removed and the tube refilled with sand if necessary. The side and end seams of the geotubes, however, are not designed to be removed and provide a much more robust seal than do the fill ports.

The contractor is placing the barrier segments as quickly as possible, filling approximately three lengths per day to lengthen the barrier by 600 ft (183 m) during each 12-hour shift.

Such alternative hurricane protection systems as floodwalls would have taken longer and cost more to construct. "If you were to build a wall, you may be looking at best at a hundred feet a day," Gilmore notes. "And then there is the cost aspect. Geotubes are just a significantly lower-cost alternative than a floodwall."

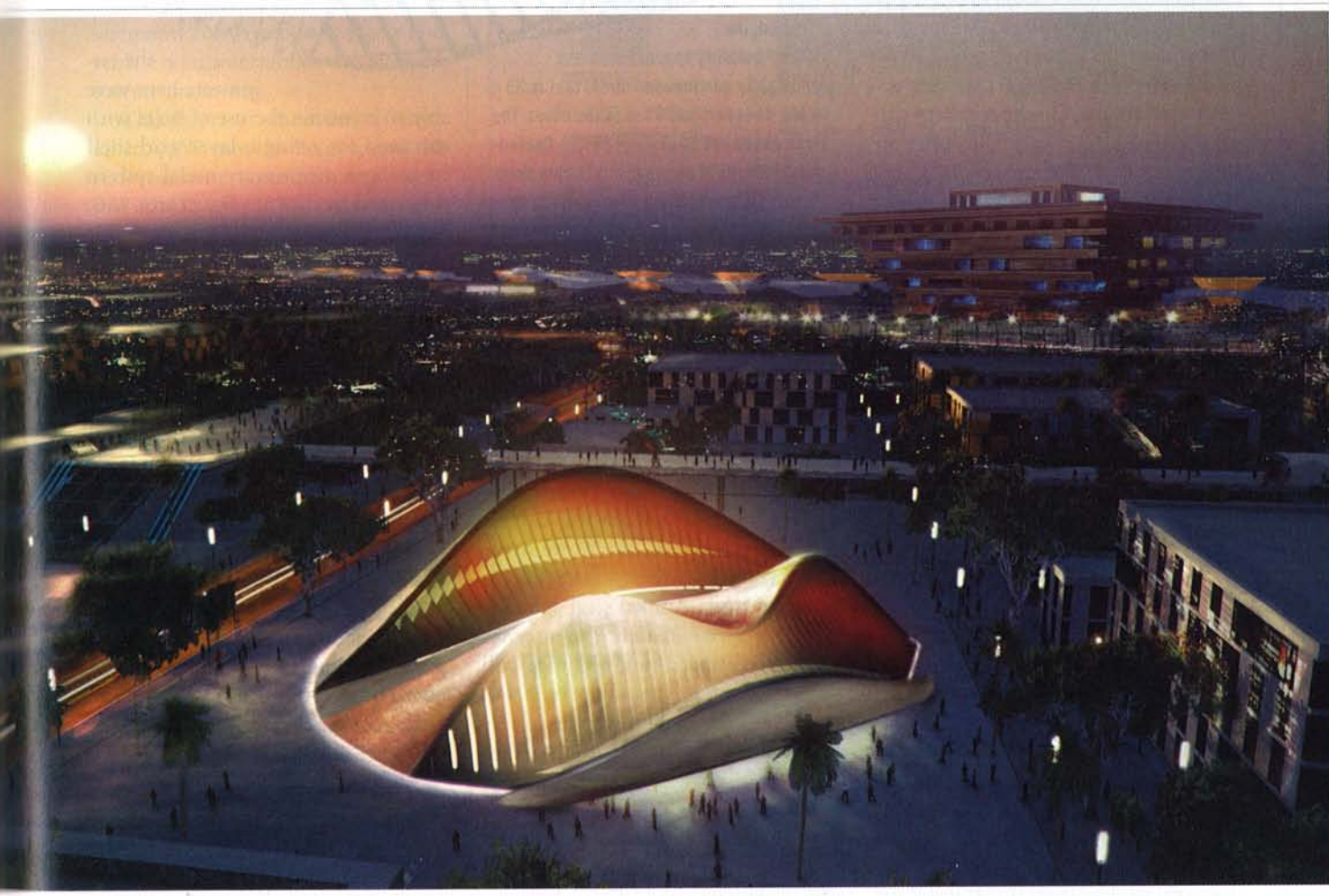
The natural contours of the sand dune itself will be re-formed with the aid of approximately 1 million cu yd (764,555 m^3) of sand dredged from a borrow site approximately 1 mi (1.6 km) off the easternmost edge of the island, according to Gilmore.

