industrial engineering expertise gave way to the current system, which provides a safe way to explore the contents of LEO.

Construction Realities

Despite the challenges, the project has progressed in a very positive and satisfactory way, in great part thanks to the team effort between all parts of the group, from the Owner to Designers, Vendors and Contractors. As a good example of this, during preconstruction, the contractor and steel fabricator proposed the addition of a jacking system to the structure to facilitate exchange of the load cells for temporary spacers once the soil was loaded. The original intent during design was to use

Figure 2: Jacking System (partially) and Temporary Spacer Installed (left) and Load Cell Installed (right). Courtesy of M3 Engineering and Technology.

the temporary spacers until the steel structure was placed in position; however, the contractor recommended using these until all welding was done to avoid affecting the load cells during the construction. The load cell, Jacking System and Spacer are shown in *Figure 2*.

The project is in its final phase, finishing the construction of the third structure and putting the final touches on the second planting tray. More information may be found at the project website **http://leo.b2science.org/**, including three webcams that broadcast real time video of the LEO project.▪

Allan Ortega-Gutierrez, P.E. is a Structural Engineer at M3 Engineering and Technology and was in charge during the structural design and the construction administration phases of LEO. Mr. Ortega-Gutierrez can be reached at ***aortega@m3eng.com****.*