DESIGNING FOR WIND IN NORTHERN CALIFORNIA

A hangar's 100-ft. height, coupled with a weight-conscious design, resulted in a seismic zone 4 structure governed by wind loading

A view from the outside (top) and inside (above) of the nose pocket of the new hangar.

WHEN A BUILDING IS SLATED TO BE ERECTED IN THE SAN FRANCISCO BAY AREA, it is almost a foregone conclusion that seismic requirements will govern the structure's design. However, the new KC-10 Maintenance Complex now under construction at Travis Air Force Base contradicts that conventional wisdom. The unique hangar rises the equivalent of more than 10 stories into the air and its space frame design was controlled by UBC code mandated wind forces rather than the Zone 4 earthquake forces normally associated with construction in northern California.

The structure's 103-ft. height is exceptionally tall for this type of building and was necessitated by the building's functional maintenance requirements. In particular, the height was needed to accommodate the vertical dimensions of a large aircraft empennage, the required jacking height for landing gear maintenance, and the safety clearances for the hook apparatus of the full coverage, 10-ton bridge crane. As a result of the hangar's height, though, the wind loading area increased substantially.

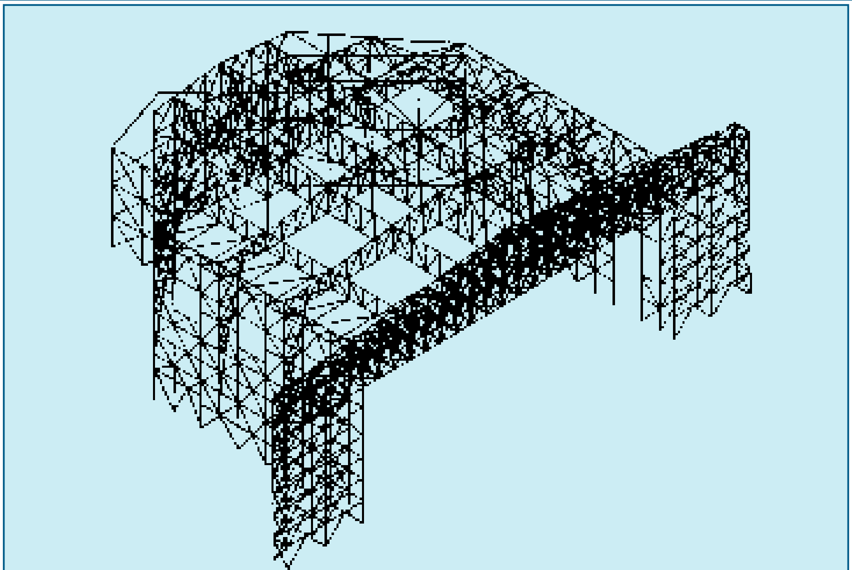
In addition to the building's height, the seismic forces were further reduced by the building's relatively light weight, which resulted from its design as a three dimensional space frame. The structure is composed of a bar joist/metal deck system supported by a lightweight steel frame.

"We managed to realize substantial savings in the size of the lateral bracing members by assuring that earthquake forces were to a maximum of 33% of the wind forces per the UBC requirements," said Kevin Crealese, project structural engineer with O'Kon & Company, the project's Atlanta-based structural engineers. "This allowed us to use bracing members with a maximum kl/r ratio of 200 instead of the 100 otherwise required by the UBC if seismic loading controlled."

The use of 3D computer modeling also substantially reduced the member sizes by achieving positive synergynetic results due to the triaxial stiffness of the frame and by predicting the drift of the structure. As a result, the engineers were able to maintain stringent sidesway criteria for high-tech functions of the building. The 3D modeling, along with a creative use of the design codes, reduced steel tonnage by more than 300 tons compared with the design after the 2D modeling phase.

Further savings, in both initial costs and in life cycle costs, were achieved by polygonal shape of the structure. Although the building uses conventional sliding metal doors, instead of the designing the building as a rectangle, the north end of the building narrows drastically in response to the shape of an aircraft and in effect creates a "nose pocket". "The functional envelope of the facility effectively reduces the spatial volume and thus introduces savings in material and life cycle costing," explained Steve Williams, a project manager at O'Kon.

The south facade of the hangar features the main door opening. Structurally, it consists of a double truss spaced 9-ft. apart. There are three columns on each side of the opening, consisting of a W14x82, W18x119 and W14x99, all of A572 Grade 50 steel. Bracing is provided by K-bracing. "We used pipe for the bracing due to its superior axial properties," Crealese explained.



Parallel to the front facade are five trusses. Three of these trusses are essentially identical and consist of haunched frame with simple moment connections. The trusses are supported on W14x283 columns. The haunched member, a W14x99 with a slight 300-ft. radius curve, begins around the 25-ft. level of the column. The lower chord begins about 15-ft. from the column line and consists of W14x90 members, while the top chord consists of W14x61 members.

The fourth truss occurs at the point where the hangar begins to narrow to form the nose pocket and is essentially a slightly scaled version of the three longer trusses. The fifth truss, however, is a true curving "cathedral" truss supported on W14x342 columns and consisting of W14x43 top and bottom chord.

Lateral bracing for the entire structure is provided by X-bracing in the east-west walls. As with the K-bracing, pipes were used for the X-bracing.

"The low mass criteria helped make the seismic requirements secondary to the wind force loadings," Crealese said.

To help reduce the visual mass of the facade, the architect, Lee Cole, introduced "racing stripes" on the exterior cladding. "The architectural palette of the base dictated a color scheme that required 'softening' of this large structure," Cole explained.

"The geometry of the space frame is an aesthetic combination of the curvature of the clearance envelope of the aircraft and the classical shape of a medieval cathedral. The "cathedral" truss that forms the entrance to the nose pocket area is most reminiscent of the architecture popular in the middle ages," added James O'Kon, president of O'Kon & Co.

Along with the pair of braced frames at the hangar entrance, the cathedral truss served as the main stiffening element in the space frame. The flexible intermediate transverse moment resisting frames transferred a large percentage of the lateral force into the lower chord horizontal truss, and finally into the stiff cathedral and hangar door truss.

The cathedral trusses are further highlights by the presence of a 50-ft.-high-by-50-ft.-wide picture window in the nose pocket of the hangar. The window was requested by the base commander who wanted a view of the nose of a plane nestled beneath the graceful curve of the cathedral truss to greet all passersby.