The project followed the requirements of the National Environmental Policy Act, and the work was coordinated with, among other groups, the Environmental Protection Agency, the National Marine Fisheries Service, and the Louisiana Department of Wildlife and Fisheries, Gilmore notes.

As of press time, Gilmore expected the geotube placements to be complete by the end of September, creating a functional barrier protection system well before November 30, the end of the hurricane season.

Once the geotubes have been filled, the dredged sand will be added to bury the geotubes, and pedestrian and vehicle crossings, sand fencing, and dune plantings will be added. The project is budgeted at $25.7 million and is expected to be completed by the end of the year.

—CATHERINE A. CARDNO, PH.D.



FOSTER + PARTNERS

The United Arab Emirates will be presenting exhibits on the past, present, and future of its technological developments at the world's fair that will be held next year in Shanghai, China. The exhibits will be housed in a single-layer diagrid structure whose form resembles three sand dunes, complete with distinct windward (curved) and leeward (flat) sides.

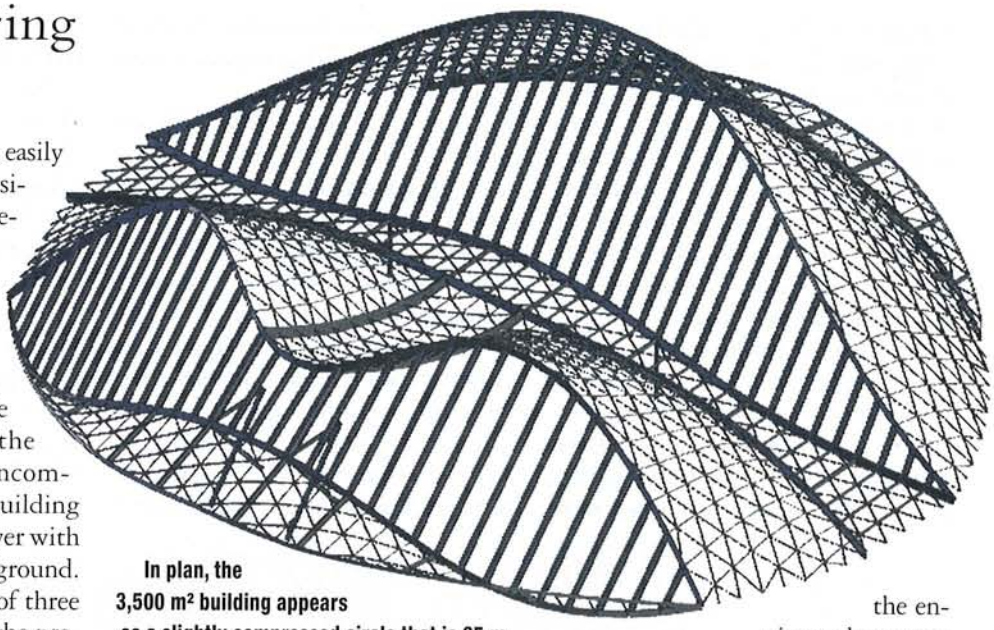
STRUCTURES

Traveling Single-Layer Diagrid Structure to Be Built For 2010 World's Fair

AS PART OF THE WORLD'S FAIR that will be held next year in Shanghai, China, the United Arab Emirates (UAE) will be presenting exhibits on the past, present, and future of its technological developments. These exhibits will appear in a building suggesting three sand dunes that has been designed by the London-based architects Foster + Partners and the Chicago-based structural engineers Halvorson and Partners. The building's form has been created with a single-layer, steel-framed diagrid shell that, rather than using welds, as is commonly the case,

is bolted together so that it can easily be disassembled after the exposition, shipped to the UAE, and rebuilt on Saadiyat Island.

In plan, the 3,500 m² building appears as a slightly compressed circle that is 65 m in one direction and 61 m in the other. To provide column-free space within the three presentation rooms encompassed by the structure, the building is framed as a single diagrid layer with a roof that curves to meet the ground. The building takes the form of three sand dune shapes that encase the presentation rooms. On the northern side of the building, two small dunes are linked together and rise to a height of 18 m; the other dune rises to a height of 20 m and occupies the southern side of the building. The sand dune forms include distinct windward (curved) and leeward (flat) sides, replicating the natural formations seen in the desert.



In plan, the 3,500 m² building appears as a slightly compressed circle that is 65 m in one direction and 61 m in the other. The three dunes act as distinct shells. Rectangular structural steel tubes 200 mm deep form equilateral triangular modules approximately 2 m on a side, although the tube lengths vary to form the building's curves.

A central spine separates the large sand dune from the two smaller ones. This spine contains the building's only interior columns, which are placed at approximately 6 m intervals and are connected to beams in such a way as to form steel moment-resisting frames that impart rigidity to this portion of the building.

The building entrances, which are perpendicular to the spine and are formed by rises in the diagrid to a height of 4 m, are located on the northern and southern sides of the building. Cantilevered canopies create 5.5 m deep overhangs above the entryways. The door openings are framed with I-shaped steel sections that transfer the building's loads to the foundations. Diagonal steel beams are placed between the cantilevered canopy beams to resist the horizontal thrust created by the dune structures.

According to Eric Fenske, S.E., the project engineer for Halvorson and Partners, the firm that developed the engineering concept for the project, the dunes act as distinct shells. The large dune is supported at grade at its two exterior sides. A steel ridge beam at the high point of the dune and horizontal beams at the entrance support the framing. The two smaller, linked dunes have a similar support system, although additional steel I beams support the linkage point of these dunes.

The leeward sides, in contrast to the dunes' curved windward sides, appear as angled lines. Angled steel columns located at approximately 2 m intervals and braced by horizontal members will form the back of the sand dunes and will support the ridge beams.

The shell-type structure that has been used for the building's framing is an efficient way to resist axial loads, explains Fenske. The grid shell features 200 mm deep rectangular structural steel tubes that typically form equilateral triangular modules approximately 2 m on a side, although the tube lengths vary to form the building's curves.

When bolts are used in a steel grid shell, there are usually two layers of framing "so it ends up becoming more of a space frame," says Fenske. The dual layers are usually necessary to carry the structure's bending stiffness. However, the engineers here were able to reconcile the use of bolts with the need for a single-layer grid shell by using a proprietary nodal system developed by Novum Structures, LLC, based in Diss, United Kingdom. "It achieved Foster's goal of having one layer, it achieved our goal of having a grid shell, and it achieved the owner's goal of making it dismountable," notes Fenske.

According to Fenske, because the grid shell has such large spans and behaves as a dome, the gravity loads dictate the design of almost all of its members.

Triangular stainless steel panels 1 m on a side form the building's cladding. By placing the goldish-red triangles together at different angles, the curves of the building are emphasized without having to use curved panels. The back sides of the sand dunes are clad with vertical louvers.

While a precast pile foundation was recommended to support the structure, Fenske notes that the building is founded on strip footings for its stay in Shanghai. When it is moved to the UAE, it will be placed on a pile foundation.

Construction of the pavilion is expected to be completed this month. As of press time, 192 countries and 49 international organizations were scheduled to participate in next year's exposition, which will run from May 1 to October 1.

—CATHERINE A. CARDNO, PH.D.

HALVORSON AND PARTNERS